The Systems Approach to Rethinking the Gender-Equality Paradox in STEM in the Context of Norwegian Educational System and Workforce

Evelina Anita Iversen
Department of Science and Industry systems
University of South-Eastern Norway
Kongsberg, Norway
evelina.a.iversen@gmail.com

Mo Mansouri
Department of Science and Industry systems
University of South-Eastern Norway
Kongsberg, Norway
Mo.Mansouri@usn.no

***Abstract*—Gender equality in Science, Technology, Engineering, and Mathematics (STEM) has been an ongoing concern of policymakers and researchers. The equality issues of socioeconomic systems are inherently complex due to their dynamic nature and many tightly coupled variables. These initial conditions of the systemic gender issue inspired the authors of this paper to apply the systems multistakeholder approach to this topic. The goal is to show that it is possible to assess and organise the dynamic behaviour of the agents influencing the mechanics of women's choices. The authors chose Casual Loop Diagrams (CLD) as a visualisation tool. Firstly, the paper focuses on socioeconomic factors that affect adolescent girls' willingness and ability to pursue a STEM-related education and career. It has been shown that the problem is multifaceted; hence, the decision has been made to focus on the mechanisms that influence college enrollment. Furthermore, the authors considered the geopolitical context with Norway in focus. The paper also outlines the choice dynamic and suggests that relatable female representation can increase gender parity in STEM. Finally, it has been shown that CLD might be a useful modelling tool for the multidisciplinary team working on solving systemic issues. CLD has the capability of bringing a middle ground between policymakers, neurologists, social scientists and other specialists required to analyse the issue thoroughly.**

***Index Terms*—Complex systems, education, gender studies, STEM.**

I. INTRODUCTION

One of the most prominent intentions of The Sustainable Development Goals is to promote fighting inequality and discrimination all around the globe. This issue is specifically targeted in *"Goal 5 - gender equality"*. There, among other ambitions, is to *"ensure women's full participation [...] in decision-making"* [4]. Since engineers and other representatives of STEM-related workforce play a great role in the shaping of humanity's future by making decisions on technology in *"a response to societal needs"* [2], it is worth analysing women's representation in this social group. One could argue that isolating a block of society to perform gender-related analysis can narrow the scope of issues of inequality.

Nevertheless, since human interaction has a high level of complexity, it is rather unlikely that isolation would eliminate the effects of society as a whole. Therefore, to reduce the complexity of the system and the issue discussed in this paper, it can be a good starting point to focus on one social group. First, however, close attention must be paid to the problem's cultural, socioeconomic, and geographic factors. That will be the main focus of Section I. The rest of this paper is organised as follows. Section II illustrates the modelling process of the mechanics of choice associated with STEM-related higher education. In Section III, the authors elaborate on the relationships visualised in the previous section while indicating a possible intervention. In conclusion, Section IV addresses the value of the systems multistakeholder approach and covers suggestions for further work.

A. Women's under-representation

Since resolving women's under-representation in STEM-related education and workforce is an issue that is often brought up on a systemic level, one could argue that it is evident that governments and industries are the stakeholders of this problem. Indeed, it is evident that a larger pool of trained professionals will positively affect the economy. That is because engineering and science, in general, are rapidly developing fields, which are often understaffed [3].

Educational institutions and research centres are motivated to employ more women since they bring their unique perspective to the projects. As an example, one could mention a rather famous *"Seat belt design case"*, where male researchers created the guidelines, which did not take into consideration gender-influenced anatomical differences [1].

On the other hand, some groups would oppose introducing more women in STEM. Those groups might be promoting "conservative gender roles," where women either engage in unpaid labour in their households or are employed in traditionally female jobs. Other groups could be against female representation since that would increase competition, making it harder to receive higher achievements. It is difficult to dismiss the existence of these undeniably misogynistic opinions, even though they are less prominent in the geographical context of this paper compared to other countries (see I-B1).

 ISBN: 978-1-61208-941-6

1) Statistics in Norway: Statistisk Sentralbyrå (Statistics Norway) has recently published data on higher education enrollment in the country. The document [7] shows that 60.2% of all applicants in 2021 are women. However, they represent only 30.9% of all junior students at STEM faculties. It has also been mentioned that engineering educational institutions experienced a slight decrease in women's representation (-0.9%), balanced by a significant increase in maritime technology ($+7\%$).

The recent statistics can be perceived as discouraging, particularly if one would take into consideration an article published by *Norges Ingeniør- og Teknologorganisasjon* (Norwegian Engineering and Technological Organisation) [6], where they call for more female representation and point out that only 26% of STEM-workplaces are taken by women.

B. Willingness and ability

Since pursuing a certain educational- and career path is guided by a choice of an individual, one can take freedom to condense factors contributing to that particular decision into two groups: individual's willingness and their ability (see Fig. 1).

One can assume that under-representation of women in

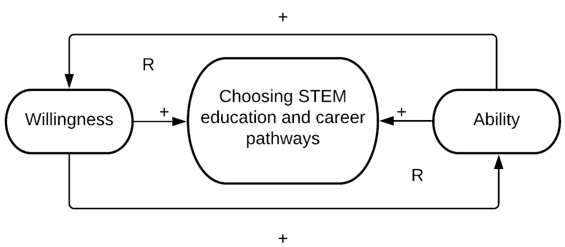

Fig. 1. Casual loop - best case scenario

STEM fields is due to their intellectual inability, rooted in biological inferiority. Even though one can find this point of view as admittedly false, Harvard University president Lawrence Summers once *"suggested that innate biological differences may help explain why men have more career success in science and mathematics than women"* [8]. This claim currently has little neurological support. Nevertheless, the statement can indicate the cultural atmosphere in some educational institutions. That atmosphere, which feeds on degrading stereotypes about women, is one of the reasons women are not willing to pursue a career in STEM, which reinforces male representation in the field (see Fig. 2). Fortunately, women's science performance concerning their male colleagues has been covered in other research articles that yielded contrary findings [9]. However, those studies alone cannot affect gender bias significantly enough to attract more women.

1) National gender-equality paradox: In 2018, Stoet and Geary [9] published an article where they analysed relative academic strengths of adolescent girls and boys concerning

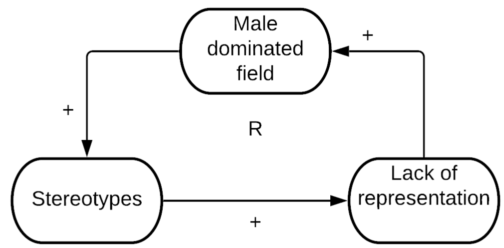

Fig. 2. Casual Loop - stereotype reinforcement

the probability of pursuing STEM educational path. It has

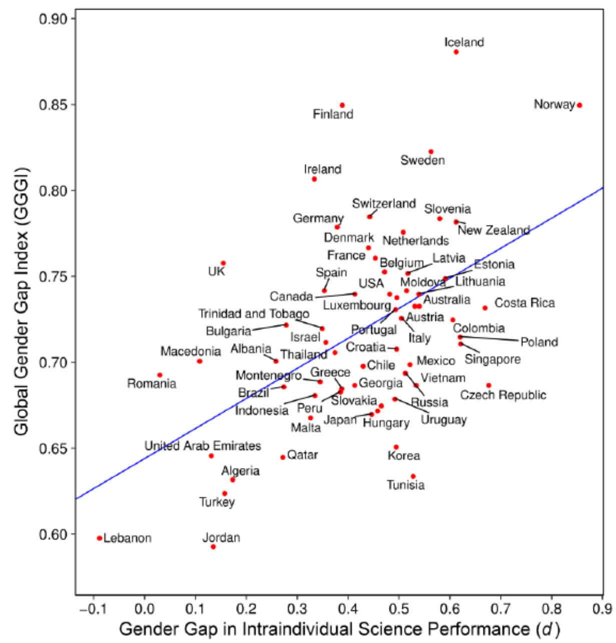

Fig. 3. Gender equality and sex differences vs intraindividual science performance

been found that in $\approx 66\%$ of countries studied in the paper, girls performed at least similarly to boys. Additionally, *"in [...] all countries more girls [...] were capable of college-level STEM study than had enrolled"* [9]. To quantify gender parity, one often refers to Global Gender Gap Index (GGGI). In the countries where GGGI is high political, economic, and educational opportunities between men and women are relatively equal. In those countries, girls often outperform boys in sciences interindividual, but simultaneously are less ready to pursue STEM education-path (see Fig. 3 and Fig. 4).

Therefore a natural question arises: "if GGGI is high (their will is free) and women's intellectual abilities are similar to men's, why are women still under-represented in STEM in Norway?" One can argue that the analysis of this issue is three-sided. Firstly, one must understand why they are unwilling to pursue a STEM educational path; secondly, they are not fulfilling their studies and not following through with their

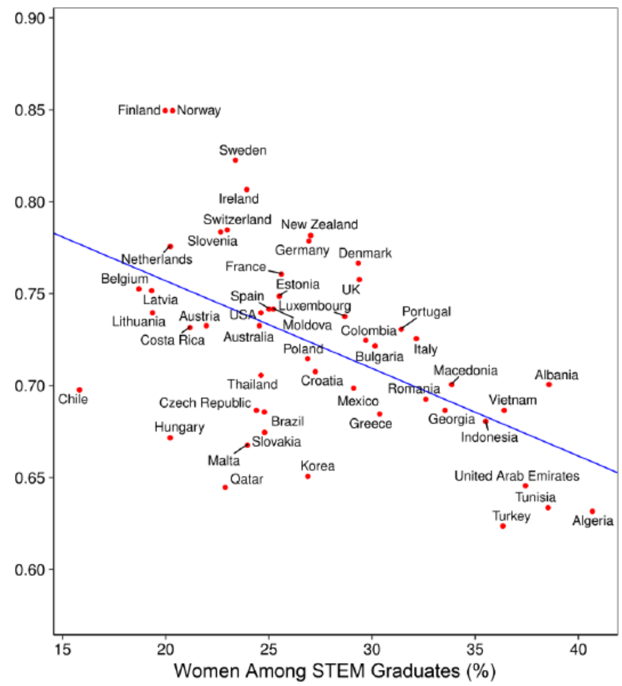

Fig. 4. Gender equality and sex differences vs women's prosperity relative to men

careers. Furthermore, lastly, why they change career paths. Since those three topics require isolated studies, the paper will continue with a case on college enrollment to provide a higher-quality analysis.

One then may attempt to structure information through Systems Thinking techniques and visualise the cause-result chains in a Casual Loop Diagram (CLD). A possible outcome of this procedure is represented in Section II together with reasoning behind factors chosen for dynamic assessment. Then, one can allocate loops that require intervention and propose a solution that benefits gender parity in STEM. The discussion and possible interventions can be found in Section III.

II. MODELING

Modelling the gender-equality in STEM in Norway was performed by relying on, among other resources, research published by Ida Marie Andersen on factors that influence the education pathway [5].

The analysis will be built on the further development of CLD represented in Fig. 1.

A. Parental influence

Ida Marie, in her paper, mentioned that parental influence is an essential factor of career and educational path choice for adolescents. The probability of a girl pursuing a STEM career is higher if she has a caregiver that has a job in that field. However, it is essential to point out that this analysis does not consider the relationship issues between a girl and her caregiver. Hence, in the best-case scenario, a caregiver or a parent increases the willingness of their child to pursue a career in STEM through encouraging and personal example. Then, engagement of a child will excite a caregiver, creating a reinforcement loop (Fig. 5).

Parental influence also affects a girl's academic performance, since they probably can help with homework and contribute to the general understanding of STEM-related syllabus, thus promoting the ability of a girl to choose a technical path in the future (see Fig. 6).

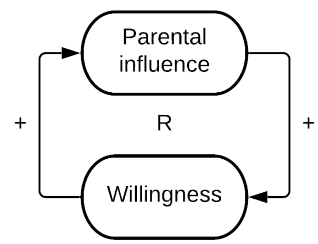

Fig. 5. Parental influence (willingness) - reinforcement loop

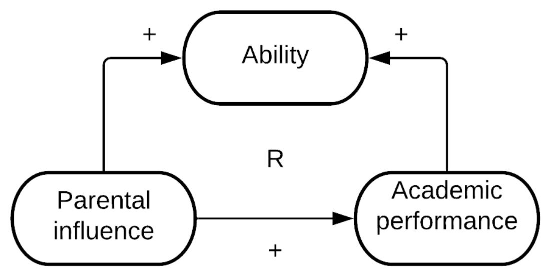

Fig. 6. Parental influence (ability) - reinforcement loop

1) Immigrant background: The work in [5] shows that parents who emigrated to Norway from other (non-Scandinavian) countries have an additional influence on their children: boys and girls. That point is supported by [9], where girls from countries with lesser general gender equality than in Norway are represented in STEM programs almost as often as boys.

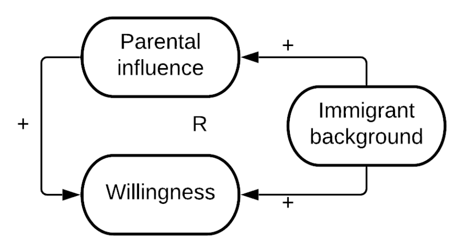

Fig. 7. Immigrant background (parents) - reinforcement loop

 ISBN: 978-1-61208-941-6

B. Gender bias - the reinforcement loop

Previous topics and loops that have been covered showed mechanisms that can positively affect a girl's decision when choosing a STEM-related career. The issues that can affect that decision negatively are generally rooted in gender bias (see Fig. 8). Interestingly enough, this destructive tendency is found both in women and men in the field. It has also been found that peer pressure in the context of general upper secondary education in Norway can swing girls away from engineering and mathematics since a STEM career path is not surrounded with the same amount of prestige as, for example, studies in Business and Administration, or Healthcare (see Fig. 9). Unfortunately, girls' unwillingness to pursue STEM careers feeds into stereotypes, reinforcing gender bias and lack of representation, making it a vicious circle.

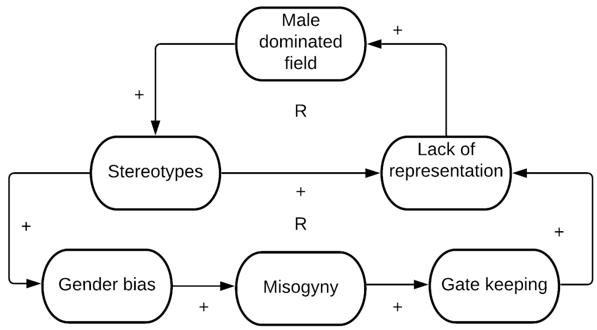

Fig. 8. Misogyny reinforcement loops

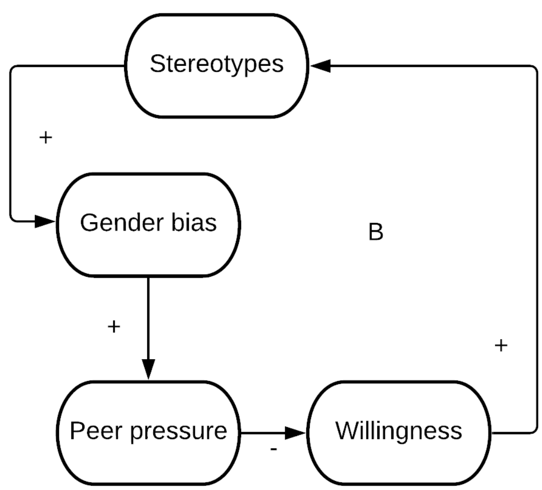

Fig. 9. Peer pressure prestige loop - balancing

C. Governmental support

The Norwegian government encourages women to enrol in STEM-related colleges and faculties by granting them additional points, thus, increasing their ability to compete for school places. It is important to point out that this support system is a part of the general gender-equality policy. This policy also gives men the same points for applying to female-dominant education paths. However, after interviewing some of their female colleagues in STEM, the author of this paper discovered that most of the women do not want to receive those points in the first place since that could suggest that they are less deserving of their current position than their male colleagues (see Fig. 10).

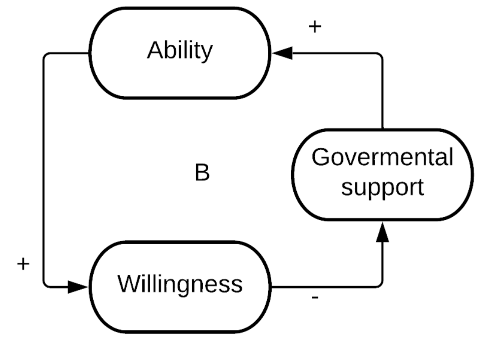

Fig. 10. Governmental policies - balance loop

III. DISCUSSION AND POSSIBLE INTERVENTIONS

It is possible to argue that fewer parameters negatively affect women's abilities than their willingness. Paradoxically, stereotypes and gender bias are at the root of those issues, even though Norway is considered one of the most gender-equal countries. That can be caused by a lack of comfort for women in the industry since there are very few success stories with female role models. And even if there is a success story, it is usually far beyond the reach of a "normal girl," since we more than often refer to Maria Skłodowska Curie or Valentina Tereshkova as an example of female triumph, which can be sometimes hard to associate with.

It is commonly known that usually, any hate, including misogyny, is fired by arrogance (willing and unwilling). One way to fight it is educating society on the topic by casting light on women studying and working in STEM *with comfort - without sacrificing their identity to a male-dominated field*. Additionally, one would want these women to be more relatable and reachable to adolescent girls than super-successful women in STEM, like Curie.

The authors propose that the positive dynamic can be encouraged by celebrating differences at workplaces and schools. Even though the industry is still overwhelmingly male-dominated, it can still be achieved even through minor changes. For example, one could end a practice of calling women in STEM "one of the boys" or expecting them to behave more masculinely not to be seen as an outcast. One could also encourage behaviours and activities that are usually perceived as feminine. That would arguably reduce the effect of bias since male colleagues would have a chance to interact with women in their comfort zone and learn from them.

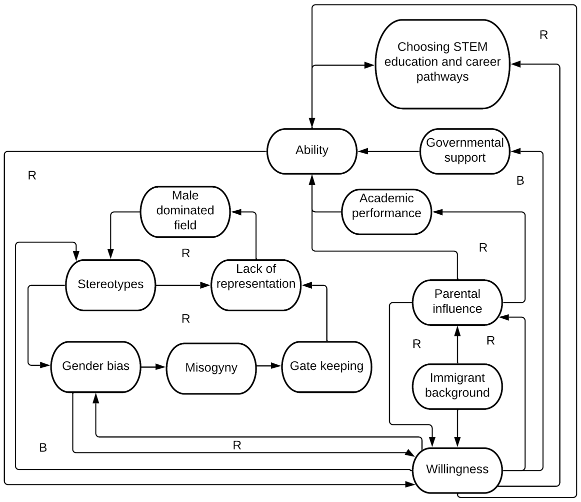

Fig. 11. Final Casual Loop Diagram

IV. CONCLUSION AND FUTURE WORK

Figure 11 shows the resulting CLD diagram, where one can see the attempt to visualise the mechanics of choice related to higher education in Norway. The resulting model demonstrates that complex socioeconomic issues can be structured understandably for specialists from different fields. That is a critical finding since continuing to build on the CLD STEM paradox model requires intervention from a multidisciplinary team with their knowledge of other agents affecting women's choice of educational path. In the future, one might reiterate existing CLD to learn more about the mechanisms of bias and gender stereotypes. That can include widening the model's scope and including some of the system's agents in the modelling process. Authors indicate that gradual holistic changes can be beneficial to make a STEM career path more attractive for women. For example, these interventions can focus on increasing the awareness of relatable female representation in the field.

REFERENCES

[1] A. Bert, "3 reasons gender diversity is crucial to science", Elsevier Connect, 2018. [Online]. Available: https://www.elsevier.com/connect/3-reasons-gender-diversity-is-crucial-to-science. [Accessed: 07-Mar-2022].

[2] H. Sladovich, Engineering as a social enterprise. Washington, DC: National Acad. Pr, 1993.

[3] M. Dahl, "Continued high shortage of labor", Metal Supply [Fortsatt høy mangel på arbeidskraft], 2022 . [Online]. Available: https://www.metalsupply.no/article /view/792477/fortsatt_hoy_mangel_pa_arbeidskraft. [Accessed: 07-Mar- 2022].

[4] Project Everyone, "Goal 5: Gender equality - The Global Goals", The Global Goals, 2022. [Online]. Available: https://www.globalgoals.org/goals/5-gender-equality/. [Accessed: 07- Mar- 2022].

[5] I. M. Andersen, "Diversity in the Academy - Higher education in the face of a complex reality" [Mangfold i Akademia – Høyere utdanning i møte med en kompleks virkelighet], Oslo and Akershus University College, 2014. (HiOA Tema-utgivelser 2014, nr.2.)

[6] A. Berger, "Women's Day March 8: - More girls should become engineers" [Kvinnedagen 8. mars: - Flere jenter bør bli ingeniør], NITO, 2022. [Online]. Available: https://www.nito.no/aktuelt/2022/3/vi-trenger-flere-kvinnelige-ingeniorer/. [Accessed: 07- Mar- 2022].

[7] Samordna Opptak, Hovedopptak til høyere utdanning ved universiteter og høgskoler juli 2021 [Main admission to higher education at universities and colleges July 2021], 2021.

[8] Nature Neuroscience, "Separating science from stereotype", Nat. Neurosci., vol. 8, no. 3, pp. 253-253, 2005.

[9] G. Stoet and D. Geary, "The Gender-Equality Paradox in Science, Technology, Engineering, and Mathematics Education", Psychological Science, vol. 29, no. 4, pp. 581-593, 2018.