Tanja Tajmel, Klaus Starl, Susanne Spintig (Eds.)

The Human Rights-Based Approach to STEM Education

WAXMANN

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Artist Statement

BASTIK (Anick Jasmin)

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Growing up in Port-au-Prince, Haiti, I learned creative expression at a very young age when I studied under the great Haitian artist Tiga. Today I define myself as a mixed media artist and engineer who takes on painting, photography, and film. My main sources of inspiration are from my roots in Haiti and from the diverse art world in Montreal where I live. Through my pieces, I explore identity, intimacy, and the acceptance of the unknown.

When I was invited to develop the idea for this book cover and thinking about STEM education as a human right, I recalled many examples of times I, as a woman of color pursuing an engineering degree, felt excluded from engineering and in general from STEM. The visual collage for this book cover came to me when I was on a plane coming back to Montreal from Port-au-Prince to complete my last semester at university. I took a picture of my hand and designed this cover to visually reinforce the notion of centering humanity and especially human rights in the four fields of STEM, a human hand holding up four symbols, each representing one field:

The pinky representing science is dressed by a ring symbol made of a simplified molecular diagram, this is a reflection on seeing science in all its forms always leading back to molecular interactions. The ring aspect of this symbol is a nod to my fellow Canadian educated engineers as we all receive a ring upon graduation as a reminder of the ethical implications of our profession. The ring finger represents technology with a circuit board diagram, the symbol demonstrates the interconnectedness possible with technology allowing all processes to evolve and be more efficient. The middle finger represents engineering with gears intelligently designed to work together in order to go forward. And finally, the index finger represents mathematics with a part of the Fibonacci sequence written. This complex sequence is found all throughout nature in visual and mathematical forms.

My work as an artist is very different from my work as an engineer. This multimedia collage allowed me to pull from both my artistic and scientific knowledge to create a design that balances it all out. Even though I know that everything is connected, sometimes it is not as visible in one's personal life, it was very interesting to discover yet another connection between two very separate parts of mine.

Introduction

> "[A]s an empowerment right, education is the primary vehicle by which economically and socially marginalized adults and children can lift themselves out of poverty and obtain the means to participate fully in their communities." (ICESCR, Art. 13, 1966)
> "But the importance of education is not just practical: a well-educated, enlightened and active mind, able to wander freely and widely, is one of the joys and rewards of human existence." (CESCR, 1999)

In the last decades, various efforts have been made to investigate and reduce the marginalization of different social groups in the fields of science, technology, engineering, and mathematics (STEM). By applying the human rights approach, questions arise whether STEM education at the primary, secondary, and post-secondary levels is equally accessible to everyone. Particularly, the Sustainable Development Goals, passed by the UN in 2015, focus on the necessity of promoting science education as a right: Is access to STEM fields (still) limited or is it open to all? What barriers and social mechanisms are limiting access? How do institutionalized STEM practices, educational standards, and scientific evaluation systems reinforce inequities, and which identities are welcome? These are some of the questions addressed from different angles in this book. We hope to provide a framework that is applicable to and supportive of efforts to reduce inequity in science and to improve science education for all.

The Background of This Book

This book is the outcome of a joint effort over several years to develop an understanding of and a framework for science education as a human right. The idea was born at the first International Symposium on Human Rights and Equality in STEM Education, which took place at the Berlin-Brandenburg Academy of the Sciences on October 1st, 2018, in Berlin. We, the editors, prepared and organized this symposium across the Atlantic. Susanne Spintig took the lead in onsite organization and conference documentation. Tanja Tajmel and Klaus Starl contributed to the program development from Montreal (Canada) and Graz (Austria). The symposium brought together educators and researchers to discuss and reflect on the meaning of the human right to education for science or STEM education.

The opening speech of Nada Al-Nashif (then UNESCO Assistant Director-General for Social and Human Sciences, and now United Nations Deputy High Commissioner for Human Rights) set the tone for this symposium: a commitment to equity in access to education, to ending discrimination in sciences, to sustainable development, to gender equality and the empowerment particularly of girls and women in the STEM fields, and to science as common good. Then, talks that followed by Petra Lucht, Susanne Herzog-Punzenberger, Lamija Tanović, Munire Erden, and Seval Fer highlighted the benefits of transdisciplinary approaches to deepening the understanding of the human right to science education. The symposium closed with the adoption of the Declaration on the Human Right to Science Education by the symposium participants, which, by referring to the 4-As of the right to education – availability, accessibility, acceptability, adaptability – comprise recommendations for policy makers and stakeholders for the realization of science education as a human right. This Declaration forms the foundation of this book.

The Authors and Their Contributions

For this book, we continued to follow our transdisciplinary approach and gathered experts from different fields who share interest in studying, addressing, and counteracting inequity and discrimination in science and STEM education.

The book is structured into three parts: Part I centers on human rights, the Declaration on the Right to Science Education, and UNESCO's position. Part II focuses on science / STEM education, curricula, standards, the politics of STEM education, and decolonizing approaches to science education. Part III places a special focus on gender and science and on gender inequities in STEM careers and scientific rewards systems, and closes with an example for diversity mentorship in STEM.

Part I: Human Rights

This part opens with the speech of **Nada Al-Nashif** given at the international symposium in Berlin on October 1st, 2018. The speech set the tone for the symposium, and we felt that it should set the tone for this book as well. It highlights both the right for everyone to participate in science and the imperative to improve science, with a particular focus on Sustainable Development Goals and gender equality as a global priority – goals that will only be reached under the premises of science education for everyone and the understanding of science as a common good. The respective contributions by the authors can be seen as responses to this call from different perspectives. **The Declaration of the Human Right to Science Education (2018)** outlines the goals with the three key aspects, (i) the right to, (ii) the access to, and (iii) the quality of science education, and concludes with recommendations for educational institutions, researchers, and decision-makers. **Klaus Starl** re-examines the right to science education by applying the 4-A scheme that structures the right to education to developments since the first postulation of the right to science education in 2009 as an outcome of the project PROMISE (Promotion of Migrants in Science Education), taking into account the significance of the right to science education in the Covid-19 pandemic. **Gerd Oberleitner** explores the development of the human right to science from the Universal Declaration of Human Rights in 1948 to 2020, highlighting two interrelated aspects: the individual right to enjoy the outcomes of scientific research and its application and the right to participate in science as a cultural human right, illustrating the tension between the positive and negative contributions of science that are central to the debate on the human right to science. In the final chapter in the human rights part, **Tanja Tajmel** presents a model for the human rights approach to science education that refers, particularly, to concepts of underrepresentation, diversity, and difference. It links the human rights approach to the intersection of structural and cultural aspects of science education, as well as identity construction in science. Presenting the right to science education as a normative framework for science education centers the individual's rights, rather than economic interests, as goals of science education.

Part II: Science / STEM Education

At the beginning of the second part, **Svein Sjøberg** sheds light on the politics of science education and sketches the development of international large-scale studies and the emergence of PISA. His chapter provides a critical account of standardized testing, along with the centering of market interests and globalization in science education. **Seval Fer** reveals institutional barriers to fulfillment of the promises of STEM education, with the example of the education system in Turkey. By outlining the entanglement of educational, organizational, structural, and institutional challenges in the development of curricula for STEM education, she concludes that successful STEM education requires frameworks that allow for interdisciplinary approaches to curricula and extra-curricular activities. **Lamija Tanović**, in her chapter, describes how post-war politics in Bosnia-Herzegovina impacted access to education and particularly to science education in an institutionally complex structure and a highly fragmented educational system focused more on infrastructure than on curriculum development and quality education. **Lorena Lacerda**, **Bruno de Jesus Brito Santana**, and **Bárbara Carine Soares Pinheiro** outline emancipatory and anti-racist education based on the principles of decoloniality of knowledge with the example of Maria Felipa Afro-Brazilian School (MFS), thus adding another facet to the requirements that science curricula must fulfill to be acceptable to learners – that is, anti-racist education which does not reinforce binaries and colonial power relations.

Part III: Gender and Science

The third part opens with a chapter by **Petra Lucht**, who presents approaches to transdisciplinary research at the interface of STEM fields and gender by linking taxonomies of research on gender in science and technology studies (STS) to research paradigms in gender studies and to transdisciplinarity. With this focus on research, the chapter contributes to the scientific field of gender in science and technology, and to the understanding of how research can counteract reproduction of difference and binary thinking. Examples of transdisciplinary research projects illustrate these approaches. **Stefanie Ruel** presents a framework of discourses and identity intersectionality as methodology used in her empirical research to reveal barriers that women in STEM experience in their careers. She illustrates this research with the stories of two early-career STEM-trained women in the context of the historical and contemporary Canadian space industry. **Gita Ghiasi** sheds light on scientific evaluation systems and inequitable practices in research evaluation. In a comprehensive overview of indicators for scientific evaluation from a gender perspective, she contributes to a better understanding of the impact of these systems and how the use of these indicators can affect the career progression of women in science. Finally, **Susanne Spintig** and **Tanja Tajmel** raise the question of challenges facing mentorship programs for women in STEM, particularly, how to address identities without co-constructing stereotypes. They present the revision of the mission statement of the mentorship program Club Lise in a participatory process as an example for critical reflection on categories of difference and the general challenges of defining a group.

How to Read This Book

The book provides an introduction to the right to science education (chapters 1–5) as well as concrete topics (chapters 6–13) that can be studied through the lens of human rights. The following recommendations allow the reader to benefit most from this book:

Chapters 1–5 introduce to the framework of human rights and outline the right to science education as a special aspect of the broader right to education. These chapters provide the lens through which the subsequent chapters 6–13 are to be read. The latter do not focus explicitly on human rights, but they address different aspects and contexts that either produce and reinforce barriers and inequity in STEM and science education (e.g., educational politics, standardized assessments, scientific reward systems, identities in STEM careers) or counteract the reproduction of inequity (e.g., decolonizing education, gender in STS research, critical mentorship). For chapters 6–13, we recommend keeping in mind the following questions:

- What inequities and barriers to access to STEM fields and to STEM education are addressed or can be reconstructed based on this chapter?
- How does the presented context relate to the 4-A scheme?

– How does the presented context relate to the three intersectional levels: the structural/institutional level, the cultural/representational level, and the identity construction level?

Acknowledgements

The chapters of this book were written in different countries and benefitted from a variety of resources and the support of colleagues, friends, families, and students. We acknowledge the Kanien'kehá:ka Nation as the custodians of the lands and waters of Tiohtiá:ke/Montreal where Concordia University is located. We are tremendously grateful for the commitment of our contributing authors who stayed with us on this journey that started long before the pandemic and turned out to be more important than ever before. Our special thanks go to Dr. Stuart MacMillan, who with great sensitivity revised and edited our chapters, considering that most of the authors are non-native English speakers, and to Melanie Völker (Waxmann) for her continuous support throughout the publication process. A big thank you goes to Tatiana Zanon, who helped with translations, and Riya Dutta, who assisted the editing process. Finally, we gratefully acknowledge the constant support of Wolfgang Gollub from Deutsche Gesamtmetall, who supported the symposium in Berlin and is also supporting the publication of this book.

Tanja Tajmel, Montreal
Klaus Starl, Graz
Susanne Spintig, Berlin

Part I
Human Rights

A Human Rights-Based Approach to Equitable Access to STEM Education

*Nada Al-Nashif**

Keynote Speech at the International Symposium on Human Rights and Equality in STEM Education, 1 October 2018, Berlin, Germany

Ladies and gentlemen, dear hosts and organizers,

Thank you for the initiative and for including UNESCO in this important reflection. It is a real treat to be in this historic city, in this grand academy of science – and humanities, let's keep in mind.

Achieving the 2030 Sustainable Development Agenda requires transformative thinking and action. Science, technology, engineering, and mathematics (STEM) have already made improvements in many aspects of life, such as health and well-being, infrastructure, sustainable energy production, agriculture, and many others. In synergy with the social and human sciences, STEM has the potential to transform and improve people's lives, while ensuring environmental sustainability and providing the basis for new approaches and solutions to current and future global challenges.

The issue is to realize that potential.

The right to share in the benefits of science and its application is a human right, enshrined in Article 27 of the Universal Declaration of Human Rights, of which we are celebrating this year the 70th anniversary. And there is no way science and technology will respond to the needs of women if women's voices are not heard – not just in discussing how to apply science, technology, and innovation, but also in producing the scientific knowledge itself. Inclusive science isn't just more relevant science – it's better science.

And the science we have today is not nearly as inclusive as it could be. In particular, if the world needs more scientists to achieve Agenda 2030, it cannot afford not to properly involve half of its population in science and its applications. This deficit is at the heart of the Sustainable Development Goals (SDGs), obviously enshrined in SDGs, but also embedded in the targeting of social justice outcomes and the promise to "leave no one behind."

Clearly, the current situation is not satisfactory.

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* Speech given as Assistant Director-General for Social and Human Sciences at the UNESCO. Since 10 February 2020, Ms Al-Nashif is Deputy High Commissioner for Human Rights.

UNESCO has two global priorities – gender and Africa – and they are at the heart of our discussion today.

Concerns are voiced by many countries about the low participation and learning achievement of girls in STEM education. In recent years, the number of women involved in science has significantly increased, notably in the life sciences and the social and human sciences, but women remain significantly underrepresented in science overall, with particular deficits in mathematics and engineering. Gender differences in science and mathematics achievement begin at the end of primary education, deepen in secondary education, and are accompanied by fewer women than men pursuing these fields in higher education. Globally, only 35 % of higher education students in STEM are women. Within STEM subjects, women are least likely to be well-represented in fields projected to be critical for jobs of the future, including information and communication technologies.

UNESCO's 2017 global report, Cracking the Code, revealed that gender differences in STEM fields do not begin with higher education. They can be traced back to numerous complex and interconnected factors embedded in the socialization and learning processes, the study of which is an important contribution by the social and human sciences to the STEM disciplines. Among the factors that lead to gender inequalities are the way boys and girls are brought up, learn, interact, and socialize with parents, family, friends, teachers, and the wider community, and gender stereotypes about ability and options in life. (We are working now on a "masculinities" initiative that tackles root causes with a more applied approach.)

The school is also an important setting for socialization, and the entire education process can influence the quality of the learning experience and either enhance or compromise girls' engagement with STEM studies. Teachers' subject specialization, professional preparation, and support for effective teaching of STEM are critical factors, influencing not only girls' performance in but also their choice of future studies and careers. Furthermore, teachers represent some of the strongest early role models for students outside the family, having the potential to promote positive beliefs about women's abilities to invalidate harmful stereotypes.

Getting more girls and women into STEM education – and ultimately STEM careers – requires holistic and integrated responses that reach across sectors and that engage girls and women in identifying solutions to persistent challenges. This is how sustainable development can build on better science. Women contribute their particular perspectives, approaches, and priorities to research and development. With more women scientists, particularly in leading positions, science will provide better solutions to the problems of women and men toward sustainable development.

UNESCO, for which gender equality is a global priority, is working precisely in that direction.

To provide you with one example, in sub-Saharan Africa, UNESCO, with regional teacher training institutions, the African Union's International Centre for Girls' and Women's Education, the Forum of African Women Educationalists (FAWE), and Microsoft, is building the capacity of teacher educators, teachers, and school administrators to engage, inspire, and empower girls to take up STEM studies. By addressing the root causes of existing gender gaps and building institutional capacity, UNESCO expects to improve the interest, engagement, and achievement of thousands of girls in STEM education today and tomorrow. Doing so moves us all toward gender equality in education, where women and men, girls and boys can participate fully, develop meaningfully, and create a more inclusive, equitable, and sustainable world.

However – as important as schools are –, the significance of gender inclusiveness in science goes deeper. UNESCO's holistic approach to the "STEM education ecosystem" addresses the numerous, complex, overlapping factors and identifies action at multiple levels – individual, family and peers, school / university, and society – targeting both socialization and learning. Reaching gender equality in STEM implies encouraging further participation of girls and women at all levels of education, and providing equal opportunities for scientists and engineers throughout their careers. How science is organized professionally and how science relates to society are crucial in shaping STEM education.

A general framework for the promotion of science is offered by the Recommendation on Science and Scientific Researchers, adopted by UNESCO's General Conference in 2017.

I'd like to refer to some key points of the text.

First, the Recommendation offers a general vision of science and of its importance. Its preamble recognizes "the significant value of science as a common good," the need in each country for a "cadre of talented and trained personnel," the importance of "open communication of results, hypotheses, and opinions," and the "necessity of adequate support and essential equipment." Furthermore, the Recommendation stresses that national policies are indispensable in giving practical substance to this vision.

Since sharing the benefits of science is a human right, the "cadre of talented and trained personnel" cannot exclude or even underrepresent women. The preamble of the Recommendation notes the importance of "a fair status for those who actually perform research and development in science and technology, taking due account of the responsibilities inherent in and the rights necessary to the performance of that work." This means, obviously, that ensuring fair status for women in science – all the way from primary school to the highest levels of professional achievement – is a commitment to which all UNESCO's Member States have signed up.

This commitment is made explicit in Article 13 of the Recommendation, which states that "Member States should take measures to… actively encourage women and persons of other under-represented groups to consider careers in sciences, and endeavor to eliminate biases against women and persons of other under-represented groups in work environments and appraisal."

The Recommendation on Science and Scientific Researchers is thus a very useful tool for achieving more inclusive science. It reflects the clear political commitments of UNESCO's Member States, and it also has a monitoring mechanism – so Member States will be reporting periodically what they've been doing to open science to women and how well they have succeeded.

In supporting its Member States to fulfil the ambition of the Recommendation, UNESCO has in particular built the foundations of gender-responsive quality STEM education through its STEM and Gender Advancement (SAGA) global project. The SAGA project is offering governments and policy-makers a variety of tools to help reduce the current global gender gap in STEM fields existing at all levels of education and research. The SAGA methodology has the potential to help address other factors of exclusion or inequitable access, such as race and income, and also to connect issues specific to STEM education and research with the social and human sciences at a time when there is great demand for new forms of interdisciplinarity.

Among the important lessons that arise from the SAGA approach is the importance of details and of looking at career paths. Alongside enrollment in STEM education at various levels, we need to be looking closely at how women's careers differ from men's, in order to understand the contributing factors and to address them. This sociological approach to science is an important example of the way in which different disciplines can work productively together to make the world a better place!

In most disciplines of the social and human sciences, women represent a majority of undergraduate cohorts. Yet, by graduate school, the gender difference has begun to fall, and gradually, as one reaches senior positions in universities, men have become the majority. The reasons for these differential paths are fairly well known. Some relate to issues of work-life balance which tend to be particularly acute in scientific careers because the timing of a PhD tends to clash with starting a family. In principle, these should not be burdens falling disproportionately on women. In practice, they are, and for reasons that obviously go beyond science. Obviously, there are many situations / contexts where women are impacted – if they are refugees, part of an ethnic minority, social construct / economically marginalized, or physically disabled; as such, this is all even more discriminatory / exclusionary.

This underlines why meaningful change in this area is a policy issue, requiring Member States to take concrete measures to facilitate scientific careers for women. Raising awareness, however important, will not be enough. Hence the value of the process to monitor implementation of the Recommendation on Science and Scientific Researchers, which offers a convenient and widely shared framework to consider both the problems and the possible solutions. I hope that all of you, in your respective institutional capacities, will feel empowered to use the Recommendation as a reference and as a tool that can focus energies at national levels to work towards practical, incremental change.

I should like to close with a reminder of why these practical policy issues matter so much.

Human rights for women, as participants in science, are part of making science better for everyone. This is not, in other words, a zero-sum game in which men will be called upon to make sacrifices in order to improve opportunities for women. Scientific truths are impersonal and timeless, but that does not mean that the value of science is indifferent to how science is done and who does it.

Let me take just one example: artificial intelligence. As you know, there is increasing concern about what specialists call "algorithmic bias" – the ways in which information processing systems produce discriminatory outcomes for reasons that are hidden in the details of their programming or of the data they are trained on. Sometimes, those hidden features are deliberate. But more often, they are a consequence of assumptions made unconsciously or unthinkingly by those who designed the systems. Any human has unconscious biases – it's part of what we are. So the only way of protecting information systems against structural bias is to make sure that a wide range of different kinds of humans are involved at all levels. The tech community isn't as inclusive as it could be, and this has potentially massive consequences.

Thus, more inclusive AI will be better AI.

This issue is currently of great importance to UNESCO, which will be convening a major international meeting on the subject in January 2019, with particular emphasis on the ethical challenges that arise from new kinds of data-driven applications. And, as you can see, it's not a separate issue from gender equality in science, technology, and innovation; the two things are essentially, intimately connected.

We could say the same for each of the Sustainable Development Goals. Ending extreme poverty, universalizing education, making cities livable, addressing climate change – all of these and more demand better science that can be more effectively applied, which means science that is embedded in the diversity of the world. Science that is not blinkered or trapped within unconscious biases, but science that grasps the full complexity of its objects and the full range of different approaches to their analysis.

There is a right for everyone to participate in science and enjoy its benefits. There is also an imperative responsibility to improve science and to use it better.

This is clearly an imperative in these challenging times when we need, more than ever, a global voice of science that speaks to truth, and facts, and evidence.

Declaration on the Human Right to Science* Education
Berlin, October 1st, 2018

Participants of the International Symposium on Human Rights and Equality in STEM education agreed upon the following final declaration on the right to science education and its implementation.

1. The right to science education and STEM

Referring to the Universal Declaration of Human Rights, participants underline the existence of a right to science education as an inherent aspect of the right to education, the rights to information and the right to enjoy the benefits of scientific progress including the right to contribute to scientific progress as enshrined in Art. 26 and 27 UDHR. As a human right it deserves a human rights approach to science education. The right to science education pursues the goals of acquiring knowledge as an end in itself, of participating as a useful member in society and of the development of the full personality of learners. The right to science education encompasses the dimensions of availability of and accessibility to science education, the component of acceptability referring to the quality thereof, as well as the dimension of adaptability of science education, in order to meet the requirements of scientific as well as societal dynamics.

2. The access to science education and STEM

Participants are fully aware of structural and societal barriers as well as their intersectional nature and effects in the access to science education, particularly for women and minorities, explicitly referring to the UNESCO Recommendation on Science and Scientific Researchers 2017. Science education needs to follow an integrated approach with the general vision of science as a common good. Accessibility encompasses access and achievement in all forms and levels of science education. Access without discrimination follows from the Convention Against Discrimination in Education and the Convention on Technical and Vocational Education.

* Science summarizes what is considered as natural sciences (e.g. physics, chemistry, biology) as well as technology, engineering, mathematics, informatics and research in these fields.

3. The <u>quality</u> of science education and STEM

Science education must be acceptable to learners. It needs to be up-to-date and presented in a way that learners can get full benefit of learning, as well as using science for their own benefit. Acceptability includes the knowledge content and research. Knowledge and research which reproduce inequality are therefore regarded as not acceptable. The identities that are co-constructed and reproduced through science and STEM education and the manner in which individuals are identified, addressed, tokenized and positioned within science education, must be acceptable to the individuals and may not harm the individuals' dignity. Acceptability of science education excludes any form of stigmatization by its content, its methodologies, its didactics or its applications.

Recommendations

Education Institutions

With reference to the UNESCO Recommendation on Science and Scientific Researchers, we call upon its member states taking measures to actively encourage women and persons of underrepresented groups to consider careers in sciences and to periodically report on their success to the international community, as stated in Art. 13. Further, with reference to the Montreal Declaration of the International Conference on Human Rights Education 2017 (3. Specific Recommendation, 3.2 Higher Education Institutions), states shall take all measures to ensure that science educators at all levels of education should be trained in human rights and should gain awareness of the right to science education.

Research in STEM

Researchers in the field of STEM should develop new knowledge and technologies being guided by critical reflection as well as by the vision of science as a common good. Novel scientific knowledge should be constantly assessed regarding the reproduction of social inequality. We call upon the decision-makers in the field of science to provide the frame for responsible research and to care for respective accountability at all levels.

Quality of STEM Education

Within the responsibility of decision makers in the education system, the knowledge content of STEM, as conveyed through teaching material amongst others, should be revised to take inclusiveness as described above and in the respective international standards into account. Furthermore, scientific content should be revised regarding the conditions of social inequality under which the content was developed.

The Human Right to Science Education Re-Examined

Klaus Starl

With *Science Education Unlimited* (Tajmel & Starl, 2009), we postulated a human right to science education for the first time. We did this within the framework of the specific support action (ref. EC FP6) called Promotion of Migrants in Science Education (PROMISE). We derived the right to science education from the broader right to education for the very reason that science is *relevant* for pursuing the objectives of the right to education. We focused on the dimension of acceptability – because it relates to quality education – as well as the dimension of accessibility – a result of our intersectional approach employed in PROMISE. In this project, we elaborated the intersectional and multi-level nature of barriers of race, gender, class, and body as limiting principles in the access to and achievement in (science) education. Individuals – rights holders – in vulnerable conditions were understood as systematically, socially, and normatively "disabled." It was obvious for us that a human rights-based approach was the adequate response to this challenge.

The right to science education expands new horizons of opportunity for people all over the world; and as a right, it needs to be recognized and protected. As a consequence, everyone is entitled to both education and science, as these are part of human culture. This makes a profound difference for those excluded from participating in science or from enjoying its benefits.

Since the publication of *Science Education Unlimited,* the world has changed rapidly and massively in terms of global(ized) phenomena, as well as in relation to the programmatic, political, and normative responses by the international community, particularly by the UNESCO, to our specific concerns.

Migration and mobility, encompassing all its forms and motives, has not only increased but has become part of the culture of a globalized world. This reality demands globalized standards on equal opportunities to live the life one values. Climate change, already discussed for decades, has been recognized as a major threat to humankind and all life on earth. Only global efforts might mitigate the tremendous impacts of climate change. Economic and political power relations have shifted and caused new tensions leading to economic crises as well as conflicts and wars. Again, a multilateral approach seems the only option to harmonize conflicting interests in a way that continues to uphold human rights and security. Digitalization, while offering many benefits, has huge disruptive potential. However, it highlights that we live in a world of technology that is also part of human culture. Anyone unable to participate through technology is at risk of being left behind. Furthermore, the coronavirus pandemic and its global dimensions have dramatically demonstrated the limits of our lifestyles, as well as the systemic deficiencies and structural disadvantages along the lines of poverty, class, race, and other factors contributing to inequality. Last but not least, the pandemic has demonstrated the lack of resilience of our governmental and social systems, particularly in the healthcare and education sectors.

Nevertheless, we have seen a wide range of developments addressing these issues, including the relevant concern of this paper: the right to science education. The *Global Compact on Migration* addresses the globalization of improved human rights standards. Besides offering critiques from human rights experts, the Sustainable Development Agenda achieved something extraordinary: it brought the dimensions of sustainability, resilience, and social inclusiveness under one umbrella. This must be highlighted as a major step in international politics which, until then, had followed these strands only separately. The development agenda recognizes the importance of education and technology in a good way. Under its slogan "leave no one behind," it focuses on equality and quality of education. It further calls for the resilience of education systems. The *New Urban Agenda* translates the sustainable development agenda, with a strong focus on the relevance of human rights, to local government agendas. In addition, here inclusiveness, education, and science are pivotal points. In order to cope with globalized phenomena and to comply with core values, including human rights, the international community organized programmes, such as Global Citizenship Education (GCED), Education for Sustainable Development (ESD), and others, ensuring and promoting quality education, including science education. UNESCO passed its Declaration on Science and Scientific Researchers in 2017, and a new comment on the right to science came in 2020 (see Oberleitner in this book).

All these developments, which will be described and analysed in more detail below, confirm that the right to science education is nowadays seen as an intrinsic part of the right to education, as well as a right required as a precondition for the empowerment of the right to science. Thus, we embrace a strengthened approach to the right to science education by combining the right to education with the right to science. Furthermore, we extend the 4-A Scheme encompassing availability, accessibility, acceptability, and adaptability – which has gained attention within both education and science – with a further dimension: accountability.

1. The Right to Education

Education is both a human right itself and an indispensable means for realizing other human rights. It is enshrined in Art. 26 of the Universal Declaration of Human Rights (UDHR, 1948). In the following, we concentrate on Art. 13 of the International Covenant on Economic, Social and Cultural Rights (ICESCR 1966) as the most extensive provision on education among all human rights texts. The ICESCR, as ratified by most states, is legally binding. The right to education has a solid basis in international and regional human rights law in general.[1]

The Committee on Economic, Social and Cultural Rights (CESCR) introduces its 13th General Comment on the right to education (as stipulated in Art. 13 ICESCR, 1966) by explaining the essence and underlining the importance of the right to education: "[A]s an empowerment right, education is the primary vehicle by which economically and socially marginalized adults and children can lift themselves out of poverty and obtain the means to participate fully in their communities." However, this is not only true for marginalized people, but for everyone. The right to education facilitates the relationship between the individual and the society in which he or she lives. Education should empower the individual to fully participate in society. "Increasingly, education is recognized as one of the best financial investments States can make." The CESCR highlights that the right to education is economically rational for the society, its economy, and the government. Further, it states that "[…] the importance of education is not just practical: a well-educated, enlightened and active mind, able to wander freely and widely, is one of the joys and rewards of human existence" (CESCR, 1999, para. 1). Thus, education is, above all, acknowledged as an end in itself and as a part of human culture.

The rationale behind the right to education can be considered from the perspective of the individual person, the society, or the state and its normative systems. Education aims to develop one's personality and enables a person to participate fully in the society to her or his benefit and is a prerequisite to "liv[ing] the life one values" and a "means to achiev[ing] well-being" (Sen, 1999). Every society or state needs an educated labor force and an informed electorate. Without education, a society cannot ensure its future. Furthermore, education functions as a multiplier by enhancing all rights and freedoms while jeopardizing them when these rights and freedoms are violated (Tomaševski, 2006, p. 7; for an extensive debate on the various benefits, see UNESCO and Right to Education Initiative, 2019, p. 30).

1 Besides the Universal Declaration of Human Rights (1948, Art. 26), the Convention against Discrimination in Education (CADE, 1960) and the ICESCR (1966, Art. 13), it is laid down in Art. 7 of the Convention on the Elimination of all Forms of Racial Discrimination (CERD, 1965), Art. 10 of the Convention on the Elimination of all Forms of Discrimination against Women (CEDAW, 1979), Art. 28 of the Convention on the Rights of the Child (CRC, 1989), Art. 24 of the Convention on the Rights of Persons with Disabilities (CRPD, 2006), a wide range of other international declarations and resolutions (particularly the UNESCO Convention on Technical and Vocational Education (1989) and the UNESCO Recommendation concerning the Status of Teachers (1966) as well as in the additional protocol (Art. 2) to the European Convention for the Protection of Human Rights and Fundamental Freedoms (ECHR 1950, Protocol 1 of 1952). The right to education, in whole or in part, is guaranteed in at least 48 legally binding instruments, 28 of which are regional, and 23 soft law instruments. For a detailed compilation see UNESCO and Right to Education Initiative (2019), The right to education handbook.

Art. 13 (1) ICESCR stipulates the following objectives: Everyone has the right to education. Here, four goals of education are mentioned: first and most fundamentally, education "shall be directed to the full development of the human personality and the sense of its dignity"; second, education "shall strengthen the respect for human rights and fundamental freedoms"; third, education "shall enable all persons to participate effectively in a free society"; finally, the goal of education is to "promote understanding, tolerance and friendship among all nations and all racial, ethnic or religious groups, and further the activities of the United Nations for the maintenance of peace."

The CESCR states that all explications and interpretations of the other conventions and declarations in respect to the right to education are implicitly encompassed by Art. 13 (1) and that these provisions are seen as concrete developments and elaborations of the objectives of education (CESCR, 1999, para. 5).

The respect for as well as the protection and the fulfilment of the right to education is the States' responsibility. However, in many countries, education was introduced and made compulsory long before the international human rights regime. As Tomaševski[2] pointed out, education is an important means to achieve collective political and economic goals (Tomaševski, 2006, p. 7; UNESCO and the Right to Education Initiative, 2019, p. 131). On the other hand, education can be abused to misguide the youth of a country. Therefore, Art. 13 (3) ICESCR guarantees the liberty to freely choose schools other than the established public schools.

1.1 The 4-A Scheme

The 4-A Scheme sets the conditions that must be met for the compliance of education, as an institution and a practice, with the human right to education. Education in all its forms and at all levels shall exhibit the interrelated and essential features of "availability, accessibility, acceptability and adaptability." This so-called 4-A Scheme was suggested and formulated by the CESCR in the General Comment 13 (CESCR, 1999, para. 6). The 4-A Scheme is both a threshold and an evaluation tool for the compliance of a respective education system with the right to education under the ICESCR (UNESCO and Right to Education Initiative, 2019, p. 77).

1.1.1 Availability

Functioning educational institutions must be available in sufficient quantity. Functionality requires, among other features, well- and appropriately-trained teachers receiving domestically competitive salaries, as well as appropriate teaching materials of good quality. The provision shall be in accordance with the terms of economic capacity and needs

2 Katarina Tomaševski was the UN Special Rapporteur on education from 1998 to 2004 and founder of the Right to Education Initiative.

of a country. This includes facilities such as libraries, computer facilities, and information technology (CESCR, 1999, para. 6 (a)).

Art. 13 (2) (b) ICESCR states that secondary as well as vocational education shall be "generally available." This signifies that secondary education is neither dependent on a student's apparent capacity nor ability nor merit. Further, it means that secondary education will be provided in a way that it is available to all without discrimination.

1.1.2 Accessibility

Education in all its forms, institutions, and programs must be accessible to everyone without discrimination. With regard to Art. 13 (2) (a) and (b), the CESCR clarifies additionally that "the principle of non-discrimination extends to all persons of school age residing in the territory of a State party, including non-nationals, and irrespective of their legal status" (CESCR 1999, para. 34). Accessibility has several interrelated dimensions (CESCR 1999, para. 6 (b); UNESCO and Right to Education Initiative, 2019, p. 77):

(i) Non-discrimination: Education must be accessible to all, especially to all individuals or groups who find themselves in vulnerable conditions. The principle of non-discrimination has to be implemented in law and fact. The Sustainable Development Goals (SDGs) stipulate in their Goal 4 on education the priority of non-discrimination, however, in a slightly different wording: "Inclusion and equity in and through education is the cornerstone of a transformative education agenda, and we therefore commit to addressing all forms of exclusion and marginalization, disparities and inequalities in access, participation and learning outcomes. No education target should be considered met unless met by all."[3]

(ii) Physical accessibility: Education has to be "within safe physical reach, either by attendance at some reasonably convenient geographic location (e.g., a neighbourhood school) or via modern technology (e.g., access to a 'distance learning' programme)" (CESCR 1999, para. 6 (b)). Physical accessibility is further specified in the Convention on the Rights of Persons with Disabilities (CRPD), as well as in the Convention on the Rights of Children (CRC). Inclusive education is based on the principle that all children should learn together, regardless of their differences. Inclusive education recognizes the capacity of every person to learn and acknowledges that each person has different strengths, requirements, and learning styles. Inclusion, therefore, takes an individualized approach with flexible and adaptable curricula as well as teaching and learning methods. By taking into account differences among learners, inclusive education promotes respect for and the value of diversity and seeks to combat discriminatory attitudes both in the classroom and society. Inclusive education ensures every child's eeffective access to edu-

3 Incheon Declaration and Framework for Action for the Implementation of Sustainable Development Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all (WEF, 2015, para. 7).

cation. Reasonable accommodation includes the accessibility of facilities for people with impaired mobility, allowing students extra time for their tasks if needed and guaranteeing the same access for students with mental health support needs (UNESCO and Right to Education Initiative, 2019, p. 91).

(iii) Economic accessibility: Education has to be affordable to all. This dimension of accessibility is often underestimated or misunderstood. Firstly, economic accessibility requires that admission to school be free. However, there are enormous costs besides school fees. Secondly, the right to education requires an effective subsidy and fellowship system (Art. 13 (2) (e) ICESCR). [Relative] poverty, social or economic status, or birth must not prevent individuals from access to all forms and levels of education.

Accessibility means having the *de facto* opportunities to access all forms and levels of education. This relates to the social and cultural capital of a person. This concept of "capabilities and the freedom to achieve well-being" (Sen, 1986) suggests a "pedagogy of poverty" (Motakef, 2006, p. 19). In respect of social class and economic standing, the considered education systems clearly fail. They tend to reproduce existing social and economic inequality, as we learn from a long list of educational research (e.g., OECD, 2018; Schleicher, 2018). The scientific literature proves that the lower the household's disposable economic resources, the less likely it is that the student will achieve a high degree of education. "Achieving greater equity in education is not only a social justice imperative; it is also a way to use resources more efficiently, increase the supply of skills that fuel economic growth, and promote social cohesion. Not least, how we treat the most vulnerable students and citizens shows who we are as a society" (OECD, 2018, p. 21).

The call for strict formal equality, building only on consistency of equal treatment, was rejected by the CESCR as it "reflects inequality." CESCR favors the concept of equal opportunities in education. In addition to compensation for past disadvantages or less favorable initial conditions (e.g., relative poverty), this includes so-called affirmative action. The committee states that "[t]he adoption of temporary special measures intended to bring about de facto equality for men and women and for disadvantaged groups is not a violation of the right to non-discrimination with regard to education" (CESCR, 1999, para. 32).

The right to education is not limited to the right to access education but, in addition, requires the right to receive an education of good quality (UNESCO and Right to Education Initiative, 2019, p. 131).

1.1.3 Acceptability

> "The form and substance of education, including curricula and teaching methods, have to be acceptable (e.g., relevant, culturally appropriate and of good quality) to students and … [their] parents …" (CESCR, 1999, para. 6 (c)).

The requirement of education being *relevant* indicates that science education certainly is, as addressed by Art. 13 (2) (b) ICESCR on secondary and vocational education.

Taking a closer look at what is meant by *culturally appropriate* reveals an obligation of the State to deliver secondary and vocational education that is culturally sensitive toward the diversity of students regarding teaching staff, curricula, and equipment. Any education shall be engaged in promoting the mutual understanding of cultures. Furthermore, education shall be committed to enabling students to acquire the necessary knowledge and skills for self-reliance in the various sectors of the economy and contribute to the general welfare of the respective society (see CESCR, 1999, para. 16). The benchmarks for the appropriateness are those measuring the achievement of the objectives of the right to education. These include developing one's personality, strengthening respect for human rights, facilitating societal participation, and promoting understanding, tolerance, and friendship among all national, ethnic, or religious groups. (For the implementation in science education, see Tajmel, 2017).

Education shall be of *good quality*. The term "quality education" already appeared in Art. 1 (2) CADE. The CRC General Comment 1 paras. 2 and 9 further specify the mention of good quality in CADE: "The curriculum must also enable students to acquire core academic knowledge (subject knowledge) and basic skills, including literacy and numeracy. Literacy and numeracy are vital to the realization of the right to education [...] That being said, education should [...] also impart 'essential life skills,' so that 'no child leaves school without being equipped to face the challenges that he or she can expect to be confronted with in life.' This includes such skills as: 'the ability to make well-balanced decisions; [...] relationships and responsibility, critical thinking, [...]'".

SDG4-Education 2030 gives particular emphasis to quality education and learning. Quality education includes a focus on strengthening STEM (science, technology, engineering, and mathematics) education (Incheon Declaration, 2015, p. 33). The content of such education must be relevant with a focus on both cognitive and non-cognitive aspects of learning, leading to informed decision-making. This can be achieved by education for sustainable development (ESD)[4] and global citizenship education (GCED)[5] (Incheon Declaration, 2015, p. 49).

4 ESD empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity. It is about lifelong learning and is an integral part of quality education. ESD is holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment. It achieves its purpose by transforming society. (UNESCO. 2014. Roadmap for Implementing the Global Action Programme on Education for Sustainable Development.)

5 GCED aims to equip learners with the following core competencies: a) A deep knowledge of global issues and universal values such as justice, equality, dignity and respect; b) cognitive skills to think critically, systemically and creatively, including adopting a multi-perspective approach that recognizes different dimensions, perspectives and angles of issues; c) non-cognitive skills including social skills such as empathy and conflict resolution, and communicative skills and aptitudes for networking and interacting with people of different backgrounds, origins, cultures and perspectives; and d) behavioral capacities to act

1.1.4 Adaptability

The principle of adaptability requires education to adapt to the needs of changing societies and respond to the needs of students within their diverse social and cultural settings. The principle of adaptability applies to the education system as a whole as well as to all forms and levels and all of its components, such as equipment in schools or universities, teaching materials, curricula, and the knowledge and skills of the teaching staff. Neglecting diversity in the supply and maintenance of education disadvantages certain groups, particularly minorities or women, by limiting their access and acceptance. This results in privilege being granted to others and is incompatible with the concept of human rights. "When considering the appropriate application of these 'interrelated and essential features' [the 4-A Scheme, remark of the author] the best interests of the student shall be a primary consideration" (CESCR 1999, para. 7).

The SDG framework contributed another concern to the dimension of adaptability of education, namely resilience. Education needs to be adaptable to emergency situations. The chapter "Addressing education in emergency situations" clearly mentions pandemics and their consequences. "Crisis is a major barrier to access to education." The fact is that education in emergency contexts has to be immediately protected, providing life-saving knowledge and skills and psychosocial support to those affected by crisis. Therefore, para. 26 states that "[c]ountries must institute measures to develop inclusive, responsive and resilient education systems." It is thus recommended to "[s]upport a comprehensive approach to making schools resilient to disaster impacts of all sizes" through "safer school facilities, school disaster management, and risk reduction and resilience education") and to "[p]rovide distance learning, ICT training, access to appropriate technology and necessary infrastructure to facilitate a learning environment at home and in conflict zones and remote areas, particularly for girls, women, [...]" (Incheon Declaration, 2015, p. 45).

What we witnessed during the coronavirus pandemic were severe weaknesses of education systems. We experienced governmental paternalism, sexism, unacceptability in respect to quality of education, lack of adaptability, limited and selective access, even availability issues in wealthy economies and self-complacency of governments deeming their education systems effective and appropriate. In general, a human rights-based approach to education by governments was lacking. The crisis revealed that too many governments share the attitude that education is a duty of learners rather than their right. Elderly male ministers were claiming that parents and students alike do not have to fear that non-compliance with their duties would be sanctioned by the government.

Obviously alerted by these observations, the SDG-Education 2030 Steering Committee published the Recommendations for COVID-19 Education Response on 2 April 2020:

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collaboratively and responsibly, and to strive for collective good. (UNESCO. 2013. Outcome document of the Technical Consultation on Global Citizenship Education: Global Citizenship Education – An Emerging Perspective.)

> "Make inclusion and equity the guiding principle of all COVID-19 education responses. Learning cannot stop – the protection of the right to education is all the more primordial in times of crisis. The SDG-Education 2030 Steering Committee calls on all governments to renew their commitment to leave no single learner behind. Inclusion and equity must be the guiding principle of every educational response to prevent educational, socio-economic and digital inequalities from widening and to ensure equal opportunities for all – especially for the most vulnerable and marginalized, including refugees."

1.2 Accountability

States' failure in complying with the standards of the right to education during the emergency situation of COVID-19 leads us to discuss one further "A": Accountability. Even though not neglected by the CESCR, it was not incorporated in the 4-A Scheme, probably because it cross-cuts all other "A's." Maybe, it was not considered an "A" because of the lack of legal accountability at that time. However, arguing that all "A's" are interrelated and because of the optional protocol to the ICESCR on the justiciability of economic, social, and cultural rights[6], I propose a 4-A^{+} Scheme with reference to the Right to Education Initiative (UNESCO and Right to Education Initiative, 2019, chap. 8).

The Global Education Monitoring (GEM) Report defines accountability as "a process aimed at helping individuals or institutions meet their responsibilities and reach their goals. Actors have an obligation, based on legal, political, social or moral justifications, to provide an account of how they met clearly defined responsibilities"[7].

Accountability has two core aspects: responsibility for compliance and liability for implementation. The latter has a value for rights-holders only if there is an accessible procedure for law enforcement available.

> "Accountability starts with governments, as primary duty bearers of the right to education. But the national legal framework must allow citizens to challenge the violation of the right to education in court. Currently, this is possible only in 55% of countries. The Steering Committee highlights the importance for all countries of ensuring the right to education be included in domestic legal frameworks and prominent in policy documents. Governments should therefore take steps towards developing credible and efficient regulations with associated sanctions for all education providers, public and private, that ensure non-discrimination and the quality of education."[8]

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6 Optional Protocol to the International Covenant on Economic, Social and Cultural Rights (adopted 10 December 2008, entered into force 5 May 2013) (Doc. A/63/435.) (OP-ICESCR).

7 UNESCO. 2017/8. Global Education Monitoring Report 2017/8: Accountability in education – Meeting Our Commitments. Paris, UNESCO, p. 2.

8 SDG-Education 2030 Steering Committee (March 2018), Statement of Support, Accountability and the Right to Education, ED-2018/SC/2.

Remarkably, the GEM 2017 gives a specific argument for the human right to science education by elaborating on the human rights accountability of SDG 4 objectives.[9] Analysing SDG 4.3 ("ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university"), the paper states that technical and vocational education and training (TVET) – however, not fully identical with STEM education – is part of both the right to education and the right to work (ICESCR, Articles 13(2)(c) & 6(2)). It applies to all levels of education (CESCR General Comment 13, para. 15) and should be understood as a component of general education (CESCR General Comment 13, para. 16). CEDAW applies TVET to women and girls. CRC reaffirms that the ICESCR and CRPD prohibit discrimination in access to vocational education and requires States to ensure reasonable accommodation is provided for persons with disabilities (Background paper, 2017, pp. 12–13).

2. The Human Right to Science

"It is our responsibility to ensure that science and its applications are in harmony with the full set of universal standards. A **human-rights approach to science** must be at the heart of what we want to be a sustainable future. Key steps are to define its normative content, to elucidate the related state obligations, and also to consider what are the necessary conditions for its implementation." (Nada Al-Nashif, UNESCO Assistant Director-General for Social and Human Sciences)[10]

"Science is more than a material dimension; it means access to knowledge. It is not only an instrument to achieve material benefits but **a cultural right in itself**. More than access to its applications, **science means participation** and is essential to build democratic societies. […] The second challenge is how to foster participation and make science as a human right a reality. Science needs to be **at the service of humanity.**" (Mikel Mancisidor, President of the International Institute for the Human Right to Science and Vice-Chairperson of the UN Committee on Economic, Social and Cultural Rights (CESCR))[11]

"When we connect science to social problem solving, we can enhance better understanding on the importance of science. We need to show how physics, chemistry, and formulas have a value to improve knowledge on how to solve problems. Three essential tools are necessary to make for continuous access to science: access to education at every level, access to information and communication technologies, and funding." (Margaret Vitullo, Deputy Director of the American Sociological Association (ASA))[12]

"Science, a Human Right: science centers and museums play an important role in **making science accessible to all**. They share UNESCO's objectives of linking science more closely

9 Paper commissioned for the 2017/8 Global Education Monitoring Report, Accountability in education: Meeting our commitments.

10 At the Latin American and Caribbean Conference on Social Sciences held by the Latin American Council of Social Sciences (CLACSO), in Buenos Aires, Argentina, on 21 November 2018.

11 See FN 10.

12 See FN 10.

with society, sharing scientific knowledge, and fostering the engagement of young people in science, technology, and innovation." (Flavia Schlegel, UNESCO Assistant Director-General for Natural Sciences)[13]

"The right to enjoy the benefits of scientific progress and its applications: A **human rights-based approach to science** can ensure inclusive access to the benefits of scientific advancements, foster the place of women in sciences, and guide the establishment of sound policies in ethical issues in science, innovation, and technology. UNESCO promotes the right to share in scientific advancement by enabling those in marginalized communities to contribute to and benefit from scientific progress. The Organization also takes action to preserve the diversity of knowledge systems and the sustainable use of natural resources **in connection with the rights of indigenous peoples**.

Science must **respond to societal needs** and global challenges. **Public understanding and engagement with science**, and citizen participation including through the popularization of science are essential to equip citizens to make informed personal and professional choices." (UNESCO, 2018)[14]

"Capacity in science and technology is a key element in economic and social development. **Promoting science education at all educational levels**, and scientific literacy in society in general, is a fundamental building block to building a country's capacity in science and technology. Science education has been a priority for UNESCO since its inception.

Science, technology, engineering, and mathematics education (STEM) is important for developing and developed countries alike, to increase public awareness, understanding and literacy regarding science, engineering and technology, [...] Particular emphasis is given to encouraging young people, and especially young girls, to pursue careers in science." (UNESCO, 2018)[15]

"All people should benefit from scientific breakthroughs, of course. But with the complex connections between emerging technologies and social systems, everyone also should have the **opportunity to engage with the science, technology, engineering and mathematics (STEM)** fields and 21st century skills that make those discoveries possible. This should not just be an opportunity, however. This **is a basic human right.**" (Dorgelo, 2018)[16]

All these important statements were made right after the UNESCO's General Conference passed the Recommendation on Science and Scientific Researchers in November 2017[17]. Out of these statements we can draw several conclusions for the right to science education and on the human rights-based approach to its implementation:

- Science must meet all universal human rights standards.
- Science and technology are characteristic aspects of human culture.

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13 At the World Science Day for Peace and Development 2018.

14 Available at https://en.unesco.org/human-rights/science

15 Available at https://en.unesco.org/news/science-human-right-need-unified-concept

16 Cristin Dorgelo 2018, Learning about science is a human right, available at https://blogs.scientificamerican.com/voices/learning-about-science-is-a-human-right/

17 The Recommendation on Science and Scientific Researchers, UNESCO 2018, Adopted on 13 November 2017 by the General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO), available online at: en.unesco.org/recommendation-on-science

- Participating in science and research is part of human culture.
- Benefitting from the results of science is a right, unless science is meaningless, as science shall be focused on societal needs, and thus it must be relevant, of good quality, and non-discriminatory in all its aspects.
- The access to knowledge, scientific practice, and its benefits must be inclusive and needs to be guaranteed without discrimination.
- Knowledge about science is a precondition for informed personal decision-making.
- Participation in science requires scientific literacy, which shall be acquired through science education.
- Science needs to be gender sensitive.
- Science needs to recognize the diversity of knowledge systems and the sustainable use of natural resources in connection with the rights of indigenous peoples.
- Science must be socially responsible.
- Science institutions and states shall be accountable for guaranteeing responsibility, quality, inclusiveness, and accessibility without discrimination.

These conclusions are in line with the provisions enshrined in the UNESCO Recommendation on Science and Scientific Researchers (2018), which guarantees that everyone has the right to participate freely in the cultural life of the community and to share scientific advancement and its benefits. Science is a common good. Science education must serve indigenous capability to perform science and scientific research and development must serve indigenous peoples' wellbeing in an enhanced spirit of responsibility towards humankind and the environment.

Institutions are responsible for research and development, including science education (Art. 2 (c)). Research and development are an explicit part of the effort to build a society that will be more humane, just, and inclusive in the protection and enhancement of the cultural and material well-being of its citizens in the present and for future generations (Art. 4). Member States should take measures to ensure that without discrimination on the basis of "race, color, descent, sex, gender, sexual orientation, age, native language, religion, political or other opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability, all citizens enjoy equal opportunities for the initial education" (Art. 13 (a)). Further, these measures should "(b) abolish inequalities of opportunities; (c) in order to remediate past inequalities and patterns of exclusion, actively encourage women and persons of other under-represented groups to consider careers in sciences, and endeavor to eliminate biases against women and persons of other under-represented groups in work environments and appraisal." Finally, the recommendation calls for strengthening all sciences, technology, engineering, and mathematics education, in schools and other formal and informal settings (Art. 14 (a)). Art. 24 (c) again highlights that the support for individuals from under-represented groups entering and developing careers in research and development is a condition for success.

3. The Human Rights-Based Approach to Science Education

Human rights are rights of self-determination under the terms of equality of rights for all. States have a threefold obligation for every human right: to respect, to protect, and to fulfil the right of everyone without distinction. The fulfilment obligation has again two important components: firstly, to promote and facilitate the *de facto* enjoyment of human rights and, secondly, to provide the means and opportunities to enjoy those rights. Complying with these obligations is currently called a human rights-based approach.

The human rights-based approach to science education underscores the complementary relationship between the right to education, on the one hand, and the right to science, on the other, linked by the principles of accessibility and acceptability, and guaranteed by the principle of accountability.

From the human rights perspective, both share the same standards, corroborated by the SDG benchmarks. Science is a culture, and education enables individuals to participate in this culture. Science and education need to be inclusive, non-discriminatory, and accessible for all. Science and education have quality standards in respect to social responsibility. Both science and education, as rights, are empowerment rights, enabling individuals to develop their full personality and to responsibly act within society. The human rights-based approach to science education follows two complementary strands: firstly, science is understood as the active act of *doing* science; secondly, science offers advancements from which we can benefit.

Science is relevant to humankind. Therefore, it needs to be accessible without discrimination. Furthermore, it needs to be acceptable in terms of quality, responsibility, and accountability with regard to science content, research methodologies, and the sharing of knowledge and scientific results. Doing science requires skills besides academic knowledge.

Enjoying the benefits of science is possible only when individuals are able to identify the benefits as such. This requires critical and reflective thinking and decision-making, as well as – again – the accessibility to these qualities without discrimination.

Education aims at the development of one's personality, the ability to participate in society, and an understanding of human rights and diversity as well as the values of humankind. These objectives are measured against the 4-A$^+$ Scheme[18].

4. The Way Forward

The right to science education is rarely denied by international institutions and even agreed upon by governments. The major question is (still) whether science education in practice meets the quality standards of being relevant and appropriate, and whether

18 See section 1.2 on accountability.

access is guaranteed so that "no one is left behind," as required by the SDG framework. Progress has been made, at least at the international policy level and with the respective normative instruments and programmes. Yet there is a long way to go until education systems and practice at the local level catch up with these developments.

Progress has certainly been made in many aspects. In *Science Education Unlimited*, we stated, "Barriers are exclusion mechanisms. We do not speak about disadvantages rooted in the identity of the individual. Barriers may be intentionally set or constructed, but barriers can also exist as a consequence of historical developments and a lack of socially necessary adaptation. Barriers, particularly barriers in the access to education, are often not visible at first glance. Individual responsibilities for underperformance, underachievement, limited access or whatever lack of opportunities are often suggested as reasons, but only serve to build a barrier itself" (Starl, 2009). Even in 2020, access to science education is limited for girls, and still some find the reason in the alleged lack of interest of girls in STEM. In 2009, Tajmel revealed that a male culture is dominant in STEM, hampering girls from participating in this area. The over-representation of men in textbooks, lack of gender-sensitive content, missing female role-models, absence of language-sensitive teaching methods, and the lack of opportunities for mentoring in STEM were identified as the driving factors for under-representation in STEM (Tajmel, 2009; Tajmel, 2017). Furthermore, Hazedbegovic and Tajmel (2009) proved in their comparison of the access to science education in Austria, Germany, Turkey, and Bosnia-Herzegovina that it is not girls' lack of interest in science but, rather, the environment which might be more or less selective. Meanwhile, these findings were confirmed by UNESCO's Global Education Monitoring reports: GEM 2016 showed that girls are underrepresented in textbooks and curricula. GEM 2017 revealed that the lack of female role-models and mentoring systems are root causes for fewer girls pursuing careers in STEM. Finally, GEM 2019 confirmed the finding that South-Eastern European countries offer better access to STEM compared to the rest of the world.

As a follow-up, the International Symposium on Human Rights and Equality in STEM Education "Is Access to Science (Still) Limited" was organized in Berlin on the 1–2 October 2018 under the auspices of then UNESCO Assistant Director-General Nada Al-Nashif. The aim of the symposium was to reaffirm the right to science education by a declaration passed by more than fifty scientists, education researchers, and politicians and their affiliated institutions. The declaration reveals three core issues: the right to, the access to, and the quality of science education. The declaration thus offers the following recommendations for governments, education institutions, and researchers:

Education Institutions

With reference to the UNESCO Recommendation on Science and Scientific Researchers, we call upon its Member States to take measures to actively encourage women and persons of under-represented groups to consider careers in sciences and to periodically report on their success to the international community, as stated in Art. 13. Further, with reference to the Montreal Declaration of the International Conference on Human Rights Education 2017 (3. Specific Recommendation, 3.2 Higher Education Institutions), States should take all measures to ensure that science educators at all levels of education are trained in human rights and gain awareness of the right to science education.

Research in STEM

Researchers in the field of STEM should develop new knowledge and technologies, being guided by critical reflection as well as by the vision of science as a common good. Novel scientific knowledge should be constantly assessed regarding the reproduction of social inequality. We call upon the decision-makers in the field of science to provide the frame for responsible research and to care for respective accountability at all levels.

Quality of STEM Education

Within the responsibility of decision-makers in the education system, the knowledge content of STEM, as conveyed through teaching material amongst others, should be revised to take into account inclusiveness as described above and in the respective international standards. Furthermore, scientific content should be revised regarding the conditions of social inequality under which the content was developed.[19]

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Understanding the Human Right to Science: CESCR General Comment No. 25 (2020)

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1. Towards a Human Right to Science: 1948 to 2020

The holistic approach of the Universal Declaration of Human Rights (UDHR) of 1948 included the cultural dimension of human life in its various expressions. The enjoyment of scientific progress was considered an important element of this cultural dimension. Consequently, the right to benefit from scientific advancements was conceived as a cultural human right in the Declaration as Art. 27(1): "Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits." As Chapman and Wyndham (2013) have argued, "the meaning and value of this choice are clearly open to interpretation." The American Declaration of the Rights and Duties of Man, adopted in 1948 shortly before the UDHR, contains a similar provision in Art. 13: "Every person has the right [...] to participate in the benefits that result from intellectual progress, especially scientific discoveries." In 1966, the right to benefit from scientific progress found its way into the International Covenant on Economic, Social and Cultural Rights (ICESCR). In Art. 15 of the Covenant, it became an internationally legally binding human right which corresponds to specific state obligations. By ratifying the ICESCR, states assume legal obligations to implement the rights recognized in that treaty in their domestic legislation and policies and accept international accountability and supervision (including in the form of individual complaints on socio-economic and cultural rights under the Optional Protocol of 2008, which so far covers 24 state parties). While the non-binding provision of the UDHR extends to all states, the legally binding human right to benefit from scientific progress extends to the 171 state parties to the Covenant. The 22 states which have to date neither signed nor ratified the Covenant and the four states which have only signed but not ratified (including the USA) are nevertheless obliged to refrain from any acts that would defeat the object and purpose of the treaty, as laid down in Art. 19 of the Vienna Convention on the Law of Treaties.

Benefitting from scientific progress is thus a human right. However, the Covenant captures three different and inter-related rights with relevance for science: it recognized "the right of everyone to enjoy the benefits of scientific progress and its applications" (Art. 15(1)(b)); formulated the duty of states to conserve, develop, and diffuse science (Art. 15(2); and obliged states to respect the freedom indispensable for scientific research (Art. 15(3). Within Art. 15, these three elements were woven into the broader framework of the right to participate in cultural life as provided for in Art. 15(1)(a), supported by the demand that states recognize the benefits of international contacts and co-operation in the scientific field (Art. 15(4)) and contrasted by the individual entitlement that intellectual property rights be respected for scientific and artistic products (Art. 15(1)(c)).[1] The complex language, overlapping interlinkages, and vague content of Art. 15 ICESCR gave rise to many questions as to the contour, scope, and utility of constructing a human right to science and, for decades, relegated this provision to the backyard of human rights theory and practice. In contrast, the issues to which the right to science were obviously linked – the right to food in Art. 11 ICESCR; the right to health in Art. 12 ICESCR; the right to education in Arts. 13 and 14 ICESCR; the right to an adequate standard of living in Art. 11 ICESCR; the right to seek, receive, and impart information in Art. 19 of the International Covenant on Civil and Political Rights of 1966; academic freedom; the right to development, and the right to a clean and healthy environment – received more attention and became better understood over time. The human right to science, however, was largely dormant. As the American Association for the Advancement of Science (AAAS) notes, "governments have largely ignored their Art. 15 obligations, and neither the human rights nor the scientific communities have brought their skills and influential voices to bear on the promotion and application of this right in practice."[2]

Attempts were made over time to clarify the human right to science, even though academic literature on the subject is still scarce (e.g., Claude, 2011). The United Nations (UN) General Assembly used its Declaration on the Use of Scientific and Technological Progress in the Interest of Peace and for the Benefit of Mankind of 1975 (UN GA Res. 3384 (XXX)) to make a cautious link between science and human rights. The Declaration was, however, framed in the pessimistic language of the Cold War and essentially argued that scientific and technological developments, while having the potential to improve the conditions of life of peoples and nations, create social problems and threaten human rights, fundamental freedoms, and peace. The Declaration merely urged states not to misuse science and research to wage wars, interfere with human rights, or oppress people. In 1993, the Vienna World Conference on Human Rights reaffirmed

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1 Art. 15 ICESCR reads in full: "1. The States Parties to the present Covenant recognize the right of everyone:

(a) To take part in cultural life; (b) To enjoy the benefits of scientific progress and its applications; (c) To benefit from the protection of the moral and material interests resulting from any scientific, literary or artistic production of which he is the author. 2. The steps to be taken by the States Parties to the present Covenant to achieve the full realization of this right shall include those necessary for the conservation, the development and the diffusion of science and culture. 3. The States Parties to the present Covenant undertake to respect the freedom indispensable for scientific research and creative activity. 4. The States Parties to the present Covenant recognize the benefits to be derived from the encouragement and development of international contacts and co-operation in the scientific and cultural fields."

2 https://www.aaas.org/programs/scientific-responsibility-human-rights-law/resources/article-15/about.

the right to benefit from scientific progress. In general language, it noted that certain advances – notably in biomedical and life sciences as well as in information technology – may have potentially adverse consequences for the integrity, dignity, and human rights of the individual, and called for international cooperation to ensure that human rights and dignity are fully respected in this area (Vienna Declaration and Programme of Action 1993, para. 11).

UNESCO, the United Nations Educational, Scientific and Cultural Organisation, took a more active standard-setting role in some important areas of human rights related to scientific progress. The Universal Declaration on the Human Genome and Human Rights of 1997, the Universal Declaration on Bioethics and Human Rights of 2005, and the Declaration on Ethical Principles of Climate Change of 2017 link scientific progress to human rights. The 2005 Bioethics Declaration was indeed the first global instrument to address the linkages between human rights and ethical questions in biotechnology and life sciences (Andorno, 2018). With its Recommendation on Science and Scientific Researchers of 2017, UNESCO positioned science as a common good and called for balancing the freedoms, rights, and responsibilities of researchers. The organization also championed the rights of marginalized groups and indigenous populations to contribute to and benefit from scientific progress, preserve the diversity of knowledge systems, and ensure the sustainable use of natural resources. In light of the gaps in understanding and evaluating the human right to science, it was suggested that the procedure established under UNESCO's Executive Board decision 104 EX/Decision 3.3 (1978) for handling complaints of alleged violations of human rights in its fields of competence could be used more often to further the implementation of the human right to science; a suggestion which has, however, not yielded convincing results (3rd Experts' Meeting Venice 2009, 10).

In 2005, the Committee on Economic, Social and Cultural Rights adopted its General Comment No. 17 on the right of everyone to benefit from the protection of the moral and material interests resulting from any scientific, literary, or artistic production of which he or she is the author. The text clarified this very specific element of the right to science but left larger questions unanswered. In 2009, experts adopted the "Venice Statement" in the third of a series of meetings on the right to enjoy the benefits of scientific progress and its applications, organised by UNESCO jointly with the European Inter-University Centre for Human Rights and Democratisation (EIUC) and in cooperation with the Amsterdam Center for International Law and the Irish Centre for Human Rights. The meetings examined the scope of Art. 15 ICESCR, the interdependence and interrelationship of the right to enjoy the benefits of scientific progress and its applications with other human rights, the protection of intellectual property, and the linkages between climate change, environmental protection, and the right to enjoy the benefits of scientific progress. The Venice Statement and the accompanying report of the meeting set the stage for subsequent debates. In 2012, the report of the UN Special Rapporteur on cultural rights to the UN Human Rights Council focused on the right to enjoy the benefits of scientific progress and its applications (UN Doc. A/HRC/20/26). The report emphasized the link between the right to take part in cultural life and the right to science in its different manifestations. The Special Rapporteur also considered the role of marginalized people, the responsibilities of the private research sector, the importance of open access to scientific knowledge and information, and the specific role of science education. In 2018, UNESCO convened an expert meeting on the right to share the benefits of scientific progress in the 8th Latin American and Caribbean Conference on Social Sciences held by the Latin American Council of Social Sciences (CLACSO) in Buenos Aires. Today, the AAAS can be considered the most active contributor to the debate on the contours and broader ramifications of the right to benefit from scientific progress (Mancisidor, 2015, 1). Within its "Article 15 Project,"[3] the AAAS has, over the past decade and together with the AAAS Science and Human Rights Coalition, explored the meaning of the right to science, which culminated in a global report in 2017 (Wyndham et al., 2017).

The most recent and influential development is, however, the adoption of the long-awaited General Comment No. 25 by the UN Committee on Economic, Social and Cultural Rights on 30 April 2020 (UN Doc. E/C.12/GC/25). Under the guidance of its Vice-Chairperson, Mikel Mancisidor, the independent expert body established under ICESCR used its powers to identify core elements of Art. 15 ICESCR. The document provides authoritative guidance on the content and limitations of the right to benefit from scientific progress, identifies individual entitlements, and clarifies state obligations. It will undoubtedly help governments, courts, and all stakeholders to better understand the right to science. The General Comment defines science, highlights core obligations of states, applies current human rights theory to conceptualize the right to science, and outlines recommendations for immediate action. Like other General Comments, it has the potential to influence future developments in international law, direct state practice, inform civil society and the scientific community, and lead to practical means and measures for implementing and evaluating progress in the human right to science.

A better understanding of the many manifestations of the human right to science is paramount to deal with the human rights-related challenges of rapid scientific and technological developments, allow meaningful participation in scientific advancement, clarify the role of the scientific community, understand and manage the impact of scientific progress on the socio-economic situation of individuals and communities, redress negative effects of globalization, and tackle discrimination, inequality, vulnerability and poverty (3rd Experts' Meeting Venice 2009, 4). The added value of a human rights approach to science is its ability to focus not only on the ethics of scientists and science but on broader societal and socio-economic impacts and to create rights and obligations

3 https://www.aaas.org/programs/scientific-responsibility-human-rights-law/resources/article-15/about.

of rightsholders and dutybearers on the basis of human rights law and principles such as universality, participation, non-discrimination and equality. In light of current disregard for science, scientific knowledge, and scientific progress in many circles, clarity on the contours and potential of a human right to science is of utmost importance.

2. Content and Scope of the Human Right to Science

2.1 "Science": Knowledge, Progress, Application

General Comment No. 25 starts from the observation that science is one of the areas of the Covenant to which states parties give least attention in their reports and dialogues with the Committee on Economic, Social and Cultural Rights (General Comment No. 25, para 2). As for the content and scope of the human right to science, the General Comment considers that Art. 15 CESCR consists of four distinct elements with regard to states parties' obligations: the obligation to respect the right to enjoy the benefits of scientific progress and its applications (Art. 15(1)(b)), states' obligations for the conservation, development, and diffusion of science (Art. 15(2)), respect for the freedom to engage in scientific research (Art. 15(3)), and obligations to promote and cooperate in the scientific field (Art. 15(4)). The General Comment relies on UNESCO's definition of science as laid down in UNESCO's Recommendation on Science and Scientific Researchers of 2017, according to which science is

> the enterprise whereby humankind, acting individually or in small or large groups, makes an organized attempt, by means of the objective study of observed phenomena and its validation through sharing of findings and data and through peer review, to discover and master the chain of causalities, relations or interactions; brings together in a coordinated form subsystems of knowledge by means of systematic reflection and conceptualization; and thereby furnishes itself with the opportunity of using, to its own advantage, understanding of the processes and phenomena occurring in nature and society (para. 1(a)(i)).

Science (understood as natural and social sciences) constitutes a process following a certain methodology ("doing science") as well as the results of this process, i.e., knowledge and applications (General Comment No. 25, paras 4–5). Knowledge is considered scientific only insofar as it is based on critical inquiry open to falsifiability and testability and is set apart from applied science as the implementation of science to a specific population need (General Comment No. 25, paras. 5–7). The General Comment also goes beyond science derived from research conducted by scientists and includes "citizen science" (General Comment No. 25, paras. 9–11). Science is thus understood in its twofold manifestation as scientific progress which allows access to knowledge and material goods and their applications and as a value and cultural right in itself because it enables creative thinking, participation, and empowerment and provides individual sense and meaning as an expression of human dignity.

Consequently, the human right to science has also two interrelated aspects: the individual right to enjoy the outcome of scientific research and its application, and the right to participate in science as a cultural human right. The legal provisions on the right to science do not make this distinction clear as they seem to stipulate merely a passive entitlement to benefit from scientific progress. This omission has already been outlined in the Venice Statement 2009:

> "Participation in scientific progress is valuable in its own right, and while the benefits of science should be shared equitably, neither of these components of the right is a substitute for the other. The right to share in scientific benefits should not be predicated on participation, particularly where there is a direct threat to fundamental rights, most notably the rights to life, health and food" (para. 11).

Different from ICESCR, the Universal Declaration of Human Rights used the phrase "share in scientific advancement and its benefits" to signal this dual nature. It is worth pointing out that the English word "share" in the UDHR is translated as "participate" ("participer", "participar") in the French and Spanish versions of the text (General Comment No. 25, para. 10). General Comment No. 25 clearly acknowledges this dual and positive character of the right to science: "The right enshrined in Art. 15(1)(b) encompasses not only a right to receive the benefits of the application of scientific progress, but also a right to participate in scientific progress" (para. 11). In effect, this is an interpretative extension of the "right to benefit from scientific progress" to a dual right "to participate in and benefit from scientific progress" (a phrase which General Comment No. 25 consistently uses instead of the wording of Art. 15 ICESCR).

The General Comment also postulates the essentially positive outcome of science. Scientific "progress" (the term used in the ICESCR) or "advancement" (the term used in the UDHR) denotes a positive perspective on science as a contributor to social, economic, technological, and societal evolution and generally "the well-being of persons and humankind" (General Comment No. 25, para. 7). The negative effects of scientific development which have been so dominant in the debate in the 1970s and 1980s are mentioned but not foregrounded. This tension between the positive and negative contributions of science will, however, remain central to the debate on the human right to science. In a recent survey of academic studies on the human right to science, observers found a range of reports which point towards the potentially negative effects of scientific progress and the possibility for the dual use of science (e.g., technologies such as CRISPR/Cas-9 gene editing), which can be used in ways respectful of, or contrary to, human rights principles (Mann, Donders et al., 2018, 10821). Consequently, General Comment No. 25 recounts some instances of such negative effects and argues, for example, that while scientific and technological advancements have contributed to the reduction of famine by making food more accessible, states still need to ensure that scientific progress does not violate the rights of peasants and people working in rural areas (General Comment No. 25, para. 63–65).

2.2 Sharing the Benefits of Scientific Advancement

The central idea of the human right to science is to share the benefits of scientific advancements with everyone. The notion of "benefit" remains, however, ambiguous. General Comment No. 25 argues for a threefold understanding: firstly, benefits are the direct material results of scientific research and its application – a new vaccine, an improved fertilizer, a refined tool. Secondly, scientific progress is beneficial in itself as it means creating and expanding knowledge which can be disseminated and shared. And thirdly, science is the primary tool for forming critical and responsible citizens able to participate fully in democratic societies (General Comment No. 25, para. 8). The General Comment elaborates at length that the human right to benefit from scientific progress must not merely be seen as science's output but that science ultimately needs to be understood as a cultural activity and thus a cultural human right (General Comment No. 25, para. 9–10).

Furthermore, General Comment No. 25 argues that the right to enjoy the benefits of scientific progress contains "interrelated and essential elements" (General Comment No. 25, para. 15) which can be understood conceptually as corresponding to the "AAAQ" framework (availability, accessibility, acceptability and quality) developed for socio-economic and cultural rights. When Art. 15 ICESCR is reframed in accordance with this framework, diverse state obligations emerge. The right to enjoy the benefits of scientific advancement needs to ensure availability (the states' obligation to take steps for the conservation, development, and diffusion of science), accessibility (which requires that everyone has equal access to scientific progress and its application as well as to information regarding the risks and benefits posed by science), acceptability (efforts to ensure science is explained and disseminated in a manner that facilitates public and community acceptance and that incorporates ethical standards), and quality (states' obligation to regulate scientific applications and ensure access to verifiable science).

More specifically, the obligation of states to ensure the availability of the human right to science and take steps for the conservation, development, and diffusion of science means that scientific progress needs to be allowed to actually take place, that scientific knowledge and its applications are effectively protected and disseminated, and that the applications and benefits of scientific progress are distributed, especially to vulnerable and marginalized groups. This includes the duty to secure a research infrastructure, research financing, and scientific education as well as providing for instruments for diffusion such as libraries, museums, or the Internet. In particular, the General Comment calls upon states to promote open science and open source publication of research (General Comment No. 25, para. 16). Accessibility means that scientific progress and its applications are accessible for everyone without discrimination. To this end, states must ensure equal access to the applications of science, particularly when they are instrumental for the enjoyment of other economic, social, and cultural rights. Information on the risks and benefits of science and technology must be accessible without discrimination, and states need to ensure the opportunity to participate in scientific progress without discrimination (General Comment No. 25, para. 17). Acceptability of the human right to science means ensuring that science is explained and its applications are disseminated so as to facilitate their acceptance in different cultural and social contexts without distorting their integrity and quality. Scientific education and the products of science need to be tailored to the particularities of populations with special needs and persons with disabilities. It also implies that scientific research incorporates ethical standards to uphold scientific integrity and human dignity, maximizes benefits for research participants, and minimises possible harm through reasonable protection and safeguards. The autonomy and free and informed consent of research participants and their privacy and confidentiality must be respected. Vulnerable groups or persons need special protection, and cultural diversity and pluralism must be respected (General Comment No. 25, para. 18). Quality in the human right to science means ensuring that the most advanced, up-to-date, and generally accepted and verifiable science is available in line with generally accepted standards in the scientific community. It also includes regulation and certification processes to ensure the responsible and ethical development and application of science, including the circulation of new scientific applications for the public (General Comment No. 25, para. 19).

2.3 Access to and Participation in Science

General Comment No. 25 elaborates at length on the participatory character of the right to science. In line with accepted human rights theory on the duty of states to respect, protect, and fulfil all human rights, the human right to science contains freedoms as well as entitlement and entails positive as well as negative obligations of states (General Comment No. 25, para. 15). Access to science is an important element of the participatory character of the human right to science. As has been argued elsewhere, "access to science" can have multiple meanings: access for everyone to science education at every level as the prerequisite to participate in science; access to information and communication technologies as part of the freedom to express ideas and opinions; unimpeded access to scientific knowledge and data as an essential precondition for any scientific inquiry; access to research funding; or access to actively work and have agency in doing science (Mann, Donders et al., 10822). Data transparency has been identified as a key issue in the debate on access to science (Barham & Hubert, 2016, p. 3). Access to science is thus a multi-stakeholder problem which affects not only researchers but pertains to the general public. Of particular importance is access to available, accessible, acceptable, and quality science education as part of the human right to education, as a contribution to equality, and as a means of opening doors to scientific careers (Tajmel & Starl, 2009). This necessitates addressing core concerns of access to and participation in science and science education, such as non-discrimination, inclusivity, affirmative action for specific groups, and gender equality in science and in STEM (science, technology, engineering and mathematics) education.

General Comment No. 25 sees the right to participate in and to enjoy the benefits of scientific progress in a broader sense as a means to realize other economic, social, and cultural rights, particularly the right to food and health (General Comment No. 25, paras. 63–71). In addition, the text acknowledges the impact of scientific knowledge in decision-making and policies, which should be based on the best available scientific evidence, as a means of participation. States are called upon to align their policies with scientific evidence, promote public trust and support for sciences, and create a culture of active citizen engagement with science, particularly through vigorous and informed democratic debate on the production and use of scientific knowledge and a dialogue between the scientific community and society. Decisions concerning the orientation of scientific research or the adoption of certain technical advancements should be subjected to transparent public scrutiny and citizen participation (General Comment No. 25, paras. 54–55).

As one would expect, the principle of non-discrimination figures prominently in considerations on access to and participation in science and makes up an essential element of the human right to science (General Comment No. 25, paras. 25–27). In addition, there is also considerable concern for the protection and empowerment of specific groups in the text. The underrepresentation of women in scientific activity is highlighted as a particular problem. States are considered to be under the obligation to eliminate barriers that affect girls' and women's access to quality scientific education and careers and ensure their access by raising public awareness to eliminate stereotypes, establish quotas for women in scientific education, ensure child care for female researchers, and enable a gender-sensitive approach to scientific research and research funding (General Comment No. 25, paras. 29–33).

States should also promote the inclusion of persons with disabilities into science by developing statistics disaggregated by disability on access to science and its benefits, implementing technologies to facilitate access to scientific education and employment for persons with disabilities, adopting appropriate measures to raise awareness of the capabilities and contributions of persons with disabilities and combat stereotypes and harmful practices, and ensuring that persons with disabilities give free, prior, and informed consent when they are subjects of research (General Comment No. 25, paras. 34–35). In order the ensure participation of persons living in poverty and affected by structural inequality, states should adopt specific strategies to enhance access to scientific education, prioritize scientific and technological innovations that serve especially the needs of persons living in poverty, and enable access to quality science education (General Comment No. 25, paras. 36–38). The General Comment is aware of the way in which indigenous peoples preserve traditional knowledge and calls for their inclusion into a global intercultural dialogue for scientific progress to harness their input (General Comment No. 25, paras. 39–40).

2.4 Respecting and Protecting Scientific Freedom

Art. 15(3) ICESCR establishes a clear obligation of states to "respect the freedom indispensable for scientific research." In order to highlight the contours of this freedom, General Comment No. 25 takes recourse to the UNESCO Recommendation on Science and Scientific Researchers of 2017. Ensuring scientific freedom means protecting researchers from undue influence on their independent judgment; ensuring their ability to define aims, objectives, and methods of their research and to establish autonomous research institutions; guaranteeing they can rely on their conscience to freely and openly question the ethical value of research projects or withdraw from projects; ensuring the freedom of researchers to cooperate with other researchers nationally and internationally; and giving them the possibility to share scientific data and analysis with others (General Comment No. 25, para. 13). This is in line with – although less exhaustive than – the 2009 Venice Statement, which considered the obligation to respect scientific freedom as a core civil-political right based on freedom of thought, to hold opinions without interference, and to seek, receive, and impart information and ideas of all kinds; respect for the right of scientists to form and join professional societies and associations; duty to actively protect scientific freedom by taking measures, including legislative measures, to prevent and preclude the use of science and technologies by third parties to the detriment of human rights; and duty to protect all human rights of persons subjected to research activities by public or private institutions and respect their right to information and free and informed consent (Venice Statement 2009, para. 14).

General Comment No. 25 also postulates that states refrain from interfering directly or indirectly in the enjoyment of the right to science; eliminate barriers to accessing quality science education and pursuing scientific careers; refrain from disinformation, disparagement, or deliberate misinformation intended to erode citizens' understanding of and respect for science and scientific research; and eliminate censorship or arbitrary limitations on access to scientific knowledge (General Comment No. 25, para. 42). General Comment No. 25 also deals extensively with the duty of states to protect science from undue interferences from third parties. The text finds that states are obliged to adopt measures to prevent any person or entity from interfering with the right to participate in and to enjoy the benefits of scientific progress and its applications through any form of discrimination in universities, schools, laboratories, cultural or scientific associations, or hospitals. States are required to ensure that scientific associations, universities, and laboratories do not apply discriminatory criteria, protect persons from participating in research or tests in contravention of ethical standards, and guarantee their free, prior, and informed consent. States must prevent private persons and entities from disseminating false or misleading scientific information, and private investment in scientific institutions must not be used to unduly influence the orientation of research or to restrict the scientific freedom of researchers. Special protection is warranted for persons who, owing to their age or capacity, cannot decide on their own whether they benefit from scientific progress. The General Comment gives the example of parents who refuse to have their children vaccinated on grounds the scientific community considers false – a situation where parental decisions entail risks for the child and society. States must also guarantee everyone the right to choose or refuse a treatment and establish protective measures in relation to messages from pseudoscience (General Comment No. 25, paras. 43–44).

2.5 Developing Diverse, Inclusive, and Cooperative Science

In addition to the obligation to respect and protect the human right to science, states have a range of obligations under Art. 15 ICESCR to fulfill the right with a view towards developing diverse, inclusive, and cooperative science. The overall aim must be to create an enabling and participatory environment for the conservation, development, and diffusion of science and technology which includes equal access and participation of all public and private actors, capacity-building and education, and technology transfer. The Venice Statement of 2009 has already envisaged the contours of this obligation (paras. 14–16). According to this text, states must adopt a legal and policy framework and establish institutions which promote, develop, and diffuse science and technology in a manner consistent with human rights. Such policies need to be periodically reviewed in a participatory and transparent process, with particular attention to the status and needs of disadvantaged and marginalized groups. It means promoting access to the benefits of science and its applications in a non-discriminatory way that addresses the needs of disadvantaged and marginalized groups. It requires states to monitor potentially harmful effects of science and technology, respond to the findings, and inform the public in transparent ways. States have to take measures to encourage and strengthen international cooperation and assistance in science and technology in line with international law, provide opportunities for public engagement in decision-making about science and technology and their development, and institute effective science curricula at all levels of the educational system, particularly in state-sponsored schools, so as to develop skills necessary to engage in scientific research.

General Comment No. 25, likewise, sees a positive duty of states to actively promote the advancement of science through education, investment in science and technology, allocation of appropriate resources in budgets, and by generally creating an enabling and participatory environment for the conservation, development, and diffusion of science and technology. States should use the maximum of their available resources to overcome obstacles for persons and disadvantaged groups to benefit from new technologies and scientific advancements. As a principle, the General Comment considers that scientific progress must be accessible and affordable to persons in need of specific goods or services. Knowledge about scientific progress and its applications needs to be made available and accessible to the general public through schools, universities, technical colleges, libraries, museums, print and electronic media, and other channels, considering age, language, or other aspects of cultural diversity. In light of the importance of scientific literacy, states are called upon to ensure equitable and open access to scientific literature, data, and content, including by removing barriers to publishing, sharing, and archiving scientific outputs. Any restriction on the right to publish research results needs to be compatible with the limitations clause of Art. 4 ICESCR, and states are called upon to ensure that contractual restrictions placed on this right are consistent with the public interest, reasonable, and proportionate, and that appropriate crediting and acknowledging of the contributions of scientific researchers to the research outcomes is ensured (General Comment No. 25, paras. 45–50).

The General Comment considers also the duty to cooperate internationally towards the fulfillment of all economic, social, and cultural rights, as stipulated by Arts. 2 and 15(4) CESCR (General Comment No. 25, para. 77). Arguing for a human right to science is increasingly understood as supportive for research collaboration, particularly for disadvantaged researchers and research communities (Gran et al., 2019). In light of recent developments, the General Comment considers pandemics as "a crucial example of the need for scientific international cooperation to face transnational threats" and comes out in support of the World Health Organization (General Comment No. 25, para. 82). It also argues for an extraterritorial obligation of state parties to regulate and monitor the conduct of multinational companies over which they can exercise control, including due diligence obligations and the duty to respect the right to participate in and enjoy the benefits of scientific progress and to provide legal remedies to victims of such companies (General Comment No. 25, para. 84). With regard to the right to health, the General Comment calls on states to prioritize the promotion of scientific progress to facilitate better and more accessible means for the prevention, control, and treatment of epidemic, endemic, occupational, and other diseases (General Comment No. 25, para. 67).

2.6 Protection From Adverse Effects of Science

General Comment No. 25 considers also the possible negative effects of new technologies, albeit in a more general way, and mentions artificial intelligence, robotics, 3D printing, biotechnology, genetic engineering, quantum computers, and management of big data as areas of concern. It considers new emerging technologies as enhancing the enjoyment of economic, social, and cultural rights but warns that adequate policies and measures must be put in place to counter social inequalities and discrimination (General Comment No. 25, paras. 72–76). This list could easily be amended: stem cell research, cloning, nanotechnologies, nuclear energy, or genetically modified organisms are all areas of potential danger, not to mention weapons research (Shaheed, 2012). Access to medical research data may provide one of many examples where such impact needs to be considered and trade-offs might be necessary, depending on the weighing of the right to privacy against general welfare (Mann, Donders et al., 2018, 10821–22). General Comment No. 25 accepts the possibility that, as with other human rights, the human right to science needs to be limited when it adversely affects other human rights. It argues, however, that any limitation on the right to participate in and enjoy the benefits of scientific progress must be established by law, promote the general welfare, and be proportionate to the aim pursued (General Comment No. 25, para. 21).

3. Limitations

3.1 Science Ethics and Precautionary Principle

Limitations of the human right to benefit from scientific progress may stem from consideration of scientific ethics, when self-imposed ethical boundaries for research restrict otherwise desired or acceptable practices and outcomes. The 2009 Experts' Meeting on the Human Right to Science has already considered that human rights impact assessments of scientific research should be envisaged as an integral part of the development of science (3rd Experts' Meeting Venice 2009, 16). In particular, the application of the precautionary principle may require limits for science based on caution to avoid irreparable harm to the public or environment, due to the open-ended nature of scientific research (Venice Statement 2009, para. 12(g)). General Comment No. 25 also accepts that, in the absence of scientific certainty, unacceptable harm needs to be avoided. Such harm is defined as threats to human life or health which are serious and effectively irreversible, inequitable to present or future generations, or imposed without adequate consideration of the human rights of those affected (General Comment No. 25, para. 56). General Comment No. 25 calls for testing scientific advancements in medicine or food production to avoid possible damage to individuals and the environment and cautions that information and communication technologies need to consider data protection, privacy, and prevention of hate speech (General Comment No. 25, para. 72–76). At the same time, it acknowledges the controversial character of this principle in relation to scientific freedom, without further elaborating on the problem (General Comment No. 25, para. 57).

3.2 Intellectual Property Rights

As the Venice Statement 2009 has upheld, "the right to enjoy the benefits of scientific progress and its applications may create tensions with the intellectual property regime, which is a temporary monopoly with a valuable social function that should be managed in accordance with a common responsibility to prevent the unacceptable prioritization of profit for some over benefit for all" (para. 10). As far as potential clashes between freedom of science and the protection of intellectual property rights are concerned, a balance must be struck among the interests of authors and inventors and public needs and interests. This tension has yet to be delineated with greater clarity. General Comment No. 25 considers states under the obligation to take appropriate measures to foster the positive effects of intellectual property on the right to participate in and to enjoy the benefits of scientific progress and its applications, while at the same time avoiding negative effects. States are expected to provide adequate financial support for research that is important for the enjoyment of economic, social, and cultural rights; delink remuneration of successful research from future sales; and guarantee the social dimensions of intellectual property in accordance with international human rights obligations they have undertaken to reach a balance between intellectual property and the open access and sharing of scientific knowledge and its applications, especially those linked to the realization of economic, social, and cultural rights such as the rights to health, education, and food. The Committee clearly sees intellectual property in its social function and demands that states prevent unreasonably high costs for access to essential medicines, plant seeds or other means of food production, and schoolbooks and learning materials (General Comment No. 25, para. 62).

4. Core Obligations and Immediate Measures

General Comment No. 25 argues that, in line with the accepted understanding of socio-economic human rights, states parties to the ICESCR have the general obligation to take steps, to the maximum of their available resources, for the full realization of the right to participate in and to enjoy the benefits of scientific progress and its applications (General Comment No. 25, para. 23). They are also under the obligation to eliminate all forms of discrimination and overcome persistent inequalities in scientific education, design, and implementation policies (General Comment No. 25, paras. 24–27). This relates in particular to groups that have experienced systemic discrimination in the enjoyment of the right to participate in and to enjoy the benefits of scientific progress (General Comment No. 25, para. 28). The General Comment is particularly focused on states' obligations to provide additional guidance and measures to remedy the exclusion of women, persons with disabilities, persons living in poverty, and indigenous peoples in scientific progress (General Comment No. 25, paras. 29–40).

In addition to these general demands, the General Comment lays down core obligations with which state parties have to make "every reasonable effort to comply" (General Comment No. 25, para. 41). Such core obligations are to eliminate laws and policies that limit access to certain groups or individuals (such as laws and policies that undermine women's and girl's participation in scientific areas), implement a participatory national framework and strategy that includes remedies for violations of this right, ensure access to basic scientific education and skills, prioritize research in areas where there is need for scientific progress (such as health, food, and other basic needs), adopt mechanisms and policies that are based on accepted scientific evidence, ensure training of health professionals on the use of technologies and medicines that result from scientific progress, promote accurate scientific information and avoid deliberately misinforming the public, implement protections against pseudoscience-based practices, and foster development of international contacts and cooperation in the scientific field (General Comment No. 25, paras. 41–51). As with other socio-economic and cultural rights, retrogressive measures are presumed to be unacceptable (General Comment No. 25, para. 24).

As a matter of principle, but without clear guidance, the General Comment also extends obligations to guarantee the human right to science to non-state entities, particularly private companies operating in the scientific field. The Venice Experts' Meeting 2009 has already flagged the problem that scientific research by private businesses needs to be considered when it comes to funding, distribution, and impact of research output, which the experts considered a public good rather than a mere investment (Experts' Meeting Venice 2009, 7). While intellectual property rights are at the centre of attention (and are dealt with by the General Comment), the broader implications of the human right to science for the private sector need yet to be explored.

Finally, the General Comment accepts a certain discretion of state parties in achieving the full realization of economic, social, and cultural rights but puts forward four key measures for the immediate realization of the right to participate in and enjoy the benefits of scientific progress: establishing a normative legal framework that protects against all forms of discrimination; developing a national plan to promote and disseminate scientific progress to all individuals which takes into account protections against misleading pseudoscience as well as ensuring ethical standards in science; identifying benchmarks to monitor the implementation and progress of the right to enjoy the benefits of scientific progress at the national level; and establishing judicial and administrative mechanisms to allow victims' access to appropriate remedies (General Comment No. 25, paras. 86–89).

5. Conclusion

General Comment No. 25 clarifies the scope, content, limitations, and utility of the human right to science and will facilitate and channel the debate and practice on this particularly challenging provision of the ICESCR in the years to come. The text is timely in light of accelerating scientific progress and parallel anti-scientific bias and backlash. It positions science as a human activity in need of guidance by the international human rights regime and considers the human right to science as a multi-faceted cultural human right which is closely connected to other cultural, civil, economic, political, and social rights. Where the General Comment moves along established human rights theory, it does so convincingly and clarifies scope and content of the human right to science. The General Comment discloses the fourfold character of the human right to science as an obligation to respect the right to enjoy the benefits of scientific progress and its applications; care for the conservation, development, and diffusion of science; respect scientific freedom; and facilitate scientific cooperation. With the General Comment, the

Committee on Economic, Social and Cultural Rights effectively rephrases the wording of Art. 15 ICESCR so as to encompass the twofold meaning of the human right to science: enjoying the benefits of the application of scientific progress and participating in scientific progress. Direct material benefits, intrinsic knowledge production, and the indirect effects of science in creating responsible, informed, and active citizens form part of the human right to science as a cultural right which presupposes access to and education in science.

This is particularly relevant for inclusive and quality STEM education as a prerequisite for effective participation in science. As the General Comment repeatedly highlights, science education is the linkage between the right to science as a cultural human right and the human right to education. Non-discriminatory, inclusive science education with a particular focus on girls and women reflects the broader societal and socio-economic impacts of the right to science. The General Comment clearly delineates the respective state obligations to develop inclusive science systems and ensure quality scientific education at all levels and acknowledges specific needs of disadvantaged groups to participate in and benefit from science education. States have to eliminate barriers to science education and scientific careers in universities, schools, technical colleges, laboratories, and other places of science. The right to science education needs to be part of national action plans, legislative measures, school curricula, and the design of educational institutions to ensure the right to participate in science.

The AAAQ scheme, which has proven to be so helpful in understanding the scope of socio-economic and cultural rights, is applied here as well and will steer states toward their obligations to secure the availability, accessibility, acceptability, and quality of the human right to science. States need to take steps for the conservation, development, and diffusion of science, ensure equal access, explain and disseminate scientific progress in line with ethical standards, and regulate scientific applications. Instead of decrying the lofty nature of the human right to science, states can now implement their core obligations such as eliminating discriminatory laws and practices, guaranteeing women's and girl's participation in scientific research, and providing scientific education to all. The General Comment tells governments clearly to adopt the legal framework and national action plans on the promotion and dissemination of scientific progress, establish benchmarks for monitoring the implementation and progress of the right to enjoy the benefits of scientific progress, and set up judicial and administrative mechanisms to allow victims' access to appropriate remedies in case of violations. The General Comment is equally strong on scientific freedom and suitably broad on states' obligations to facilitate (national and cross-border) scientific cooperation in times of COVID 19. It has also taken a position on the link between the protection of intellectual property rights, which it considers in its public function and its implications for the human right to science.

Beyond that, the General Comment will certainly be vigorously debated. Many of the topics dealt with and much of the guidance given will undoubtedly lead to discontent and will lead to a robust engagement by the human rights movement, the scientific community, and policy circles. The General Comment reveals a range of difficult questions awaiting answers in theory and practice. What exactly does it mean that states are under the obligation to promote accurate scientific information, avoid deliberately misinforming the public, and reject pseudoscience-based practices, e.g., in the field of medicine? How can political decision-makers be asked to rely on the best available scientific evidence in light of scientific disagreements? What are the contours, means and limits of "citizens' science"? Should scientific communities implement quotas for female scientists? How does private research funding have to be regulated in line with international human rights law? Which barriers to publishing, sharing, and archiving scientific outputs need to be removed? And what exactly does the General Comment say on the human rights implications of vaccinations? The General Comment is also, understandably, tentative in reaching into the regulation of private research entities and businesses and extraterritorial human rights obligations for research corporations as it needs yet to connect with ongoing debates and initiatives in these fields.

With General Comment No. 25, the Committee on Economic, Social and Cultural Rights has marked an important milestone. The human rights movement will read the text and so will governments. More importantly, however, the scientific community should engage with the arguments in the General Comment so as to live up to its particular responsibility to act on human rights and be aware of the impacts of scientific developments on human rights (Wyndham & Vitullo, 2018, p. 975). There are promising signs that ever more scientific disciplines have begun to embrace the human rights framework and particularly the human right to science as a starting point for building consensus on governing principles for responsible scientific and technological advancements (Boggio et al., 2019, p. 134). General Comment No. 25 provides a starting point, guidance, and challenge for this necessary debate among members of the scientific community.

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Modelling the Human Rights Approach to Science Education

Tanja Tajmel

1. Introduction

The aim of this chapter is to highlight different, albeit mutually interacting dimensions which shape and enable or disable access to what is broadly understood as science or STEM education. STEM stands for science, technology, engineering, and mathematics and is an acronym that has become common in the context of education. In this chapter, I posit that human rights – and particularly the right to education – provide a suitable normative framework for the evaluation and definition of the values of science and access to science education. It is an approach grounded in the principles of sustainable development and anti-discrimination for a more equitable science.

The human rights-based approach centers on the individual's right to science education and, thus, helps to decenter other interests that are linked to science education. It also provides a framework to reflect on the definition and standardization of science education. It contributes to a reassessment of the values of science and its education and opens discussion on the benefits of science by simultaneously questioning assimilative approaches that lead to marginalization of other knowledge traditions. It also requires scrutiny of power relations beyond the classroom. Historically, the sciences and science education have been an exclusive field. Institutionalized with the establishment of the academies of sciences across Europe in the 17th and 18th century, the sciences and academic education were accessible only to men, and the construction of science as a masculine endeavor was closely linked to social order and the distribution of labor (Schiebinger, 2004; Wajcman, 2010).

Today, the STEM fields are considered of utmost relevance to the development of modern societies, for innovation and progress. Education and STEM are of both socio-political and economic interest. Arguments focusing on the promotion of STEM to increase the pool of workers required by industry have become indistinguishable from arguments to promote STEM for the empowerment of the individual and for the sake of social equity and public welfare. The importance of *diversity* and a *diverse workforce* is often expressed in managerial terms without addressing underlying power relations (Zanoni & Janssens, 2004; Zanoni et al., 2009), a shift also apparent in science education research (Tajmel, 2017). A skilled workforce in STEM fields is highly sought after (Bybee & Fuchs, 2006), accompanied by intense promotion activities and generous funding in industrialized countries.

The very special approach of this book is its focus on human rights and, more specifically, the right to STEM education. Aligned with this approach, underrepresentation is understood as a result of exclusion and discrimination, practices that enable access to STEM for some and hamper access for others (Tajmel & Starl, 2009). The field of STEM represents a certain scientific culture and reproduces or reinforces certain social inequalities in an intersectional manner. To contribute to a better understanding of these intersections, I present in the following a model of a rights-based approach to science education that draws on research and concepts from different disciplines. I refer to law and social studies to further an understanding of social difference and intersectionality (Baer, 2009; Crenshaw, 1989; Anthias, 2013; 2003; Winker & Degele, 2009; 2011), and to feminist theory to inform an understanding of science as gendered (Keller, 1985; Harraway, 1988; Harding, 1991; 2006; Schiebinger, 2003). I further draw on educational studies that deal specifically with marginalization in education (Leiprecht & Lutz, 2006; Gomolla & Radtke, 2009) and address science education from a socio-cultural perspective (Lemke, 1990; 2001; 2011; Aikenhead, 1996). Furthermore, the considerations presented here draw on studies that lay out how "others" are produced discursively (Fairclough, 1989; van Dijk, 2001) and in the context of colonial power relations (Said, 1978; Spivak, 1994). Notably, science education research that looks at representations of science and scientists in textbooks and the curriculum contributes to the understanding of how science education reinforces and co-constructs stereotypes (Costa, 1995; King & Domin, 2007; Willems, 2007; Sunar, 2011; Zanon et al., 2021) and how these are reflected in students' views of science (Chambers, 1983; Kessels & Taconis, 2011). Finally, decolonizing research methodologies (Kovach, 2009; Smith, 2012) are considered fundamental to a redefinition and reassessment of scientific values to make science education acceptable to learners.

I aim to explain why it is necessary to critically investigate the mechanisms of exclusion that are embedded in science and science education to better understand disparities in STEM fields. This approach distinguishes itself from others that conceptualize disparities in science as consequences of individual differences between students. Such approaches focus on individuals and their (non-)match with science rather than on science itself. I posit that human rights can provide a normative framework to inform changes in science and science education that go beyond compensatory measures for so-called underperforming students. Further, I explain the limitations of the diversity approach, as it does not provide a critical framework to question underlying power relations that shape and define science and its accessibility. I argue that only by recognizing science education as social-difference-constructing and -reproducing activity is it possible to realize the right to science education as an empowerment right that respects the dignity of all human beings.

2. Human Rights *in* or *to* STEM Education?

Two different concepts need to be distinguished to further understand what the human right *to* STEM education means as opposed to human rights (plural) *in* STEM education.

The latter describes the incorporation of human rights content in the science curriculum. Students might learn about human rights in the science classroom. For example, discussing human rights violations in the context of demonstrations against a nuclear power plant would be teaching human rights. Teaching the Sustainable Development Goals and focusing on specific goals that relate to science would also make human rights a topic in the science classroom.

The human right (singular) *to* STEM education describes the right of individuals to access science education. Such human rights can be – but are not necessarily – the content of science education and thus part of the science curriculum. From this perspective, every individual has the right to education in science or STEM fields. The right *to* science education neither defines what science education is nor what science is. But whatever is considered science education must be accessible for every individual.

The human rights approach thus provides a possible normative framework for science education that is independent from usability considerations and centers on individual human beings and their rights rather than the importance of STEM education for national or economic interests. The human rights approach is a rights-based approach – neither opinion-based nor usability or employability-based – and as such provides a robust alternative framework to the output-oriented usability approach widely used in science education and also in shaping standardized tests and curricula (see Sjøberg in this book). The difference between the two approaches can be best illustrated in differing answers to the following questions: *Why should people gain a science education? Why is the marginalization of certain groups (often referred to as "lack of diversity") in STEM fields a problem?*

From the output-oriented perspective, one would say "People should get a science education because a scientifically literate and skilled workforce is important for national development and progress, for the economy and technological innovation." Another more management-oriented argument would claim that "diverse" teams produce better outcomes and, therefore, it is necessary to increase "diversity," which includes increasing the representation of people from underrepresented groups in STEM. These arguments rarely question the underlying social power relations and historical-political causes of underrepresentation or marginalization, such as discrimination based on gender, race, social class, body, and other grounds. Likewise, these approaches generally do not question science as socio-cultural praxis that has actively contributed to difference-making. (Think of the "scientific proof" of race or gender.)

The answer to the above-mentioned questions from a human rights perspective is rather simple: People should get a science education because it is their right. This right is independent from economic exploitation and national purposes. Regardless of whether there is a (national) "need" for a scientific workforce, everybody must have access to science education. This is probably the most challenging point in understanding the right to science education and the right to education in general. If a justification was to be given, it would probably be something like "because everybody wants it to be everyone's right, and nobody wants to be excluded" [1]. There is neither question of purpose nor need for further justification. It is like the right to free speech: Why should everybody have the possibility to express their opinions freely if they wish? Because it is their right. Similarly, everybody must have access to literacy education because it is fundamental to full participation in society. Human rights provide a normative framework that does not require further justification. In this sense, the right to science education can be compared to a scientific axiom, that is, taken to be true without further justification required.

3. The Politics of STEM Education

To understand the interrelation of STEM education, participation in society, contributions to science, and social (in)equity, I look more closely to the socio-political aspects of science education*: What is science education and who defines it?*

3.1 Science Educational Standards

What a society considers as science – and thus science education – is a product of the historical development of the sciences, knowledge traditions, power relations, and educational politics (Latour, 1987; Haraway, 1988; 1991; Lemke, 1990). STEM education has commonly been defined as learning about content and methods in the sciences, technology, engineering, and mathematics (and related fields), whereas science traditionally comprises disciplines such as physics, chemistry, and biology. We could, then, further ask, "What is science, technology, engineering, and mathematics?" and we will find a variety of definitions. Jay Lemke emphasizes the need to see the natural sciences and their mediation as parts and instruments of power-political interests, stating that "science had to be understood as a very human activity whose focus of interest and theoretical dispositions in any historical period were, and are, very much a part of and not apart from the dominant cultural and political issues of the day" (Lemke, 2001, p. 298).

Currently, educational standards define what science education is. They provide the framework for curricula and for student assessments. Standards are considered necessary to ensure quality and to prevent malpractice in whatever context. Setting standards is a means toward consensus on what can be expected from a person who gains a science education. However, standard setting also includes judgement, selection, and valuation of which knowledge is relevant, which content and methods should be taught, which skills are important, and which knowledge traditions should be carried forward. Standards legitimize what is meaningful and worth training for. Standard setting decisions are

1 In his "Grundlegung einer Ethik des Willens" (Foundation of an Ethics of the Will), Malte Hossenfelder shows that the normative of human rights is not only a set norm but also an *intended* norm based on the will of individuals (Hossenfelder, 2000).

based on value systems and are, therefore, closely linked to culture and politics. Science has politics, and science education has politics, too.

Setting standards is a powerful act, as it means no less than defining science education (see Sjøberg in this book). In other words, competencies and skills that are not represented by official standards are not considered "science competencies." Neither this chapter nor this book claims to define science education; however, it emphasizes that any definition or institutional legitimation of science education is an act of power that manifests knowledge authority. In a merit-based system, so-called underperforming students or students who do not meet the standards of STEM education do have much lower chances of accessing the STEM fields and of actively participating in scientific and technological development. Meeting the standards is the entrance ticket to colleges, universities, and a scientific career. Testing scientific standards is a process that filters those who, from the socio-cultural perspective, have successfully adapted or assimilated to the science culture and acquired the required skills and competencies, and even the required ways of thinking and behaving. Sjøberg (in this book) highlights the many skills and competencies that are not being tested in international student assessment programs but which are important nonetheless, such as collaborative skills essential to scientific research activities. In summary, it is important that educational standards be based on a broad consensus of all social groups. Currently, they predominantly reflect output-oriented interests and values.

3.2 Critique and Values

The STEM fields are currently confronted with unprecedented critique from different angles. Recent movements such as #ShutDownAcademia and #ShutDownSTEM (Chen, 2020; Crane & Liverpool, 2020) indicate a lack of acceptability of the STEM fields. STEM fields are seen as closely related to White supremacy for several reasons, just to name a few:

- they predominantly refer only to knowledge of Western/Eurocentric tradition as legitimate knowledge;
- scientific narratives center Europe and the Greek ancient world as the origin of science;
- White persons are predominantly presented as scientists; and
- science and technology played an important role in making imperialism and colonization possible.

Another angle of critique comes from science deniers – with scientific scepticism booming during the Covid-19 pandemic. Thus, a reconsideration of scientific values and constructive critique of science proves challenging at the interface of scientific conservativism and scientific denial. Research funding plays an important role in triggering and steering re-evaluation processes in science. Recent developments in some countries' funding policies, e.g., Canada's Social Sciences and Humanities Research Council (SSHRC, 2019), that may allow for a redefinition of what science is (and could be) include funding of research and knowledge creation that includes diverse knowledge traditions, such as Indigenous knowledges, and modifying eligibility criteria to provide access to funding for people with other than formal academic degrees. Tying funding to the condition of training students from marginalized groups, requiring that questions of equity, diversity, and inclusion in research design be addressed, increasing diversity of research teams, and promoting interdisciplinary research are all promising mechanisms to trigger processes that re-evaluate academic and scientific values in the long term.

4. Diversity and Difference

Increasing diversity in STEM fields is commonly seen as a solution to counteract marginalization and inequity in STEM fields. Diversity is often defined as "differences in race, color, place of origin, religion, immigrant and newcomer status, ethnic origin, ability, sex, sexual orientation, gender identity, gender expression and age" (for example, SSHRC, 2021). For the human rights-based approach, it is important not to focus on diversity categories in an essentialist manner; therefore, it is necessary to examine the meaning of diversity further.

Based on certain characteristics and attributions, categories are formed, people are categorized, and social group affiliations are constructed. Categories are used in prohibitions of discrimination, such as the anti-discrimination directives applicable to the private sector, which, for instance, refer to the categories gender and (dis)ability. We consider difference important because it structures social power relations and enables discrimination as a common and systemic practice. Considering sexual orientation is important because there is discrimination on grounds of sexual orientation. Considering religion is important because of discrimination on grounds of religion, and so forth. However, this approach carries the risk of trying to fix problems through compensatory measures, and not through fundamental structural changes.

The right to education refers to the human rights system, and since differences are constructed by immanent classifications, in this system no categories are allowed. Instead of categories, the European equal treatment law uses the term "discrimination grounds." Prohibited grounds include gender, ethnicity, age, religion, and disability. Since grounds of discrimination are ultimately the result of attribution processes, Baer et al. argue for the term *categorization* instead of grounds, characteristics, or identities (Baer et al., 2010). The term categorization implies the processual character in which categorizations are produced constantly. Instead of ethnicity, Baer et al. suggest ethnicized belonging (racialization instead of race, and culturalization instead of culture); instead of gender, they suggest gendering; instead of disability, they suggest disabled development; instead of age, they suggest biochronologization.

Yet here arises a dilemma: on one hand, ascriptions fix people to certain characteristics and construct identities; on the other hand, there seems to be no solution other than constructing groups to counteract inequality and discrimination. It seems that co-construction of categories must precede their deconstruction. For example, counteracting discrimination against Black women requires the characterization of a particular group that invokes the categories gender and race. In short, categorization is useful and necessary as long as it reduces and prevents disadvantages or discrimination. However, categorizations fail in their purposes if the processes of categorization contribute to discrimination and result in disadvantages such as the reinforcement of stereotypes. Which and how many categories are taken into account depends also on research traditions that differ internationally (e.g., the differences between North American and European research with regard to the construction vs. deconstruction of gender [see Winker & Degele, 2009, p. 14]).

5. Conceptualizing Disparities – The Difference Approach

Although problematic for a variety of reasons, international student assessment programs provide evidence of the unequal distribution of education among different social groups in society. Disparities in student performance are an indicator of unequal opportunity and the existence of barriers that hamper access to science education.

From a standards- and output-oriented perspective, underperformance is interpreted as a lack of skills and competencies – a deficit in students. A solution could be found in supporting underperforming students through pedagogical measures, such as teaching and learning practices, to help them reach the standards. Let this approach be called the *difference approach*. In the difference approach, students are differently distributed among levels of performance, and we see respective underrepresentations and overrepresentations of specific groups at these different levels (Fig. 1).

Problematic with this approach is that underlying principles of power relations remain unconsidered. Poor performers are not simply individuals, but their representation among different social groups is significantly different. Since underperformance and educational disparities are closely linked to marginalization, science education becomes a question of social equity rather than learning and teaching styles. In fact, reducing the problem (that is, the different performances of different social groups) to a pedagogical question would mean to de-contextualize science education from its politics.

When we consider standards as constructs, the measured scientific performances of students assessed according to these standards are constructs, too. Students who perform well are those who have successfully acquired skills and knowledge in line with the standards. Glen Aikenhead speaks of assimilation processes (Aikenhead, 1996), and Jay Lemke highlights the important role of language in delineating who belongs to science and who does not (Lemke, 1990; 2001). "Speaking science" encompasses more

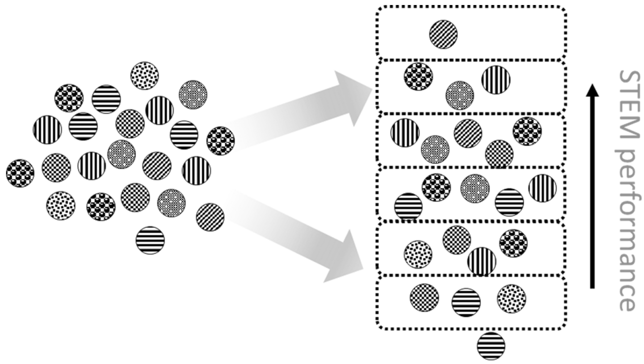

Figure 1: Diverse students distributed among performance levels in STEM. The differently filled circles represent different social groups.

… well performing students; could be White, from academic families,male

… poorly performing students; could be Black, poor, female

than communicating a certain scientific content. It includes communicating knowledge authority and knowledge power relations by using certain linguistic means (cf. Tajmel, 2009; 2011). Students' assessments also measure how well students have adapted to this specific culture and language of science.

Training more students from marginalized groups in STEM and increasing diversity without simultaneously considering underlying power relations leaves the culture of STEM fields and its inequity-reproducing praxis rather unquestioned. To sustainably counteract marginalization in science, the processes that are embedded in science education and that reinforce social difference must be revealed, too. The right to education provides an appropriate framework for this endeavor.

6. The Human Rights Approach to Science Education

Translating the right to education as norm into the research and praxis of science education and scrutinizing science educational efforts requires the frameworks and underlying principles that I outline below.

6.1 All Human Beings are Equal in Dignity and Rights

The human rights approach is a pragmatic approach centered on the individual human being. There are only two a-priori conditions for this approach that one must agree on: equality and equity (fairness). Equality encompasses the consensus that all human beings are equal, at least in the one fact that they are human beings. Equity means that no group should be privileged in their rights. This is the essence of human rights.

The starting point for examining education from the perspective of human rights cannot begin with "diverse" students since diversity categories are regarded as social constructs. Likewise, the concept of individual student – or even "student" itself – is a social construct. For example, when we talk of the underperformance of Black female students in STEM, we are dealing with a manifold of social constructs: Black refers to racialization, and female to gender. Student, too, is a social construct because it describes a position in a pedagogical relationship. Even STEM is a social construct, a body of knowledge compiled, selected, and defined by a certain knowledge authority (be it scientists, curriculum makers, or standard setting institutions). The starting point for the human rights approach must lie before the social constructs, in other words, with human beings themselves, as illustrated in Figure 2. The empty circles are human beings, they are equal in being human beings, and they all have the same rights. From this starting point, there is no need to consider age, gender, class, body, race, etc., as these "filters of difference" are removed from our considerations to understand the deeper meaning of human rights. Each single human being – every circle – has the same right to science education.

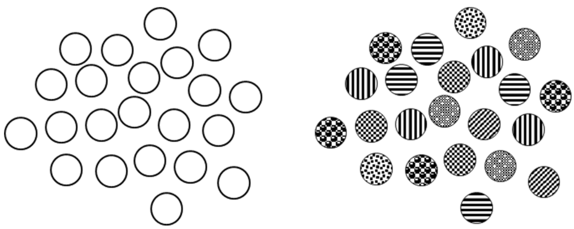

Figure 2: Human beings versus diverse students

The next step is to look at the disparities in STEM performance from the perspective of the equality of human beings. This picture differs from Figure 1, which illustrates *different students* distributed differently among the performance levels. In Figure 2 we see equal human beings vs. diverse students, and, in Figure 3, we see equal human beings *becoming* different AND being distributed differently among the performance levels.

For example, Figure 1 illustrates that, for example, female students are performing more poorly than male students, whereas Figure 3 tells us that human beings are *becoming* female / male AND poor / good performers. It links the construction of social difference

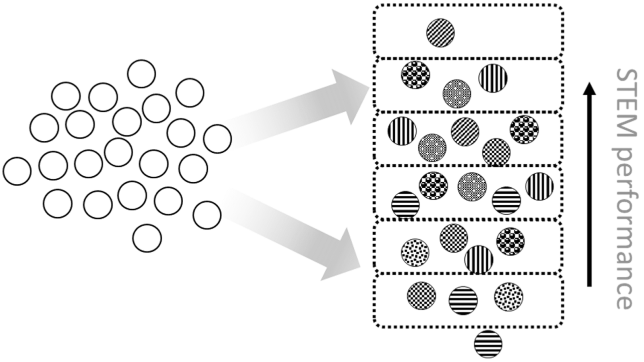

Figure 3: Human beings becoming different and distributing unequally among different performance levels in STEM

to performance. From this perspective emerges an important question for the field of science education: *How is science education contributing to these difference-making processes*?

6.2 Considerations of Difference and Intersectionality

For the human rights-based approach to science education, it is important to avoid using categories of difference in ways that essentialize and naturalize them. Difference is regarded as constructed, and to understand the intersection of different factors that produce inequity, different levels of analysis and their connections must be taken into account. Gabriele Winker and Nina Degele suggest a multilevel approach which makes it possible to link the construction of difference to three levels: (i) the level of societal structures, institutions, and organizations as macro and meso levels, (ii) the processes of identity formation as micro level, and (iii) cultural symbols as representational level (Winker & Degele, 2011).

For the field of science education, the three intersectional levels can be described as follows:

(i) Structural level: The structural level is essentially spanned by institutional frameworks and specifications at all levels of science education. These include, for example, the structure of the educational system, entrance and transition regulations, regulations for formal qualifications in STEM fields, STEM teacher education, approval of STEM teaching material, educational standards for STEM fields and their institutionalized assessments, and institutionally accredited content, curricula, methods, and knowledge traditions.

(ii) Identity level: On the level of identity construction are located both the addressing and positioning of students. Here, "STEM identities" are developed which determine the "fit" of students to STEM fields. Attributions of "interest" or "talent" can be located

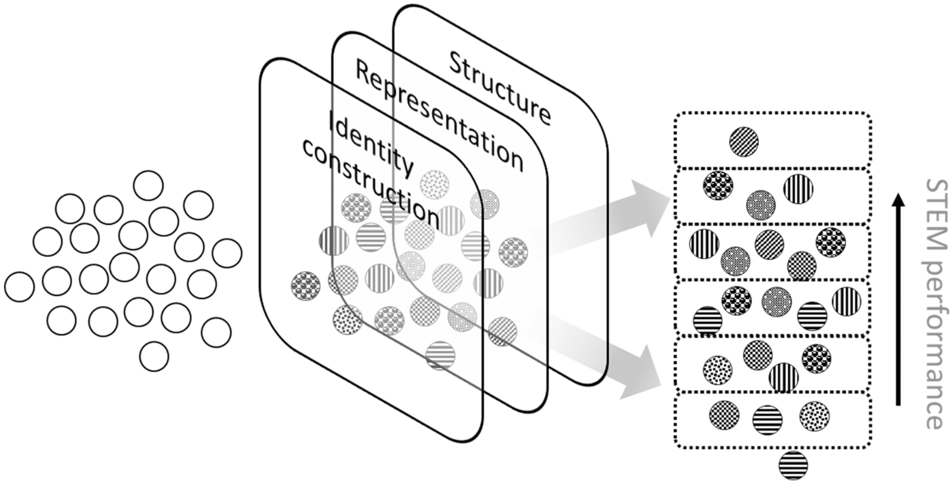

Figure 4: Levels where difference-making happens: Identity construction, representation, and structure.

on this level, too. A student's self-perception of talent in science is seen as the result of identity-constructing processes and of the provided identity options which are internalized by students and contribute to how they identify themselves. Support measures that address these constructed identities are also located on this level since they are co-constructing identities. For example, the measure to counteract underrepresentation of women in engineering by establishing a "women in engineering" group addresses human beings as "women" (and, thus, co-constructs gender), and is also co-constructing the "woman as engineer," which evokes certain attributes and identity options provided by the engineering culture[2]. (For the problem of operating with categories in diversity mentorship programs, see also Spintig & Tajmel in this book). Commonly known statements such as "you do not look like an engineer" are also located on the level of identity construction since they inherently suggest that there are certain characteristics of a person's appearance based on which engineers can be identified.

(iii) Level of representation: This level includes STEM symbols, rituals, behavior, habitus, and values. Also included on this level are authorities and "heroes" in STEM fields – those considered famous and important scientists. The level of representation also includes everything that is generally considered "usual" and common sense (Geertz 1997), such as the idea that "physics is difficult" and requires specific "talent."

The intersectional multilevel analysis provides a valuable framework to consider discrimination in access to science education in a differentiated way. Another framework

2 Wendy Faulkner describes the dilemma resulting from these options in the gender in/authenticity – in/visibility paradox (Faulkner, 2006): The more engineers are perceived as women, the less they are perceived as authentic engineers, and vice versa.

that helps to structure the analysis of access to science education is the 4-A scheme (see Sec. 7).

6.3 Examples for Intersection on Different Levels

Depending on the intersections of identity construction, structures, and representation, access to science education is either guaranteed or hindered. Intersections arise, for example, in areas of teacher training, teaching processes, and specific support measures. Regarding teacher vocational training, the factors to consider are structural (What is the institutional role of the teacher?), representational (What is science? What is to be taught?), but also identity-constructing (Who is considered a good science teacher?). Structural-level factors determine whether science is taught as a subject, in which grades the subject is taught, which standards apply to the subject, which teaching materials are approved for the subject, and how formal degrees in science can be obtained. Representational-level factors determine understanding of the subject and the profession, such as what makes a good science teacher and what constitutes science teaching, or who and what belongs to the culture of science. Another example is teaching and learning processes, which are intersections of representational factors (What is science?) and identity-constructing factors (Who identifies with science? Who is considered "talented" for science? What does a scientist look like?). Specific support measures represent an area largely determined by educational policy, thus, structural-level factors (What should be supported?) as well as identity-forming factors (Who should / needs to be supported?).

7. The 4-A Scheme of the Right to Science Education

The 4-A scheme structures the right to science education and overall access to this right. The understanding of access to science education represented here means access that is non-discriminatory and economically, geographically, and physically possible on the one hand, as well as access to all forms of education (and thus to formal educational qualifications and educational success) on the other. This understanding of access is specified in the 4-A scheme and includes the aspects *availability*, *accessibility*, *acceptability*, and *adaptability*, which together define access to education in a broader and differentiated way (Table 1). According to this understanding, the fact that science is offered in school as a school subject – indeed that there are schools and teachers – demonstrates availability of science education, but it is not sufficient to consider access to science education as given.

The 4-A scheme has already been outlined by Klaus Starl in this book. Here, I briefly describe the specifications that apply for the case of science education and link the 4-A to the intersectional levels of identity construction, representation, and structure.

(i) Availability of Science Education

The provision and availability of science education is considered given where there are schools, educational equipment, and teachers sufficient for exercise of human rights, and where teacher training and employment respect labor rights. Availability entails an educational offering that is available to a sufficient extent. This also includes extracurricular initiatives, such as projects. However, no privileges must be created for certain groups due to scarce educational resources. Availability does not automatically imply that science education is accessible to and acceptable for all learners.

(ii) Accessibility to Science Education

Science education must be legally, physically, and economically accessible to all. Accessibility refers primarily to the independence of science education from the person's social or cultural capital. The current disparities in science education indicate that these general institutional barriers also indirectly hinder access to science education. Accessibility entails that the content and subject matter of science education is designed such that all students can relate to it. On the one hand, this includes making science lessons understandable for all students in terms of language and content and enabling them to connect science to everyday contexts without privileging experiences of a certain group (cf. Lemke, 1990; Aikenhead, 1996). On the other hand, all students must be enabled to participate actively in the classroom (e.g., by specific support measures to acquire proficiency in the language of schooling). Accessibility to science education also implies that educational success must be accessible.

(iii) Acceptability of Science Education

Acceptability is closely related to levels of identity construction and representation. Acceptability means that science education must be free of discrimination and must not place specific groups of students in privileged positions. Support measures that are based on deficit-oriented attributions of characteristics, or that directly or indirectly co-construct difference in unnecessary ways by evoking the impression of homogeneity of "the other," must therefore be questioned (e.g., "physics for girls"; "science camp for marginalized groups"). Critical reflection on acceptability entails reflecting on the construction of STEM identities and cultural representations of science. For example, textbooks that predominantly showcase male White persons as scientists are not considered acceptable because they privilege a specific group by providing role models for identification, while not empowering other groups in a similar fashion. The Declaration on the right to science education outlines acceptability of science education as follows:

> *"Science education must be acceptable to learners. It needs to be up-to-date and presented in a way that learners can get full benefit of learning, as well as using science for their own benefit.*

> *Acceptability includes the knowledge content and research. Knowledge and research which reproduces inequality is therefore regarded as not acceptable. The identities that are co-constructed and reproduced through science and STEM education and the manner in which individuals are identified, addressed, tokenized and positioned within science education, must be acceptable to the individuals and may not harm the individuals' dignity. Acceptability of science education excludes any form of stigmatization by its content, its methodologies, its didactics or its applications."* (see *Declaration on the human right to science education* on p. 24)

This definition calls for a reconsideration and re-evaluation of the content of science education. Content that reinforces binaries and harms students' dignity (e.g., by positioning them as inferior) is not considered acceptable. Of particular interest is the assessment of acceptability of science education for Indigenous students. The Declaration on the Rights of Indigenous Peoples states in Article 15, para 1: *"Indigenous peoples have the right to the dignity and diversity of their cultures, traditions, histories and aspirations which shall be appropriately reflected in education and public information."* (UN General Assembly, 2007, Art. 15, para. 1)

Translating the Rights of Indigenous Peoples to the 4-A-scheme would mean that science education which does not appropriately reflect traditions, histories, cultures, and aspirations of Indigenous peoples in a non-discriminatory way cannot be considered acceptable and is, therefore, not appropriately fulfilling the right to education for Indigenous peoples.

(iv) Adaptability of Science Education

The principle of adaptability states that science education must be flexible enough to adapt to the changing needs of society and its individuals. Adaptability refers particularly to the structural level but also to the level of representation and identity construction. The Covid-19 pandemic has tested adaptability of educational systems in unprecedented ways. How quickly were educational systems able to adapt to distance learning and to provide continuous education? Which groups were privileged in this situation? Did science education address the new realities, especially of vulnerable groups, and was the content adapted accordingly to empower all students equally? How quickly was science education able to adapt to principles of anti-racist and anti-sexist education? Adaptability is measured not only in terms of effort but, more importantly, in terms of outcomes. The persisting underrepresentation of women, racialized people, and Indigenous peoples in STEM fields, as well as the dependence of educational success on social background indicate that it has not yet been possible to adapt science education accordingly. Adaptability also means that teachers have a repertoire at their disposal to be able to respond to differentiated needs. Adaptability also entails having the necessary flexibility at the structural / institutional level to enable quick adaptations.

<table>
<tr><td rowspan="4">RIGHT TO EDUCATION</td><td rowspan="2">Availability</td><td rowspan="2">– fiscal allocations matching human rights obligations
– schools matching school- aged children (number, diversity)
– teachers (education & training, recruitment, labour rights, trade union freedoms)</td><td>Schools</td><td>– Establishment/closure of schools
– Freedom to establish schools
– Funding for public schools
– Public funding for private schools</td></tr>
<tr><td>Teachers</td><td>– Criteria for recruitment
– Fitness for teaching
– Labour rights
– Trade union freedoms
– Professional responsibilities
– Academic freedom</td></tr>
<tr><td rowspan="2">Accessibility</td><td rowspan="2">– elimination of legal and administrative barriers
– elimination of financial obstacles
– identification and elimination of discriminatory denials of access
– elimination of obstacles to compulsory schooling (fees, distance, schedule)</td><td>Compulsary</td><td>– All-encompassing
– Free-of-charge
– Assured attendance
– Parental freedom of choice</td></tr>
<tr><td>Post-Compulsary</td><td>– Discriminatory denials of access
– Preferential access
– Criteria for admission
– Recognition of foreign diplomas</td></tr>
<tr><td rowspan="2">RIGHT IN EDUCATION</td><td>Acceptability</td><td>– parental choice of education for their children (with human rights correctives)
– enforcement of minimal standards (quality, safety, environmental health)
– language of instruction
– freedom from censorship
– recognition of children as subjects of rights</td><td>Regulation and Supervision</td><td>– Minimum standards
– Respect of diversity
– Language of instruction
– Orientation and contents
– School discipline
– Rights of learners</td></tr>
<tr><td rowspan="2">Adaptability</td><td>– minority children
– indigenous children
– working children
– children with disabilities
– child migrants, travelers</td><td>Special Needs and Out-Of-School Education</td><td>– Children with disabilities
– Working children
– Refugee children
– Children deprived of their liberty</td></tr>
<tr><td>RIGHT THROUGH EDUCATION</td><td>– concordance of age-determined rights
– elimination of child marriage
– elimination of child labour
– prevention of child soldiering</td><td></td><td></td></tr>
</table>

Table 1: The 4-A Scheme by Katharina Tomaševski (2001, p. 12f.).

8. Conclusion

In this chapter, I have outlined a model for the right to science education based on the 4-A scheme, taking into account intersectional levels of difference making. The aim is to place equality of human beings and their rights as individuals at the center, and to contribute to the understanding of difference and diversity, of underrepresentation in performance, and of marginalization of groups in the context of science education. For assessing and evaluating the fulfillment of the right to science education, the 4-A scheme provides the necessary structure, differentiating between availability of science education, accessibility, acceptability, and adaptability. Acceptability, in particular, is an important notion which refers to quality of science education, as outlined in the Declaration on the right to science education (see chapter in this book). Science education that entails content, knowledge, methods, and applications that reinforce power relations and increase binaries is not considered acceptable. The rights-based approach to science education provides an alternative for education researchers and practitioners, policy makers, curriculum developers, to reassess values and goals of science education apart from outcome-oriented usability considerations, and to understand science as a common good and science education as a human right.

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Part II
Science/STEM Education

PISA and the Politics of Science Education

Svein Sjøberg

1. Introduction

1.1 Background

International large-scale studies of educational achievement (ILSAs) have a long history. The International Association for the Evaluation of Educational Achievement (IEA) was established already in 1958, "when a group of scholars, educational psychologists, sociologists, and psychometricians met at the UNESCO Institute for Education in Hamburg, Germany, to discuss problems of school and student evaluation" (IEA, 2018).

Science and mathematics were, from the beginning, the key subjects for studies organized by the IEA. Based on feasibility studies in the 1960s, more focused studies were undertaken in the following decades: the First International Science Study (FISS) in the 1970s and the Second International Science Study (SISS) in the mid-1980s. In mathematics, there was a similar development with the FIMS and SIMS studies.

A major change in the IEA studies came in 1995, when science and mathematics were combined in the same study, the Third International Mathematics and Science Study (TIMSS). The acronym TIMSS was maintained for studies that followed, where the "T" now stands for "trends." As the name also suggests, the TIMSS studies are designed to measure trends in student achievement over time. Results from the TIMSS usually receive wide attention in the media, and they have, over the decades, been used as inputs to educational decision-making and policy in many of the participating countries.

Data from the TIMSS studies have also been extensively used by the OECD (Organisation for Economic Cooperation and Development) in their influential policy documents and reports, but in the late 1990s the OECD started to plan for their own study, organized on behalf of the governments of member states, the wealthiest industrial countries. PISA was launched in 2000, and since then we have had two large and costly "competing" international studies of student achievement in science and mathematics. Over the years since then, PISA has by far become the largest and most influential study. Some 75 countries took part in PISA 2018, and about 90 countries are expected to take part in PISA 2021. (Testing is postponed to 2022 due to the Covid-19 pandemic).

1.2 Introducing PISA: The Gold Standard

The first PISA testing took place early in 2000, with results published in December 2001. Since then, PISA results have gradually become a kind of global "gold standard" for educational quality. As proudly stated by PISA director Andreas Schleicher (2013) in a well-visited TED talk: “PISA is really a story of how international comparisons have globalized the field of education that we usually treat as an affair of domestic policy.”

Although the political and educational importance of PISA varies from one country to another, the results often set the scene for public debates on the quality of education. PISA league tables are widely published in mass media and are also used by politicians and educational authorities. In many countries, educational reforms are launched as direct responses to the PISA results (Breakspear, 2012).

The PISA testing takes place every three years, and the three core subjects (reading, science and mathematics) are rotated. Science was the core subject in 2006 and 2015. Results from PISA 2018 testing were published in December 2019 (OECD, 2019b, 2019c, 2019d), so we now have data from seven rounds of PISA, and new rounds are already under preparation for every third year up to 2033. Calls for tender and documents for bidders are issued many years upfront. Reading, mathematics, and science are still to remain the core subjects, with financial literacy as an option.

The PISA core subject receives much more testing time (60%) than the two other subjects (20% each). The core subject also addresses subject-specific questions in a student questionnaire. In each round, PISA includes an optional assessment of an “innovative domain.” These domains have included Learning Strategies (2000), Complex Problem Solving (2003), Computer-Based Assessment of Science (2006), Electronic Reading Assessment (2009), Dynamic Problem Solving (2012), Collaborative Problem Solving (2015), and Global Competencies (2018). For PISA 2021, (to be postponed to 2022, due to the COVID-19-pandemic) the intention is to have a unit that assesses Student Creativity (OECD, 2019e). Many countries opt out of these units.

The intentions of PISA relate to the overall aims of the OECD and its commitment to a competitive global free-market economy. (The E in OECD is for Economy, not for Education!) PISA was originally intended for the 30+ industrialized and wealthy OECD countries, but a similar number of developing countries and “economies” have since joined. When PISA is presented, its importance is stated by claiming that participants “make up nine tenths of the world economy” (OECD, 2010a, Foreword, p. 3). This is a most telling way of representing student participation, and it indicates that the focus of the PISA project is concern for the economy. Because “common sense” suggests that high student scores on reading, mathematics, and science are assumed to be predictors for a country’s future economic competitiveness, poor rankings on PISA are expected to be negative signals for the future of the country.

Given its underlying agenda, size, and importance, PISA has to be understood not just as a study of student learning but also as a social phenomenon in a wider political, social, and cultural context, and as a normative instrument for educational policy and governance. PISA rankings have been known to create panic and discomfort in many countries, including those that score highly (Alexander, 2012). This “PISA-shock” produces an urgency for politicians and bureaucrats to do “something” to rectify the situation. But PISA cannot, through its "snapshot" research design, say anything about cause and effect. Hence creativity in interpretations blooms and educational reforms that are not empirically founded are introduced, often overnight.

This paper provides a critical account of the PISA project, including its key features, development, and claims. The first relates to the PISA project *per se*: some problems are inherent to the PISA undertaking, and hence cannot be "fixed." The main point is the underlying belief that the quality of a nation's education system can be reduced to and measured by a single, universal, and global metric – independent of that nation's history and culture, let alone the purposes, values, and ideals of the nation and its school system. Problems also arise when the categories and intentions of the PISA testing framework ("curriculum") are translated into concrete test items to be used across a wide variety of languages, cultures, and countries. The requirement for "fair testing" implies by necessity that local, current, and topical issues be excluded.

The second criticism relates to the rather intriguing results that emerge from analysis of PISA data. For example, it seems that pupils in high-scoring countries have the most negative attitudes toward the subject. The data shows that PISA scores are unrelated to public spending on education, time spent on the subject, class size, etc. PISA scores are also negatively related to the use of active teaching methods, inquiry-based instruction, and the use of ICT.

The final part of the paper looks at how the OECD uses PISA as an instrument of power in well-planned, media-oriented reports and the release of results. Normative power is exerted through seemingly neutral and objective numbers, statistics, rankings, and indicators. In reports and recommendations, they celebrate "successful" examples of teaching and learning for schools and school systems, suggesting that these should be copied. "Success" here is defined as high (or increasing) scores on the PISA test, which is assumed to be an objective overall measure of educational quality.

2. Constructing PISA: Challenges and Problems

The PISA project has many of the characteristics of what is called "big science" and "technoscience": It involves the cooperation of research groups, external consultants, commercial providers, as well as policy-makers in around 75 countries. The logistics of the project are complicated, and there are substantial numbers of project documents with detailed instructions to be followed by the national groups responsible in each of the participating countries. Hundreds of experts from several fields of expertise are involved, subcontractors are awarded following a bidding process, thousands of schools and teachers are recruited, and nearly half a million students spend 2½ hours answering the test and the questionnaire. Data, carefully coded by thousands of specially trained markers, are then submitted to the organizers to be cleaned, verified, and then through a complicated process, converted to the scores that are published.

The PISA undertaking is a well-funded international "techno-scientific" enterprise, undoubtedly the world's largest and most costly empirical study of schools and education. An analysis of the costs of PISA in the U.S. alone estimates a total cost of about 6.7 million USD per round (Engel & Rutkowski, 2018). Much of this amount goes to commercial sub-contractors. Some money also goes directly to the individual students who participate in the study. Teachers and school coordinators are also offered money to take part. On top of these costs, each state in the U.S. pays to participate (Engel & Rutkowski, 2018). These practices vary between countries. In some countries, participation is obligatory for schools as well as for students.

2.1 OECD and Emergence of PISA

The OECD has developed since the end of WW2, originally as a part of the U.S.-driven Marshall Plan to rebuild the European economy after the war. The member states included 18 countries in Western Europe. The key aim was to promote and support a free market, capitalist economic system. An obvious agenda was to provide defense against communism and influence of the Soviet Union. The present (2021) OECD has 37 member states.

Since the 1960s, the OECD has gradually increased its interest in human resources / human capital as a key factor in economic development, with emphasis on the training of a skilled workforce, in particular, technical and scientific personnel. A key person in this development was Norwegian economist Kjell Eide, who was central in the development of educational involvement of the OECD in the period from the early 1960s up to the beginning of the 1990s. Eide (1995) describes the political debates and how various positions on the role and importance of education competed within the OECD and its various sub-committees. While some countries argued for the importance of a broad-based curriculum with an emphasis on human development and "Bildung", others were oriented toward a more instrumental role of education: the development of a skilled workforce for the labor market. The notion of "school efficiency" became a contentious issue in debates within the OECD. Eide writes:

> In the 1980s, in particular, the U.S. aggressively put forward more conservative political ideas on the OECD's educational agenda: quality in education, free school choice, new modes of financing, cooperation with industry and commerce, accountability, efficiency in use of resources, performance pay, etc.
> The ambitions may be that the OECD takes responsibility to arrange international tests and examinations (like TIMSS) on behalf of the governments. […] If so, this will make the OECD a strong instrument of power, and will contribute to a harmonization that will exceed everything that we have feared from the EU. (Eide, 1995, p. 104, author's translation)

This was written just two years before the planning of PISA commenced. One may argue that Eide's fears have fully been realized. In the first report from PISA/OECD, the joint commitment of the OECD "owners" was clearly stated:

> PISA represents a new commitment by the governments of OECD countries to monitor the outcomes of education systems in terms of student achievement, within a common framework that is internationally agreed. (OECD, 1999, p. 11)

This report was written a year before the first PISA testing and indicates the intentions and ambitions of the PISA undertaking. In later reports, the normative nature of PISA is even more explicit.

The economical mandate of the OECD also explains why the "PISA subjects" are reading, mathematics, and science. These subjects are seen to be key elements for national competitiveness in a world economy driven by science and technological development. The selection of PISA subjects also carries a direct message about what is deemed important in schools and in the development of young people.

PISA is owned and organized by the OECD member states and governed by their politicians and appointed bureaucrats. The PISA Governing Board is composed of representatives of OECD members, clearly expressed as follows:

> Representatives are appointed by their education ministries. [...] The Board determines the policy priorities for PISA and makes sure that these are respected during the implementation of each PISA survey. (http://www.oecd.org/pisa/contacts/pisagoverningboard.htm, visited December 14, 2020)

OECD's mandated focus on the preparedness for the global economy distinguishes PISA from studies like TIMMS, which are organized by the IEA and grow out of academic communities and their research interests. Although the IEA studies have also enjoyed political and economic support, they do not have the same direct commitment to political or ideological stances. In later years, however, governmental departments are IEA member institutions and do play a more active role in the policies of the IEA, not only in the funding of their many projects.

The current normative power of PISA stems from the political and economic status of the OECD and its ownership by member state governments. When PISA was introduced by the OECD, it immediately started to influence the education sector, which was also the purpose of the program.

2.2 Claims, Framework and Test Items

What does PISA claim to measure?

The official statements about what PISA measures are in many ways confusing, even contradictory. In some places, PISA declares that they do *not* measure school knowledge or competencies acquired at schools; in other places, they state that they actually *do* measure the quality of science and mathematics teaching, and indeed the quality of a nation's entire school system.

The overall aims of PISA were already stated in 1999, before the first PISA testing took place in 2000. These are the first words in the presentation of the ideas behind PISA:

> How well are young adults prepared to meet the challenges of the future? Are they able to analyze, reason, and communicate their ideas effectively? Do they have the capacity to continue learning throughout life? Parents, students, the public, and those who run education systems need to know. (OECD, 1999, p. 11)

These exact words have been repeated in most PISA reports from the OECD over the years. In other parts of their reports, claims are more modest. They stress that PISA scores do not actually provide measures of the quality of *education systems*, but the *collective results* of school, home, and social environments.

PISA is explicit that they do *not* measure according to national school curricula, but rather on the assessment framework made by OECD-appointed PISA experts (OECD, 2016a). The PISA Technical Reports clearly state that the knowledge and skills tested on PISA "are defined not primarily in terms of a common denominator of national school curricula but in terms of what skills are deemed to be essential for future life" (OECD, 2009, p. 11).

So, although PISA states that it does not test school knowledge, and that it does not test according to national curricula or test school knowledge, PISA results are presented as valid measures of the quality of national school systems.

Constructing PISA: Crucial choices

The translation of PISA ambitions to actual tests that students take moves through several stages, each with serious obstacles where many decisions have to be made. The first step from the overall intentions behind PISA to actual testing is the selection of knowledge domains (or school subjects) that should be included. The OECD chooses three domains ("literacies") for PISA testing: reading (in mother tongue), mathematics, and science. These are important and basic subjects, of course, but one should keep in mind that most domains are *not* included.

International differences make it impossible for PISA to embrace all possible school subjects, but by selecting some and ignoring others, they implicitly convey a message to the public, as well as politicians, about what is important for schools and future life. When, in 2012, PISA extended its repertoire, the chosen domain was "financial literacy" (OECD, 2013), a subject that does not exist in schools in the majority of countries. Not all countries included this option in their PISA testing, and it remains an option.

The PISA framework

The next step is to create a testing framework for the chosen domains – in reality, a "PISA curriculum." Key external institutions (the successful bidders) and the nominated subject matter specialists are in charge of a lengthy process to develop this framework. The persons selected for this purpose are well-known international experts in their fields. But, of course, they work within the politically established frames decided on by PISA as a project, and they must all be fluent in English, the language of all deliberations and working documents. In addition to these subject matter specialists, psychometricians play a key role in the whole process.

Most educators in science and mathematics will probably find the PISA frameworks developed by these expert groups to be interesting, with ideas, perspectives, and subject matter details that are of very high quality (see, for instance OECD, 2016a).

It is, however, noteworthy that the term "human rights" is not mentioned in the 200 page PISA Assessment framework for the three domains that PISA addresses (OECD, 2019a). Noteworthy is also that neither the UN Sustainable Development Goals nor the related initiatives for Education for Sustainable Development are mentioned. The term "Human rights" is not mentioned in the framework.

A universal test for "real life" challenges?

An underlying, fundamental premise of PISA is that it is possible to measure the quality of a country's education by indicators that are universal and independent of school systems, social structure, traditions, culture, natural conditions, ways of living, modes of production, etc.

As noted above, PISA claims to measure "how well the young generation is prepared to meet the challenges of tomorrow's world." Such an ambition assumes that the challenges of tomorrow's world are already known and that they are more or less identical for young people across countries and cultures. Although life in many countries has similar traits, one can hardly assume that 15-year-olds in, for instance, the USA, Japan, Norway, Turkey, Mexico, and Brazil face the same challenges and that they need identical and measurable skills and competencies in their future lives.

One should also keep in mind that the PISA test is meant for young students in the relatively rich and modernized OECD countries. When this test is used as a benchmark for educational standards in the 40 non-OECD countries that take part in PISA, the mismatch becomes even more obvious. In years to come, another version of PISA – PISA for Development (OECD, 2020b) – will be implemented, targeting developing countries. Through this move, the OECD also provides their "advice" to developing countries about what they should teach in schools and how they should organize their schools and education system.

The ambitions of PISA are high but are contradicted by the very format of the testing. The PISA test is, like most exams and tests, an artificial situation, where students sit for two hours to answer written questions, in solitude and without access to sources of information.

How much does this test situation resemble "real life" and relate to the "authentic challenges" that young people may face in their future life as citizens, as participants in tomorrow's democracy, and as members of a skilled workforce? Put this way, these questions are, of course, rhetorical; the PISA test situation does not resemble any real-life situations. The only place where you sit in solitude with a written test is in fact in exams at schools and universities. The PISA test situation is no different from most other tests and exams. Moreover, since the PISA test is anonymous, results cannot be traced back to the students, their teachers, or schools. Such tests may also be seen as tests of student loyalty, obedience, and respect for authority.

PISA item selection and test construction

Once the PISA testing framework is constructed, the next step is to "operationalize" it, that is, to use the framework to develop and select the test items and build the PISA test as a whole. This complicated process is described in voluminous technical reports (see, for example OECD, 2009). These reports are often published more than a year after the release of PISA results, which makes critique and scrutiny by peers difficult (Rutkowski & Rutkowski, 2016).

The item development process involves the following steps: Each PISA country (solely the OECD members) is invited to submit test items that fit the framework and are based on "authentic texts" for "real-life situations." The final series of test items is decided through a complicated process with initial screening and selection, national and international piloting, pre-field trials, a main field trial round, and psychometric analysis, all of which involve many actors and subcommittees and many meetings for negotiations and debate.

A logical consequence of wanting to make a fair international test is that an item cannot be used if it behaves in an "unfair" fashion. While this is a sensible argument from a statistical, psychometric point of view, it also implies that items that are too close to real-life contexts in some countries but not others have to be removed. Other principles for exclusion are described as follows:

> The main reasons for assessing units as unsuitable were lack of context, inappropriate context, cultural bias, curriculum dependence, just school science and including content that was deemed to be too advanced. (OECD, 2009, p. 34)

Thus, test units (items) that relate to issues that are considered "inappropriate" (controversial in a particular country), have a "cultural bias" (be it positive or negative), or are too close to the school curriculum (in some countries but not in others) were excluded. The statement also explicitly states that items that are "just school science" should be excluded. This is, again, a clear statement that PISA does *not* measure school knowledge or issues related to school curricula. Given the above statement, it seems somewhat strange that such a test is used to judge the quality of science taught in schools.

In reality, the test items in the final test are decontextualized, or the context is contrived or historical. The need stems not from intentions expressed in the testing framework but, rather, from statistical necessity and concern for "fairness." This runs contrary to recommendations from educators as well as many national curricula promoting a curriculum that is relevant, interesting, and context-based, at least for the compulsory school levels.

2.3 Intriguing Results and Growing Critique – is PISA off Target?

The OECD and its PISA researchers are, of course, well aware that PISA data cannot establish causality. This is clearly expressed in the Introduction in the summary report from PISA 2015:

> While PISA cannot identify cause-and-effect relationships between policies/practices and student outcomes, it can show educators, policy makers and the interested public how education systems are similar and different – and what that means for students. (OECD, 2018, p. 3)

In spite of such assurances, the official results from PISA are presented in a language that suggests that such causalities exist. Lists of "what works" are based on co-variation between PISA scores and constructs from, for instance, student questionnaires and data from the schools' principals. Many of the problematic "results" presented in this paper are of this nature. Readers – including national policymakers, school "owners," principals, or teachers – will interpret such results as showing cause and effect. Moreover, from the vast number of possible relationships between PISA scores and other variables and constructs, readers may easily find "evidence" to support their own agendas – support, for example, that class size does not matter, that teacher education does not matter, or that public money spent on education has no influence on the quality of schools. PISA scores are also negatively related to the use of active teaching methods, inquiry-based instruction, and the use of ICT. These findings are further explored by Sjøberg (2019) and Sjøberg and Jenkins (2020).

Limitations, errors and uncertainties are under-communicated

The reported PISA numbers and indicators are, of course, not clearly defined and operationally objective measurements as in natural sciences like physics. PISA constructs are imperiled by several sources of error and uncertainties. These are seldom reported properly, or are only found in footnotes and technical reports. In a comprehensive review of uncertainties, sampling errors and technical limitations of PISA, Sellar, Thomson & Rutkowski (2017, p. 53) conclude:

> Unfortunately […] there is a growing amount of evidence that these limitations are not being clearly and simply communicated to the broader scientific, policy, and practice communities. More care needs to be taken to ensure that the results are understood as fallible measures.

In an article in the prestigious *Journal Educational Researcher* Rutkowski and Rutkowski (2016) give several examples of how the PISA project has weaknesses and shortcomings that are not communicated, and that their conclusions and recommendations are doubtful. They make a "call for a more measured approach to reporting and interpreting PISA results". It falls outside the scope of this paper to go in detail on this most important limitation of PISA, but it seems fair to say that the criticism of PISA and the way it is used and abused is widespread among academics concerned about schooling and education. This critique has increased over time, also because PISA is extending its scope and influence in several ways.

PISA results and spending on education

Right from the first PISA round, the reports produced graphs and indicators that showed small or negligible correlations between a country's PISA scores and its spending on education (OECD, 2001). This finding led to OECD advice that more public spending on education will not necessarily improve its quality. More concretely, it is interesting to note that in the five Nordic countries, the relationship between public spending and PISA scores is actually strongly negative. Finland, for instance, scores highest but is lowest in spending. These relationships are used in political debates in various ways: Finnish teachers have difficulties asking for higher salaries, more funding, or other changes because they are already on top in the rankings. Norway, on the other hand, has been much lower in the PISA ranking, but with higher public spending on schools. Based on PISA, Norwegian politicians argued that it has been "proven" that more spending would not increase the quality of schools.

PISA findings on cost and funding, such as the above, are frequently used in influential OECD publications, such as the annual *Education at a Glance.* This publication concludes that "averaged across OECD countries, there is potential for reducing inputs by 30.7% while maintaining outputs constant" (OECD, 2007, p. 16). That is to say, the OECD is suggesting that reducing spending on education might not impact its quality.

3. The OECD and PISA Project: Politics and Global Educational Governance

The OECD is not hesitant to claim that PISA has globalized educational policy and lifted it out of the national sphere (Schleicher, 2013). More concretely, an OECD Education Working Paper provides details of the normative effects of PISA. The report states that

> PISA has been adopted as an almost global standard, and is now used in over 65 countries and economies. […] PISA has become accepted as a reliable instrument for benchmarking student performance worldwide, and PISA results have had an influence on policy reform in the majority of participating countries / economies. (Breakspear, 2012)

In this report, the OECD reviews literature as well as results from their own questionnaires and provides a ranking (!) of the impact that PISA has had on all OECD countries. The report notes that even "high-performing countries such as Korea and Japan have enacted reforms in response to a large range of PISA results" (Breakspear, 2012).

As previously noted, international comparative studies of student achievement have existed for at least 50 years, and they have influenced and informed educational debates and policies in many countries for decades. But the scene changed dramatically when the OECD launched PISA. Now (2021), after seven published rounds of PISA testing, TIMSS and other international achievement studies play a much smaller role in most countries, although these studies actually measure knowledge that is much closer to existing school curricula. Much of the power of PISA resides in its "ownership" by the OECD, an organization that is owned and directed by its member states' governments.

3.1 Competition, Market Thinking, and Globalization

The PISA project should be seen as part of a wider international policy trend where concepts and ideas from the market economy are used in the education sector. Key words here are competition, success, market, and globalization. They are visible in many sectors of society, including education. These concepts are part and parcel of the free-market, capitalist economic system and its underlying beliefs. A most visible aspect of PISA is its focus on league tables and numerical scores. This creates competition where there are winners and losers. The countries at the top are celebrated as "successful," and PISA reports hold them up as winners and models. Everything seems to center on having success: PISA reports celebrate successful systems, successful schools, successful reformers, successful learners (OECD, 2010a, 2015b, & 2016c). The underlying belief is that competition in a market always generates quality and leads to success. And the purpose and meaning of life is to have success and to be competitive.

The term "New Public Management" is used to describe a market-driven system that is supposed to make the public sector more efficient. Terms like quality, efficiency, transparency, accountability, productivity, and "value for money" are among the (often positively laden) terms that are used in these policy reforms in many public sectors. Public services like schools and higher education, culture, health, and care have been invaded by these market terms. Other (previously) public sectors – health, police, security, postal services, transport, water supply, handling of household garbage, sewage and wastewater treatment, etc. – have experienced the same trend: Traditional public services are increasingly subjected to competitive bids where they compete with private actors. Outsourcing of key public services is an international trend, and bids are often taken over by multinational companies, a process that is eased by new regulations on international trade. This trend towards marketization and privatization characterizes the development in several countries as part of a pervasive wave of neoliberal reforms (Münch, 2020). In this development, the education sector is at the forefront, with the OECD as actor and the PISA project as an efficient tool (Meyer & Benavot, 2013).

A related political / economic perspective is that of globalization. The economy has become globalized and large multinational companies have increased their influence. This demands a workforce that is flexible and mobile. Hence, there is a need for common standards in education, common systems for exams, degrees, and qualifications. Such tendencies operate within units like the European Union, where an example is the "Bologna process" and its introduction of a common degree system and standardized ways of describing courses and competencies in higher education. In key areas, the OECD is playing an increasingly important role by developing and monitoring common standards, indicators, and measures (Grek, 2009).

This PISA-fueled process represents a political pressure to standardize, harmonize, and universalize national institutions – including countries' school systems – and to promote competition on the global educational scene (Ball, 2012). While most educators argue for context-based science teaching and localized curricula, at least in the obligatory school years, the pressure from PISA is in the opposite direction. A driving force behind these reforms is often the use of indicators – quantifiable and measurable standards that can be used for calculations (Popkewitch, 2011). PISA test scores and rankings are ideal for this purpose.

Human Capital Theory: Test scores and economic prosperity

The importance of human resources as prime drivers in the modern economy was the main reason for the OECD to focus more on education. The theoretical underpinning of this is often referred to as Human Capital Theory. The competencies of the workforce in the contemporary economy are considered even more important than other forms of capital, such as machinery, buildings, and infrastructure. Hence, the efficient development of a productive workforce becomes a key concern for development of the economy. From this perspective, money spent on education is not only for individual growth but an investment that will pay off in the future of the country's economy and competitiveness.

Today, it therefore seems "common sense" that high scores on science and mathematics tests at school are good predictors of future economic prosperity. Poor rankings on PISA are presented as negative signals for the future of the country. This postulation is probably the main reason for the extreme importance given to PISA results and rankings. PISA is, in fact, also "sold," presented, and understood from this perspective.

It falls outside the scope of this paper to go in detail, but only to mention that the "common-sense" relationship between student test scores and future economic prosperity has been forcefully rejected by scholars from widely different academic fields. See, for instance, Komatsu & Rappleye (2017) and Rappleye & Komatsu (2019).

PISA and the market

As indicated earlier, PISA is a most complicated project, involving thousands of people. Most of the work is done by sub-contractors, at the central as well as the national level. Some of the contractors are commercial providers. The most important has been Pearson, the world's largest company for testing and education programs, with more than 22 500 employees operating in 70 countries. Presently (2021), 80 percent of Pearson's revenues come from education, maybe the world's fastest growing market sector. Pearson won the bid for important parts of the PISA 2015 testing and developed strong ties with the OECD. In PISA 2018, Pearson even increased its grip on PISA. A joint press release from the OECD and Pearson proudly announced that

> Pearson has won a competitive tender by the OECD to develop the Frameworks for PISA 2018. [...] The frameworks define what will be measured in PISA 2018, how this will be reported and which approach will be chosen for the development of tests and questionnaires. (Joint Press release PISA/OECD and Pearson, Dec 10th, 2014)

This key role in PISA does not, of course, imply that Pearson's staff is doing the work. But they do organize and administer the process. Pearson continues to forge personal ties with countless academics in key positions and numerous representatives of national educational authorities. For PISA 2021,

> Pearson, in collaboration with the Oxford University Centre for Educational Assessment (OUCEA), has been awarded the PISA 2021 contract [...] to operate as the National Centre for England, Wales and Northern Ireland. (http://www.education.ox.ac.uk/oucea/our-research/programme-for-international-student-assessment-pisa-2021/ accessed December 14, 2020)

The market for educational services and contracts is huge, since all countries use a substantial amount of national spending for schools and education. Commercial, private, and for-profit providers take an increasing slice of this cake. "Edu-business" has become a blooming global market, often fueled by the results of the large-scale international studies, in particular PISA. The *World Yearbook of Education* in 2016 had *The Global Education Industry* as its main topic (Verger, Lubienski & Steiner-Khamsi, 2016). Large portions of what used to be public services are subcontracted to commercial providers, often in close cooperation with academic insitutions . It falls outside the scope of this paper to elaborate on this most important issue.

PISA: Redefining the purpose of schooling

The most fundamental and serious influence of PISA is that it redefines the very purpose of schooling and education. PISA claims to measure skills and competencies that are important for the future economy and employability. It thereby ignores that schools serve the much broader purpose of contributing to the personal, human, and social development of the child, with an overall aim to help them become well-informed and well-functioning individuals and citizens. In each country, compulsory schooling is the key socializing agent. The school provides the induction to the nation's culture, values, history, and norms, and the school is a place where the developing child is exposed to a broad variety of disciplines and ways of thinking and acting.

PISA appears to assume that this complex set of purposes of the school can be reduced to one common, standardized, and measurable metric – independent of country, culture, and context. It is this postulate that gives rise to the most basic objection to the whole PISA undertaking. PISA reduces the purpose of schooling to be what can be measured on a single dimension in a single test at a particular time from a sample of 15-year-olds in school. This number, in the form of the PISA score, is presented as – and too often taken to be – a neutral and objective measure of quality and efficiency of the whole education system.

The fundamental debates about the meaning and purpose of schools and education are replaced with a reference to numbers and test scores. Philosophical, ethical, and cultural debates are silenced and replaced with a simplistic, technocratic number game and an interest in "what works." Statistics, rankings, and numbers replace reflection, debate, and politics. Terms like Human Rights are irrelevant in such a discourse, and they do not appear in PISA frameworks or other documents.

3.2 Governance by "Soft Power": Numbers, Rankings, and Comparisons

Neither PISA nor its "owner," the OECD, has any formal, legal power. They exert influence by what is often labeled "soft power" (Bieber & Martens, 2011; Pons, 2017): setting the agenda, naming the challenges, defining the indicators, publishing statistics, and providing expert advice through different sorts of reviews and country reports.

A key role is played through the provision of statistics. Over the years, the OECD has become a key global provider of statistics, not only for its key concern, the economy, but also in the education sector. The OECD statistics are increasingly used by other global actors, including the European Union, the World Bank, and, increasingly, UN organizations like UNESCO.

Good and reliable statistics are, of course, important. But statistics and indicators do not just describe reality; they construct and shape reality. What one chooses to measure also defines what is seen as important. All indicators build on underlying assumptions and value-based priorities that are often forgotten when league tables are constructed and presented.

Breakspear (2014) makes the same point clear in a report with the telling title *How does PISA shape education policy making? Why how we measure learning determines what counts in education*.

PISA results create competition, not only between countries but also between states, territories, and districts within one country (e.g., Canada, Australia, Germany, U. S. A.).

Some researchers describe PISA as "a global educational race" (Sellar, Thompson, & Rutkowski, 2017; Sjøberg, 2016).

PISA reporting: targeting the media and policy makers

The educational governance by PISA has many facets. The great institutional authority of the OECD is mentioned. This authority is strongly exercised when new results of PISA are released in early December every third year. Well-attended and coordinated press conferences are arranged in all participating countries. The press is provided with well-prepared briefs, and the international and national reports are released. Then there is the wait to hear that "the winner is…" and that "research shows …"

These PISA reports are not regular peer-reviewed publications written for an academic audience; they are directly addressed to the media and policymakers. These products are glossy and colorful, well written, with simple messages, conclusions, and recommendations. Presentation videos and interactive data animations are also made available. The invitations to the press briefings and the release of reports send a clear message: PISA results should be seen as indicators for the future the of the country's economic competitiveness.

For example, when PISA 2006 was released in the U.S., the invitation had the heading, "Losing Our Edge: Are American Students Unprepared for the Global Economy?" The text states that "[t]he lessons learned from PISA results […] can, and should, be used to inform U.S. education policy so that our students graduate … ready to compete, thrive, and lead in the global economy of the twenty-first century" (Alliance, 2006). Similar wordings are regularly used at PISA launches in other countries.

In the 3-year period between the releases of new PISA results, a series of "policy briefs" are released, thereby maintaining the pressure through media coverage. Many of these "user-friendly" media-oriented products are made in close cooperation with commercial providers. As of December 2020, 110 such policy briefs had been published (OECD, 2020c).

As exemplified above, the so-called PISA shock is not "created by the media," as often claimed, but is created by the OECD itself at the PISA release and through subsequent policy briefs and reports, often adapted to the national context. In most countries, the PISA researchers depend on continued funding from the government. They have a vested interest in maintaining close contact with political levels. The national PISA teams have an objective interest in having good relations with their respective ministries of education. They seldom react in public if politicians abuse or misinterpret PISA results to serve their own interests.

For young researchers, hoping to make a career and secure funding, it may not be a good idea to be too critical toward the funding agencies for research, in particular those under strong political control.

The modes of marketing of PISA create and maintain an atmosphere of urgency in many countries. This also provides a "window of opportunity" for reforms: a perceived crisis provides the need “to do something.” But since PISA cannot, by design, explain either success or failure, the “crisis” opens opportunities for all sorts of reforms being legitimized by PISA results.

Expanding and extending PISA

From the viewpoint of the OECD, PISA has been a remarkable success. By providing rankings, data, and indicators based on its data, the OECD sets the scene for discussions about quality of schooling and entire school systems. And in most countries, politicians and policy-makers follow suit. Given this success, it is easy to understand that the OECD is also broadening its scope within, and influence on, the education sector with other “PISA-like” studies with focuses ranging from kindergarten to adult life, from the national level to school level, and from highly-developed OECD countries to developing countries.

Over the last decades, the OECD has become the prime provider of high-quality data, statistics, and indicators to describe and understand what is going on in education worldwide. Given the authority of the OECD and the power of numbers and statistics, this can also be seen as the power to define the purpose of education and set the political agenda.

4. Summary and Conclusions

The PISA project has led to increased interest in and concern for education and the competencies that young people need to develop to achieve the different “literacies” needed for their future lives as well as the wellbeing of their societies. The data generated by successive rounds of PISA is remarkable, and is most likely the largest and most professional data source in the history of social science and education. These data are also well documented and are open for potentially interesting research, but the limitations, errors and uncertainties in the data are not evident for the possible user.

International comparisons in education are important; they can open up new perspectives, and they can provide inspiration and ideas for educators, researchers, and policymakers. However, international comparisons have a Janus face: they can be understood and used in two contrary ways. On one hand, such studies may be eye-openers to acknowledge and celebrate the great variety among youth, nations, and cultures on aspects of education, and as such serve as sources of inspiration. On the other hand, such studies can also be used normatively, providing pressure to oblige and fit to allegedly universal and common standards set from the authority of external specialists. We experience what is seen as a prime example of New Public Management as well as a kind of global governance and standardization of education, as also noted by a range of experts (Ball, 2012; Rinne, 2008). The Finnish educator Pasi Sahlberg (2011) characterizes the current PISA-driven educational reforms by the acronym GERM: Global Educational

Reform Movement, characterized by privatization, market driven neoliberal reforms, free school choice, competition, and test-driven accountability.

The official aims of PISA, as cited earlier in this paper, can easily be endorsed. No one disagrees with the need to ensure that young people develop the knowledge, skills, and competencies needed to face the challenges as citizens of the future. But the underlying economic and political rationale behind the OECD's PISA project is often ignored or under-communicated. Even researchers in the PISA project seem not to realize (or accept) the overall political / economic aspects of the project. Many national reports do not quote the key statements that describe the normative intentions of PISA. Maybe they feel embarrassed by the bold claims being made?

The inherent difficulties in measuring what PISA asserts to measure are seldom realized. The road from the noble intentions to actual test instruments and published data is long and murky. In this paper, I have pointed to some of the problematic issues in this process, including the selection of subjects (at the expense of other subjects). Fundamental problems are also inherent in the development of an international, fair test, which by necessity demands context-free items. Further complications arise when items are translated to other languages. In this paper and elsewhere (Sjøberg, 2007, 2020), I argue that it is not just problematic to live up to the intentions laid down in the overall statements of PISA. I argue that it is in fact a "mission impossible." The public, media, and policy makers, however, often take the PISA scores and rankings as given facts. They trust that the experts know what they are doing, and that the numbers are objective and neutral measures. They trust, too, that PISA scores are valid measures of the total quality of their education systems.

No test is better than the items it consists of. Yet the secrecy surrounding development of most PISA items makes critique and scrutiny from the academic community and the public difficult. Many of the published PISA items have met serious critique, both for the content and for the language and relevance. Translations into many different languages have only to a limited degree been examined, but it is easy to find flaws and even substantive changes and mistranslations. More research is needed here.

The problematic and relatively opaque use of statistics receives considerable critique. Suffice it to note that the statistical procedures leading from individual test scores to the published population parameters, such as PISA mean scores, have been seriously challenged. Kreiner and Christensen (2014) write that their findings "do not support the claims that the country rankings reported by PISA are robust." In the analysis of the PISA 2015 data, the procedures were changed, in part to address this criticism. This caused the resulting PISA scores of some countries to change dramatically, much more than deemed educationally possible over a three-year period. The details of these discussions are only for specialists in psychometry, and not for a paper like this. But it indicates the danger of accepting PISA scores as simply given and unproblematic.

There seems to be little attention to the fact that many of the results of PISA are at odds with what educators recommend as well as with what politicians propose as medicine to improve the quality of schools. Many politicians want their nations to catch up with the PISA winners, but to do so they often prescribe measures opposite to what these winners actually do. Moreover, the PISA winners are actually doing very different things, so this provides policy-makers the opportunities to choose examples that fit their own priorities. (Should we copy Singapore or Finland?) There is a need to seriously address these paradoxical results.

PISA has a profound influence on educational policy in many countries, and this is indeed the clearly stated intention behind the project. It is clear, however, that PISA results are used selectively, misused, and even distorted for political purposes in many countries. The reference to PISA to justify and legitimize educational reforms is widespread. This influence ought to be better researched and scrutinized. PISA is, in essence, a political project, a perspective that often falls outside the agenda of the educational research community.

Large resources are used to run the PISA project and to produce their reports and publications, but critical research is scarce and not well funded. A key aspect of the academic ethos is to provide a critical voice and to question and challenge conventional wisdom. Given the great political and educational importance of PISA, there is a strong need for critical and independent research.

This brings me to a most important concern: critique of PISA may be risky business. The research communities in many countries are currently under pressure to secure funding and support for their activities. When positions are advertised, a track record of earning external money is important, often among the criteria for a successful application. The funding for free critical research is limited and often under pressure. More funding is available for contracted and commissioned research, from governmental and ministerial sources as well as from private interests. Academic freedom and the basic ethos of science and research are under increasing pressure. Many universities and their departments are run like companies, and the bottom line on the budget trumps academic ideals. Large contracts depend on winning tenders and bids. In such an atmosphere, the leaders and staff often exercise a form of self-censorship, not wanting to upset or criticize the interests that sit on the funding. The ILSAs (International Large-Scale Assessments) – and PISA in particular – provide solid funding for many academic institutions. Hence, it becomes important to keep a close relationship with the funding agencies, in this case the governments and the ministries of education and research.

It is important that people (including researchers and teachers unions) who are critical and skeptical toward PISA have thorough knowledge about the project and the other PISA-like studies mentioned in this paper. Data never talk directly and "for themselves" but needs to be selected and put together to produce an argument in support of a stance. Given the enormous amount and variety of data from PISA, "evidence-based" stories can be constructed for any point one wants to make.

Finally, in a book like this, we should notice that neither the UN Sustainable Development Goals nor the concern for Human Rights seem to be important for the PISA undertaking. PISA winners and successful education system are celebrated without any concerns for the situation for democratic governance or human rights in their schools or in the wider society.

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STEM Curriculum Development: The Case of Turkey

Seval Fer

1. Introduction

With a discipline-integrated and student-centered approach, STEM education supports and presents an inter-disciplinary approach to teaching and learning. STEM education promotes active, collaborative, and effective learning via interdisciplinary work and applied activities.

The main aim of STEM education in Turkey is to increase the interest and knowledge of students in STEM. Thus, the major challenges in implementing STEM education in schools include the integration of knowledge and the application of science, technology, engineering, and mathematics in various situations and learning environments, especially as activities in schools. On the other hand, although the Ministry of National Education, universities, and other institutions are interested in improving STEM education, more is needed to develop such efforts as indicated in this chapter.

This chapter begins by addressing the question of what STEM education tells us. Then, the connection between the STEM curriculum and instructional design is explained. In addition to STEM studies in the Ministry of Education in Turkey, STEM centers and laboratories at universities are also covered. The chapter concludes with some research findings from Turkey regarding STEM.

2. What Does STEM Education Tell Us?

Is STEM simply a trendy word or does it reflect a real need? We need to ask such questions because STEM education has been the center of attention lately. We also observe that the concept is widely used in academic, school, and non-school environments. So, whether the concept is a popular trend or has emerged from real need is an important issue to consider; therefore, it may be appropriate to start this section of the book by examining what STEM education is.

The STEM acronym was introduced in 2001 by science executives at the US National Science Foundation (NSF). The organization used the abbreviation SMET to refer to career areas in these disciplines or curricula that integrate knowledge and skills in these areas. But in 2001, American biologist Judith Ramaley rearranged the words to form the STEM acronym (see Hallinen, 2020). Today, STEM, formed from the first letters of science, technology, engineering, and mathematics, refers to activities within these academic disciplines.

The term, STEM, is also used in a broader sense to include psychology, the social sciences (e.g., political science), economics, the physical and life sciences, engineering fields, physics, chemistry, biology, and mathematics. On the other hand, it is also used with a narrower definition that generally excludes the social sciences and focuses specifically on mathematics, science, computer, and information sciences, and engineering; however, in recent years, some analysts have argued that field-specific definitions are too narrow and that definitions of STEM should focus on "an assemblage of practices and processes that transcend disciplinary lines and from which the knowledge and learning of a particular kind emerges" (Congressional Research Service, 2018, p. 2).

As can be easily seen, there is no consensus on the concept of STEM education and the disciplines it covers. It is understood that the concept is used with meanings that extend from narrow to broad. However, generally speaking, STEM comprises four main disciplines: science, technology, engineering, and mathematics. In recent years, the acronym SMET has also been preferred to STEM. It consists of the first letters of the disciplines of science, mathematics, engineering, and technology, among which the positions of two disciplines have changed.

Typically, the term STEM education refers to teaching and learning in the fields of science, technology, engineering, and mathematics. It typically includes educational activities across all grade levels – from pre-school to post-doctorate; therefore, STEM education might be used for instructional activities in both formal (e.g., classrooms) and informal (e.g., afterschool programs) settings (Congressional Research Service, 2018).

STEM education is an intentional, multidisciplinary approach to teaching and learning. Thus, students cover and acquire a joint set of concepts and competencies in science, technology, engineering, and mathematics via STEM education. It is also applied in and transferred to both academic and real-world contexts (Rider-Bertrand, 2015; cited in, Erden, & Fer, 2018). STEM education is regarded as an interdisciplinary approach that integrates the areas represented by its name; it involves use of these disciplines together in an instructional platform for learning and teaching.

The answer to the question "What does STEM education tell Us?" varies depending on the purposes of the STEM user. On one hand, as understood from the explanations presented above, it is possible to use the term in teaching environments; on the other, it is possible to use the term in its popular sense.

3. Connection Between STEM Education and Curriculum and Instruction

STEM education includes planned education, and planned education is provided only through curriculum and instructional design. Therefore, we need to design a STEM-oriented curriculum to teach students and others interested in STEM.

The STEM curriculum and instruction support active, collaborative, and meaningful learning, as well as mastery of skills (Innovate, 2014; cited in, Erden, & Fer, 2018) via a multidisciplinary, integrated, and student-centered approach. According to Larmer and Mergendoller (2012, cited in Misher, 2014), the ideal learning environment engages students in interdisciplinary work and project-based learning using real-world contexts.

The main aim of the STEM-oriented curriculum is to increase the interest of students in STEM. STEM education also seems an effective approach to improving the skills of students in courses by using technological tools and producing new technologies. Thus, the STEM-oriented curriculum might also provide a good solution to students with poor concentration and wavering attention spans who quickly become bored in traditional courses. Therefore, equal opportunity can be provided to such students.

On the other hand, Bybee (2010; cited in Erden, & Fer, 2018) noted that one of the major challenges in implementing STEM education is the integration of technology and engineering knowledge into the teaching curriculum (Erden, & Fer, 2018). Still, the STEM-oriented curriculum has been extended to a great number of countries along with United States (Hallinen, 2020).

The most appropriate curriculum design might be a broad-fields design, often called interdisciplinary design, which is an interdisciplinary approach to teaching and learning that can be transferred and applied in both academic and real-world contexts. With a discipline-integrated and student-centered approach, the STEM curriculum and instruction, including extra-curricular activities, promote active, collaborative, and meaningful learning for students via interdisciplinary work and project-based learning by using real-world contexts.

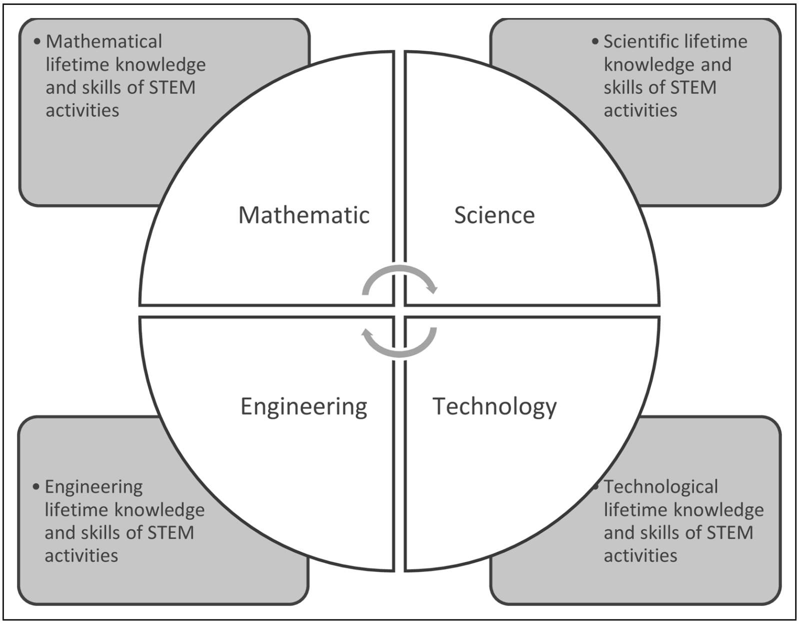

Figure 1: Broad-Fields Design for the STEM Curriculum

According to Ornstein and Hunkins (2018), the curricular emphasis of broad-fields design is on linking separate subjects and disciplines, while maintaining their separate identities. The underlying philosophy of broad-fields design is both essentialism and progressivism. The source of the curriculum in broad-fields design is knowledge and society, inspired by the pioneering work of Broudy and Dewey.

As shown in Figure 1, broad-fields design allows students a comprehensive understanding of all content areas because it not only interconnects well-accepted content fields but also attempts to integrate all content that logically fits together. According to broad-fields design, the separate subject is impractical and ineffective. Instead, we need to make use of emergent clusters of problems and questions that engage students in constructing and reconstructing information. On the other hand, like other designs, the design faces problems, the most important being breadth at the expense of depth. "The issue of depth is even more central when we expand the broad-fields design to integrated curriculum design" (Ornstein & Hunkins, 2018, p. 191). The philosophies of schools and educators influence their responses. For instance, in science, how much depth will students achieve on the theme of dinosaurs or machines? And how will they construct the webs of related concepts (Ornstein & Hunkins 2018)?

4. STEM Studies in Universities

Some universities have STEM laboratories or centers thanks to which they can organize STEM workshops and provide training and consultancy services for students and teachers. Some universities also conduct STEM-based projects. In addition, they build strategies to learn STEM-based research for life. In general, many studies are carried out for teachers to help them conduct their lessons with a focus on STEM. Some examples collected from university web pages are presented below.

At Hacettepe University, the STEM & Maker Lab was established in 2009. The lab has been conducting projects and research, providing teacher education, and evaluating strategies to learn STEM for life. Moreover, teacher workshops, projects, and training related to STEM are organized at Middle East Technical University. Similarly, there is a STEM Academy-Openfab at Ozyegin University.

The STEM school, STEM lab, STEM projects, and STEM teacher certification program are carried out at Aydın University. The STEM school has been open since 2005, and has been providing STEM education to primary and secondary schools who want to study STEM. Within the scope of the STEM project, it aims to educate both teachers and students in STEM fields and to introduce appropriate programs (Akgündüz et al., 2015; cited in Erden, & Fer, 2018).

The studies presented above appear to focus on teacher training, research, or projects in STEM studies at universities. However, STEM education requires going beyond the studies offered in centers or laboratories. In other words, STEM education requires instructional design with a holistic approach. Furthermore, it should also be addressed in curriculum development with a broad-fields design. and should not be considered only when training teachers or conducting projects. In short, STEM ought not to be thought of as just an activity that enriches teaching..

5. STEM Access in Private Primary, Junior, and High Schools

STEM education in private schools in Turkey draws intense interest. On the website of these schools, it is emphasized that most provide STEM education. There are examples of information and implementation of STEM on these websites, but their reliability is controversial. For correct implementation of STEM, the best example among these schools is Bahcesehir College. STEM centers have been established in this college uniting different areas such as science laboratories, computer laboratories, innovation laboratories, production workshops, and art workshops in one place to create interdisciplinary work and production environments.

Emphasized on the web site of Bahcesehir College (2020), they adopted a STEM+A model, which is a project-oriented model based on the combination of multiple disciplines; science, technology, engineering, mathematics, and arts are taught together. The model is implemented at all campuses of the institution, starting from the preschool grades. The main aim of the STEM+A model is to nurture individuals who are able to solve the problems of the future, think creatively, and convert ideas into results.

> "At STEM+A centers featuring multi-purpose laboratories for production-based education with STEM+A focused projects, students are enabled to use state-of-the-art instruments such as 3D printers, CNC lathe & turning, laser cutters such as computerized hot wire cutting tools that are hard to find even at universities. In order to manufacture prototypes for their projects, which are "Computer Assisted Drawing and Modeling," "RC Model Production Club – RC CLUB," and TUBITAK projects, patenting and utility model production classes are offered within Bahçeşehir College curriculum as elective courses in all campuses of Bahçeşehir College." (Bahcesehir College, 2020, p. 1)

6. STEM Studies in the Ministry of National Education

The Ministry of National Education is the only institution responsible for the implementation, decision-making, and supervision at all levels of education up to higher education in Turkey. Therefore, it is necessary to mention the work of this institution under separate headings and in more detail below.

STEM education in primary, junior and high schools in the Ministry of National Education: In Turkey, mathematics has always been taught in K12 classes as a separate course; however, science courses have been taught with an integrated approach from the establishment of the Turkish Republic until now.

In 1924, as a guest of Mustafa Kemal Atatürk who is the founder and first president of Turkey, Dewey came to Turkey, stayed for two months, and prepared a report after making examinations. One of Dewey's suggestions was the practical and interconnected teaching of courses (Akkutay, 1996). Following this suggestion, science courses, including biology, agriculture, physics, and chemistry, were connected and subjects were also prepared with real-life experiences in the new curriculum.

Although it does not cover the same disciplines, a similar approach has been applied in another science curriculum up to now, yet the name the course has changed from Science and Technology to Technology and Design (Ministry of National Education, 2016).

Although Turkey does not have a STEM action plan prepared by the Ministry of National Education, there are some strategic goals to strengthen STEM education in the Strategic Plan. According to the plan, the STEM-related goals have to match with the outcomes of Technology and Design courses. It is already understood that the objectives of STEM overlap with the aims of the Technology and Design course to some extent (Milli Eğitim Bakanlığı, 2019a).

There is also a Science Application course that has been available as an elective in secondary school. The outcome of this course is to educate scientifically literate individuals who will be able to do research in science, read science-related books and articles, and improve science skills. Students who know how to gain this knowledge and these skills will also find it easier to understand the scientific solutions to problems they encounter (Ministry of National Education, 2016). It is understood that the objectives of STEM overlap with the aims of the Science Application course to some extent.

The following can be said regarding the inclusion of STEM education in primary and secondary school science and mathematics curricula implemented in Turkey: The aim is that students will be educated as scientifically literate individuals with knowledge, skills, and positive attitudes toward science, technology, society, and environment (Ministry of National Education, 2016). This situation implies that, even though science and mathematics curricula give importance to the interaction between science, technology, and society, STEM integration and engineering skills are neglected in the curricula.

Recently, courses related to STEM do not seem adequate in K12 schools. In addition to mandatory courses – which are mathematics and science, technology and design, information technologies and software –, it is understood that elective courses related to STEM are needed (Ministry of National Education, 2014; cited in Erden, & Fer, 2018).

Generally speaking, at academic and vocational high schools, there are mathematics and science courses related to STEM; nevertheless, all of them are designed in accordance with a subject-based curriculum. Although the importance of interaction between science and technology and society is emphasized in the curriculum, STEM integration and engineering are not directly involved.

In general, primary and middle school curricula compatible with STEM education can be characterized as follows: progressivism- and constructivism-based, broad-fields-based, and inquiry- and project-based for science courses. Contrary to the requirements of STEM education, secondary school curricula can be characterized as follows: essentialism-based, subject-based, and built on content-based instructional design (Erden, & Fer, 2018). Thus, it might be said Turkey has applied curricula with STEM-oriented principles in primary and middle schools while the high school curricula is quite remote.

Recently, it has been understood that there are two important factors to consider while adopting STEM curricula for K12 schools in Turkey: whether STEM should be addressed through a series of separate courses (i.e., a combination of science, technology, engineering, mathematics, algebra, geometry, physics courses) or whether STEM concepts should be included in the content across all courses (e.g., combining velocity in a physics course with calculation in mathematics) (Ministry of National Education, 2016). In other words, a decision should be made regarding curricular design for a subject-based curriculum or a correlational-based design curriculum.

STEM Studies: A study group consisting of experts, private school teachers, and academicians has been formed, and, as a result of the initiative, sample lesson plans including STEM practices have been prepared in order for private schools to correctly understand and put STEM into practice. With this initiative, a resource that will set an example for private schools has been created in order to organize teaching in accordance with the STEM approach (Ministry of Education, 2019b).

In addition, the Ministry of Education (Milli Eğitim Bakanlığı, 2018) printed a teacher handbook to guide teachers on STEM concepts and STEM practice and to show them how to carry out a STEM project.

STEM Centers of the Ministry of National Education: Within the scope of these studies, the Ministry of Education has been opening STEM centers in various provinces and districts outside of schools in recent years. The centers are for students from preschool to high school, and students in these centers learn by engaging in integrated activities in STEM fields. The first STEM centers were established in some provinces, including Istanbul and Hatay, in 2016. Also, 160 teachers were trained for the centers in the same year. Moreover, in-service training was given to teachers within the scope of basic and advanced STEM training.

The STEM center is a positive step for the proper use and development of STEM, but these centers are also needed at or near schools. In addition, curricula should be organized in accordance with the STEM qualifications, and more in-service training is needed to educate teachers about STEM. Also, the STEM Report of the Ministry of National Education (2016) pointed out that more STEM education centers for the transition to STEM education are needed, as is more STEM education research. Furthermore, training of STEM teachers is needed regarding STEM curricula.

Scientix Project and the Ministry of National Education: In 2014, the Ministry of National Education joined the Scientix Project run by the European School Network.

Scientix (The Community for Science Education in Europe) is a community in which about "30 European countries participate with the aim of the dissemination of good practices, projects, and materials used in STEM education in Europe" (Ministry of National Education, 2016, p. 26).

The purpose of the Scientix project is to promote education based on inquiry, research, production, and innovation in STEM education in Europe. The project aims to create a community of teachers who create project / problem-based STEM education activities for their students in order to encourage scientific humanity and engineering. The project also aims to encourage elementary and secondary school teachers who have the skills in inquiry, research, production, and invention and who are capable and interested in STEM to emphasize science, technology, engineering, and mathematics at schools (Milli Eğitim Bakanlığı, 2019a).

Scientix (2019) has been promoting a European-wide collaboration for STEM in the community including teachers, educators, researchers, policymakers, and other professionals since 2009. Now, funded by the Horizon 2020 program of the European Union for research and innovation, Scientix activity is continuing in the third stage (2016–2019). Within the scope of the Scientix Project, STEM workshops have been held in different provinces in Turkey. In addition, a STEM training handbook, which includes information and sample applications about how teachers can implement STEM, has been published.

7. What do Projects and Research Tell Us About STEM?

In recent years, there has been an increase in the number of projects and studies related to STEM education in Turkey. In general, according to one study (see Akdağ & Güneş, 2017; Altun & Yıldırım, 2016; Ceylan, 2014; Ensari, 2017; Öztürk, 2017; cited in Demirci, 2018) carried out in Turkey, STEM education increases motivation of students as well as encourages them to learn more effectively.

Contrary to findings describe above, another study conducted with 3rd-grade high school students found no difference between the final test scores of the experimental group, in which STEM-based instructional design was applied, and those of the control group, in which modular instructional design was applied (Demirci, & Fer, 2019).

The research findings of yet another study showed that interests of female students are higher for biology, livestock & veterinary, and medical sciences, whereas those of male students are higher for computer sciences, energy, ship-aircraft, and engineering. Also, it was found that engineering and space sciences are the most preferred occupations, and agriculture, aquaculture, and energy are the least preferred. It was seen that high school students' attitudes toward STEM are generally positive. Overall, male students had more positive attitudes toward STEM than female students (Ocak, 2017).

The Ministry of National Education (2016) collected data from teachers of primary and secondary schools regarding their opinions about STEM education. Results are as follows: The participants stated that STEM education should be integrated into the curricula of primary and secondary schools and that an interdisciplinary curriculum is needed. In addition, participants also stated that STEM course activities should be integrated into the curriculum. Moreover, participants stated that it is necessary to renew science labs and provide new experiment equipment in schools. Finally, participants stated that STEM teacher training programs should be launched so that STEM course teachers can be trained by faculties of education of universities. It is interesting that the above-mentioned findings were obtained from questionnaire items completed by the vast majority of teachers participating, which can be considered an indicator of teacher awareness of STEM education.

Another study conducted by the Ministry of National Education included a nationwide survey of 13,958 students and qualitative interviews with students participating in STEM activities in Ankara. The attitudes toward STEM activities of the students participating in the research were found to be positive. In addition, students stated that they found STEM activities useful and enjoyable, learned the lessons more easily, and wanted to choose a profession in the field of STEM in the future (Ulutan, 2018). While the research findings reveal positive attitudes of students toward STEM, they also show that students have difficulties finding solutions and solving problems in STEM activities.

In other research conducted by the Ministry of National Education, a questionnaire was given to 42,207 teachers in order to gather their opinions on STEM learning practices. It showed that teacher opinions about STEM activities were positive and that teachers wanted to improve themselves in STEM. In addition, it was found that mostly secondary school teachers prepared STEM practices, and that teachers who received postgraduate education showed more interest in STEM education (Bal, 2018). Findings suggest attitudes of teachers toward the STEM approach improve as their education progresses.

Furthermore, it was seen that the employment rate of people who graduated from STEM education departments of universities was 19 %. It also found a significant difference between those in STEM-related occupations and those whose jobs were not related to STEM in companies where they work. In terms of gender, a research finding indicated that the gender gap of people working in the field of STEM occupations was quite high with 64 % of men and 36 % of women TUSİAD, 2014).

According to research findings, STEM has some limitations. STEM is a practice-oriented approach; therefore, the most important limitation of STEM applications is that it is time-consuming. Some studies (see Kumtepe, 2017; Tarkın-Çelikkıran & Aydın-Günbatar, 2017; cited in Demirci, 2018) also support this idea. Teachers or teacher candidates using STEM activities stated that these activities are time consuming and limited.

Another limitation of STEM as a practice-based approach is that it is difficult to practice in crowded classrooms. According to 2016–2017 data, the average number of students per classroom is 31 in Turkey in general and 39 in Istanbul (Ministry of National

Education, 2016). This makes it difficult for teachers to implement time-consuming STEM activities.

Since the STEM approach has become widespread in Turkey only in the last 10 years, there are not enough academic and practical resources in Turkish. This situation makes it difficult for teachers who practice STEM to have enough information about it. In the study by Tarkın-Çelikkıran and Aydın-Günbatar (2017; cited in Demirci, 2018), pre-service teachers stated that they had difficulty finding information related to STEM.

In general, although STEM is predominantly a practice-oriented approach, few studies and projects can be found to guide practitioners. Consequently, there are few manuscripts, theses, books, or other resources in Turkish. Because of the limited resources for practitioners, STEM is not thought to be used widely throughout Turkey or implemented correctly.

8. Conclusion and Future Directions

STEM's popularity and its high demand in Turkey, as well as around the world, is, in a sense, promising for the development of STEM in education. On the other hand, this intense interest causes STEM to be misused or deformed in its purposes with a populist approach. As Akgündüz (2016) emphasizes, STEM has been misunderstood and applied from a populist point of view in recent years; as a result, it is perceived more as a type of activity than a teaching approach. These misperceptions and practices sometimes cause more harm than good to STEM and inhibit its implementation.

In addition, while planning training for the STEM approach, some mistakes are made within the framework of the trendy STEM concept. Among these mistakes, the most common is to evaluate activities that can only be produced as a kit – robotics, coding, makers – and applying these kits as STEM education. Another mistake is the view with which STEM training is applied in all countries in Europe. Considering science experiments or school activities as STEM education also increases the seriousness of the mistake (Bal, 2018). While STEM practices encourage the relationship between real-life problems and course content, they should also transfer theoretical knowledge into practice, encourage individuals to search for answers to questions, and ultimately increase productivity.

In conclusion, the Ministry of National Education, universities, and other institutions are all interested in improving STEM education; however, much more effort is needed, including integration of curricular and extra-curricular activities. As long as STEM studies are not reflected as an interdisciplinary approach in curricula and supplemented with extra-curricular activities, it seems difficult to achieve successful results.

The Ministry of National Education, universities, and other institutions are clearly interested in improving STEM education; however, much more effort is needed in order for students, especially for female students, to benefit from STEM training.

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Education and Post-War Politics: The Case of Bosnia-Herzegovina

Lamija Tanović

1. Introduction

1.1 The Nature of the Conflict: The Bosnian War (1992–1995)

The education sector in Bosnia and Herzegovina (BiH) has suffered as a result of the recent conflict in the country, the Bosnian War, which lasted from 1992 until 1995. In order to understand the state of education in post-conflict BiH, therefore, we must consider the effects of the war on the physical, political, and social environment in the country. During the war, towns and villages were reduced to rubble, bridges were destroyed, and roads were demolished; many civilians were killed, and entire populations were driven into exile. [1]

In addition to damaging practically all aspects of life in the conflict zone, war can have a tragic impact on education. The education system in Bosnia and Herzegovina is a case in point. Education facilities across BiH were badly affected by the war. Many school buildings and classrooms were rendered essentially uninhabitable:

Well over half of all school buildings in Bosnia and Herzegovina have been seriously damaged, destroyed, taken over by the army or used to house people displaced by the war. In the remaining available spaces, pupils, students and teachers occupy many classrooms that have been poorly maintained and have no glass in the windows, no doors and no heat (Almeida et al., 1996, p. 27).

At the same time, the provision of educational services was also made difficult due to an acute shortage of qualified teachers (Arnhold et al., 1996). Many qualified teachers left the country. Others were mobilized into the armed forces. Some were victims of war-related violence. Furthermore, many children and young people were displaced and forced to change school, sometimes multiple times, or were unable to attend school at all (Magill, 2010, p. 37). Although valiant efforts were made to continue providing education to the country's youth under these near-impossible circumstances, it is clear that the education sector in BiH suffered greatly during the Bosnian War.

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1 According to the International Criminal Tribunal for the former Yugoslavia (ICTY) demographics unit, it is estimated that at least 104,732 persons were killed during the war. This includes a disproportionate number of civilians, and especially children (Zwierzchowski & Tabeau, 2010, p. 15). Millions of others were displaced and sought refuge either in other countries or in other parts of BiH (Stabback, 2007, p. 450).

1.2 The Nature of the Peace: The Dayton Agreement

The war ended with the main parties to the conflict reaching a peace agreement, officially known as the General Framework Agreement for Peace (GFA), and also known as the Dayton Agreement. The agreement was negotiated in November 1995, at a United States army base in Dayton, Ohio. It contains eleven annexes treating various aspects of life in a country that had been ravaged by war in the years preceding it. The agreement and its annexes were conceived by United States diplomats under the leadership of Richard Holbrook. Negotiations on the final text included delegations from the countries of Bosnia and Herzegovina, Croatia, and Serbia. The presidents of these three countries were signatories of the agreement. Guarantors and witnesses to the agreement included European Union special negotiators, and the presidents of France, Germany, the Russian Federation, the United Kingdom, and the United States. The full and formal agreement was signed in Paris on December 14, 1995 (Fig. 1).

Figure 1: Signing the Dayton Peace Accord in Paris, 14 December, 1995; Source: https://en.wikipedia.org/wiki/Dayton_Agreement#/media/File:Signing_the_Dayton_Agreement_Milosevic_Tudjman_Izetbegovic.jpg

The Dayton Agreement proposed a new political structure for Bosnia and Herzegovina. This new structure was agreed upon as part of Annex 4, one of the eleven annexes to the agreement, which established a new constitution for BiH. What had hitherto been the Republic of Bosnia and Herzegovina was transformed into a state made up of two entities – the Federation of Bosnia and Herzegovina (FBiH) and Republika Srpska (RS) – and one district around the town of Brčko, known as Brčko District (BD) (Fig. 2). The rotating state presidency of the country was to consist of three members: a Bosniak member, a Bosnian Croat member, and a Bosnian Serb member. The highest governing institution would be the Parliamentary Assembly, which has two chambers, the House of Peoples and the House of Representatives. This state-level government, however, retained only the functions that would enable it to act as the government of the

Figure 2: New composition of BiH created by Annex 4 of Dayton Peace Accord. Source: https://www.mapsland.com/europe/bosnia-and-herzegovina/large-political-map-of-bosnia-and-herzegovina-1997

internationally recognized state of Bosnia and Herzegovina. Other functions, including education, were transferred to RS and FBiH (Almeida et al., 1996, p. 11).

This peace, long-awaited, brought with it its own troubles. The peace agreement changed the organization of the country and turned it into an ungovernable state. In other words, the Dayton Agreement, under the patronage of the United States and the European Union, reconstructed the country in a way that allowed the war to continue in different guises, though the weapons had been silenced.

2. Education in Bosnia and Herzegovina

2.1 The Dayton Agreement and Education

Education was not high on the agenda during the peace negotiations in Dayton, Ohio. However, the post-war education sector in Bosnia and Herzegovina is in many ways a product of the Dayton Agreement. Namely, as previously mentioned, the agreement created two political entities in the country – the Republika Srpska and the Federation of Bosnia and Herzegovina – each with its own governmental structures. The Republika Srpska was given a centralized administration; the Federation of Bosnia and Herzegovina was to consist of ten cantons, each with its own administration. In other words, one entity (RS) was established as a centralized mini-state, which decided to develop a much more intense level of cooperation with a neighboring state – Serbia – than with the rest of its own country. The other entity (FBiH) was fragmented into ten mini-states or cantons, each of which has almost unlimited power over the education sector (Fig. 3). Additionally, there is a third piece of Bosnia and Herzegovina – District Brčko – with its own education policies. Therefore, the state of Bosnia and Herzegovina was left with no responsibilities in the education sector.

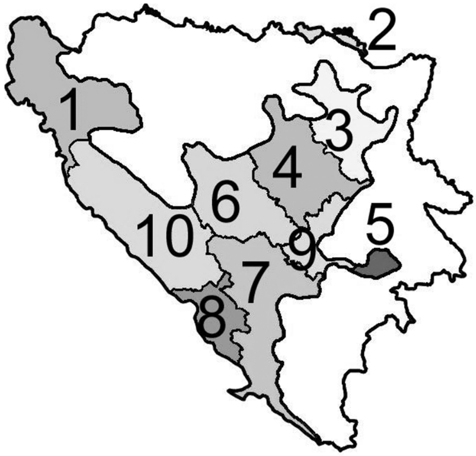

Figure 3: Fragmentation of F BiH into ten mini-states, cantons

This complicated administrative structure has hampered the organization of many sectors, including the education sector. In the education sector, this complexity is reflected in the fact that education is administered from fourteen different ministries: ten at the cantonal levels, two at the entity levels, and one at the state level (though it lacks a significant mandate), as well as one department at the level of the Brčko District. Each of these education authorities makes its own laws regulating various segments of education. Although there exists a framework law at the state level governing education, this is not sufficient to enable the necessary reforms and modernization of education in its various aspects.

The Dayton constitution provides the perfect framework for all the political mistakes in the education sector. The BiH Constitution accommodates this state of affairs because, according to Article III (Annex 4 of the Dayton Agreement), all powers (that are "not expressly assigned" to state institutions) are given to the entities (Republika Srpska and the Federation of Bosnia and Herzegovina), while Section III, Article 4(b) of the Federation Constitution gives the cantons responsibility for "making education policy, including decisions concerning the regulation and provision of education." Education is thus highly decentralized in the Federation of BiH and highly centralized in the RS, while remaining decentralized in the state as a whole. In other words, the Dayton Agreement has created an immensely institutionally complex structure that has made the task of educational reform not merely difficult but gargantuan.

The extravagant state structure inaugurated by the Dayton Agreement has resulted in, among other things, a series of negative effects on the education sector. According to a recent study, "From the very beginning, the Constitution created a decentralized, asymmetric and defective education management system that has undermined unity in educational policies, common educational goals, common values, positive and patriotic feelings for one's country and homeland, etc." (Pašalić-Kreso, 2008, p. 360). As a direct result of this decentralized organization made possible by the Dayton constitution, local politicians have been given the opportunity to vie over education, and education has become a battleground in their continued war.

2.2 The Fragmentation of Education in Post-War Bosnia and Herzegovina

One of the main consequences of the Dayton Agreement has been the high degree of fragmentation of the education sector, making coordination at the state level almost impossible. The post-Dayton fragmentation of the education system in Bosnia and Herzegovina has also had serious implications on the price of education. The institutionally complex structure and the politically imposed segregation in education have led to inefficient spending and considerable duplication. The administration of education is fragmented into fourteen education authorities and, furthermore, schools have also been fragmented into smaller institutions, in comparison to average sizes needed to set up a school. All of this has led to a large percentage of gross national income being spent on education.

Furthermore, the fragmented nature of the education system is to blame for the lack of a database and official statistics at the state level. This has had serious implications. Namely, such a database is necessary, among other reasons, to ensure that all children and young people in BiH, whatever their ethnicity, enjoy the right to education equally. It is also a way to monitor the quality of education provided.

2.3 The Neglect of Education in Post-War Bosnia and Herzegovina

In the past twenty-five years, during a post-war period of often misguided activity, education has been a neglected area in Bosnia and Herzegovina. Namely, throughout this period, education was never a priority either for domestic authorities or for the international community, which has had a wide-reaching and strong mandate and has been

Infrastructure	42.98 %
Economic development and social protection	27.60 %
Good governing and institutional development	8.63 %
Conflict prevention, peace, and security	5.68 %
Mixed sectors	4.56 %
Local governing	4.10 %
Agriculture and forestry	1.97 %
EDUCATION	**1.64 %**
Health	1.61 %
Environmental protection	1.19 %

Table 1: Sector share of ODA (Official Development Assistance) in Bosnia and Herzegovina (2007) SOURCE: Magill 2010, p. 24

present in Bosnia and Herzegovina ever since the war. There are a number of reasons for this. The 1992–1995 war in the country disrupted all areas of life, including education. The country suffered large-scale destruction. Post-war recovery was slow. Priority was naturally given to the physical reconstruction of infrastructure: rebuilding roads, bridges, housing, and demining, etc. Truth be told, along with bridges, roads, and houses, many schools were also rebuilt, but almost nothing was done in those early years to improve the content and quality of education. Most of the initial post-war focus on education was concerned with the rebuilding of infrastructure, rather than issues of curriculum reform and teaching quality (Stabback, 2008, p. 450).

Since the war, the international community has made large financial and material donations in order to help the reconstruction and recovery of a heavily damaged and war-torn country. However, comparatively speaking, they have also neglected education, which is particularly visible from an analysis of donations to different sectors in BiH. In the post-war period, BiH received significant funds for reconstruction. However, only a very small percentage of these were used for the education sector, as can be seen in the following table:

2.4 Other Issues in Education in Post-War Bosnia and Herzegovina

2.4.1 Primary Schooling

Contrary to popular belief, education in Bosnia and Herzegovina is not without costs. Primary schools do not provide free textbooks, free lunches, or free transportation, and state funds for these essentials are minimal. For this reason, some parents, especially in rural areas, do not send their children to primary school.

2.4.2 Secondary Schooling

In gymnasia, the overloaded curricula are an unsuitable preparation for higher education. The four years of secondary schooling in gymnasia would function better if split into two years for general education and two years for focused pre-university studies. Also, there is no externally assessed graduation exam. This type of graduation exam is much needed. Without external assessment, there is a lack of impartiality and objectivity in awarding grades, and this opens up the system to chronic unevenness, unreliability, and corruption. Vocational schools are comparable to gymnasia. They also suffer from overloaded curricula, with too little practical work and training.

2.4.3 Failed Mechanisms

A state-level Agency for Pre-Primary, Primary and Secondary Education and the Conference of Ministers of Education have been set up as permanent and supreme advisory bodies responsible for the coordination of education in Bosnia and Herzegovina. The nine-year system of primary education, based on the Framework Law on Primary and Secondary Education (2003), is being introduced at different speeds and in different ways across the country. A common core curriculum was also promulgated by this same law during the 2003/04 school year. The Strategic Directions for the Development of Education in Bosnia and Herzegovina, in principle already adopted, envisages the modernization of teaching and learning at all levels of education. According to this document, all students of the gymnasium will undergo an external graduation exam.

Notwithstanding these measures, Bosnia-Herzegovina still has three separate school systems, three national curricula, three sets of textbooks, and three different sets of legislation. Access to education, ethnically-biased curricula, and the physical segregation of pupils remain key issues. Furthermore, teacher training, both pre-service and in-service, is not standardized, and there are no financial mechanisms in place to support improvement in the quality of teachers' work. For this, standardization of learning outcomes is also an essential pre-requisite.

3. Education and Human Rights Issues in Bosnia and Herzegovina

3.1 Three Education Systems and the Politicization of Education

Even after the war officially ended, it continued in and through the education sector. Divisions, the conquest of territories, and ethnic cleansing that were not achieved by war continued after peace was established. In fact, during and immediately following the war, part of the efforts to divide the country along ethnic lines took the form of carving up the education system. Beginning in 1992, three separate educational systems based on three separate curricula were established, and the choice of curriculum in any given school depended on the dominant ethnic group in the territory where the school was located (Pašalić-Kreso, 2008, pp. 357–358). This has continued to the present day, with the majority of children and young people in Bosnia and Herzegovina attending separate, mono-ethnic schools with separate curricula.

These separate curricula, with separate textbooks and separate alphabets, are often justified on the basis of the right of every child to be schooled in his or her own mother-tongue. As of 1991–1992, the Serbo-Croatian language officially stopped existing in Yugoslav successor states. In BiH, although everyone understands all three versions of the language, the claim (refuted by linguists) that Bosnian, Croatian, and Serbian are three different languages was constitutionally recognized in the Dayton Agreement. This left the possibility for the issue of language to be used to put up barriers between the three main ethnic groups in education.

3.2 Segregation in Education: Two Schools Under One Roof

Although a signatory of the Convention on the Rights of the Child (Article 28), the European Convention on Human Rights, and the UN Declaration on Human Rights, Bosnia and Herzegovina has still not provided equal rights to all its children. In some parts of the country, the segregation of children along ethnic and religious lines is permitted. One of the most illustrative examples of this type of discrimination is the "two schools under one roof" phenomenon, a bizarre invention of an international organization responsible for education following the 1992–1995 war.

Namely, in some parts of BiH, there are public primary and secondary schools where children are divided into two systems based on their ethnic and religious belonging. Furthermore, only three ethnic groups and three religions are recognized. Children who do not belong to any of the three must opt for one. In the two schools under one roof system, children are not only learning in what is presented as three different languages (though linguists maintain that this is one language with three variants that have negligi-

Figure 4: Segregated gymnazium in Travnik (Torsti et al., 2013)

Figure 5: Schoolyard with the fence and young couple in their parts of the yard (Radio Slobodna Europa), https://twitter.com/SamBeharic/status/1147480554977275904/photo/1

ble differences), they also study three different histories, geographies, etc. Furthermore, they are also physically segregated. Opportunities for contact are reduced to a minimum by having children use different classrooms or go to the same school building in two different shifts.

The case of the Travnik Gymnasium has become well known in this respect (Fig. 4). There, not only is the school building divided, the schoolyard features a fence so as to prevent students from coming into contact during breaks between classes. This is precisely why recent news of a marriage between two young people who used to go to the two separate parts of this school building sparked such incredulity (Fig. 5). Of course, they only met while attending the same university together; they fell in love, graduated, and got married. Unfortunately, they never had a chance to meet while attending the divided Travnik Gymnasium.

There is a similar example of two students from the Stolac Gymnasium. Although they attended school in the same building, they only met when a reporter interviewed them (Fig. 6). For years, they went to school in two shifts in the same school buildings – two shifts that were separated by a time gap long enough to ensure the two sets of students would never meet. Of course, all of this is made possible by the extravagant state structure inaugurated by the Dayton constitution.

Figure 6: Segregated school in Stolac and two students who had no chance of meeting in the school. Photo: IWPR

3.3 Emigration of Young People

All of the abovementioned problems in the functioning of the state and the education system have resulted in mass emigration, especially of young professionals. Although job opportunities are gradually increasing, BiH is still among the three countries in Europe with the highest unemployment rate. The high rate of youth unemployment, which is currently around 40 %, is a particular concern.

3.4 Gender Equality and Education

It should be noted that Yugoslavia, which used to comprise Bosnia and Herzegovina, had a unique and specific form of socialism, quite different from the socialism of other Eastern Bloc countries. The Socialist Federal Republic of Yugoslavia existed for 46 years, from 1945 until 1991. The socialist system in Yugoslavia, which was markedly different from that in the Soviet Union or in other Eastern Europe countries, insisted on the equality of women in all spheres of life. As a result, a good foundation for the equality of women was created in the former Yugoslavia.

It was perfectly acceptable and normal for a woman to be the prime minister. (Yugoslavia had a female prime minister already in the 1980s.) There were many female ambassadors. Women served as CEOs of construction companies. Women worked as welders, and even as miners. And, of course, many women chose to study in traditionally male-dominated fields. During its heyday (the 1970s and 1980s), the socialist system in the former Yugoslavia provided a lot of support for mothers. A full year of maternity leave, for example, was an important factor that allowed a career woman to also dedicate herself to her family. A wide network of affordable state kindergartens also allowed women to have a family without giving up their careers.

As part of the former Yugoslavia, Bosnia and Herzegovina is home to a generation of women who grew up during this period. They teach their children that a woman can do any job that a man can do. Young women studying at the universities today have mothers and female relatives who have chosen various professions, and these young women are therefore very ready to choose similar or the same professions. These are probably the most significant reasons why a larger percentage of women in Bosnia and Herzegovina than in Western Europe choose to go into traditionally male-dominated disciplines such as the natural sciences and engineering.

3.5 Economic Transition and Education

The biggest shift in the wake of the war in the 1990s was the transition from socialism to capitalism. This change caused many others, most of which were changes from better to worse. The fact is that the transition to capitalism has spoiled many aspects of life in BiH. It has already brought a high degree of social inequality to many areas and is slowly encroaching on the education sector. Namely, those with the means to pay become privileged not only in healthcare and personal living standards but also in education. However, being able to pay the price of a private education does not afford one access to knowledge. In the unsettled system in BiH, those who are able to pay are merely afforded diplomas. This fact will have long-term detrimental consequences for the BiH economy and society as a whole. Still, even as BiH entered into a period of transition from socialism to capitalism following the 1992–1995 war, there remained a strong presence of STEM disciplines in the majority of schools, both public and private.

4. Moving Towards Solutions

4.1 Education and Economic Indicators

The growth of modern economies is increasingly based on knowledge and the creation of knowledge. The first step in that process is investment in so-called human capital. A knowledge-based economy, where there is awareness about the importance of research, technology, and innovation in producing knowledge, is a successful economy. Such economies rely directly on producing, distributing, and using knowledge and information.

Judging by economic indicators, Bosnia and Herzegovina is still far from a knowledge-based economy. There are a number of reasons for this:

- a fragmented, impoverished, and extravagantly administered education system, fundamentally unsuited to a knowledge-based economy;
- poorly organized lifelong learning;
- a lack of quality links between the education system and the labor market;
- meagre funds invested in research; and
- a brain-drain.

These are the five key reasons the BiH economy is not based on knowledge and cannot get there in the foreseeable future.

Among the 141 countries included in the World Economic Forum's *Global Competitiveness Report 2019* and ranked according to 12 groups of parameters, BiH is in 92nd place. It does better or worse than this in individual parameters. However, its worst ranking is in the group of parameters that determine readiness for innovation, where it takes a very low 117th place. The fact that research and development are allocated only 0.2 % of the GDP also places it in a low competitive ranking. Particularly interesting is a group of parameters on capability for various activities. In this group of parameters, BiH sometimes does significantly better than its average ranking, so that, for example, the parameter "mean years of schooling" of almost ten years (9.7 years) puts it in 67th place out of 141 countries. On the other hand, in terms of the parameters for "skillset of graduates," "quality of vocational training," and "critical thinking in teaching," the country ranks much lower, at 135th, 134th, and 133rd place, respectively. These rankings show that despite a relatively long period of mandatory schooling (9 years) and a relatively long period in school on average (9.7 years), the results of this long-lasting schooling are poor, as reflected in our rankings according to the parameters for "skillset of graduates" and "critical thinking in teaching."

In other words, the big difference between the rankings in indicators "mean years of schooling" (9.7 years), on one hand, and "skillset of graduates" and "critical thinking in teaching," on the other, indicates that the long years of schooling in BiH result in a poor education. This is the gap that a stronger STEM-based approach could fill if introduced into our educational system.

4.2 STEM and Efforts to Modernize Primary and Secondary Education

Aware that research, science, and technology are the foundations of progress in any society, its economy, its ethics, and its ability to sustain itself, education strategists have begun introducing the STEM component into the education system because progress in science, technology, and the economy comes from successfully applying knowledge. Therefore, STEM competences should be developed from the earliest years of learning.

The integrated approach to studying natural sciences, mathematics, and technology is based on connecting knowledge across disciplines. This approach helps students better understand what they are learning and prepares them to better apply what they have learned. It is expected that the integrative approach to teaching STEM competences will have many positive effects on our education system by

- increasing student motivation;
- introducing goal-oriented behaviors into learning;
- increasing cooperation among teachers of different subjects;
- changing and improving the evaluation of student achievements; and
- intensifying learning based on problems and projects.

4.3 ENABLE BiH

Three years ago, USAID designed a project titled Enhancing and Advancing Basic Learning and Education in Bosnia and Herzegovina (ENABLE BiH), aiming to modernize education in BiH. The goal of the project was to develop a sequence of topics in all STEM fields that would enable BiH teachers to implement the Common Core Curriculum in a way that engages students, integrates learning across STEM disciplines, and connects to skills needed to support employment in today's knowledge based economy (KBE).

One of the officially proclaimed goals of education in BiH is training for a KBE. Official documents state that "the areas of sciences, math, engineering and information technologies are of particular importance for the entire economic and technological development of state." The advancement and modernization of education is one of the key goals in the development of the education sector.

With this goal in mind, the following documents have been drawn up as part of the ENABLE BiH project:

- Draft of the Operational Teaching Curriculum (OTC) for STEM Proficiencies and Competences
- Implementation Guidelines for the implementation of the OTC for STEM Proficiencies and Competences
- Teacher's Training Manual for the implementation of the OTC for STEM Proficiencies and Competences

Where did the idea for this project come from? The European Commission has recommended education based on the promotion of key competences, which means that curricula and syllabuses are directed toward educational goals and learning outcomes. The BiH Agency for Pre-Primary, Primary and Secondary Education has identified the key competences that should be developed and has started to develop a Common Core Curriculum (CCC) for eight educational areas. Three of those eight areas are 1. natural sciences (biology, chemistry, physics, geography); 2. mathematics; and 3. technology and information science. These are areas necessary for STEM competences and skills development.

An Operational Teaching Curriculum (OTC) for STEM competences and skills has been created based on those knowledge economy sectors identified as important for the economic progress of Bosnia and Herzegovina. This addresses one of the proclaimed goals of education: training for the knowledge-based economy. At the same time, the OTC has followed the structure of the CCC for each of the six STEM subjects (biology, chemistry, physics, geography, math, technology, and information science). As part of the OTC framework, a correlation of learning outcomes and associated indicators in all STEM subjects has been established.

Furthermore, instead of a lecture-based, lesson-plan-centered curriculum, the new approach prioritizes a teacher's capacity to engage students with the right methods and an understanding of the learning process as it pertains to each specific subject. This integrated approach is known as pedagogy, psychology, didactics, and teaching methods (PPDM). Bosnia and Herzegovina needs to implement a PPDM-centered classroom approach for STEM teaching because schools still operate using antiquated teaching methods, with teachers reciting scripted lessons and students dutifully writing them down. Exams merely reflect how effectively students have memorized the teacher's lectures. Therefore, the ENABLE BiH project aims to improve student learning outcomes.

We still do not know what the results will be for this ambitious project which has been implemented in several pilot schools. But we certainly hope for significant improvements in teaching methods in STEM fields which should, as a result, transform the old system into a student-centered one in which STEM subjects are taught through blended, inquiry-based education. This could then provide a model for the reform of education across Bosnia and Herzegovina.

5. Conclusion(s)

In conclusion, in order to initiate changes and improvement across the education system in Bosnia and Herzegovina, the best place to start is with STEM disciplines. This is both because they are less contested in an ethnically-divided and biased system and because they are key contributors to a knowledge-based economy. Improvement in this regard would certainly bring positive changes for the future of the country and its young people.

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Maria Felipa Afro-Brazilian School

A Proposal for Emancipating and Antiracist Child Education[1]

Lorena Lacerda, Bruno de Jesus Brito Santana & Bárbara Carine Soares Pinheiro

1. Introduction

This text is based on an experience report on the implementation of an Afro-Brazilian school in Salvador, the Blackest city in the world outside the African continent. Salvador is a Brazilian city that has a population of more than 80 % of Black people; however, institutional racism reserves for this population a social place of inferiority and subservience. In this sense, we present in this article the first steps of structuring the Maria Felipa Afro-Brazilian School (MFS), an emancipatory and anti-racist institution based on the principles of decoloniality of knowledge. At MFS, we educate our children to anti-racism by moving beyond European hegemonic knowledge and valuing other civilizational milestones, such as those born of African and Afro-Brazilian culture, as well as Amerindian culture.

In Brazil, a country that has a majority Black population, there is Law 10.639, sanctioned in 2003 by the President of the Republic, which alters the Law of Directives and Bases (1996) and establishes the obligation in elementary and high school, both public and private, to teach African and Afro-Brazilian history and culture. This is especially important for the dissemination / appreciation of the African cultural legacy that we have received since the 16th century because, in addition to expanding the knowledge we have of this culture, it supposes a new look at African and Afro-Brazilian histories and their possible relations within Brazil's historical path. However, due to institutional racism that we experience in our country, this law is rarely enforced in educational institutions. In this sense, the Maria Felipa Afro-Brazilian School counters this injustice, understanding that our social commitment is to educate by unveiling hegemonic structures of power that segregate individuals on grounds of race, religion, gender, sexuality, social class, disability, or other social conditions.

The concept behind MFS arose from the process of adopting a Black child. The child's mother, Bárbara Pinheiro, a Black woman, and father, Ian Cavalcante, a non-Black man, found themselves without anti-racist educational alternatives that value the historical knowledge of our African and Amerindian ancestors, as well as our Black identity, our culture, our aesthetics, our existence. For this reason, MFS was founded in Salvador in 2018 and had its first academic year in 2019.

1 Text translated from Portuguese into English by Tatiana Zanon.

To build a revolutionary and emancipatory model of education, from our perspective, we sought to start from a decolonized perspective of education – one that does not ignore knowledge that is considered socially hegemonic but that also gives voice to other disadvantaged and sometimes erased narratives of our socio-historical construction. To this end, we bring – as cruelly subjugated historical knowledge – African and Afro-Brazilian expertise, as well as Indigenous, which, in our view, needs to be rescued not only to promote social justice but fundamentally as a way of understanding who we are, as subjects constituted ancestrally also by these peoples.

We propose an Afro-Brazilian children's school, as we understand that a large part of our ancestral origin resides in the African Diaspora in the Americas – a horrible and painful episode in universal history, but one that needs to be remembered and analyzed to understand the current condition of the Black population in Brazil. It is not just about remembering and honouring our ancestors and ourselves but also understanding where we have come from to understand what we are and to articulate steps for where we want to go.

Being Afro-Brazilian means valuing Afro-Brazilian culture, recognizing in it the same or superior significance that we give to European culture. It means socializing the history, the cultural and intellectual production of our people in a diaspora that helped to build high epistemic systems and territorialities, but which was sometimes plundered and erased from history (Freitas, 2016). It means envisioning a school that problematizes racial issues from an early age to overcome, through education, the structural racism that we live in our society.

Our school is named for Maria Felipa, heroine of Bahia's independence. Born on the island of Itaparica, a descendant of enslaved Africans from Sudan, Black, a fisherwoman and manual laborer, she led a group of 200 people, including Black women, Tupinambá Indians, and Tapuias, in the battles against the Portuguese who attacked Itaparica Island in 1822. Maria Felipa's group alone was responsible for burning 40 Portuguese vessels that were close to the island.

Leading a group of women and men of different classes and ethnicities, she fortified the beaches with the construction of trenches, organized the sending of supplies to the Recôncavo and the so-called "vedetas" (watchmen on the beaches), fought day and night to prevent the landing of enemy troops, and actively participated in various conflicts. During the battles, her group helped to set fire to numerous vessels: the Canhoneira Dez de Fevereiro, on October 1, 1822, at Manguinhos beach; the Barca Constitution, on October 12, 1822, at Praia do Convento. On January 7, 1823, she led approximately forty women in defense of the beaches of Itaparica. All of the women of her group were armed with pexeiras (a special kind of knife used to cut fishes) and branches of cansanção (a plant which causes burns on skin). They also seduced and beat the Portuguese, and then set the boats on fire using torches made of coconut straw and lead.

Maria Felipa, like so many other Black women, was a great warrior silenced from history. Our intention in naming our school with her grace is to honour this great Black woman who taught us the value of resistance and combat through the organization of her people, strategy, and quilombola thinking.

In this article, we seek to present the results of some of our work that has sought to build an emancipating and anti-racist early childhood education.

2. Decolonial Education

According to Santos and Menezes (2010), throughout modernity, we have born witness to "epistemicide" (the systematic destruction of some forms of knowledge in the name of the designs of colonialism). The production of scientific knowledge has been configured by a single epistemological model, as if the world were monocultural.

In the 20th and 21st centuries, with the advance of capitalism, the West experienced the end of historical colonialism; however, coloniality remains a mechanism of domination, structuring the new hegemonic economic system (Quijano, 2005). To make a paradigmatic assessment of knowledge production in Brazil, it is necessary to analyze the historical and geographic movement that led to the colonization of Brazilian territory, as well as the genocide and epistemicide of native and African peoples by Europeans. In the common readings of history, we find references to North Africa as the cradle of civilization. Yet, in general, we see African history and societies portrayed in terms that are anecdotal, cartoonish, or infantilized when compared with an exemplary society – that of Greece, especially Hellenic (Piza & Pansarelli, 2012).

From the perspective of colonization, the European world was not only able to undermine new territories, exploring our bodies and expropriating our natural and intellectual wealth. It went further, plundering our knowledge, denying our cultures, destroying our aesthetic standards, seeding in our minds an ideal of denial of ourselves – a kind of "mental slavery" that encourages us to always look at ourselves as inferior in all senses. We do not recognize ourselves as the first peoples to inhabit the world, as millennial producers of knowledge, as beautiful, and as equally human. The pattern of European coloniality created a universal, monocultural historical narrative, which envisages a world centered on Europe – an "Old World" – even though it is known that the oldest human fossil found on earth is located in East Africa.

The Eurocentrist ideology extracted from a racist model ignores and makes invisible the plurality and productive dynamism of different forms of social organization, of ways of thinking, and instead reproduces a geopolitically singular existence, inferiorizing the other types, aiming to establish itself as naturally hegemonic. As expressed by Dussel (2005, p. 12),

> This view is doubly false: firstly, because, as we shall see, there is still a world history (but juxtaposed and isolated stories: the Roman, Persian, Hindu kingdoms, Zion, China, the Meso-American world or Inca in America, etc.). Secondly, because the geopolitical place prevents it from being the "center." (The Red Sea or Antioch, the place where the commerce of the East ends, are not the "center," but the western limit of the Euro-Afro-Asian market.)

The most obvious victims of racism are people and groups whose identities were forged in the colonial melting pot: Africans, Asians, and the native peoples of the Americas, as well as those displaced by colonialism. Identity is how subjects identify with something, present themselves to the world, and it is formed by a set of symbols responsible for culturally demarcating belonging to certain social groups. Focusing on the process of building the identities of Black and Black subjects, according to Gomes (2002, pp. 2–3), Black identity is understood

> […] as a process historically built in a society that suffers from ambiguous racism and the myth of racial democracy. Like any identity process, it is built-in contact with the other, in contrast with the other, in negotiation, exchange, conflict and dialogue.

Therefore, identities are constituted from a relational perspective – relational because the identity of a group is not the identity of other different groups; that is, the system of representation that marks a given identity is not the same system of representation of other identities. Therefore, the difference and the relational (comparison with the other) are predominant factors in the process of constituting identities (Woodward, 2005).

Eurocentrism, in its epistemic and universalizing tendency, imposes a fallacious superiority created to protect its hegemony from criticism through the mastery of the way of producing thought. As stated by Grosfoguel (2008, p. 125),

> Precisely, the success of the colonial/modern world-system lies in making subjects socially situated on the oppressed side of colonial difference to think epistemically as those who are in dominant positions. Subaltern epistemic perspectives are a form of knowledge that, from below, originates a critical perspective of hegemonic knowledge in the power relations involved.

This domination mechanism has its success because it is a-historical, within an epistemic process, preventing the colonized from recognizing this timeless colonization. According to Quijano (2005), modernity is one of the myths of coloniality. In this sense, Europe emerges in a world built on a dominant hierarchical pattern – one based on fallacious dichotomies such as modern versus traditional, civilized versus barbarian, reason versus emotion, scientific versus mystical among others – to make use of a place, supposedly for them created, of superiority.

European coloniality patterns created "white masks" around the world, reflected in cultural attempts at social acceptance (Fanon, 2008). The hair issue is one of these white masks that needs to be dropped to allow our Black faces to surface. Decolonizing this and other European traditions perpetuated through the path of domination is necessary today, mainly in the pedagogical field.

Decolonizing the curriculum is another challenge for school education. We have already denounced much about the rigidity of curricular grades, the impoverishment of the content of curricula, the lack of dialogue between schools, curricula, and social realities, and we recognize the need to train reflective teachers on cultures denied and silenced in curricula. However, it is important to consider that some change is on the horizon (Gomes, 2017). The strength of cultures once denied and silenced in curricula has increased in recent years. Social changes, the hegemonic and counter-hegemonic processes of globalization, and political tensions surrounding knowledge and its effects on society and the environment are introducing, increasingly, another cultural and societal dynamic that demands a new relationship between inequality, cultural diversity, and knowledge (Gomes, 2017). The so-called excluded people have started to react differently: they resort to collective and individual strategies; they find voice articulated through networks. As we witness globalization that would break down borders, bringing markets closer together and intensifying capitalist exploitation, we see, too, movements toward counter-hegemonic globalization, in the words of Santos (2006), but also autonomous forms of reaction, some of them harsh and violent. This complex context affects schools, universities, fields of knowledge production, and teacher training. Along with the new forms of capitalist exploitation, there are movements of struggle for democracy, popular governments, counter-hegemonic reactions from countries considered peripheral or developing.

This process affects the curriculum, school subjects, and practice, urging renewal. And this renewal is no longer restricted to theory; it demands real connections between theory and practice and, moreover, a renewal of the pedagogical imagination and the relationships between subjects taught. Curricula become territories in dispute, especially for the new social subjects organized in collective actions and social movements (Arroyo, 2011). In this sense, Law 10639/2003 helps us, as a legal instrument, in pushing for the implementation of an educational curriculum proposal that values other narratives, in particular those of African and Afro-Brazilian history and culture.

3. Methodology

The Maria Felipa Afro-Brazilian School is an early childhood education school that operates from Group II to Group V, with pedagogical activities taking place in two shifts: the morning and the afternoon. In addition to these, the school offers the option of a full shift. Activities in the afternoon shift take place in Portuguese and English, so that, for Groups II to V, all didactic development carried out at school, until the children's lunch break, occurs with the teacher speaking in English. After the break, until the children go home, the activities are conducted in English. In the full shift, we have, during the morning, the usual didactic activities of the school, privileging games, reading, drawing, films, songs, painting and portfolio production, circus classes, Capoeira, and Latin dances.

The purpose of training in these languages lies in the fact that our children need access to the instruments of domination by the dominator. We believe that we must not create a ghetto that isolates our children by reinforcing the instruments of segregation. In our view, it is not a matter of surrendering to the imperialism of English-speaking countries but of giving our children conditions of social parity and access to their origins, since much of the literary material about African and Afro-diasporic culture is in English. Through Spanish, we seek unity with our Latin American sisters and brothers who have experienced the same processes of cultural expropriation and violation. We also work with visual art, and everywhere in the school we seek to display figures representing Blackness in spaces of power in society.

The pedagogical practices of the Maria Felipa Afro-Brazilian School are geared toward a daily routine that guarantees moments of care, play, integrated learning, and critical development of a social reality aligned with the concept of child and education that we embrace.

In this text, we seek to present the results of some of our work that aims to build an emancipatory and anti-racist early childhood education.

4. Results and Discussion

Early childhood education at Maria Felipa Afro-Brazilian School is organized based on the following progression: Group II, Group III, Group IV, and Group V. Table 1 shows relationships between group, target audience, and the number of children per class.

Groups	Number of students	Age
Group II (Inca Empire)	12	2 years-old
Group III (Kingdom of Dahomey)	15	3 years-old
Group IV (Mayan Empire)	7	4 years-old
Group V (Ashanti Empire)	4	5 years-old
Integral Shift (Kush Empire)	22	From 2 to 5 years-old (second shift)

Table 1: Organizational Structure: Elaborate by the authors

We were brought up with standards of subordination that tore apart our history and broke our ancestral ties so that we linked our origins to “slaves” or “wild Indians.” Our aim is to re-read these lines of history, aiming to restore our great references, which will help our children construct a positive sense of self. For this purpose, each group at MFS is named for an African or Amerindian kingdom/empire about which the class deepens its knowledge throughout the year. Our first academic year included an annual project entitled “What’s in America with us.” Project work revolved around three axes: an ancestrality axis (Unit I), and identity axis (Unit II), and a community axis (Unit III). This organization reflects an African philosophical perspective called Sankofa, which establishes that we can only know who we are if we respect and value where we have come from, thus allowing us to build new social networks based on collective care and solidarity.

Each class was accompanied by a teacher who was, in turn, supported by one class assistant, except for groups II and III who had two class assistants. The classes were made up of a maximum of fifteen students, of which two places were allocated through full scholarships offered to Black or Indigenous children from families with an income of up to 2,000 reals [Brazilian currency]. We also awarded many partial scholarships through the financial support of benefactors of the project.

We highlight below some activities of a decolonial-critical nature with an anti-racist basis developed in our project:

We conducted a gardening workshop from an Ubuntu perspective. Ubuntu points to an existence marked by harmonious coexistence with the Other. In this way, the spirit of this philosophy translates to respect that valorizes the human (muntu) and nature (kintu). The term "We" applies, of course, to the other person (muntu), both individually and collectively, pointing to an existence supported by intersubjectivity. However, "We" can also refer to nature (kintu). In this case, it indicates that there is no existence for the human person other than an existence through nature; in other words, the human being is one with nature. This implies that attacking, disrespecting, and putting at risk the human person and/or nature means denying Ubuntu and acting contrary to its ethics. The following is a photo of the children during the workshop:

Figure 1: Ubuntu gardening workshop (source: authors' personal file)

An Abayomi doll production workshop also took place at our school. These dolls were created by enslaved Black women who produced the dolls on the tumbeiro ships (small craft used to transport slaves between Africa and Brazil). To cherish their children during the terrible voyages aboard the tumbeiros, African mothers tore scraps from their skirts, and with these they crafted small dolls, using braids or knots, which served as protective amulets. The dolls, a symbol of resistance, became known as Abayomi, a term that means "precious encounter," in Yoruba (language of one of the largest ethnic groups on the African continent, whose population inhabits parts of Nigeria, Benin, Togo, and the Ivory Coast). Without seams (using only knots and braids), the dolls do not have facial features, which favors the recognition of multiple African ethnicities. Below is an image of the children with the Abayomi dolls they produced.

Figure 2: Abayomi dolls (source: authors' personal file)

We ran a "deprincessing" workshop, which started with the question: "How is the princess?" … The answer was a chorus: "blondyyyy." So, examples of non-thin, non-white, non-blond princesses were presented… princesses not dependent on men (or a man's kiss) to live and who understand that it is difficult to be happy forever… princesses like Anastácia, who was a warrior, or like Shure de Wakanda, who is a scientist, among many others. The following is a photo of a Black child with a Black princess produced by her during the deprincessing workshop:

Figure 3: Deprincessing workshop (source: authors' personal file)

We chose to construct our own books (portfolios) because we understand that the representation of Black people in textbooks, in general, reinforces the social pattern of stigmatization and inferiority of this group, as it also does for Indigenous people, reproducing them through subordinate images and/or caricature (Silva, 2011). In this sense, we did not include a textbook in our pedagogical proposal because our young children need to build representations of themselves and their classmates with self-esteem and dignity.

From the conception of the Pedagogical Political Project (2017–2018) to the current days of the first academic year (2019), Maria Felipa School has been receiving visits from collectives of Black women and Black men from different regions of the country, such as the Southeast and South regions; exchange students and teachers from African countries, such as Angola, Guinea Bissau, Mozambique, São Tomé and Príncipe; as well as educators from the United States and Brazil. The institution managed to arouse the interest of diverse education professionals from different areas of knowledge interested in learning more about the decolonial pedagogical perspective and pioneering institutional policy. In particular, it is important to note the diasporic connections made through these visits from academics, student groups, and teachers. Below, we present some of our visitors:

Dr. Elisa Larkin Nascimento paid a visit to the school. Elisa is one of the biggest names in the anti-racist struggle in Brazil; author of a number of books, including *Afrocentricity*;

President of the Afro-Brazilian Research and Studies Institute (IPEAFRO); and widow of the immortal Abdias do Nascimento. (1st semester – 2018)

Quilombo Boca Preta presented us with much musicality at a seminar on decolonizing science. (1st semester – 2018)

The Fulni-ô Indigenous people visited Maria Felipa to discuss cultural riches and the struggles the people face. Doyá Fulni-ô, Txale Fowá Fulni-ô, Satle Fulni-ô, and San Fulni-ô taught us a little about their children's education and also presented us with their art. (1st semester – 2018)

Conversation Circle (Literature for children and youth and Federal Law 10.639/03): Dr. Maria Anoria de Jesus Oliveira and Master Reijane Maria de Jesus Oliveira of the Educational Union of Brasilia [UNEB, for the initials in Portuguese] presented *New Paths* and *Other Crossings*. (2nd semester)

Conversation Circle: Ana Luísa Araújo Dias (psychologist) and Altair dos Santos Lira (anthropologist) presented "Health of the Black Population and Confronting Racism in Education: A question of Equity."

Conversation Circle: Professor Dra. Wlamyra Albuquerque presented "A history of Afro-Brazilian culture for early childhood education."

Conversation Circle (Crespo empowerment in early childhood education): Lorena Lacerda (museologist), Daílza Araújo (educator), and Laíse Neres (sociologist), all representatives of the organization March of Crespo Empowerment, presented "Self-image, representations, and Black self-esteem."

Several icons of Bahian music, including Tonho Matéria (singer, composer, and capoeirista), Mácia Short (singer and ex-Banda Mel), Marinêz (singer, ex-Banda Reflexu's), and the percussionists of Ilê Ayê joined us for a carnival project named "The origins of Axé."

On March 8, 2019, women from different social perspectives joined us for a conversation entitled, "What does it mean to me to be a woman?" Visitors included

- Thifany Odara (trans woman, social educator, damage reducer, member of the Operative Group of the Citizenship Ombudsman of the Public Defender of the State of Bahia);
- Rutian Pataxó (Indigenous woman of the Pataxó people, graduate student in Law, young leader, member of the United Movement of Indigenous Peoples and Organizations of Bahia [MUPOIBA, for the initials in Portuguese]);
- Elane Boa Morte (Black woman, mother, scientist in the field of chemistry, PhD in Chemistry, and professor at the Federal Institute); and
- Maria Aparecida (Northeastern woman from Bahia, educator, specialist in early childhood education, member of the research group Social Development in Early Childhood Education).

The presence of Black female writers and Black writers in the literary field is quite frequent in the playful education process and in the construction of children's identities in the institution. All work starts from the place of the writer, as the positive aesthetic characteristics of the characters and the voice that narrates the stories are constructed. (Cycle Continuous / 2018)

Lívia Natália (poet, PhD in Literature, and professor of Theory of Literature at the Federal University of Bahia [UFBA, for the initials in Portuguese]) visited the school. She is the writer of several books, including *Água Negra*, *Correnteza e Outros Estudos Marinhos*, *Água Negra e Outras Águas*, *Dia Bonito Pra Chover*, and *Sobejos do Mar*. While visiting the school, she was invited to launch her first children's book, *As férias fantásticas de Lili*.

Luana Assiz (journalist) worked with Group IV (Mayan Empire) and Group V (Ashanti Empire) within our project to raise awareness of Black and Amerindian people in spaces of power. The journalist talked about her hair transition, spoke about her trip to Angola, and showed her artistic side, singing and playing the song "Linda e Preta," which inspires appreciation of the Black aesthetic of the Bahian singer Nara Couto.

Vilma Reis (sociologist, human rights activist, former public ombudsman for the State of Bahia [Public Defense – BA], candidate for the mayor of Salvador [2019]) is one of the Black women whose trajectory is significant for the Black Movement of Bahia. She was at the school for a proposal to make Black and Amerindian people visible in the spaces of power. She, with her powerful voice and striking representativeness, showed us that her path came from afar, and told the school's educators the story of quilombola leader Tereza de Benguela.

As part of the project "Deconstructing myths of Black intellectuality," we were joined by Dr. Katemari Rosa and Dr. Nadinalva Ferreira.

- Dr. Katemari Rosa (physicist, Black woman) talked about her trajectory and demonstrated experiments which involved physics, toys, and playfulness.
- Dr. Nadinalva Ferreira (graduate in medicine from the Bahiana School of Medicine, Black woman) has a postgraduate degree in Obstetric Gynecology, Occupational Medicine, and Cytology. The presence of Dr. Nadilva was significant for building a positive image of Black people in different professional and social positions of power.

Educators of the collective Quilombelas of Porto Alegre visited the school. They had learned about Maria Felipa's educational proposal through social networks and had taken the opportunity of coming to Salvador to participate in a pedagogy congress at the Federal University of Bahia. The moment was a lively exchange of experiences among a group of Black women teachers who recognized in themselves much of the decolonial pedagogical work performed at the school.

AFRICA

Dr. Mamour Sop Ndiaye (African from the Senegal region) gave a lecture in partnership with Quilombro Boca Preta at the seminar "Decolonizing Science." (1st semester – 2018)

Conversation Circle (Brazil-Africa dialogues: sharing educational experiences with University of International Integration of Afro-Brazilian Lusophony [Unilab, for the initials in Portuguese]): We were joined by scholars such as Chitungane Chachuaio (Mozambique), Margarido Bendo (Angola), Yoursany Correio (São Tomé and Príncipe), Daniel Tchuda (Guinea Bissau), and Cássia Vale (Brazil). Cássia launched her children's book *Calu: A Girl Full of Stories*, and was at the school at different times, as a writer and partner! (2nd semester)

CONNECTION – AFRICAN DIASPORA

The group of professors and students from Wheelock College, a faculty linked to Boston University (USA), was received to give the lecture, "Education of the Black population in the diaspora." (1st semester – 2018)

Sedrick Miles (North American) carried out training with the school teachers with the theme "Black Critical Pedagogies."

Niyi Tokunbo Mon'a-Nzambi (professor, native of Salvador [BA], Angolan descendant, researcher of African languages) was received at the school. He taught several courses on "Kimbundu – Language of Angola and Brazil," for example, and told the children stories from the Yoruban worldview.

Christopher Estrada-Salazar (USA) and Abraham Asante (Ghana), exchange students, were received at the school for a month in partnership with the Steve Biko Cultural Institute and Pitzer College. The days they spent at the institution involved a lot of learning, both for them, with the daily practice of Portuguese, and for others, as Christopher and Abraham were able to contribute with English classes and share knowledge of the African Diaspora.

5. Final Considerations

We conclude this text stating that it is inconclusive. Our work has been a path to new paths, a crossroads, from which we have the right to follow different directions, as long as these do not lead our children to subjugation, human hierarchization, or devaluation of life. The purpose of our school – 'ours' because it belongs to everyone who dreamed this dream together with us and even long before us – is to educate our children for cognitive and social development by valuing and recognizing their different civilizing matrixes and recognizing that it is the diversity of who we are that builds the material and immaterial wealth of our people, always developing respect for differences as long as they do not make us inferior, and valuing and enhancing the plural composition of our collective.

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Part III
Gender and STEM

Transdisciplinary Research on 'Gender' in Science, Technology, and Society

Petra Lucht

1. Introduction

Invited to a talk about research on gender in science and technology, I usually start with the image of a turtle that jumps from a glass bowl. The image of such an impossible jump serves as an entry point to convey to the audience how impossible it might seem, at first, to integrate research on gender into science and technology. At the same time, I hope that the image of such an impossible jump allows the audience to think "outside of the box" to create new and reimagined perspectives on integrating gender dimensions into research and development in science and technology.

Figure 1: Jumping out of the glass bowl[1]

In order to carry out research and teaching on gender in science, technology, and society, I refer to transdiciplinarity as one of the overarching principles or paradigms. For this first step, it is necessary to leave behind the disciplinary context to which one is accustomed and in which one has been trained. This paper, then, is an invitation to jump from one's own glass bowl – be it science and technology or gender studies. To conduct transdisciplinary research that contributes to the scientific field of research on gender in science and technology, it is necessary to acquire skills both in the scientific and technical disciplines as well as in research on gender. By jumping from one's own disciplinary bowl, over and over again, inter- and transdisciplinary perspectives on science and technology are gradually developed and integrated.

1 This image was used for the programme flyer for a symposium at the RWTH Aachen that I co-initiated in 2011: https://www.rwth-aachen.de/cms/root/Die-RWTH/Aktuell/Pressemitteilungen/November/~ddvu/Symposium-zum-Thema-Gender-in-den-Wissenschaften/ (June 14, 2020)

In the first part of this paper, three paradigmatic frames are outlined. These include taxonomies, paradigms, and transdisciplinarity. I refer to these frames when advising students in teaching and for carrying out research projects. In the second part of this paper, I present such teaching and research projects as case studies investigating gender in science, technology, and society. Case studies in teaching were carried out as final qualifying projects by students in scientific, technological, and planning disciplines who took part in a new and innovative study programme, Gender Pro MINT[2], at Technische Universität Berlin. Secondly, I describe a range of research projects currently being carried out in the team of my Chair in "Gender in STEM and Planning / Feminist Studies in Science, Technology and Society"[3] at the Technische Universität Berlin. Both the teaching projects and the research projects are investigating in science and technology, including (a) professional / scientific cultures, (b) epistemologies and knowledges, and (c) artifacts, developments, and possible innovations. The most recent project aims at investigating (d) possible de-entanglements in science and technology of professional / scientific cultures; epistemologies, knowledges, and artifacts; and developments and possible innovations by establishing reflective and participatory formats. In the conclusion, I point at implications and consequences of a Declaration of Human Rights in Science Education informed by expertise in transdisciplinary research on gender in science, technology, and society.

2 The certificate study programme Gender Pro MINT was developed by Bärbel Mauß (Mauss, 2017), who has been coordinating it since its establishment in 2012. The acronym "MINT" stands for "mathematics, informatics, natural sciences, and technology." Therefore, it corresponds to the acronym "STEM," which stands for "science, technology, engineering, and mathematics." This study programme is being offered exclusively to students in STEM fields by the Zentrum für Interdisziplinäre Frauen- und Geschlechterforschung (ZIFG) (Center for Interdisciplinary Women's and Gender Studies) at the TU Berlin (see http://www.genderpromint-zifg.tu-berlin.de). It comprises five modules of up to 30 ECTS: After completing introductory and in-depth modules, students complete project modules and work on inquiry-based study projects that constitute the final theses for the certificates of Gender Pro MINT (cf. Lucht & Mauß, 2015). These final theses in Gender Pro MINT can be carried out as singular study projects or as integrated parts of qualification theses in the natural sciences, technical sciences, and planning sciences (bachelor's, master's, and doctoral theses). The final theses in Gender Pro MINT extend pre-given tasks from STEM by integrating gender and diversity dimensions into tasks that have been initially developed in STEM fields.

3 Since August, 2017, I am holding the newly established Chair in "Gender in MINT und Planung / Feminist Studies in Science, Technology and Society (Feminist STS)" at the Zentrum für Interdisziplinäre Frauen- und Geschlechterforschung (ZIFG) (Center for Interdisciplinary Women's and Gender Studies) at the Technische Universität Berlin. For more information, see https://www.stsgender-zifg.tu-berlin.de/menue/wwwstsgender_zifgtu_berlinde0/parameter/en/

2. Taxonomies – Paradigms – Transdisciplinarity

2.1 Taxonomies: Research on 'Gender' in Science, Technology, and Society

In 1995, Evelyn Fox Keller, one of the pioneering scholars in research on gender and science, suggested dividing this evolving field into a range of different perspectives (Keller, 1995). In her view, investigating the participation of women* in science differs profoundly from critical inquiry into how gender is investigated through science and also how gender is embedded implicitly in scientific knowledge. To date, similar distinctions within the field of gender and science have shaped research, politics, and policies: Reaching gender equity in science, on the one hand, and establishing research on gender in science, technology, and society, on the other, are viewed as distinct endeavors. The first endeavor results in policies aimed at reaching gender equity. The second aims at investigating how gender is configured through historical, social, and cultural processes that, at the same time, shape the formation of science and technology and their possible results. However, these two distinct endeavors are also bound together as "twin sisters." Research on gender in science and technology translates into gender equity policies. Conversely, gender equity sheds light on the limits of research on gender in science and technology, especially when goals of gender equity can't be reached based on existing knowledge and require further regulations and policies.

Referring to the German context, I outline which taxonomies have so far been favored for carrying out research on gender in relation to science, technology, and society. These still resemble the distinctions that Keller (1995) described.

Since the 1970s, gender research in the German academic context has evolved mainly in academic and disciplinary fields of the social sciences and humanities and in cultural studies such as history, sociology, pedagogy, literature studies, psychology, theology, media studies, and economics (cf. Becker & Kortendieck, 2010). Yet research on gender in science, technology, and society has not reached the status of an academic field – neither as a subfield in the humanities and social sciences nor as a subfield in the natural sciences, technology, mathematics, or engineering sciences. This limited status is reflected in the major handbook on women's and gender research: While the second edition (Becker & Kortendiek, 2010) includes several contributions to research on gender in STEM fields of physics (Götschel, 2010), computer sciences (Bath et al., 2010), mathematics (Blunck & Pieper-Seier, 2010), biology (Palm, 2010), chemistry (Bauer, 2010), technology (Paulitz, 2010), and engineering (Ihsen, 2010), only three articles on research on gender in STEM can be found in the third and latest edition of the handbook (Kortendiek et al., 2019).

Regardless of whether gender studies in science, technology, and society has reached the status of an academic discipline or subfield, a range of taxonomies have been suggested. They highlight paradigmatic perspectives or foci of research. Following the differentiation of the field into these focal points, it can be argued that the contours of an independent, academic subject area are revealed on the basis of numerous research contributions. Extending Keller's (1995) schema to technology, I'd like to suggest a taxonomy of research on gender in science, technology, and society based on the following areas:

(a) women* in science and technology;
(b) epistemes and knowledges linked to gender in science and technology; and
(c) results and applications linked to gender in science and technology.

In order to more effectively de-entangle the close but mostly implicit connections of gender with science, technology, and society, we also need to investigate how

(d) de-entanglements of the above research perspectives linked to gender can be achieved.

Research on the situation of women* investigates the historical and current situation of women in STEM fields. Works include, for example, historical research on biographies and on the conditions under which women* have struggled and continue to struggle to gain access to the professions in science and technology. This research includes investigations of processes of socialization as well as the public or stereotypical images of a given STEM discipline or how a disciplined is portrayed through its curricula, didactics, or pedagogy. Also, investigating the current professional cultures of STEM disciplines is viewed as a way forward to analyze and contribute to changes of situation for women in STEM.

A second overarching perspective highlighted in reviews of the field involves work addressing the production of knowledges in science and technology, and how this research may be linked to implicit and explicit connotations and codifications of gender. Prominent case studies may be found in biology (cf. reviews of Keller, 1995; Palm 2010; recent conference papers in Palm et al., 2018). In the so-called abstract sciences, such analyses are rarer. One argument is that explicit notions of gender are not part of the self-understanding of disciplines such as physics (Keller, 1995; Götschel, 2010). In physics, such examples include research on gender in high energy physics (Traweek, 1988) or thermodynamics (Heinsohn, 2005).

Finally, epistemes on gender manufactured in science and technology leave the ivory tower; results of research, including implicit and explicit notions, connotations, and codifications of gender are applied, shaping everyday knowledge as well as everyday experience. Numerous analyses may be found in the previously mentioned handbook on women's and gender studies in the German context (Becker & Kortendiek, 2010; Kortendiek et al., 2019) and in international contexts (Keller, 1995; Riley et al., 2009; Schiebinger, 1999 & 2004; Wajcman, 2004; to name just a few). Prominent case studies from the field have been collected by Schiebinger and Klinge (2013) in an anthology that has also shaped research policies of the European Union through presentation of paradigmatic exemplars of gender research on science and technology (Schiebinger, 2011).

2.2 Co-Existing Paradigms in Research on Gender – Or is 'Gender' Vanishing?

Research has shown that gender is not (biologically) determined. Rather, it is fabricated through multiple historical, social, and cultural processes and contexts. Since its establishment in the middle of the 20th century, research on gender has undergone several shifts in its research perspectives and foci. In the following, I outline some of these perspectives that may also be viewed as paradigms in gender studies. These paradigms co-exist within the current landscape of research on gender, and they allow to focus on social inequalities related to particular concepts of gender. Here, I sketch some of the main approaches to research on gender to show its potential variety, without claiming to present a complete review of the field.

In response to calls from the second wave of the women's movement, institutionalization of research on gender at universities started with the gradual establishment of women's studies in the 1970s and 1980s. Emblematic of this shift are paradigmatic guidelines offered by one of the movement's pioneers, Maria Mies. She defined women's studies through an approach that she called the "methodological postulates for women's studies" (Mies, 1983), demanding an epistemological shift that could be reached through "research by women with women and for women." In the process of establishing more research projects and of producing results on the conditions and fabrications of women's lives, a first shift took place. Research investigated the fabrication of relations between women and men, while taking these relations no longer as predetermined and fixed. Such research on gender was called "gender studies" rather than "women's studies." With this shift in the 1980s, a distinction between "sex" and "gender" also gained currency, since it proved productive for analyses of fabrications of gender through historical, societal, and cultural contexts without relating these fabrications directly to assumed sex differences from biology or medicine. However, beginning in the 1990s, this distinction was criticized as misleading when examined in the light of pre-existing dualistic assumptions about gender. Butler's prominent monograph *Gender Trouble* (1990) proposed that the very distinction between "sex" and "gender" needs to be questioned. The construction of sex was analyzed, to a large extent, as a result of recurring processes of discourses on heteronormativity.[4] In light of this approach, interactionist approaches in research on gender gained momentum; these investigated "doing gender" as part of all performative practices that stabilize heteronormative societal structures. Recently, the notion that sex and gender should not be viewed as oppositions or structured in binary categories – "sex" is not structured as "female versus male" and "gender" is not structured as "feminine versus masculine" – has been manifested through laws in several nations worldwide. In

4 In the German context, Gildemeister and Wetterer (1992, pp. 205) pointed out a danger and, at the same time, a false belief in a mimetic analogy of "sex" and "gender." The dualism of biology, on the one hand, and history, society, and culture, on the other, is in itself part of the dualisms that stabilized the actual structure of gender. As a result, "sex" is viewed as non-binary and changeable over time.

the German context, a "third option" was established that demands that "intersexuality" as well as "transgender" be allowed and placed by law under the umbrella of a "third option" (Bundesverfassungsgericht, 2017).

In Germany, one recent, prominent shift in foci of gender research took place during the first decade of the 21st century, namely with the gradual integration of "intersectionality," a term coined by Kimberlé Crenshaw (1989). Taking up Black feminism, Crenshaw investigated lawsuits within the context of affirmative action during the 1980s in the United States. Based on her analyses, she suggested that the discrimination against black women needs to be understood as an interplay of sexual and racial discrimination. The metaphor of an intersection of streets is used by Crenshaw to suggest that sexual and racial discrimination should be understood neither as independent of each other nor as cumulative. Rather, both forms of discrimination intersect. Therefore, black women experience structural discrimination at the intersections of race and gender.

The transfer and integration of intersectionality to the German context was debated vigorously at first. Some questioned to what an extent intersectionality should be viewed as a new paradigm and to what extent concepts developed in the U.S. context could be transferred to the German context (Knapp, 2005). Among others, Katharina Walgenbach (2007) took up the challenge to re-contextualize the intersectional approach for the German context. She offered a framework for reflecting on the transfer of intersectionality into German debates in gender studies through (1) inclusion of women's movements in Germany and (2) discussions of a range of intersectional approaches. Based on this work, Walgenbach suggested that gender should be viewed as an "interdependent" category rather than an intersectional one. With interdependence, Walgenbach focuses both on the "mutual dependence of social categories" and on "inner-categorial interdependence" (Walgenbach, 2007, p. 61). Finally, Walgenbach concludes that (3) gender as an interdependent category needs to be re-invented for each research project, re-designing the architecture that serves as analytical tool to investigate gender as an interdependent category.[5] Walgenbach (2013) takes up the criticism that the concept of intersectionality unintentionally plays into the hands of a levelling of power relations.[6]

5 Although I am in favor of the concept of interdependency over that of intersectionality, this shift in terminology has not prevailed in the debates on "intersectionality research" in gender studies. Walgenbach (2013) herself shares this assessment. Therefore, I subsume Walgenbach's work under the umbrella of intersectional approaches in gender studies.

6 Walgenbach (2007) points out, for example, that queer interventions in debates on gender studies and the possibility of connecting different strands of theory in queer studies may have taken place but, at the same time, could be relativized or suppressed again in debates on intersectionality. At the same time, she comments on the constitution of current gender orders by means of heteronormativity (Walgenbach, 2007, p. 41, with reference to Hark, 2005, among others). Also, Dietze et al. (2007) elaborate on this objection to intersectionality research in detail, thereby anchoring historical and current references between intersectionality research and queer theory in these discourses. In addition, "intersectionality" entails the risk of levelling power structures that where the very reason of the invention of intersec-

More recently, another approach has become prominent in research on gender in science and technology, namely aligned with "new materialism." This is supported through, for example, funding of "COST Action IS1307 – New Materialism: Networking European Scholarship on 'How Matter Comes to Matter'" by the European Commission,[7] a recent conference on gender studies in the German context (Palm et al., 2018) that called extensively for papers that contribute to this branch of research and by the most recent handbook on interdisciplinary gender studies in the German context (Kallmeyer, 2019). At the same time, branches of research that focus on global power structures in connection with gender research in science and technology are also part of the picture in the German context, as portrayed and mapped out in the handbook on interdisciplinary gender research (Kortendiek et al., 2019) mentioned before. To pick two perspectives among several, I'd like to mention here the contributions of ecofeminism (cf. summarized in Bauhardt, 2019) and postcolonialism (cf. Harding, 2019).

2.3 Transdisciplinarity Research on Gender in Science, Technology and Society

In my paper, I restrict the interpretation of transdisciplinarity to two meanings in order to highlight the place of research on gender in science, technology and society. To explain these two meanings, I refer to Figure 2.

The first meaning of "transdisciplinarity" that I want to point to understands it as "cross-disciplinarity" between the so-called "two cultures" within academia. In the

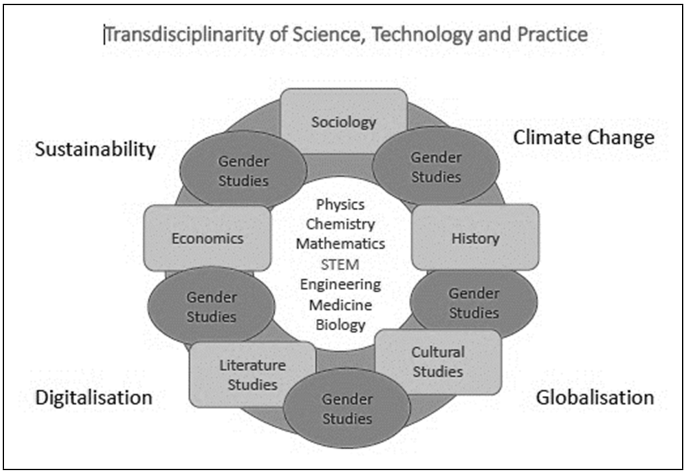

Figure 2: Transdisciplinarity of Science, Technology and Society

tionality by Crenshaw: namely, to analyse structural, racist discrimination (Gutiérrez Rodríguez, 2011). My own reception of Walgenbach's suggestion to establish gender as an interdependent category can be found in Lucht (2014), Lucht (2017), and Lucht (2018).

7 https://newmaterialism.eu/ (14.6.2020)

inner circle the STEM disciplines are located. These diciplines include physics, mathematics, informatics, engineering, chemistry, and biology, and are subsumed under the "culture" of science and technology. Historically, gender studies have been developed and established as part of a second "culture," located in this figure in the outer circle of academia, which includes the humanities, social sciences, psychology, literature, philosophy, cultural studies, educational sciences, and economics. However, gender studies in academia are often perceived as "peninsulas" even within these disciplines. Therefore, I place gender studies in "eclipses" in the outer green circle. Still missing is an integration of gender studies within the disciplines in the green circle, and particularly within the STEM disciplines in the inner circle. Although one might argue that gender equity policies have been established for science, technology, and society, inclusion of research on gender in approaches to scientific research and technological development has almost not taken place at all.[8]

A second meaning of transdisciplinarity surfaced increasingly toward the turn of the 21st century and is related to the so-called "Grand Challenges" that global society faces in current times (Hadorn et al., 2008). In this sense, transdisciplinarity points to a crossing of boundaries between academia, on one hand, and society and practice, on the other, while aiming at solving real-world challenges such as globalization, securing a sustainable future, dealing with digitalization of society, or preventing and or managing climate change. Both meanings of transdisciplinarity require integration of a range of paradigms in science and technology inherent to particular disciplines. Crossing boundaries between multi-paradigmatic gender studies and science and technology presents many challenges to academia and to society since real-world problems need to be solved in ways that include gender-just perspectives. Integrating gender as an interdependent category in transdiciplinary research requires integration of its internal "architecture" (Walgenbach, 2007) into research design for technological development. The need to transform established approaches might be addressed during scientific research and/or technological development. As a consequence, transdisciplinary research and development that includes gender studies perspectives may result in transformative knowledge about given problems – knowledge that includes the gender dimensions of problems or Grand Challenges for which solutions are being sought.

8 To make this more concrete, I'd like to point out that in the German context only about 12 professorships on Gender Studies in STEM can be found in academia. Only two thirds of these professorships are permanent ones, and about two third of them are to be found at universities. Currently, not one permanent professorship can be found at a technical university in the German context. (Source: Datenbank des Margherita-von-Brentano-Zentrums (2020), Freie Universität Berlin, https://www.mvbz.org/genderprofessuren, January 22, 2020)

3. De-Entangling Gender from Science, Technology, and Planning Through Transdisciplinary Research at the Chair in "Feminist Studies in Science, Technology and Society"

Following Winner (1980) and the adaption of Bath (2009), two overarching questions lead research and research-based teaching projects on gender at the Chair in "Gender in STEM and Planning / Feminist Studies in Science, Technology and Society (Feminist STS)" with respect to investigations into the fabrication of gender (Lucht, 2014, 2017, & 2018):

(1) Do (a) professional / scientific cultures, (b) epistemologies and knowledges, as well as (c) technological artifacts and developments have intersectional gender politics?
(2) How and to what an extent are (a) professional / scientific cultures, (b) epistemologies and knowledges, and, finally, (c) technological artifacts and developments entangled? How may possible de-entanglements be investigated?

Figure 3 below illustrates programmatic research and teaching programmes at my Chair. Three distinct perspectives in research and teaching are covered: (a) professional / scientific cultures in science and technology, (b) epistemologies and knowledges on gender, and (c) technological artifacts and developments. Transdisciplinary approaches in gender research on science, technology, and society are being developed that aim at fostering a gender-just and diversity-just everyday life-world in a globalized, pluralistic society. In the following, I present projects of research-based teaching (2.1) and on research (2.2.) on gender at my Chair.

3.1 Research-Based Teaching Projects in the Study Programme "Gender Pro MINT" at TU Berlin

Against the background of schemas outlined in Section 1.1, the examples of research-based teaching projects outlined below relate to investigations of (a) professional, scientific cultures, (b) epistemologies and knowledges, and (c) technological artifacts and developments. These projects were carried out in modules for the certificate study program "Gender Pro MINT" (GPM) that I advised at the Technische Universität Berlin between 2013 and 2015 (cf. Lucht 2014, 2017, 2018; Lucht & Mauss, 2015).

3.1.1 Professional, Scientific Cultures

In recent decades, many measures have been taken to reduce structural barriers for women* in STEM disciplines and in planning. However, becoming a member of an academic discipline or a professional field is not only formally but also informally significantly influenced by unwritten rules in everyday practice. In order to further investigate the persistence of social inequality, it is necessary to look more closely at these informal mechanisms of inclusion and exclusion. The following two projects in the field of engineering and in urban gardening have adopted this research perspective.

The work world of female engineers in mechanical engineering is still considered a male-coded domain. Lisa Henrichs, a mechanical engineering student, wrote her bachelor thesis on her experiences at a medium-sized company at which she contributed to quality assurance of materials at the test bench. Henrichs (2015) retrospectively identified forms of masculinity that shaped everyday practice in this professional environment. Following Faulkner (2008), Henrichs used interviews and participant observations to develop practice-oriented typifications for the creation of professional identities in engineering (such as the technician or the problem solver) as well as theory-oriented typifications (such as the manager or the project leader). Based on this example, Henrichs assigned a "somewhat gender-neutral" identity to quality assurance in engineering and pleaded for shifts in the symbolic structure of femininity and masculinity in engineering in order to realize gender justice.

"Are gardens gender-coded and queer places?" asked Toni Karge with reference to his diploma thesis (Karge, 2016) in urban and regional planning. He pointed out that in the everyday practice of an urban garden project, gender-segregated task divisions had been established in the course of development and maintenance of the project. Female team members were mainly responsible for project coordination, marketing, contact management, and the coordination of cooking and baking activities, while male team members

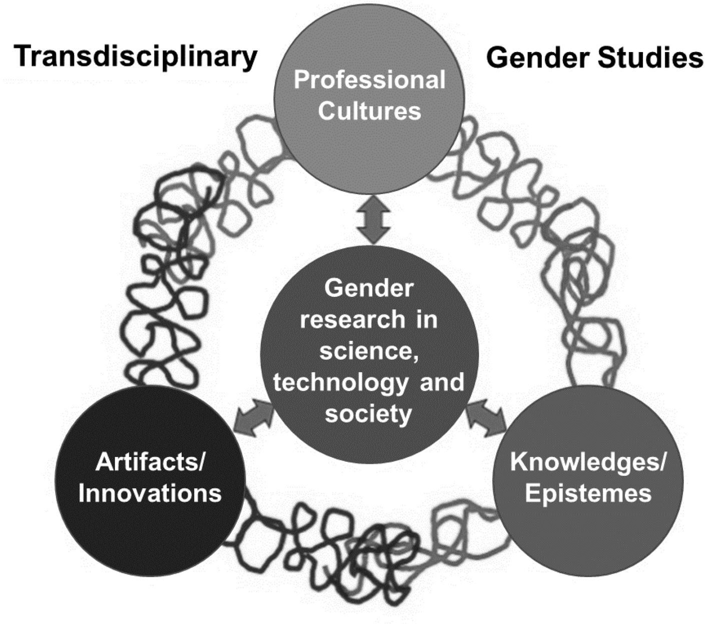

Figure 3: Transdisciplinary research on 'gender' in science, technology and society (Lucht, 2017)

were responsible for construction and technical tasks (cf. Karge, 2015, p. 21). In contrast, the double conception of the garden as a "community garden and as a leasehold garden" was interpreted as transgressing classical, gendered divisions of labor in production and reproduction (cf. Karge, 2015, p. 22). Karge's analysis thus points to current simultaneities of re-traditionalization and de-traditionalization of gendered societal orders. These simultaneities might open up possibilities for shifting divisions of labor and gender segregation in production and reproduction toward more gender-just societal structures.

3.1.2 Knowledges on Gender in Science, Technology, and Planning Sciences

Gender studies on knowledge in the natural, technical, and planning sciences have repeatedly shown that, although dualistically-coded knowledges are organized flexibly in terms of history and context, dualistically-coded gendered orders are also legitimized in recurring ways with reference to these very knowledges (cf. Lucht & Paulitz, 2008). Following from Angela McRobbie (2010) among others, it can be argued that we must currently speak of a "simultaneity of non-simultaneity" with regard to gender-coded dichotomies (i.e., that gender-coded dichotomies are changed, but nevertheless re-stabilized). These shifts are also taking place in the professional and everyday life-worlds of the natural, technical, and planning sciences. Femininity is included in these professional and life-worlds, but at the price of de-thematizing the associated re-stabilization of gender hierarchies in a "new guise." The research projects described below are examples of studies on the stock of knowledge in the natural, technical, and planning sciences that point to this simultaneity of non-simultaneity.

Max Metzger and Franziska Kaiser (Metzger & Kaiser, 2015) analysed the documentary film *Thin Ice* about the climate sciences. The analysis showed that the media production of actors, laboratories, everyday practices, narratives, and conceptions of nature represented a mixed-gender scientific community. However, the analytical knowledge about climate change is portrayed in this film as being conveyed exclusively by male-socialized climate scientists. Thus, epistemic authority is coded as masculine in this documentary film.

How is it possible not to reify (gender-)stereotypical ideas of childhood in the (urban) planning process? In a master's thesis in landscape architecture, Regina Otters (2015) explored this question using the example of "nature experience areas" (NER) for children in the city, and subsequently developed an open, participatory space design. Otters pointed out that NER concepts do not include epistemological reflections of the concepts of "space," "nature," and "childhood" – as well as their mutual entanglements. Thus, the social conditionality of the later concepts is not portrayed in the concept of NER. As a consequence, NER do not offer space for the design of play but only for gendered stereotypical portrayals of childhood and nature.

Melanie Irrgang (2014, 2015) investigated the gendering of concepts of violence in the development of algorithms in semantic search, a sub-area of computer science.

Clarifying the technical possibilities and limits of such a technology and showing that gender-coded concepts of violence are included in software development for semantic search, Irrgang (2015, p. 32) sums up:

> Thus, male perpetrator-victim contexts in particular are reproduced in war-like settings, while domestic violence, which mostly happens to women, remains invisible. Violence is also reduced to physical violence regardless of the context of an action. Furthermore, sexualized, structural, and psychological violence and neglect were not operationalized as further forms of violence by means of the semantic search to be developed.

This represents an example of a technological development in the course of which gender-coded concepts of violence were inscribed in artifacts developed through computer science, stabilized beyond social and political negotiation processes, while omitting knowledge of concepts of violence that have been extensively investigated in research on gender in relation to concepts of violence.

3.1.3 Technological Artifacts and Developments

The following case studies in research-based teaching show that gendered stereotypes are also entangled in technological artifacts, technological development, and spatial planning. In addition, suggestions are made as to how, in contrast, gender-equitable diversity could be enabled for use and appropriation in technology and planning.

The digital media upheaval has, so far, hardly reached music lessons in schools. This observation motivated Christof Schultz and Marten Seedorf (Schultz & Seedorf, 2016) to develop an open-source ensemble loop in their master's thesis in audio communication. Firstly, students were involved in the partially participatory development of this technology. Secondly, the development of the loop reflected gender and diversity aspects, referring to Maaß, Draude, and Wajda (2014) (see Schultz & Seedorf, 2016). The authors took up these questions to achieve a systematic integration of gender and diversity perspectives into a given procedure or procedural model in computer science. In this way, Schultz and Seedorf addressed – and partially avoided at early stages in their own work – stereotypical use of gendered attributions in tonality and hierarchization of instruments of the ensemble.

Retrospectively, Mareike Okrafka analysed a study project from the field of medical technology that aimed to develop dynamic seat shells for wheelchairs to be used by cerebrally paralysed children. Okrafka (2015) developed the following questions, among others:

- How did it come about that therapists and not patients – as initially intended – were involved in the participatory development of the technology?
- Are gains in autonomy achieved for users of this technology?

Thus, development of a technological artifact was comprehensively explored from a gender and diversity perspective.

Anne Miersch (2015), a student in landscape architecture and gender studies, investigated design of playgrounds in an interdisciplinary master's thesis. Through an exploratory comparison of the design of playgrounds in Berlin in the 1950s and the 2000s, Miersch pointed out that planning of play and sports areas in the 1950s was motivated by stereotypical and binary gender concepts. Yet current playground concepts are no exception, as they, too, are increasingly designed in accordance with gender mainstreaming that still refers to binary concepts of gender. Miersch advocates non-binary, gender- and diversity-friendly designs (cf. Miersch, 2015, p. 30) that open a wide range of possibilities for appropriating space. As an example, she developed a concept for a queer-feminist inspired playground entitled "Performance – The Travesty of the Square."

In relation to these research-based teaching projects, I would like to echo Miersch's (2015) plea for gender and diversity-friendly approaches in science, technology, and planning: In order to promote gender-just and diversity-just development and use of technological artifacts as well as project planning, participatory approaches should be followed. In addition, potential stereotyping in these approaches needs to be countered through reflection that takes into account the results of research on gender.

3.2 Research Projects

3.2.1 Professional Cultures: Investigations of Physics and Computer Science

Franziska Kaiser and Andrea Bossmann aim to expand research on the professional culture of physics from an intersectional perspective. Their project "Intersections of ethnicity, gender, and sexual identity: Case studies to investigate the culture of physics in Germany"[9] consists of two subprojects combining approaches from higher education studies, gender, migration, and queer studies. Kaiser investigates discrimination in physics based on (assumed) ancestry/origin and focuses on the experiences of female physicists who have a history of migration. Andrea Bossmann investigates the experiences of queer physicists. Both interview physicists at universities and research institutes in Germany. The interviewees' experiences will be the basis for an analysis of how gender is created and performed within the culture of physics from a differentiated point of view. So far, these research perspectives have not been considered much in research on the professional culture of physics in Germany. Additionally, the project aims to raise awareness on topics of inclusion and diversity in the physics community.

The professional culture of computer science is investigated by Judith Schütze in the research project "Participation and computer science: An investigation of the subject culture of computer science within the framework of a participatory educational

9 This project has been funded by the doctoral seed funding program at Technische Universität Berlin (10/2019–03/2020): https://www.stsgender-zifg.tu-berlin.de/menue/forschung_research/fachkulturforschung_zur_physik/parameter/en/ (June 21, 2020)

research project with a special focus on female students of computer science."[10] That girls* and women* are underrepresented in computer science is confirmed by personal experience and by a multitude of figures and statistics in reports. Computer science and the associated information and communication technologies are professional fields of great relevance, since they increasingly shape areas of everyday life. The low presence of women* in computer science leads to the assumption that there are, at best, only limited career opportunities for women* in information technology. Judith Schütze aims to investigate and to counteract the under-representation of women* in computer science. The interdisciplinary framework includes (1) educational research, (2) cultural research, as well as (3) participatory research as the underlying approaches.

3.2.2 Fabrications of Gender Through References to Scientific Knowledges

In her master's project "Semantics of the gendered body at the International Olympic Committee's Medical Commission between 1967 and 1972," Émilie Filion-Donato explored the decision-making processes of the International Olympic Committee (IOC) with regards to the selection of tests chosen to verify athlete sex.[11] In the thesis, gender testing is placed in the historical context of various classifications of the body that biomedical and social sciences have put forward. A subsequent content analysis is carried out on the minutes, correspondence, and studies read by the Medical Commission between 1967 and 1972. It portrays discourse on the gendered body with respect to its discursive architecture and its relations to discourses in the biomedical sciences. The research raises epistemological questions that pertain to relationships between knowledge, decision making, and action, with a particular interest in how decisions are made in the face of doubt.

In her inter- and transdisciplinary postdoctoral research, Sahra Dornick investigates knowledges of relationality. As such, she is interested in onto-epistemologies of entanglements, and works on a range of projects on sustainability, care, and diversity.[12] Her work relies on approaches from literature, sociology, arts, gender studies, and science and technology studies. With her research, she aims to open up new perspectives for cohabitation and possibilities for alternative ways of being. In her study "Towards a utopian society: Relationality in the works of Judith Butler, Sara Ahmed, and Édouard Glissant" (Dornick, 2019), she explores the possibilities of queer and postcolonial understandings of relationality for imagining future societies. In her work on sustainability and diversity in engineering, she analyses how care – in Maria Puig de la Bellacasa's understanding

10 See: https://www.stsgender-zifg.tu-berlin.de/menue/forschung_research/parameter/en/
11 See: https://www.stsgender-zifg.tu-berlin.de/menue/teaching/betreute_qualifikationsarbeiten/parameter/en/ (December 6, 2020)
12 See: https://www.stsgender-zifg.tu-berlin.de/menue/team/sahra_dornick/parameter/en/ (December 6, 2020)

as "caring for human and more-than-humans" – can be a useful frame for deeper understanding of diversity issues in engineering. Recently, she started a study[13] on the creation of online teaching in care. Here, she aims to explore possibilities, disruptions, and displacements for / of diversity issues that occur in the process of shifting teaching from personal interactions to generalized online units.

3.2.3 Artifacts and Technological Developments and Possible Innovations

Over the last decade, the development of sex dolls equipped with AI has made dramatic progress. It seems clear, now, that in the medium term, sex robots might fundamentally change sexual behaviors and disrupt traditional dichotomies like man / woman, man / machine, nature / culture, etc. In her postdoctoral research "Living and Loving with Robots,"[14] Tanja Kubes examines the conception and design of sex robots from a queer-feminist, neomaterialist, and critical-posthumanist perspective (cf. Kubes, 2019). Building upon discourse analysis and qualitative empirical research, the study explores sex robots from a sociological, philosophical, and anthropological point of view and discusses the chances and dangers of extending sociality to machines. Kubes argues that by moving beyond hegemonic and heteronormative objectivations in their design, queer- and diversity-sensitive sex robots may actually inspire optimism about sextech's role in opening up new spheres of post-human relationships and, thus, broaden our erotic futures.

Currently, online tools for learning and teaching are increasingly being integrated into education at all levels. But how can these tools be developed in ways that acknowledge necessities of heterogeneous target groups of learners, teachers, and practitioners? The work at the Chair on investigating technological artifacts most recently included a new research project on digital competencies as part of the educational training of future careworkers. As part of the joint project "Digitale Akademie Pflege 4.0 (DAPF 4.0): Digitale Kompetenzen für die generalistische Pflege(aus)bildung"[15] ("Digital Nursing Academy 4.0 (DAPF 4.0): Digital skills for the generalist nursing education"), the

13 This study is related to the joint project "Digitale Akademie Pflege 4.0 (DAPF 4.0): Digitale Kompetenzen für die generalistische Pflege(aus)bildung" ("Digital Nursing Academy 4.0 (DAPF 4.0): Digital skills for the generalist nursing education"). See footnote 15.

14 The research of Dr. Tanja Kubes is funded by the TU Berlin's postdoctoral sponsorship program (02–07/2020) and by the city of Berlin's joint program DiGiTal – Digitization: Design and Transformation (08–12/2021).

15 The joint project DAPF 4.0 is funded by the Federal Ministry of Education and Research (Bundesministrerium für Bildung und Forschung, BMBF) in the funding line "Digital media in vocational training in the health care professions (DigiMed)" (05/2020–04/2023) (FKZ: 01PG20004). Partners of the joint project "Digitale Akademie Pflege 4.0 (DAPF 4.0): Digitale Kompetenzen für die generalistische Pflege(aus)bildung" ("Digital Nursing Academy 4.0 (DAPF 4.0): Digital skills for the generalist nursing education") are the FrauenComputerZentrumBerlin e. V. (FCZB e. V.) (coordinator), Berlin School of Economics and Law (HWR Berlin, Prof. Dr. Heike Wiesner) and nursing schools in the Berlin-Potsdam metropolitan region.

Chair of Feminist STS at TU Berlin will be responsible for the subproject "Participatory evaluation." The project "Digital Nursing Academy 4.0" will be developed together with nursing schools in the Berlin-Potsdam metropolitan region.

2.2.4 Transdisciplinary Research on Gender in Science, Technology, and Society

In order to develop solutions for global challenges, science and technology should be organized in a more transdisciplinary way. Also, a greater diversity of scientific and technological professional cultures ought to be achieved. In the debates on how to ensure social cohesion, scientific and technological developments are perceived as co-responsible for key societal problems. Simultaneously, their contributions to the analyses and solutions of these problems is demanded. By fostering transdisciplinarity and diversity, societal challenges can be linked more closely to problems that are being driven by science and technology. These are the central objectives of the joint project "Social Cohesion as a Challenge for the Formation of Science and Technology" of an interdisciplinary group of researchers from the natural sciences, computer sciences, and science and technology studies with a focus on gender and diversity research that is guiding future research projects. The aims of this project are intertwined. Participatory formats are sought that contribute to a more diverse community of learners and practioners in science and technology. Transdiciplinary reflection forums are established within research institutions that foster inclusion of gender and diversity dimensions into scientific knowledges and developments of technologies that refect a plural society. The Chair in "Feminist Studies in Science, Technology and Society" is part of this group and will focus on technological developments in the area of digitization.[16]

4. Conclusion

In the first part of this paper, I outlined a programmatic matrix that links three areas of research and teaching: (1) taxonomies of research on gender in science, technology, and society, (2) research paradigms in gender studies, and (3) transdisciplinarity. Until today, gender studies in academia has been established in correspondence with feminist movements beginning in the second half of the 20th century. Referring to reviews in the area of research on gender in science, technology, and society, I presented a taxonomy

16 This project is funded by the Berlin University Alliance (BUA) as part of the initiative "Social Cohesion" (11/2019–12/2020), funding reference no. GC_SC_PC_33. The Berlin University Alliance (BUA) is funded as a group in the Universities of Excellence funding line of the German government's Excellence Strategy, see: https://www.berlin-university-alliance.de/en/excellence-strategy/index.html. Further information on this project may be found here: https://www.stsgender-zifg.tu-berlin.de/menue/forschung/gesellschaftlicher_zusammenhalt_als_herausforderung_der_wissenschafts_und_technologiegestaltung/parameter/en/

of the field that divides research into three areas: (a) research on professional cultures in science and technology, (b) research on epistemologies and knowledges of gender in science and technology, and (c) research on technological artifacts and technological developments in science and technology. Over time, these areas of research on gender have been approached from a range of perspectives and paradigms from gender studies. These paradigms are associated with a shifting terminology over recent decades. In my paper, I could only briefly touch upon women's studies, gender research, gender studies, queer studies, disability studies, intersectionality, new materialism, ecofeminism, and postcolonial studies. The category "gender," for that matter, is not a pre-existing entity. Rather gender is a temporary fabrication – a result of historical, social, and political processes. In this paper, I refer to two meanings of transdisciplinarity. The first views transdisciplinary research as transgressing differences between the so-called "two cultures" within academia. The second views transdisciplinary research as transgressing academia and the Grand Challenges. This second understanding of transdisciplinary research is linked to the aim of solving problems that cannot be solved by academia alone. In light of these two meanings of transdisciplinarity, I looked at the place of gender studies in relation to academia and to the Grand Challenges. Despite development of a broad range of paradigms over the last five decades, gender studies are still mostly located outside of the disciplines in science and technology, namely the STEM fields. Also, gender studies may still be viewed as peninsulas in the culture of social sciences and humanities. In addition, gender studies perspectives are mostly missing when solutions for today's Grand Challenges are sought. In the second part of this paper, I offered examples of research-based teaching on gender and research projects on gender in science, technology, and society that have been carried out or that are currently being undertaken at my professorship in "Gender in STEM and Planning / Feminist Studies in Science, Technology and Society (Feminist STS)" at the Technische Universität Berlin.

To what end must we include competencies in research on gender in curricula as well as in research and development of STEM and in planning disciplines? Integrating research on gender into research and development in STEM fields and planning sheds light on fabrications of gender in STEM and how these fabrications partly shape everyday knowledge and life in society. It is necessary to integrate such knowledge into the curricula of STEM and planning disciplines to enable future generations of scienctists and engineers to consider and evaluate suggested transdisciplinary solutions to Grand Challenges in light of research on gender. Only then can we aspire a sustainable future that will also become a gender-just future.

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Barriers to Space

"One Giant Leap" for Canadian Early-Career STEM Women

Stefanie Ruel

1. Introduction

Picture the following: you do an internet search on Canadian women scientists or engineers, at the start of their careers, who are working in space. The top two results are links to a webpage on a Canadian astronaut, Dr. Roberta Bondar, or on one or two early-career science, technology, engineering and mathematics (STEM)-trained women who work in the United States (U.S.) National Aeronautics and Space Administration (NASA). Canadian women, who are recent STEM graduates and who are interested in working in space or those who are at the start of their space career, are not often heard from or seen even in this digital age. This is in spite of the fact that the space industry is important to the Canadian economy, generating $ 5.5B in yearly revenues in 2016 alone (Canadian Space Agency [CSA], 2016). This hidden existence for early-career STEM-trained women is a multilayered one, and is not attributable to any single event or practice. This type of existence in the shadows is indicative of possible barriers to space that early-career STEM-trained women may experience.

Focusing on the U.S. space industry for just a moment longer, the histories surrounding the race to the Moon are more often than not on the military-trained White men and their exploits in space (McComb, 2012; McQuaid, 2007). These men are accorded an almost exclusive hyper-masculine voice with respect to their contributions to Cold War space exploration. Think of Wolfe's (1979) *Right Stuff* as an example of this hyper-masculine voice. This exclusive voice is in the process of being disrupted with popular media books such as Shetterly's (2016) tale of African American STEM women as *Hidden Figures* or Weitekamp's (2004) *Right Stuff, Wrong Sex: America's First Women in Space Program*. Women who worked on the Apollo program are also coming forward. Notably, Rhoda Shaller Hornstein, an aerospace technologist during the Apollo era, addressed the 70th International Astronomical Congress in October 2019. She talked of her early-career at NASA's Goddard Space Flight Center, outlining the systemic discrimination she endured, not only at the beginning of her career but throughout her tenure in the industry (Hornstein, 2019). There are also academic studies that are starting to break down these U.S.-based historical space barriers. These works include Ruel et al.'s (2018) retelling of the story of Ruth Bates Harris, the first African American woman hired as a senior manager at NASA in the early 1970s, and Ruel et al.'s (2019) study of White women at the Guided Missile Range Division during the mid-1960s.

Turning back to Canada, STEM-trained women and their role in space exploration are not the subject of much scrutiny in Cold War histories except for a handful of studies (Gosztonyi Ainley, 1990; Herzberg, 2010; Korinek, 2004; Ruel et al., 2020). Canadian women and their contributions are shrouded in obscurity, unknown to both insiders and outsiders of the national and global space industry. For example, the activities surrounding the Alouette I satellite, that marked Canada as the third space-faring nation (Godefroy, 2011), are typically accorded to one hundred STEM men. A single photograph of a woman appears in the media reports of the time; a 'space princess' attempting to climb atop an Alouette mockup (see Figure 1). Otherwise, women in Canadian space histories do not seem to exist.

Figure 1: Alouette Space Princess (Brebner, 2014, used with permission)

The cisgender[1] Canadian space industry histories, that divide visible men from the invisible women, are but one of the barriers women face in this industry. Other barriers include limited to no entry-level STEM positions in this industry (CSA, 2013). Women,

1 Butler's (1990) and Boje's (1991) understanding of gender roles as a socially constructed performance, that adhere to masculine and feminine-ideals, informs the use of this term. I use cisgender and gender interchangeably in this chapter.

a designated Canadian employment equity group (Department of Justice, 2014), also find it difficult to attain management positions in for-profit companies, universities, and in federal government departments that work in the space industry (Ruel, 2019). The few women who do hold STEM management positions appear to be token (Kanter, 1977). Worse still, the lack of visibility into the contributions made by STEM-trained women who self-identify as members of other Canadian employment equity groups, that is Aboriginal / First Nations, visible minorities, or as persons with disabilities (Department of Justice, 2014), speaks volumes to this hidden existence.

All is not lost, however. By shedding light on these barriers, we can actively undo them, taking that proverbial "giant leap". In this chapter, I introduce the context of the historical and the contemporary Canadian space industry. I also present a framework of discourses and identity intersectionality (Collins & Bilge, 2016; Crenshaw, 1989, 1991) and the methodology I used in this empirical research that will help us dive into the narratives and stories of two early-career STEM-trained women, Geirit and Eliya[2]. I close with a message of hope, inviting you to join others in recognizing and then undoing these barriers to space for early-career STEM-trained women.

2. Canadian Space Industry Context

2.1 Historical Canadian Space Industry

Engineering and science have roots in masculine-dominated military institutions (Hacker, 1989; Royal Military College, n.d.). Along with the goal of instilling rigid military discipline, creating the best engineers, mathematicians, and officers were also central concerns of such institutions (Hacker, 1989). For example, the Military College of Canada, founded in 1874, was and continues to be focused on training officers in military tactics and fortification, as well as on engineering and objective scientific knowledge acquisition (Hacker, 1989; Royal Military College, n.d.). It is noteworthy that this Canadian military college system specifically excluded women from entering its halls until 1979. Hacker (1989) argues that the military provides the first instance of a structured, masculine-ideal hierarchy for those learning within the engineering and science professions. She similarly argues that military engineering serves to maintain occupational stratification along cisgender lines.

There are important influences from the military in Canada's efforts to explore space (Gainor, 2006; Godefroy, 2011). Notably, the Defense Research Board (DRB) and the Defense Research Telecommunications Establishment (DRTE), home to the Alouette satellite program, were organizations focused on establishing reliable communication over long distances by studying the ionosphere. These types of scientific and engineering

2 These are pseudonyms to protect these individuals' identities.

efforts came to prominence during World War II, and thereafter during the Cold War. In particular, Dr. John H. Chapman, a former radar officer in the war and a physicist trained at Western and McGill Universities, along with two colleagues at the DRTE led important discussions with their counterparts at NASA regarding studying the ionosphere from space (Green, 1957). To Dr. Chapman's credit, he did try to hire qualified women scientists to join his team, succeeding in convincing others to bring women onboard as student trainees (Chapman, 1958), such as Doris Jelly (Gainor, 2006), or as full-fledged staff members, as is the case with Dr. Luise Herzberg (Herzberg, 2010).

In spite of these efforts, the one-hundred men involved in Alouette I are the ones celebrated today, to the detriment of the more than one-hundred and twenty women (Ruel et al., 2020) who also worked on this initiative. Such names as Frank T. Davies, Dr. Chapman, Colin Franklin, David Florida, Philip Lapp, Leroy Nelms, Keith Brown, John Mar, and George J. Klein, to name just a few of these one-hundred men, are rightfully recognized for their important contributions to Canada's foray into space. However, names like Dr. Herzberg and Ms. Jelly are not celebrated or known. Dr. Herzberg was able to produce an impressive body of knowledge for the DRTE. She was one of the last Jewish women accorded a PhD degree in Germany before the start of World War II, and following her and her husband's escape from the Nazis, she managed to cobble together Canadian summer student positions into the late 1950s while also raising her two children and looking after her parents and her in-laws effectively on her own. Her work, in solar spectroscopy and limb-center displacement of infrared solar lines, and then her focus on low-earth orbit and Alouette data analysis (Herzberg, 2010), seems to be lost in these masculine-centered Canadian space histories. Similarly, first hired as a summer student working on data analysis at the DRTE in 1953, Ms. Jelly later became a full-time physicist at DRTE in the Radio Physics Laboratory (RPL). The RPL was concerned with "basic studies of the upper atmosphere, and particularly with the disturbances that result therein under the influence of charged particles from the sun"[3]. Ms. Jelly, at the time a member of the Canadian Association of Physicists and the American Geophysical Union (N.A., 1969), is still active at the time of writing, ensuring that Alouette and other important scientific work accomplished by the DRTE are not forgotten. Ms. Jelly does acknowledge, during interviews with her, that she was surrounded almost exclusively by military men within DRTE; she does, however, recall working with Dr. Herzberg. Ms. Jelly also recalls, which we later confirmed via archival research, that she oversaw a number of women in technical positions including scalers in the Upper Atmospheric Physics Section. These women would "scale", or retrieve information from the Alouette

3 To facilitate archival references I am putting this one in a footnote. This quote is attributable to Library and Archives Canada, Box MG 31 J43 Vol 3, file 1960–1965 DRTE Scientific and Administrative Organization guides, DRTE Scientific and Administrative Organization, DRTE Publication No. 1037, January 1960, p. 3.

ionograms, and then they would investigate large numbers of these ionograms, looking for particular features (Ruel et al., 2020).

2.2 Contemporary Canadian Space Industry Context

The Canadian space sector took formal shape following the 1990 proclamation of the *Canadian Space Agency Act* (CSA, 2015b). The CSA, the brainchild of Dr. Chapman, is responsible to the Canadian parliament with respect to spending, ensuring that space initiatives are funded and that all activities comply with various legislations in place. The CSA is at the center of what is considered non-military efforts in coordinating, financing, and promoting the Canadian space sectors (Godefroy, 2017). While it is beyond the scope of this chapter to present all of the CSA's responsibilities, the organization does provide access to key space resources, such as the International Space Station and other microgravity vehicles, via extensive formal rules and international partnerships. In addition, there are over one hundred and fifty for-profit companies, universities, and government departments in the Canadian space industry, with "the top 30 space organizations generating 97% of total space revenues and 79% of space employment" (CSA, 2016, p. 6). Many if not most Canadian space initiatives continue to be conducted by privately-run organizations, such as MacDonald Dettwiler and Associates (MDA), and universities such as McGill University and York University.

Individuals who work in this industry handle important science, technology, and engineering challenges that untrained STEM individuals would find challenging to address. Specifically, the global workforce of space professionals is recognized in the literature as being resilient, and able to weather a number of cancelled programs that exceeds completed programs (Allan, 2004; Lang et al., 1999). These STEM-trained individuals are also able to master communication skills beyond the technical (Lang et al., 1999). They also have a capacity for working through tremendous amounts of paperwork (Allan, 2004). Significant challenges to working interdependently also characterize this industry, notably for individuals in the Japanese Space Agency or the Russian Space Agency as compared to those who work with the European Space Agency, NASA, or CSA (Sandal & Manzey, 2009). In their study of active duty and retired astronauts, and of international space agency personnel, Lozano and Wond (2000) identified fourteen cultural factors that affect work in this industry. Traits, such as humor, were highlighted as necessary given the long hours of intense work. However, culture may dictate what is considered funny for one and not for another. Lozano and Wond (2000) also noted that cisgender can affect role interdependence in space; cisgender roles, norms, and stereotypes can create tension and conflict among crew members.

The outcome of contemporary occupational stratification along cisgender lines is an ongoing issue and continues to be the subject of a number of studies (e.g. Cardador, 2017; Cardador & Hill, 2018; Hewlett et al., 2008). Specifically, Canadian STEM-trained women represent fewer than 20% of managers across the Canadian space industry (CSA, 2012; Catalyst, 2013). One of the largest private space organizations, MDA, has a history of contributing important work in the Canadian space industry dating back to 1969. In 2012, they had no women in senior officer positions out of a possible eight positions (Catalyst, 2013). At the time of writing this chapter, MDA had undergone a number of mergers and acquisitions including finding itself under the U.S. banner of Maxar Technologies Inc. (Byers, 2017). Under Maxar, MDA had two women on its board of directors: Roxanne Decyk; and, Joanne Isham (Maxar Technologies Inc., 2019). Another private company, Calian's SED Systems, a small space organization established in 1965 (Calian Ltd., 2019), has an executive made up entirely of eight White men (Calian SED Executive Team, 2019). As for the CSA, in 2015, 22 % of the scientific and professional workforce positions were held by women (CSA, 2015a). From my personal experience in this organization until late 2016, only one executive position was held by a White / French Canadian / mother with a PhD in engineering. This translates to an 8.33 % representation rate for women in scientific executive positions at the CSA.

With this historical and contemporary Canadian space industry context in mind, I now turn to the framework of discourses and identity intersectionality. Such a theoretical framework is important to consider at this time, as this structure helps to support the empirical findings that I will present later in this chapter.

3. Framework of Discourses and Identity Intersectionality

Empirically speaking, there are few discourses by and of STEM-trained women in the technology industry or space industry that are published. If there are any, these discourses are tales centered on what to do and how to act like the masculine-protagonists in question; think of Sandberg (2013), who extols 1960s liberal feminist norms in the technology industry. I believe that we need to hear about day-to-day practices with the rose-colored glasses removed. Painful, mundane, and triumphant discourses need to be shared in such a way to influence and to transform the social interactions in organizations. Ultimately, I don't want to be part of a silent majority that helps to maintain barriers to women entering and being part of the space industry.

The concept of discourse, as I use it in this chapter, reflects "everyday attitudes and behavior, along with our perceptions of what we believe to be reality" (Grant et al., 1998, p. 2). Discourses can be constructed as sets of statements and practices that bring an individual, or sets of individuals, into being within a larger context of meanings (Parker, 1992). This idea of melding in larger meanings through discourse offers us a way of restructuring the social, where we can make sense of everyday events by telling and retelling these broader meanings within stories and narratives, two tangible examples of discourses. Stories engage, excite, frustrate, and can make one mad. The emotions conveyed in shared stories draw you in, making you part of that story. Stories can also reveal values, rules, and boundaries (Saleebey, 1994), without the individual necessarily recognizing these stories in such a way. Narratives, on the other hand, inform the present and guide the future. They are widespread, attentive to form and style, and often relate to prototypical matters (Saleebey, 1994). In essence, "they instruct, chasten, and lend rhetorical weight to norms and conventions" (Saleebey, 1994, p. 354). Examples of narratives include interpretations, arguments, and opinions which lack plot, characters, and action (Gabriel, 1998). Stories, to be clear, are not the same as narratives. Stories are more loosely organized and more idiosyncratic than narratives. Furthermore, stories typically focus on a single event with the goal of entertaining, inspiring, and educating (Gabriel, 1998).

Stories and narratives do draw on who we are and who we want to be, or our identities. This centrality of identity, as Thurlow (2007) found, can be teased out of stories and narratives, and the making of sense of these discourses, to reveal an individual. This centrality of identity is, however, not fixed or stable in these discourses as we continually make sense of events and experiences, and of who we are (Helms Mills et al., 2010). Our identities ebb and flow throughout our discourses, in other words. As a result, discourses are plausible in the moment they are told, and our interpretations are also plausible in the moment that we interpret them. This plausibility does not imply, though, that identities will not or cannot change in the future.

This concept of identity and its centrality comes to us from many different schools of thought. It is beyond the scope of this chapter to consider all of these; a high-level introduction to 'who I am' is required in order to understand what the stories and narratives of Geirit and Eliya are going to tell us. The self – 'who I am' and 'who I am becoming' according to Mead (1932, 1934) – is constructed around a sense of identity that each of us possesses as a result of social activities and events. This self comes to light through our capacity to use language, to assign meaning to the narratives and stories, and to reconstruct an image of ourselves in social interactions (Anderson, 2016). The self is (re)created in our ongoing "adjustment and adaptation" (Anderson, 2016, p. 179) through discourses experienced in those social interactions. Discontinuities in the social allow the self to (re)create fragmented stories of 'who I am' and of the positioning that can occur in social interactions.

The concept of identity, within such a framework of the self, can be constructed along self-identity and social-identity lines. Self-identity is the "notion of who he/she is becoming" (Corlett & Mavin, 2014, p. 262). This concept also permits us to explore self-perception as a question of 'who I am'. For example, my perception of 'who I am' includes being a French-Canadian and depends on the social world I find myself in. For example, June 24th is the *Saint-Jean Baptiste* holiday in Quebec, a nationalist cry for the *Québécois* (masculine)[4] to embrace their cultural, independent status. In this milieu, I would not state that I am French-Canadian but rather *Québécoise* (feminine) to avoid

4 Typically, the masculine is a discursive norm used in French to embrace everyone in society.

possible political – or bodily – harm. While my discourse is different, I still reflect my cultural heritage as being part of me, of who I consider myself to be. This example surrounding my self-identity is also an example of a resistance discourse; I actively choose to politically name this self-identity, depending on the context I find myself in, to fit a social world with its own cultural norms and rules that I navigate on a daily basis.

Social-identity consists of 'inputs' into this self-identity (Watson, 2008). These inputs are socially constructed; that is, they involve an experience, a history, or a position in society that is external to and coercive to the individual (Anderson, 2016). Attachments, such as emotional involvements, can also be considered inputs (Ashmore et al., 2004). Social-identities can be manifested in and influenced by discourses. For example, when I worked in the Canadian space industry, my occupational social-identity was Life Sciences Mission Manager. This social-identity reflects a position in society; that I was employed, that I was STEM-trained and knowledgeable in the field of life sciences, and that I was socially categorized within the Canadian space industry. The difference between self-identity and social-identity in these two examples is that my self-perception is one of being French-Canadian, but my social-identity of Life Sciences Mission Manager was assigned or attributed by an organizational structure that said this was 'who I am becoming'.

The ephemeral and changing states of identities are both fascinating and a bit daunting to analyze, especially when we meld in identity intersectionality into this framework. Intersectionality, coined by Kimberley Crenshaw (1989, 1991), is concerned with addressing identity categories (cisgender, race, class, etc.[5]) that are interdependent and that constitute each other. These intersecting identities change through time, context, and social interactions (Calás et al., 2013). Empirical research conducted by Crenshaw (1989) and Collins (2000), along with many others (e.g. Calás et al., 2013; Van Laer & Janssens, 2014), demonstrate that complex identity intersections can position individuals in society, creating an order often manifested as discrimination. This order, reproduced in discourses, can position the complex individual along their intersecting identities, erecting a variety of barriers. For example, someone may identify a Black woman who is dependent financially on her partner. She is, in other words, not 'just' a Black woman, or 'just' a woman, or 'just' a financially dependent woman; she is an amalgam of all these identities. An anchor point, a financially-dependent Black woman, is a temporary and fluid construction of this individual's self (Ruel, 2018). This anchor point highlights not only the intersection of race, cisgender, and her socio-economic status but also that an order exists; that is, this financially-dependent Black woman is positioned below her partner, perhaps an employed Black man. Empirically, such an

5 Fourteen possible identity categories were identified by Lutz (2002): race or skin color, (cis)gender, sexuality, ethnicity, class, culture, religion, age, able-bodiness, migration or sedentariness, national belonging, geographical location, property ownership and status in terms of tradition and development. I choose to identify three categories with an 'etc.' at the end for writing economy purposes only.

individual has been shown to be treated differently than a White woman or a Black man within a legislative context (Crenshaw, 1991) or within other social realities (e.g. Bowleg, 2008; Ruel et al., 2018).

Anchor points are a sub-branch of social-identity. They are temporary, fluid, intersecting, influenced by and through social interactions, and are attributed through discourses (Glenn, 2004; Ruel, 2018). The exercise of identifying anchor points is not to generate an exhaustive list; instead, it is to plausibly understand these positionings and to begin to undo unjust social orders that support these positionings. With these concepts in mind, I now turn to the research design I used to capture, extract and analyze Geirit and Eliya's discourses.

4. Research Design

The overall participant sample recruited for the study on STEM-professional women in the Canadian space industry was diverse.[6] I drew from a range of STEM-education levels (i.e., bachelors, masters, PhD), professional and occupational roles (i.e., executives, managers, engineers, scientists), Canadian-specific career stages (i.e., early-career [under 5 years], mid-career [over 5 years but under 15 years], late-career [over 15 years]), and types of Canadian space organizations (i.e., public and private). I organized the participant sample by career stage, as I found this scheme helped me to trace the individual and her experiences. Interestingly, this categorization led to themes emerging from all collected data, and resulted in this chapter on early-career STEM-trained women. Table 1 summarizes some of the demographic information for these early-career women.

Career Stage	Name	Cisgender / Ethnicity / Cultural / Sexual Preference	Profession / Education	Marital Status / Family Status
Early	Geirit	Woman / White / Anglophone (Canadian) / Sexual orientation not defined	Tech Lead / Senior Engineer / PhD	Single
Early	Eliya	Woman / White / French (European*) / Heterosexual	Employee* / Junior Engineer / master	Single

* To protect the participant, some of her specific cultural, professional and academic identities are not shared.

Table 1: Early-Career STEM-Trained Women and Their Intersecting Identities

6 The complete research initiative on STEM-professional women's exclusion in the Canadian space industry can be found in Ruel (2019). This chapter is based on two participants from this larger study; they and their stories are presented in a more in-depth fashion in this chapter and are framed for a particular audience.

Data collected included the participant's narratives and stories and a variety of documents, including participant e-mails and publicly available corporate reports. I chose to specifically use unstructured interviews with the participants following quantitative and qualitative empirical studies that show that identities are best left to the individual to identify through their own voice (Ashmore et al., 2004). The option to conduct the interviews in French or in English was offered as this reflects the bilingual reality of the Canadian space industry. This option to be interviewed in French or in English also takes into account Pavlenko's (2001) call for the inclusion of bilingualism in research.

The interviews were tape-recorded and maintained in three separate physical locations, each with separate password protection. A copy of the recorded interviews was provided to two professional transcribers. Interviews were either transcribed directly by one professional transcriber when participants chose to speak in English, or the interviews were translated and transcribed from French to English by the other professional transcriber. This French-English live translation/transcription was a viable financial option, given the experience of this professional transcriber and my own bilingual experience in this industry. The resulting transcriptions and other collected documents were similarly kept in three different physical locations and were password protected.

I focus, in this chapter, on the narratives and stories that Geirit and Eliya used to construct both their occupation and their self. To be able to find and then share these narratives and stories, I analyzed the transcripts and extracted those narratives and stories that would interest an audience of undergraduate and masters-level students. I also analyzed the transcripts in such a way to (re)construct Geirit and Eliya's complex selves. Specifically, I looked for discourses that revolved around self- and social-identities as well as their anchor points, asking myself repeatedly what a reader would want to know about these women and about their experiences in such a way to better understand the daily barriers these women faced. I also surfaced dominant practices, values, and rules that this audience would want to know about. I did this as a way to shine a light on various hidden elements of this industry. I turn now to these findings.

5. Early-Career STEM-Professional Women in the Canadian Space Industry

5.1 Geirit

Geirit's stories and narratives reveal some aspects of 'who I am' along with 'who I am becoming'. She emphatically self-identified as someone who never wants children, also labeling herself as "long term single": "I never had any interest in having kids, so that's not an issue either. I think if you don't want – if you actively don't want – kids, it sort of changes the importance of all that." She did not identify her sexual orientation, choosing to leave this unspecified during our conversation. She also self-identified as someone who is very hard working. She underlined that she "needs change," comparing a number of times where she used to live – a beautiful European city – to where she lives now, a place that is anything but beautiful:

> I don't know if you've been to [specific city]? It's kind of a hole. [...] I was coming from [a specific European city] and just small towns in North America. Great if you want to live, you know, raise a family or something [in the specific city that is a hole]. Just not what I was looking for. So, I got to the point where I was like, "I am really not happy here. I need to change," and I was starting to think about looking for a new job.

Her social-identities are influenced by ideologies relating to her academic credentials, occupations, and social attachments. Geirit is internationally educated, with an undergraduate and a master of science degree. She also holds a PhD degree for which she developed a prototype flight hardware. She is recognized internationally as an engineer but not within the provincial Order of Engineers where she works. This subtlety is important given previous research done by Porter (2013) on the Order of Engineers, a professional association that certifies engineers to work in various engineering fields. Specifically, Porter (2013) found empirical evidence of sexual harassment and sexual discrimination in this Order. In Geirit's case, she did share her experiences with me regarding her provincial Order. Notably, that a colleague, who is a man with a similar undergraduate background as hers, was asked to write only the ethics exam for the Order. She, on the other hand, was asked to write seven technical exams at the cost of $ 500 each. This experience highlights one example of what appears to be a gendered educational barrier to joining the Order of Engineers in this particular province, and how this could impact Geirit's social-identity (i.e., not recognized as a 'professional' engineer) and her career progression potential in this province.

With respect to Geirit's occupational influences, she works within a private Canadian space organization, the Hexagon Company. She states that:

> My first job [for Hexagon] was to interface between the engineering teams and the customer. They were looking for somebody with an education in physics and experience in their aerospace field. [...] I do anything from initial concept studies, proposal work quite a bit. So like a lot of early-phase program work where its orbital mechanics or its requirements definitions. I've been tech lead on a number of programs, and then the other half of what I've done is a lot of systems testing. [...] And now I work at operations, so I have a lot of experience in the beginning and the end, from a systems perspective.

Geirit finds that technical work, by those in a technical position, at this Hexagon company is done mostly by men, while women represent the "standard 20%" in technical positions: "There is one functional manager for software who is a female. The other managers are all male. It's your pretty standard 20% of the personnel is female." Geirit also gained some STEM work experience beyond Canada's borders:

> Well, for the first six or eight months [after my PhD] I was looking for a job and then waiting for a Visa. I did my PhD in [specific European country], decided to go back to [Europe],

> worked [for another company]. I was a subcontractor too [at another company] for about a year and a half.

Even during her short tenure in the Canadian space industry, Geirit experienced many organizational changes. Some of her stories highlight challenges that some early-career STEM-trained individuals can face with respect to attachments, and the need to develop resilience in the face of such relentless changes:

> Well, over the past years, there's been a couple restructurings within [Hexagon] before [this latest change]. And since [this latest change], there's been, you know, upper management of course moved on. There was a few layoffs. [...] [That group that I was a part of] was only like a year and a half old when I joined. Since then, it sort of dissolved back into the bigger part of [the company] [...] And now that [this latest change has happened], everything's sort of getting shifted around; it's still in flux.
> I'm now on my third manager since I got hired [...] There was a bit of a restructuring. His group was me and another girl. She – I think she got laid off in one of the rounds of layoffs – and just as a whole our group got smaller [...] That put me under a different manager. He resigned, and that group has sort of re-formed a couple of times, but basically that group reports to the person that was his manager [...] [This latest change happened], so who knows what's going to happen with that.

As a plausible explanation for surviving such extensive changes, the idea of merit seems to be at play for Geirit. This merit ideology appears to be embraced by women in this industry as Faulkner (2000) and Morgan (2000) found. Technical know-how, in particular, is used extensively in Geirit's stories and narratives. Geirit does talk to working in diverse projects, with minimal supervision and with growing responsibilities. She is recognized as a "technical lead," building on these experiences and on her skills to gain this elusive merit.

A subset of her social-identities, or her anchor points, reveals her positioning in this industry, along with some of the daily barriers she faces. Starting with 'The Bitch' anchor point, Geirit recounted the circumstances surrounding this positioning:

> I'm probably known as a bit of a bitch; I've lost my patience with people that just can't do their job. So not the manager that hired me but the manager after him, we worked together on [specific project] [...] and he didn't really see eye-to-eye with the rest of the team, and I was the most outspoken member of that team [...] He and I butted heads quite a bit [...] We were always arguing: "Why are you worried about that?" "That's not a problem" or "Why aren't we doing it this way?"

She found herself, at times, having to underline that she is 'The Leader' – another one of her anchor points – while wondering why she was forced to do this. 'The Leader' anchor point reflects different organizational behaviors, such as influence, vision, and motivation (Bratton & Chiaramonte, 2007) more so than, say, the gendering anchor point of 'The Bitch'. In spite of the risks associated with working in an unstable environment, Geirit continued to resist day-to-day interactions that attempted to, in her words, "put her in her place" as 'The Bitch':

> There's another guy in that program [. . .] He had like 40 years of experience in the space industry, so he knows a lot, has a lot of experience and he would sometimes talk like, "We're going to do this," and there were a couple of times where I had to be like, "You know, I appreciate your input but we haven't decided yet, and even that's not really your decision to make, but, you know, don't stop giving me an input, but that's not your [hesitates] you know, I'm leading the program."
>
> I do have annual performance reviews and sometimes these sorts of things [overstepping my bounds, being 'The Bitch'] come up.
>
> I was thinking of a specific instance where I had basically said to this guy, "Thank you, but that's not your role" in front of a room full of people! And then I went and asked my functional manager if that was overstepping my bounds because, you know, a) outside perspective, and, b) somebody with more experience than me – my senior.

These stories and narratives showcase some of Geirit's struggles in her day-to-day social interactions. In the first passage, she did not hesitate to forcefully stand her ground, embracing 'The Leader' anchor point in spite of interacting with a colleague well beyond her years of experience. In the second and third passages, she struggled with 'The Bitch' anchor point, wondering if she had overstepped her bounds. Historically, women who try to lead are indeed labelled 'The Bitch' (Mavin, 2008). While there is no evidence that Geirit is being 'The Bitch', she is clearly assertive, knowledgeable in her field, and has been assigned programmatic mission responsibilities. It is plausible that Geirit may be trying to conform to the masculine-dominant culture in order to survive in the everchanging environment she finds herself in. She is trying to "walk a very fine line between being 'like' the valued-masculine prototype" (Miller, 2004, p. 68) – assertive technical lead – while also navigating what she calls her "female-ness" via 'The Bitch' positioning.

Linked to this "female-ness" is the 'Females are More Serious' anchor point, which surfaced in numerous stories about her educational and work experiences. The following story showcases this anchor point:

> So, I'm there [in a European country] for a couple years, and everybody that started after me was female and I said flat out to one of the managers: "This is weird. Why [. . .] I mean, I know what the statistics are – the number of [females] in school – right?" And he told me that: "we prefer to hire females because we find that they're more serious about their work than the guys are."

She emphatically and forcefully stated during our interview together that her "female-ness" has nothing to do with her abilities and skills: "that's just ridiculous. If I had been in a different situation when I got hired, I might've considered quitting based on that! I don't want to be hired based on that." Another brief narrative, reproduced below, introduces another facet to this "female-ness": "they knew me; they had seen my work [. . .] so, that's positive toward females, but I don't want to see that." Here, Geirit admits that she doesn't want to see that her "female-ness" has anything to do with her work. Her ability to do her job, her knowledge, her training, etc., – in other words, her merit and skills – needs to carry her work and not her "female-ness". Furthermore, Geirit appears to have a cisgender understanding of merit and skills with respect to her expectation for "reasonable" career progression:

> **Geirit:** I can't picture myself being happy, doing the same thing for 20 years. So, whether it's up or sideways, I'm interested in going where it's interesting, where I can be useful, where I can be good at what I do [...] I feel like you can go toward management, but it's hard to go back toward technical if you haven't been doing something technical for 10 years [...] My management's always given me positive feedback. You know, that's a reasonable expectation [to become a manager] for me. Let's put it that way.
> **Interviewer:** Are they helping develop your management potential?
> **Geirit:** Specifically, management potential? I would say not yet. Leadership potential, I would give you that. [...] I'm fairly outspoken, so I think it falls naturally that I go into that role as a leader.

Her "technical lead" positioning helps her, she believes, to develop her eventual managerial abilities. She also interprets positive feedback in her appraisals as signs of a "reasonable expectation" that she will become a manager. Importantly, however, her management potential is not being developed by the organization, or, from what I could tell, by her. What is being developed is her ability to embrace 'The Leader' anchor point. Specifically, she is following what she believes to be a reasonable progression: developing technical skills / merit, embracing 'The Leader' identity, and then "naturally" or "organically" becoming the manager. These expectations for progress run counter to the demographic realities of this industry, where STEM-trained women rarely become managers in spite of their strong technical skills and merit.

5.2 Eliya

Eliya self-identifies as very hard working, wanting to be the best at whatever she does, to the point of compromising her health:

> I expect a lot of myself and from others too – which isn't bad – but I'm always disappointed by the work.
> I gave my all when I was a student and I don't want to study anymore. There was a year where it wasn't working out; yeah, I wasn't feeling it, and I wasn't very good. I had to be top five of 160. I ended up with three ulcers. That was horrible!

Similar to Geirit, Eliya stated that she does not want children: "No, I never really wanted any [children]. People always said, 'You'll see when you are 30,' and I'm [specific age] now. 'You'll see when you're 30; it'll hit you like a ton of bricks,' but, no, it hasn't changed yet." In her narratives and stories, Eliya appears to offer more of a back-and-forth inner dialogue than a definitive statement on 'who I am'. This is interesting from a sociological perspective, as it showcases that her self-identities are, indeed, fluid and subject to influences not only from internal dialogue but also from external interactions.

Eliya's social-identities seem to reflect understandings such as those discussed by Pavlenko's (2001), with calls to include language[7], academic credentials, occupations, and her gender. With respect to the influence of language, Eliya specifically requested that the interview be conducted in French. This is important, as it underscores a cultural ideology that helps define her social-identities. Significantly, she began her interview by sharing a defining moment for her:

> So, even before university, there was an experience that really had an impact on my life: I went to the United States at 16 to learn English. Before that I liked to travel, but for this trip I went alone, at 16 [...] After that, I told myself that I needed to pick a field that would allow me to travel in addition to following my passion for space, something I've been wanting to do since I was very little.

Eliya was able to follow her passion for space, graduating with a master's degree after passing through a "prestigious" European system of education:

> For my Lycée, I studied in [specific European country]. I was a good student. In [this specific European country], there's a stream you can take when you are good in math and physics – very elite. So I applied to that.
> I went to an engineering school. In [specific European country], there's a specific branch for engineering, with a specialization in space and aeronautics. [...] I worked hard. Only the best get to go, so I worked hard to be one of the best and have the opportunity to do this double diploma. So I did two and half years in [Europe] and two years in the U.S. Both diplomas were in aeronautics and space, and in the U.S. it was a master's of science, for which I did research during a year and half.

We also discussed her movement in different jobs through her international experiences:

> My last year of studies in the U.S., I found work in [Europe], as a consultant. I was a subcontractor for [specific space company], and there I validated the flight software for [specific] satellites. My contract was up after a year, and the company for whom I was working wanted to transfer me over to a different department that wasn't my thing [...] So I left. I looked at international postings because I was ready to leave, and I found something in Germany at [another specific space company], the company that does European [specific space missions]. So we [my boyfriend and I] applied to aerospace jobs in South Africa, Argentina and in Canada. I found my current job here in Canada, so we came to Canada. During that phase, between Germany and Canada, I worked for three months for the [specific] Space Agency.

7 I chose to focus on French as a cultural ideology. I could have also done the same for English interviews; however, those participants that spoke English did so without clearly identifying this influence while French-speaking participants made this an explicit request.

Eliya did find it challenging to find a position after her first contract:

> It's hard to find work. Apparently it's getting better, but in my experience, when I decided to leave again, it was because I couldn't find anything in [a European country]. I also wanted to leave, but I spent a month and a half looking full-time, sending CVs out six hours a day, and I got no answers. Not even a 'no'. No interview, nothing.

She now works within a private Canadian space organization, the Octagon Company, and has diverse responsibilities:

> I was working only for [specific manager] in [specific satellite] operations until January [2016]. Since January, I've changed to the development of [specific] operations. I got the offer in September. The posting was for [specific location], and I really wanted to move there, but the conditions that were offered were [hesitates] a bit tough.
> I was a project lead last year, managing the budget, the planning, the training for [specific country]. So, I was project lead on that, coordinating the trainers, building the course programming, and all that. I liked it a lot – the subject, the training. I love what I do.

Eliya shared that she is not "career-oriented" and that there is a lot of change in the particular organization she works for:

> I'd like to leave for a year and really take advantage of discovering new things. [...] I imagine becoming an expert and maybe do consulting one day in satellite design. I'd really like to work in South America one day. There's the aspect of work that is actually fascinating, but there's also the discovery of a new country and culture. I really love that.
> At the moment, there are lots of people leaving. Two just left, and there are apparently two others who want to leave.

With respect to her gender, Eliya also touched upon her heterosexual relationship with her boyfriend. Specifically, she had to make various choices with respect to her career where she deferred to her boyfriend's wishes:

> I looked at international postings because I was ready to leave, and I found something in Germany [...] That would have worked for me, but in the meantime, I met a boyfriend who didn't want to go to [there], so I said no to this offer.
> The posting was for [specific location] and I really wanted to move there, but the conditions that were offered were [hesitates]. Well, not in the state I was in. My boyfriend and I had separated.

This idea of deference is important to consider as an ideology that can influence women in the space industry. As Ruel et al. (2019) presented in their historical study of White women who worked in the U.S. space industry in the 1960s, women were expected to leave their careers to marry or to have children. I am talking to this influence on Eliya's social-identities not as an admonition but rather as an observation that these types of cisgender choices – those between romantic relationships and work – continue to be made by women in the space industry even today.

Among Eliya's range of anchor points, I am focusing on a select few of them in this chapter; notably, the 'Not Very Serious'/'You're so Funny' and the 'The Only Girl'. I found myself attributing the 'Not Very Serious'/'You're so Funny' anchor point to Eliya, during the interview, without realizing I was doing so. I was mirroring what others had done in her daily interactions and we discussed it further together:

> It's spontaneous; lots of other people said it [being refreshing/funny] could be harmful, but not so far. I think something I discovered here – one of my strengths – is that I don't stress over losing my job, and that allows me to [hesitates] I tell myself that it doesn't matter if it doesn't go well; there are [other] things I can try.

This particular anchor point was challenging to extract from transcripts, and then to analyze, because I could easily categorize it as a self-identity, so prevalent it was during the interview. Eliya played with this 'Not Very Serious'/'You're so Funny' identity, at times unsure of it. Given my own impulse to attribute and use 'You're so Funny' with her, and her uncertainty about attributing it to herself, it is plausible that this identity is not yet a self-identity.

This 'Not Very Serious'/'You're so Funny' anchor point also relates, importantly, to another aspect of women's experiences in this industry. Women are targets for men's teasing and, in light of this value, Eliya recognizes that she needs to be "adaptable" within this masculine-dominant context:

> There were so many times that, well the others were a bit rough around the edges. At lunch, I'd get corks thrown at me. One guy came to me and told me he was watching me all day – yeah, that was a bit [hesitates]. Some were very cultured, knew lots of things, but not educated in terms of good manners [...] It still left an impression on me.
> We sometimes had Italians who [...] who had come, and they had pulled that on [specific woman's name], checking her out from head to toe. She was furious. And me, I barely noticed. That's how it is for me now.

From the literature, Powell et al. (2009) found that within engineering professions, women perform by accepting these types of gendered jokes and teasing as a way to get by. Linked to accepting such practices is the ability to endure them. Eliya's ability to withstand the teasing is, arguably, found within her 'You're so Funny' anchor point. This anchor point disarms others in a way that is novel, with a focus on what she calls "fun ways" of undoing the positioning she faces on a daily basis.

Earlier in Geirit's experiences, we gained some insight into the unstable work context she found herself in. Eliya's shared experiences also underscore this instability. What differentiates Eliya from Geirit is Eliya's approach to this instability. While Geirit internalized the "need for change" into her self-identities, Eliya seemed to make sense of this instability through her anchor point of being 'Not Very Serious': "the worse that can happen is that I leave and find something else [...] It's no big deal if you fire me; I'll have some time off! [laughs!]"; "After [specific program], I'd like to leave for a year and really take advantage of discovering new things." These brief narratives, along with others, appear to be repeated calls to taking time off, planning for travel, etc. Through these shared discourses, I was able to gain a better understanding of how Eliya could be attributed the 'Not Very Serious' anchor point: if she consistently shared with others in the industry a wish to "discover new things" or a plan to take "some sabbatical leave to travel," colleagues would start to question her commitment to the industry, reflecting this in her 'Not Very Serious' anchor point. Alternatively, these repeated calls to leaving the industry could also be interpreted as a resistance discourse. To protect herself from the ever-present and tangible prospect of losing her job, Eliya chooses to embrace this anchor point by using a devil-may-care attitude with respect to her job.

The demographic reality of the Canadian space industry, as I presented earlier, supports the emergence of another one of Eliya's anchor point, 'The Only Girl': "in the U.S., there were classes where I was the only girl. Or we were two among 30."; "and, yeah, I was pretty much the only girl, and there were so many times that, well the others were a bit rough around the edges." Eliya also did acknowledge that most meetings or social encounters reinforced her sense of being 'The Only Girl'. Surprisingly, in light of this anchor point and the demographic reality of the industry, Eliya presents her supervisor, a STEM-trained man, as head of a "harem of girls". Eliya no doubt experienced the disparity of, on the one hand, being part of this "harem" and, on the other hand, being 'The Only Girl'. Similar to Geirit, Eliya also walks this gendered fine-line acknowledging that the first two years of working in the Canadian space industry were difficult:

> I was always a bit lost, I didn't understand anything in meetings, acronyms, and it was complicated with [company #1], with [company #2] and the [specific man who yelled at me]. And I couldn't ask [company #1] too many questions; there was no contractual agreement for them to be paid to answer my questions. So yeah, the guy [who yelled at me] was eventually removed. Sometimes I hear him in meetings. Not sure why he reappears [laugh].

Digging deeper into this "guy who yelled at me", Eliya's day-to-day interactions with certain individuals is challenging to say the least. The following two stories underscore her self- identified need to be "adaptable", if she wishes to continue to work in an industry that condones such behavior:

> [A specific company] gave us two people, one of whom everyone had warned me about – how it was hell working with him, how tons of people had quit because of him. He hates women, he has no emotional intelligence, he's always back-stabbing – I heard this from everyone.
> I was insulted over the phone by a guy from [a specific company]. Apparently, he has an issue with girls at work. With [specific girl], there had previously been a concern. So, in fact, I found a problem on the [specific project] [...] and as he had worked on it, I asked him about it. He replied that it wasn't his fault if I didn't know my stuff, and it definitely wasn't his job to train me, and so on. He had yelled so loudly that two offices down, behind closed doors, they had heard [...] Yeah, not only being young, but also being a girl, it wasn't always easy.

Eliya's ability to navigate these types of interactions with individuals who have "issues with girls" reveals much about some of the barriers she faces on a daily basis. She believes she was yelled at because (1) she is a "girl" and, (2) as a "girl", she was asking too many questions. That it is acceptable that this individual should react to Eliya in this way does not seem to be an issue – if she wasn't a "girl" asking such questions, then she would not be yelled at. Yet as someone looking from the outside, you can perhaps see that it should not be Eliya who has to make sense of a co-worker's microaggressions; rather, the coworker himself should be the one asking why he is yelling at her or why he has issues with "girls at work".

6. Concluding Thoughts: Undoing Barriers to Space

The barriers to working in the Canadian space industry emerge not only through accounts of the historical influences of women in the space industry but also from the exploration of contemporary experiences of early-career STEM-trained women. Some of these contemporary experiences can be seen through such dominant practices as gendered educational barriers, women representing the "standard 20%" in technical positions, the need to develop resilience – including embracing merit above everything else and dealing with being yelled at – in the face of relentless change, deferring to boyfriend's wishes with respect to career choices, and navigating a variety of temporary anchor points that can position women below others. From the stories and narratives of two early-career STEM-trained women, we also learned about their specific experiences having to navigate the gendered fine-line, the teasing and the microaggressions that victimize them.

There is evidence, via the analysis of their discourses, that these early-career STEM-trained women do not yet see some of these barriers and these anchor points. As a case in point, Eliya "barely notices" when she is being "checked out at work. That's how it is for me now". Geirit's gendering 'The Bitch' anchor point, too, does not incite her to resist such a label; rather, she tries to move towards an acceptance of this anchor point, with a need to run to others to ask if she has, indeed, "overstepped" boundaries. Perhaps most worrisome, Eliya makes sense of being yelled at because she is "young" and a "girl" who asks (too many) questions. She appears to accept these microaggressions as reflective of her state of being a "girl". The question of how these barriers for early-career STEM-trained women come to be does not result in a cause-and-effect type of answer. Specifically, I did not look to make a causal link between if I call a STEM-trained woman 'The Bitch', she is or becomes the 'Bitch'. The empirical findings I share in this chapter support the notion that barriers are being erected and practiced on a daily basis in this industry, and this through multilayered activities including attributing anchor points, found in stories and narratives occurring in the everyday social interactions.

Although the identities surfaced in this study are momentary snapshots of what is going on in this industry, these snapshots also bring hope that such positioning experiences can be undone. In other words, the barriers and anchor points do not have to be given life and reproduced repeatedly, if we take the time to recognize them. We can stop microaggressions, for example, by telling offenders that it's unacceptable to yell at an early-career STEM-trained woman or any woman for that matter. We can encourage organizations to work toward improved job stability in the industry, and to offer more tangible support for activities such as management skill development, career development skills, etc. To be clear, many early-career STEM-trained women working in the space industry are already highly trained, sometimes surpassing the training that men hold in this industry. The broader issue of resources to move into leadership positions needs to be examined, not just the issue of women-versus-men in management.

In closing, I challenge all in the space industry to construct identities, stories, and narratives that can disrupt the status quo and that do not position STEM-trained women below others, regardless of career stage. Let's be catalysts for change, part of a movement that acknowledges that barriers exist. Reveal these barriers, and take that "giant leap" to undo them.

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Gender Barriers to Scientific Rewards

Inequitable Practices in Research Evaluation

Gita Ghiasi

1. Introduction

Evaluations have historically rested on the judgement of experts in the field. Yet over recent decades, quantitative measures have increasingly taken root in scientific evaluations, and peer-review has become tightly entangled with – if not replaced by – a variegated set of quantitative indicators commonly associated with publications, patents, citations, and collaborations. This is largely due to the large-scale applicability, high degree of clarity and objectivity, and the increased efficiency in effort, cost, and time that these indicators could offer to the peer-review process (Haustein & Larivière, 2015). The decisions made based on scientific evaluations are hence more tangible and often more transparent.

While the ease and accessibility of such metrics are appealing to experts and non-experts for scientific evaluation or reward allocation, these indicators are not entirely neutral and contribute to the "Matthew effect" (Merton, 1968) – a term coined after the "Parable of the Talents" in the Gospel of Matthew, and alluding to the famous adage "the rich get richer and the poor get poorer." The Matthew effect draws attention to inequities in the scientific recognition system in two situations: (1) eminent scientists tend to receive disproportionately greater credit for their contributions to science, and (2) relatively unknown scientists receive disproportionately less to no credit for similar or comparable contributions. While lesser-known and disadvantaged scientists fall into the latter case, for women scientists, the Matthew effect leads to more than cumulative disadvantage; it results in systematic underestimation – or even denial – of women's contributions to science, work that is often attributed to their male peers. This effect, known as the "Matilda effect," was named by Rossiter (1993) after Matilda Joslyn Gage, an American women's rights activist who had already written about the effect in the 19th century.

Given that the inflated importance of these measures could lead to uneven or, often, unfair evaluations, these indicators must be applied with caution because they are prone to misinterpretation. Since gender inequality still prevails in science, with women highly underrepresented, the misuse of bibliometric indicators for science evaluation could have dire consequences for women and, thus, exacerbate existing inequalities. This chapter focuses on four main elements of scientific evaluation – authorship, inventorship, citations, and collaborations – for which a plethora of indicators have been introduced. It further presents an overview of each of these elements from a gender perspective and provides a better understanding of how the (mis)use of these indicators could affect the career progression of women in science.

2. Authorship

Publishing is undoubtedly one of the most – if not the most – significant and essential practices in science. This can be explained through three interrelated aspects (Rosenbaum, 2017): (1) Because published research results are officially qualified as scientific or scholarly, publication is the main channel through which new knowledge is communicated; (2) scientific reward systems are centered around publications, attributing credit and reputation to a researcher; (3) publications are an attestation of peer-approval and thus define the mechanisms through which the assessment of scientific performance is conducted.

Although publishing is essential to science, it is "authorship" – including all stages of design, conduct, analysis, and publication of a scientific paper – that defines the attribution of *credit* and *responsibility* in the publishing process. In this context, scientific capital is not often equally attributed to authors, and often relies on the authorship order in the byline. Authorship order is practiced differently across disciplines and classified under three categories:

(1) Single / sole authorship: Sole authorship was historically common in science, but is declining (Abt, 2007; Barlow et al., 2018; Kuld & O'Hagan, 2018). As a response to the complexity inherent to science and technology, multiple authorship has gained momentum over the years. Notwithstanding, sole authorship is still of great importance in several review and evaluation processes (including promotion, tenure, and funding allocation), mainly because it is highly associated with an author's ability to work independently (Gasparyan et al., 2013; Moore & Griffin, 2006). For some authors, however, sole authorship offers more than credit or reward; it offers a distinctive recognition for scientific work in the field hardly possible through multiple authorship (Moore & Griffin, 2006). Sole authorship, thus, is undoubtedly valued in the reward system of science and gives authors a distinctive level of recognition and credit.

(2) Alphabetical authorship: This type of authorship, in which authors are listed alphabetically in the byline of a publication, is less and less practiced. Nowadays, it is most commonly used in certain disciplines (e.g., mathematics, economics, and high-energy physics) or in publications with either a small or a large number of authors (Waltman, 2012). This type of authorship does not provide information on the contribution of authors to the scientific publication, and it is, therefore, not possible to determine to what extent credit should be apportioned to each author for their contribution. Ideally, alphabetical authorship should be equally valued in the

scientific reward system (when no other information on the contribution of authors is present); however, more credit and recognition is often inadvertently assigned to better-known researchers listed in the publication's byline.

(3) Contribution-based authorship: In this type of authorship, the position of authors in the byline is based on the contribution that each has made to the publication. Here, authorship analysis helps identify the lead authors, institutions, or even countries involved in the scientific work. When authorship order is contribution-based, there is general consensus in the scientific community that the most important positions are attributed to the first, the last, and the corresponding author (often the same person as the first or last author). The first author is often associated with highest contributions (Larivière et al., 2016), and thus deserves more credit than other authors. This position is generally attributed to early-stage researchers with lower professional rank. The last author in the byline is typically a higher-ranked researcher: the principal investigator or group leader of the published scientific work (Mattsson et al., 2011; West et al., 2013). The corresponding author is often either the first or the last author. In publications where the corresponding author is different from the first author, the correspondence is generally the responsibility of the senior author responsible for research conception and supervision (Mattsson et al., 2011), such as program director or principal investigator (Nahata, 2008). Authorship positions are sometimes more valued in the scientific reward system than the count of publications alone, and first, last, and corresponding authors are those recognized and rewarded the most.

Along these lines, the demographics of authors involved in scientific publishing could offer interesting insights into the representation of women in science. Similarly, gender differences in various types of authorships may indicate how the reward system of science is structured around these differences, which could ultimately manifest as gender-related bias in recruitment, retainment, and promotion in the research workforce.

Women are involved in fewer than 30% of total scientific authorships (Larivière et al., 2013; West et al., 2013). Not surprisingly, women's presence is least evident in the Middle East and Japan, but, most interestingly, it is most prominent in South American (Larivière et al., 2013) and East European counties, where scientific output is low and research-related or academic jobs are not well paid. Looking into disciplinary differences, women are least present in engineering, robotics, military sciences, aeronautics and astronautics, high-energy physics, mathematics, computer science, philosophy, and economics. On the other hand, they are most present in disciplines associated with care, such as nursing; midwifery; speech, language, and hearing; education; social work; and librarianship (Larivière et al., 2013).

Regarding various authorship practices, women are highly underrepresented as sole authors. For example, women accounted for only 17% of total sole-authored publications indexed in the JSTOR corpus up to early 2011 (West et al., 2013). In fields where alphabetical authorship is practiced (e.g., mathematics, economics, and high energy physics), women are also highly underrepresented (Larivière et al., 2013; West et al., 2013). Moreover, given that contributions of individuals are not discernable in this type of authorship ordering, women are less likely to receive credit for their contributions when they co-author with men, where credit is often attributed to their male peers. They are thus less likely to be rewarded for their contributions. This phenomenon has been scrutinized for women economists and the probability of them receiving tenure (Sarsons, 2017). However, when contribution-based authorships are practiced, women are still underrepresented in leading authorship positions. Although women are more represented as first authors than last or corresponding authors, there exists nearly two articles first-authored by men for every article first-authored by a woman (Larivière et al., 2013). When comparing with the total author population, men are more highly represented among authors as last or corresponding authors or those with a long publication history (Elsevier, 2020). This could be explained within the context of the "glass ceiling" (Hymowitz & Schellhardt, 1986) or "leaky pipeline" (Berryman, 1983), where both concepts shed light on gender-related barriers that prevent women from reaching high-level positions, causing them to leave science.

Given that the proportion of women awardees are closely entangled with the proportion of women among corresponding and last authors (Elsevier, 2020), the underrepresentation of women in senior authorship positions as last or corresponding authors carries strong implications for the reward system of science. Nevertheless, these disparities presented in authorships are unlikely to disappear unless reforms are enacted to explore and eliminate the barriers women face in science. It has been suggested that gender disparity in publishing is likely to persist for decades (Holman et al., 2018; Wang et al., 2019). This timeline is even longer for last and single authors. Closing the authorship gender gap could take generations in some disciplines, particularly in physics (258 years), computer science (280 years), mathematics (60 years), and surgery (52 years) (Holman et al., 2018). These predictions could represent systematic biases in authorship conducive to lower publication rates for women. It has also been shown that papers are less likely to be accepted when the last or the corresponding author is a woman. Acceptance rate dwindles even further when reviewed by all-male panels (Murray et al., 2019). This would greatly favor men in authorship, as women are highly unrepresented as journal editors and as journal reviewers.

The aforementioned gender disparities are indicative of gender inequality that still prevails in science, and the barriers to women in science remain despite the implementation of several gender-related initiatives across the globe. This draws attention to a new dimension of concerns around credit attribution based on authorship practices and opens up new discussions on how to orient the scientific reward system, which is founded on authorships and publications, towards gender equity and quality in science.

3. Inventorship

Innovative activities are commonly measured through patents (Acs & Audretsch, 1989), as patents are often seen as inherent involvement of research and development (R&D) in economic development. Patents are thus used as a measure of commercial success and are rewarding for researchers in technology-related fields (Hagedoorn & Cloodt, 2003). These rewards offer far more than recognition and prestige, as they are directly associated with intellectual property rights and monetary gains (Göktepe-Hulten & Mahagaonkar, 2010). Therefore, involvement in patenting is sometimes rewarded more than involvement in scientific publishing, and is increasingly used in scientific evaluation for employment, promotion, and retention (Ganco et al., 2015; Ge et al., 2016).

Inventorship, similar to authorship, is described in attribution rights – a form of intellectual property acknowledged by the social norms of science (Merton, 1957) and by international conventions on the moral rights of performers (UNESCO, 2003; WIPO, 2008). Inventorship is a concept defined beyond mere contribution to a specific invention. It is a legal concept, and a patent could be declared invalid if contributions of inventors do not comply with the legal definition of inventorship: Two individuals are considered inventors on one patent only if they worked jointly and provided contributions to the *conception* of an invention, defined by the US Supreme Court as "the formation in the mind of the inventor of a definite and permanent idea of the complete and operative invention as it is thereafter to be applied to practice" [1].

Therefore, there is a clear distinction between inventorship norms and authorship norms. Being involved in the conception of scientific discovery is not a necessary component to authorship attribution, but it is to inventorship. Therefore, a scientist who is involved in acquiring funding, performing the experiments, and/or revising the drafted manuscript could qualify as the author of a paper but not as the inventor of a patent. The same applies to those who merely follow the instructions of a peer or supervisor. Also, it is essential to note that the order of the names of inventors in the patent byline has no bearing on the amount of contribution of each inventor to the invention, and alphabetical name ordering is the most common practice.

As mentioned above, the social and legal norms regarding authorship and inventorship attribution can be different and are often dependent on negotiations among team members. This negotiation process was formalized in a study by Lissoni et al. (2013) that looked into related sets of patents and publications (patent-publication pairs) and found that junior and female scientists are more prone to be excluded from inventorship when litigation costs are high so that they can secure their position as first authors on articles. In a similar study, Mongeon (2017) studied patent-paper pairs and found that even when women occupy key authorship positions (listed as first and last authors) and even when

1 *Townsend v. Smith, 36 F.2d 292, 295, 4 USPQ 269, 271 (CCPA 1930)*

they are involved in the conceptual performance, they are less likely to be included as inventors in the patents derived from those specific scientific activities.

Patenting is a highly male-dominated activity, with women representing only 11% of total patent inventorship (Sugimoto et al., 2015). Female inventorship is the highest in patents owned by universities (which represent only 2.2% of total patents) and is the lowest in patents held by firms (which account for 72.4% of total patents) (Sugimoto et al., 2015). These results may suggest that due to its less hierarchical organization (shown to be an essential factor in the advancement of commercial activities), academia provides women with an environment more conducive to patenting than corporate or governmental institutions. Women's patents are also more likely to be rejected than those of men, and those rejected patents are less likely to be appealed by the applicants, including inventors, assignees, and patent representatives (Jensen et al., 2018). Even when women's patents are granted, their patents receive lower citation rates than those of men (Jensen et al., 2018; Sugimoto et al., 2015).

The gender gap in patenting is often explained by the lack of women in science, technology, engineering, and mathematics (STEM) fields. However, this explains the gap only in part, as it has been shown that women with STEM degrees are barely more likely to patent than women without (Hunt et al., 2013). Other explanations include, but are not limited to, exclusion from industry relationships; women's fewer contacts in industry; demands balancing academic careers (Ding et al., 2006); organizational structure and fewer networking opportunities (Whittington & Smith-Doerr, 2008); lack of training and support (Murray & Graham, 2007); women's attitudes toward risk, competition, and scientific commercialization; and gender discounting (Stephan & El-Ganainy, 2007).

On one hand, patenting, as one of the main innovation indicators, is intricately associated with economic development. On the other hand, economic development cannot be achieved unless inclusive growth is ensured. It is, therefore, of great importance to have a comprehensive understanding of gendered practices in patenting. Given that institutions are increasingly rewarding and promoting patenting activities, these gendered practices need to be recognized and addressed, as they present consequences for hiring, promotion, and retention of women in science and technology, and could ultimately hinder women's career advancement.

4. Citations

Citations are considered one of the main components of the reward system in science. They represent the interaction and engagement of new pieces of research with earlier scientific publications upon which new scientific discoveries are grounded. Citations are often applied to provide background to research, conceptualize research problems, structure arguments, derive or justify methods, and support or refute a perspective (Sugimoto

& Larivière, 2018, p. 64). Due to the cumulative nature of science, aggregated citation measures have become an important indicator in depicting the growth of knowledge. A reference list indicates to what extent a new piece of research relates to scientific work preceding it, with works that are cited repeatedly more likely to influence new scientific insights. For these reasons, citations have been considered a measure of scholarly impact. However, scientific impact is often associated with field and year normalized citations to avoid disciplinary differences in the number of citations and the differences in citations that can be accumulated in years. Similarly, patent citations are often considered as patent or technological impact (Sugimoto et al., 2015). Patent impact is a measure of the citations received for each patent normalized by technological field and year of issuance. Citations and citation-based indicators are becoming more important and are widely used to measure "scientific impact" or even sometimes "research quality." Although the latter association (between citations and research quality) rests on little to no evidence (Aksnes, Langfeldt, et al., 2019), this dubious association has given rise to the further use of citation indicators in scientific evaluations.

The increased importance of citations has led to the development of different indicators to measure the quality of research work or the researcher, the top among which is journal impact factor and h-index. Journal impact factor (JIF) is the number of total citations received by the papers published in a given journal during the two previous years divided by the number of papers published in the journal over the two years. In simple words, JIF is developed to indicate the "average impact" of papers published in the journal. Although there are several flaws to this association – including the lack of consideration of document types, the inflating impact of self-citations, disciplinary differences in citation levels, the short length of citation window, dependency on the success of an individual article, and the like (Sugimoto & Larivière, 2018, pp. 93–96) – this is the best-known practice for journals, and this factor is commonly used to quantify the quality of a specific journal. H-index was developed as an author-level metric to measure both the productivity and impact of an individual researcher. This measure, therefore, involves both the total number of publications and citations, where researchers have an index of h when they have at least h papers with h citations each. Evidently, this measure depends heavily on the number of publications, seniority of the researcher, collaborative publication activities, and discipline. Despite these limitations, this measure has gained popularity and is wrongly associated with researcher performance.

These (flawed) associations of citation-based metrics with scientific quality have given rise to the importance of these metrics in the scientific community, where they are used frequently for decisions on hiring, promotion, tenure, remuneration, and the like. Self-citations could thus play an important role, as they contribute in increasing citation-based metrics. Author self-citations and self-references occur when an author receives a citation from or makes a reference to another study written by the same author. Self-citations are made, ideally, to expand on earlier work of the author and to further research in a specific topic domain. However, as citation-based measures have gained in popularity for evaluation purposes, self-citations are sometimes applied in capacities beyond their original intent. They could also be used to artificially inflate an author's citation counts, manipulating the scientific reward system and thus influencing the career trajectory of the researchers.

Citation practices are not neutral and objective. These practices are affected by cultural and social behaviors that differ between disciplines, and their use for evaluation purposes has been heavily criticized (MacRoberts & MacRoberts, 2018). Moreover, citation measures are likely to be subject to the Matthew effect in the sense that highly-cited researchers are more likely to garner more citations than lower-cited ones, leaving lesser-known researchers underrecognized or even invisible (Fowler & Aksnes, 2007; Merton, 1988). Women, lamentably, are not immune to this systematic effect, and several studies have shown that women receive fewer citations than men, even after controlling for authorship order (Larivière et al., 2013), journal impact factor and field (Larivière & Sugimoto, 2017), first author seniority, number of references, total number of authors (Caplar et al., 2017), affiliation, tenure status, methods, and context (Maliniak et al., 2013). These findings, on their own, are of great importance as they could testify to the under-recognition of work of women in science, despite recent progress toward gender equity and equality in science.

Along these lines, men's higher likelihood to self-cite (Ghiasi et al. 2016; King et al. 2017) and gender homophily in citations (Ghiasi, Mongeon, et al., 2018; Potthoff & Zimmermann, 2017) could also contribute to gender differences in citations. When comparing self-citation practices by gender, men tend to cite their own publications at a higher rate than women, and their publications receive more citations from their own papers than those of women. However, women's first-authored papers receive higher citation rates from papers written by their immediate co-authors (Ghiasi et al., 2016). This reveals that although women do not self-promote their own work as much as men, their work is promoted at a higher rate by their immediate co-authors. In addition, gender differences in citation practices are evident across all disciplines, primarily reflected in "gender homophily" in citations (Ghiasi, Mongeon, et al., 2018; Potthoff & Zimmermann, 2017). This means that men tend to cite men more often than women cite men and vice versa. Gender homophily in citations is persistent even after excluding self-citations and controlling for research field and subject similarity (Ghiasi, Mongeon, et al., 2018), which, combined with the fact that men represent more than 70 % of total authorship (Larivière et al. 2013), could contribute greatly to lower citation rates for women.

On another important note, across all disciplines and regardless of authorship positions (first or last authorship), the gender gap in relative citation impact is higher than the gender gap in relative impact factor of journals where male- and female-authored publications are published. In some fields, including earth and space sciences, biology, social sciences, and engineering, women first-authors publish their papers in higher IF journals but receive lower citations from their community (Larivière & Sugimoto, 2017).

When a paper is published in a higher impact factor journal, by the very definition of impact factor, it is expected that the paper will receive higher citation rates on average. However, this is not the case for females' first-authored papers. This is often explained by the Matilda effect in science (systematic under-recognition of women's contributions to science) in the sense that women's publications receive lower recognition than what is expected (Ghiasi et al., 2015). Gender differences in citations could have a direct impact on the h-index score of an author and contribute to gender inequality in evaluation, hiring, promotion, and resource and salary allocation. It is evident that the h-index is double biased when considering the systematic biases in citations and authorship practices.

These results are of great importance as they show how the application of citation-based metrics could contribute to the persistence of gender inequality in science and lead to the under-recognition of women's contributions to science. Use of these measures will remain a barrier to gender equality in science unless accompanied by the development and introduction of gender-equitable strategies and practices.

5. Collaborations

Scientific research is a collective effort – the result of interactions that are informal (e.g., exchange of ideas and information at meetings, symposia, and conferences) or formal (e.g., co-supervision and co-application on a grant or funded project). Despite the various forms that collaborations take, the most observable, quantifiable, and measurable collaborations identified in the reward system of science are those that result in a scientific publication or a patent. The former are referred to as co-authorship collaborations, and the latter, co-inventorship collaborations. In this sense, a manuscript or a patent is considered a result of a collaborative endeavor when more than one entity (i.e., scientists, institutions, cities, countries, etc.) are listed in the article or patent byline, providing a basis for collaboration indicators. There has been a substantial increase in co-authorship and co-inventorship collaborations as research has become more complex and interdisciplinary. Moreover, increased mobility, technological infrastructure, and cross-national grants and funding programs facilitate a higher rate of research collaborations (Hara et al., 2003). Collaboration indicators can be defined beyond individuals, and be aggregated at the levels of departments, research groups, institutions, cities, institutional sectors, and countries.

These collaboration indicators are often defined in two groups (Sugimoto & Larivière, 2018, p. 59). The first group reflects the representation of various entities and is defined as the share of articles or patents in which more than one entity is represented. One of the main collaboration indicators is engagement in international collaborations – an activity that is increasingly rewarded in research evaluation and governmental evaluation systems. This measure is shown to be associated with the visibility and citation impact of the research work (Chinchilla-Rodríguez et al., 2019; Glänzel & Schubert, 2001; Schmoch & Schubert, 2008). The second group indicates team size and is often defined as the average or the median number of entities involved in a paper or patent. The latter indicator needs to be applied with caution as it is subject to outliers and disciplinary differences.

To better understand relations and positions of entities within scientific communities, social network analysis (SNA) techniques have been extensively used to map co-authorship and co-inventorship collaborations. In these networks, each node represents a researcher, and two nodes are connected when two researchers collaborate with one another on at least one publication or patent. The weight of each link (also called "edge") represents the number of papers (or patents) on which the two researchers are listed as co-authors (or co-inventors). SNA measures (explicitly centrality measures) are also used to explain interactions and the position of scientists/entities in their network within a scientific system. It has been shown that researchers associated with higher degree and betweenness centrality measures – i.e., those with a higher number of collaborators and those who control the inflow/outflow of knowledge between clusters of scientists, respectively – are directly linked to the higher research productivity (Cainelli et al., 2015). Clustering coefficient (CC) is another important measure that represents how well-connected the direct neighbors of a node are. The higher the CC, the more likely it is that neighbors of the node can still collaborate with one another when the node is removed from the network. Therefore, a higher CC is associated with a less important position within the network.

Collaboration and research production are evidently interwoven within the scientific system (Fanelli & Larivière, 2016). It has been shown that highly productive researchers (i.e., researchers with the highest number of papers) also collaborate the most (Lee & Bozeman, 2005). However, this could also show that collaboration measures are subject to the "Matthew effect," meaning that higher research productivity brings more collaboration opportunities to a researcher, and more collaborations result in higher production of papers (or patents). However, this might also mean that the gender gap in productivity and collaboration interest (Knobloch-Westerwick et al., 2013) could exclude women from this virtuous circle, and could systematically leave them disadvantaged and disconnected from the scientific network.

Regarding the collaboration patterns of women in their scientific networks, it has been found that lack of research collaboration, along with childcare, is a primary contributor to gender differences in scientific publishing (Kyvik & Teigen, 1996). When coupled with the lower inclusion of women in co-authorship collaborations of highly productive researchers (Ghiasi et al., 2021), this tends to perpetuate a vicious circle of lower research productivity and collaboration that could present dire obstacles for women, excluding them from co-authorship collaboration teams.

Researchers, regardless of their gender, form their collaborations mainly with men (Bozeman & Corley, 2004; Ghiasi et al., 2015; Knobloch-Westerwick & Glynn, 2013). This is inevitable, given that women are highly underrepresented in science. However, studies show that gender homophily also exists in co-authorship collaboration patterns: Women include a higher share of women in their collaboration teams than men do, and men include a higher share of men in their collaboration teams than women (Ghiasi et al., 2015; Ozel et al., 2014). Although women form more gender-balanced teams, their collaboration ties with other women are weak, and they are more likely to repeat their collaborations with men (Ghiasi et al., 2015). Often, this is associated with the fact that junior female researchers include more women in their co-authorship teams than women senior faculty (Ghiasi et al., 2021). Interestingly, when women collaborate with women, their chances of receiving tenure are greater than when they collaborate with men (Sarsons, 2017). Policies are needed to support these collaborations and provide incentives for women to maintain these relationships as they climb the academic ladder and dive further into the male-dominated scientific system.

Of total scientific publications, 35% are written by only male authors, while 6% include only female authors. Citation impact is highest when articles contain both male and female authors and is lowest when an article is written exclusively by women (Larivière & Sugimoto, 2017). This could be a direct result of gender differences in various types of collaboration, in which women are engaged more in domestic than international collaborations (Larivière et al., 2013). Since involvement in international collaboration is correlated with higher productivity and visibility of a researcher, women's lower engagement in international collaborations can play to their disadvantage, and these associations definitely hinder women's academic career development (Aksnes, Piro, et al., 2019).

Using SNA analysis and mapping the positions of women in their networks of collaboration, it is shown that researchers who are involved with mixed-gender teams are more productive and central in their network (Ghiasi et al., 2015). Moreover, women who have the same degree centrality (i.e., a researcher's total number of collaborators) as their male peers include more central and productive researchers in their collaboration teams (Ghiasi et al., 2015). Researchers with a high degree centrality are seen as collaborative and popular, and are associated with prominent positions because they might have and provide greater access to information and resources. However, women might need to put extra effort into forming collaborations with prominent researchers in a male-dominated scientific system, as prominent researchers (mostly men) tend to collaborate mostly with men. In this regard, women are more likely to work harder to reach the same position and to access the same resources as their male peers. Moreover, in these networks, the average clustering coefficient is higher for women, which highlights the vulnerable position of women in their scientific networks. This measure shows that the researchers with whom women collaborate are well-connected and are able to communicate with one another even if women are removed from their scientific network. Concerning gender inequality in science, these studies, in summary, conclude that women need to work harder than men to occupy central positions in their scientific network (Ghiasi et al., 2015; Ghiasi, Harsh, et al., 2018). Despite this, their position in the network is vulnerable, and networks are formed around them such that their exclusion might not highly affect the flow and transmission of knowledge. It is therefore of utmost importance to reflect on these concerns and introduce policy mechanisms to incorporate more support in funding and research agendas for gender-responsive collaboration and supervisory team building.

6. Conclusion

This chapter provides an overview of the primary elements of the reward system of science, namely authorship, inventorship, citations, and collaborations. It reviews various bibliometric indicators associated with these elements from a gender perspective, suggesting that these indicators need to be applied with caution because their increased use for evaluative purposes could create circumstances for gender inequality in science.

These reward elements sustain the Matthew effect and reinforce one another in a virtuous cycle, where authorship and inventorship productivity, citation impact, and collaboration rates of researchers are positively associated. For example, highly productive researchers are more likely to be of collaboration interest and to have more collaborators, and thus are more prone to become involved in papers with higher citation impact. However, gender differences in authorship, inventorship, citation, and collaboration practices can turn this virtuous cycle into a vicious cycle for women.

The use of measures developed from these elements for research evaluation can leave women disadvantaged and hinder their career progression in science unless accompanied by strategic gender-equitable considerations. It is therefore of great importance to develop and implement policies to change current practices in the reward system of science and reinforce a more equitable context for research evaluation.

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Diversity Mentoring Mission Statements

A Case Study of a Participatory Approach

Susanne Spintig & Tanja Tajmel

1. Introduction

At universities, mission statements are important instruments to represent the political attitudes, the development, as well as the vision of a project, and to provide guidelines to act accordingly. This also applies to the project *Club Lise*, a mentorship program for girls and women in STEM (science, technology, engineering, and mathematics). Named after physicist Lise Meitner, Club Lise was founded in 2005 within the framework of the Project PROMISE (Promotion of Migrants in Science Education) and with the financial support of the European Union and Germany's Employers' Association in the Metal and Electrical Engineering Industries (Deutsche Gesamtmetall). The first mentorship program of its kind in Europe, Clubs Lise were established at universities in four different countries (Germany, Turkey, Austria, and Bosnia-Herzegovina) between 2005 and 2007. The program brought together students and mentors from countries of origin with students and mentors of countries of residence to address questions of availability, accessibility, acceptability, and adaptability of science education at secondary and post-secondary levels. Students of grades 10–12 are paired with graduate students, scientists, and professionals from science and engineering fields who serve as mentors (see also Tajmel & Starl, 2009). In 2011, Club Lise expanded to become the Lise Mentoring Network, extending its mentorship activities across Germany. The mission statement of Club Lise (Spintig & Tajmel, 2017) is based on the right to science education, and the project is grounded in the concept that structural conditions lead to unequal chances to access education for different groups, such as girls and women with migration backgrounds (in German "Migrationshintergrund").

For this chapter, a special focus lies on a general problem encountered by many projects and measures when addressing a specific group that has been identified as marginalized: the identification and characterization of the target group itself, and the challenge in addressing and counteracting social difference without reinforcing difference (cf. Mecheril & Plößer, 2011).

In the following, we present the steps of a participatory process of discussing and addressing this issue, as well as revising Club Lise's mission statement together with Club Lise mentors. The outcome of this process is an addendum to the original mission statement of Club Lise that includes reflection questions that help to translate the mission statement into non-discriminatory mentoring practice.

2. Identifying the Target Group

The target group supported by Club Lise is "women with a migration background." There are three aspects important to this limitation that need further explanation: First, when addressing women, gender is a relevant category. It is important to ask which women are going to be addressed exactly, where the line between target and non-target group lies, and what attributions are associated with these women. Second, when categorizing based on migration background, the question of where gender and migration intersect also becomes relevant in this context. And third, it must be questioned how this target group can actually be supported in order to empower members individually and thus counteract disadvantage in the STEM context in a diversity-sensitive way.

With our participatory approach to further developing a mission statement for a diversity mentoring program in STEM, we assume that the mentors, as bearers of the mission, must not only understand but also help to shape it in order to successfully translate guidelines into practice as mentors. Therefore, the updated version of the mission statement includes the experiences and wishes of the mentors. The outcomes reflect an agreement that certain basic principles, presented in the first part, were *not* negotiable in this participatory process.

3. Club Lise's Core Principles

Three principles constitute the core of Club Lise: (i) the human rights approach and the associated goal of increasing the individual empowerment of the mentees, (ii) the intersectional perspective and the associated power-critical deconstruction of categories of difference, including their attributions, and (iii) the discrimination-critical perspective including confrontation with discriminatory structures.

(i) Club Lise is conceptualized as a diversity mentoring program. In this context, the term *diversity* does not stand solely for "diversity and its appreciation" or "diversity as a human resource," which entails the notion of exploitability. Instead, Club Lise's diversity mentoring stands for individual empowerment by acknowledging and considering diverse realities and experiences of discrimination (cf. Spintig & Tajmel, 2017). This entails measures that expand mentees' self-determination as well as self-actualization perspectives by linking them not predominantly to economic purposes (e.g., to increase the employability of mentees) but to lifeworlds (taking into account the individual wishes and needs) of the mentees. Accordingly, their successes cannot be quantified by enrollment or employment data, but only evaluated qualitatively by and together with the individuals themselves.

(ii) Diversity is considered a product of socially constructed categorizations with attributions (cf. Baer, Bittner, & Göttsche, 2010) that cause unequal power relations and access (see also Tajmel in this book). Thus, the underrepresentation of "women with a migration background" in STEM is not attributed to a "lack of talent" as a group-specific characteristic, but to institutional decision-making processes and structures. In addition, the process of *addressing* based on categories of difference – such as mentoring for *girls* with a *migration background* – is problematized. Here a dilemma arises: On the one hand, there is a need to name disadvantages in order to counteract them but, on the other hand, doing so runs a risk of confirming differences as essentially and naturally given. Thus, it is important to be critical and reflective when invoking categories of difference, and to always weigh the positive and negative effects associated with such categorizations. From an intersectional perspective, one must always be critically aware that there are no group-specific characteristics such as the interests or potentials of supposedly homogeneous groups such as girls or migrants, and that these supposedly group-specific characteristics do not automatically culminate in an assumed need for support (cf. Mecheril & Vorrink, 2012).

(iii) Supposed "deficits" of the mentees and associated feelings of personal failure are exposed as non-fits between habitus and structure (Eickhoff & Schmitt, 2016). In the case of mentees, these are the discriminatory structures of the educational institutions school and university. From this perspective, mentoring can be seen as an instrument that can create fit. For example, mentors can provide access to their research and pass on important experiences so that mentees with a non-academic habitus are prepared for academic structures. With habitus-structure reflexivity, mentees – as well as their mentors – gain new self-understandings of their and others' positions, discriminatory structures, and new possibilities for action.

As far as the discriminatory structures themselves are concerned, however, mentoring also has its limitations. Although it has the potential to empower mentees and reflexively prepare them for certain structures with regard to diversity and to possibly even give impetus to the surrounding professional cultures, it cannot change discriminatory structures per se.

4. Club Lise's Mission

Club Lise's original mission statement (Spintig & Tajmel, 2017) is structured according to the following three areas:

The *role of the mentors* included dealing with experiences of discrimination, reflecting on one's position(s) in social space, developing knowledge of construction processes of categories and intersectionality, and focusing on accompanying mentees individually without prescribing one's own career.

The *values in interaction with each other* entail the need to provide a safe space where no one is forced, but where every experience can be shared and criticism and problems can be addressed openly.

The *goals of diversity-oriented mentoring* included highlighting the potential and personal strengths of mentees and mentors, encouraging mentees to act in a self-determined manner, and broadening their perspectives for self-realization.

	Club Lise mission statement (2017)
Role of the mentors	– The mentors accompany the mentees in a supportive manner without prescribing solutions or perspectives. They respond to the mentees' personal needs and wishes. – Mentors reflect on their own careers and do not expect them to be copied. – The reflection on careers is in turn used for joint reflection on opportunities. – Mentees should find their own way without being pushed in a certain direction. – The mentors act as a network and faciliate access to the university and industry through internships, visits to workplaces, and personal discussions. Coaching of the mentors: – Mentors receive training in considering intersectionality and understanding construction processes of categories, and learn to systematically reflect on them. – Mentors reflect on their own values and norms as well as their own social position(s), which are also determined by lines of difference.
Values in interaction with each other	– Categories of difference are understood as *constructed*, and diversity is conceptualized as the intersection of categories of difference. – The coordination / management of the project provides a safe space to talk about attribution processes and possible stereotypes. – Conversations about diversity are encouraged and guided by specific diversity training tools. – No one is forced to reveal anything about themselves or to answer questions. – The goal should be to move out of perceived inequality, reduce any insecurities, and find common ground. – Mentoring relationships are characterized by a mutual exchange of knowledge and experience at eye level. – Experiences, wishes, views, and ideas are taken seriously. – Criticism and problems may be addressed openly. If necessary, the coordination takes over conflict management.
Goals of diversity-oriented mentoring	– Diversity-appropriate mentoring should focus on commonalities. – During the mentoring relationship, diversity categories and the associated attribution processes are targeted for deconstruction. Content-related discussions in the context of joint scientific projects should be the focus of the mentoring relationship. – Focus lies on the potentials and personal strengths of mentees as well as mentors. With the support of the mentors, the mentees are encouraged to act in a self-determined manner. – Diversity mentoring broadens self-fulfillment perspectives as well as the spectrum of study and career choices for students.

Table 1: Club Lise mission statement in its original form (cf. Spintig & Tajmel, 2017).

5. Participatory Process

In 2018, in a participatory approach together with mentors, the viability of the mission statement was tested based on the mentors' experiences. A coaching process provided an adequate framework for this purpose. In a safe space, participants expressed experiences, wishes, suggestions, and criticisms. There was a particular need for discussion related to the conceptualization of the target group. The following gives an overview of the main topics and the discussions.

5.1 About the Target Group

The target group of Club Lise is women with a migration background because persons addressed as such are strongly underrepresented in STEM fields. This sounds logical, but a demarcation of target group and non-target group on the basis of binary-constructed categories of difference such as *gender* or *origin* must be viewed critically. This is because non-reflective addressing of the target group as *schoolgirls*, *women,* and *migrants* assumes a group-specific need for support that cannot exist in this way. At the same time, addressing the target group according to categories of difference can exclude people who are in inferior positions precisely because of their gender identity or origin and who therefore need support.

There was discussion about how Club Lise could solve the dilemma of addressing. Drawing boundaries based on binary-constructed categories of difference such as gender or origin was found to be insensitive to diversity. However, the mentors also communicated that Club Lise should not lose sight of the target group and should primarily reach those who are actually affected by exclusions.

Results of the discussion were practical proposals for solutions: Although the program should primarily address women, transgender persons should also be invited to participate in the program indicated by the gender asterisk after "schoolgirls*." A migration or refugee background is not a condition for participation, but Club Lise advertises predominantly at relevant schools with a high proportion of migrants. The only access criterion decided upon is interest in STEM, which makes access low-threshold. In addition, attention is paid to diverse lifestyles and career pathways among the mentors, who represent diversity and address the target group without a categorical label.

5.2 On the Role of Mentors

There was agreement that a diversity mentoring program should not be about mentors focusing on their own career pathways; however, reflecting on them is essential, and this includes mentors knowing their own resources and capital well and being transparent about the position from which they speak to mentees. The key term is diversity discrepancy (cf. ZtG, 2016), because when reflecting on careers, it is crucial to know one's own realization possibilities and those of the mentees, as well as to put them into perspective.

Accordingly, the mentors came to the conclusion to offer their careers as examples for reflection and adaptation and not to impose them on the mentees.

Further, the mentors wanted to share their identification and enthusiasm for STEM and to provide a self-image that women belong and are successful in STEM. The mission of the mentors – to provide women with access points in STEM – was based above all on the fact that STEM affects a great deal of our lives and is therefore very powerful. Women are thus doubly disadvantaged: they have little influence on the design of technologies and, as a result, they have few advantages in the use of these technologies. The mentors agreed that they would like to act as a network for orientation and advice and create access points in STEM.

5.3 On the Values of Interaction with Each Other

Mentoring relationships should take place on equal terms so that a mutual exchange of knowledge and experience is possible and goals can always be renegotiated.

Experiences of discrimination should be given a trusting space where they are taken seriously and discussed together. The aim is not to develop avoidance strategies but to analyze the reasons for these experiences. A sociological analysis (hermeneutics) with which conflicts such as discrimination are traced back as non-fits between the habitus and the structure and not, for example, to a supposed lack of ability of the person concerned, is very helpful (Schmitt, 2006; 2014)

Pointing out diverse life paths should inspire mentees to go their own way. The group discussed how experiences of failure and supposed weaknesses (stumbling blocks, disadvantages, fears) are important to empower mentees and to be authentic as a mentor.

The mentors collectively came to the conclusion that they want to support the mentees without prescribing solutions or perspectives or expecting their career pathways to be emulated. The mentees' lifeworlds and personal needs should always be at the center of the mentoring relationship, and the goals of the mentorship should always be renegotiable. Personal goals should be put behind those of the mentees: mentees' decisions, even those that appear contrary to the mentors' experiences or proposed solutions, should be accepted and acted upon. In addition, mentees are not expected to be grateful or to adopt the experiences, proposed solutions, or strategies without question. Appreciation of their mentoring work is expressed through the program coordination and cannot be the mentees' responsibility.

Conflicts are discussed with the coordination and among the mentors and seen as opportunities for reviewing the project goals.

5.4 On the Objectives

Diversity is understood as cross-sectional. Diverse lifeworlds of the mentors should help to address diverse experiences of exclusion and discrimination on behalf of the mentees. The program is open regarding outcomes, mentees are not persuaded to choose STEM fields, and STEM fields are not prioritized among other career options. This approach centers on the mentees' wishes and interests rather than a general interest in increasing the participation of women in STEM. Nonetheless, the group discussed that orientation in STEM should not be neglected, as it is important for the purpose of promoting and nurturing the mentees' special interests and talents in STEM, such as giving support in preparing for youth science competitions. Experiences of the mentors, however, showed that, especially in competitive situations, care must be taken not to push mentees and not to focus on the mentors' own personal goals or ambitions. The right to science education is the foundation of Club Lise and the goal is to open doors for mentees that would otherwise remain closed to them. Usability (in terms of skills, for example) only becomes an issue when explicitly requested by the mentees and under the stated criteria.

The goal is thus to empower mentees to develop self-actualization perspectives in STEM fields and beyond. In doing so, however, mentors must always keep the mentees' personal goals in mind and constantly revisit them. Mentors' own goals – such as increasing the proportion of women in their field – will only be persued if they match with the goals of the mentees.

6. The Revised Mission Statement

Based on the presented discussions from the coaching process, the mission statement of Club Lise was revised by adding an addendum to the original mission statement. Key to the mission statement update are questions that stimulate reflection on diversity, on categorization, and on othering, addressing, and positioning of mentees. The reflection questions are assigned to the three areas of the original mission statement and provide a framework to systematically and continually review diversity mentorship in an antidiscriminatory way. Given the open character of the questions, they are applicable to diversity mentoring programs in general. The reflection questions emerged out of mentors' experiences and acknowledge that a diversity mentoring program cannot function according to a standard formula, but must be renegotiated in every situation (Andreotti, 2012; ZtG, 2016; Mecheril & Vorrink, 2012).

	Addendum to Club Lise's original mission statement: *Questions for reflection*
Reflection questions on the role of the mentors	– *Do mentors provide diverse solution proposals at any time from which the mentees can freely choose?* – *Is the objective of the mentoring relationship regularly reviewed as to whether it meets the current needs of the mentees?* – *Do mentors refrain from assuming that they could decide which solutions are the "right" ones for the mentees?* – *Are mentees supported in their decisions, even if they do not correspond to the mentors' ideas?* – *Are supposed conflicts seen as opportunities to question different perspectives and clear up misunderstandings?* – *Is it ensured that the mentors do not impose their careers on the mentees but make them available as sample models for adaptation?* – *Are career pathways illuminated in the context of unequal access, power inequalities, and structural discrimination?* – *Are career pathways presented authentically, i.e., are moments of failure and stumbling blocks also addressed?* **Expectations on mentees:** – *Is a view of mentees as "in need of help" who should be grateful for the support of the coordination and the mentors problematized?* – *Is there an expectation that mentees should make a special effort to advance their careers during their mentoring relationship?* – *Are mentees expected to identify with their mentors and their career pathways?* – *Do mentors expect mentees to follow their example and emulate their careers?* – *Do mentors expect mentees to implement their tips and solutions?*
Refection questions on values in interaction with each other	– *Do the participants reflect on the images of the supposed "others" (for example, mentees with refugee experience) and how they relate to them?* – *Do the participants acknowledge diversity discrepancy between mentors and mentees (such as unequal power positions in terms of privileges and disadvantages, self-actualization perspectives, and lifeworlds) and do they take it into consideration in every situation?* – *Are group-specific attributions avoided? For example, the assumption is that the mentees lack opportunities (networks, capital, and access) rather than talent to advance their careers.* – *Are discriminatory structures and non-fits between habitus and structure addressed?* – *Are experiences of discrimination taken seriously and is there a safe space provided to share?* – *Does this protected space ensure that individuals are not pressured to explain their experiences?* – *Is the handling of experiences of discrimination, critical moments in the mentoring relationships, and criticism regulated in cooperation with the coordination?*
Reflection questions on the goals and objectives	– *Does the program actually reach people who are affected by exclusion and discrimination?* – *Are diverse life realities represented among the mentors and mentees?* – *Does the program serve as an orientation in STEM career trajectories, taking into account the mentees' realities and personal wishes?* – *Does the program enable networking and access for mentees to whom doors would otherwise remain closed?* – *Are there constant re-evaluations to ensure that the goals of the mentoring relationships meet the mentees' current needs and aspirations?* – *Are mentees individually empowered and perspectives for self-actualization developed?* – *Is the program open-ended so that mentees are empowered to plan their careers in a self-determined way?*

Table 2: Addendum to the Club Lise mission statement with reflection questions

7. Outlook

This chapter provides insight into the participatory process of the revision of a mission statement for a diversity mentorship program based on the underlying principles of the right to STEM education, the understanding of social categories as constructs, and the awareness of intersectional discriminatory structures. Questions for reflection are considered key in translating the mission statement into a non-discriminatory praxis and in supporting mentors to continuously review their relationships with mentees. The revised mission statement recognizes that there is no formula for a diversity mentoring program that, applied only once, will ensure a discrimination-free program in the long term. Phrasing the guidelines as questions for reflection makes it possible to constantly re-examine every situation, every measure, every conversation, every event, etc. in a way that supports critical awareness of discrimination. It is recommended that the mentors carry out this review for themselves as well as in regular exchange with each other coordinated by means of supervision and collegial consultation.

The guiding principle for diversity mentoring is to continuously review the content in a way that is critically aware of bias; discrimination, including othering, tokenizing, and stereotyping; and underlying power relations. In such a process, the entire mentoring program, including attitudes, content, and objectives, is constantly scrutinized. Finally, the mission statement itself should also be tested at regular intervals for its validity, particularly in the view of changing societies and changing political and public discourse, and adapted if necessary. Only then, will mentorship programs for underrepresented groups that address diversity contribute to counteracting unequal opportunities in STEM fields rather then reinforcing the structures that lead to inequity.

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