STEAM FOR STEM - INCLUDE "ART" in STEM (Science, Technology, Engineering and Mathematics)

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***Abstract*— After a fairly recent study discussed in IEEE Spectrum, (https://spectrum.ieee.org/view-from-the-valley/at-work/education/want-girls-attracted-to-tech-put-a-for-art-in-stem), on the strategies of attracting more female students to opt for studies in the fields in STEM (Science, Technology, Engineering and Mathematics) the acronym has been modified to STEAM (Science, Technology, Engineering, Art and Mathematics), by adding "art" as a topic in the curricula. In a recent study, the authors of this paper noted: "There has been and there is still an on-going discussion on the low percentage of females in STEM (Science, Technology, Engineering and Mathematics) related studies. Some initiatives of engineers in the USA and current discussions in the IEEE community support the idea of adding an A (for Arts) in STEM leading to STEAM (Science, Technology, Engineering, Art and Mathematics). With the element of gamification in many subjects and associated elements of Art in many disciplines, this strategy may help to improve the number of female students, as confirmed by a study performed in 2016. Topics with the hue of art are found in many STEM subjects and the staff responsible for courses can tune the content to accommodate these in already existing programs by putting more emphasis on "art". Selecting two disciplines related to STEM subjects with the aim of increasing the number of female students in traditional STEM in EIE. This paper presents possibilities of incorporating elements of "art" related topics in disciplines under focus in the EAEEIE-community. Experiences from these cases are provided with some pertinent conclusions for studies in STEAM.**

Keywords—Gender balance; Electrical Engineering and IT; STEM; STEAM; Gender stereotypes;mentoring

I. INTRODUCTION

Member states of EU and Norway have declared recently their concerted commitment to encourage women actively in digital and technology sectors collaborating with public and private sectors simultaneously empowering and encouraging the civil society to achieve equality in all sectors of technology, [1]. Gender equality and women's empowerment are topics of many aid agencies working in countries particularly well known for gender gap in many sectors, particularly with barriers and constraints to women's participation in businesses and economic activities, [2]. Bridging the enrolment gap at all levels of education and improving access to education in STEM of USAID, [2] and STEM and Gender Advancement (SAGA) of UNESCO, [3], are some examples of the engagement of international organizations striving to achieve gender balance in higher education and employment in STEM. In another interesting development barring the gender gap, University of Berkeley has banned the words with its gender neutral language ordinance: he, she, her, him (substitutes, they and them), manhole (substituting it with maintenance hole), fireman/firewoman (firefighter as the substitute), manpower (substitutes workforce, human effort), pregnant woman/women (substitute pregnant employee(s), etc.,[4].

The domain of gender balance is full of acronyms, STEMM (Science, Technology, Engineering and Medicine), Strengthening Entrepreneurship and Enterprise Development (SEED), Workforce Improvement and Skills Enhancement (WISE), European Institute for Gender Equality (EIGE), gender empowerment measures (GEM), etc. The webpage of EU's EIGE ponders with the following opening remark on women's status in society: "What do expressions like policeman, female lawyer and ladylike handshake have in common? They are all examples of gender-discriminatory, even sexist language. They imply that all police officers are men and that a woman lawyer is an exception. And a 'ladylike' handshake is usually used as an insult", [5].

In a recent publication, the authors contemplate on ways of encouraging girls to select higher education in STEM and a new acronym STEAM (Science, Technology, Engineering, Art, Mathematics) is now frequently used in the context of higher education with focus on gender balance, [6-8]. IEEE Orlando webpage has the following statements showing their strategies in encouraging girls to select education in STEM by incorporating Art as an element in its curricular portfolio, [8]: citation from [8], starts here: "**"STEAM Rocks"** 4th Grade Girls Hands-On Outreach Workshop photos that were taken at ACE (Academic Center of Excellence) downtown. The girls were building flying saucer snap circuits"; "*Excite K-12 students through Science, Technology Engineering and Math (STEM) in Central Florida. To accomplish our mission,*

a. We recruit Professionals to share STEM with K-12 students. We continually promote volunteering to all local civil engineers as well as those of other STEM disciplines. We offer Train-the-Trainer workshops to anyone who is interested in the rewards of volunteering.

b. We share STEM at annual, periodic, and one-time STEM events that suit their age including STEM Pros in the Classroom, MATHCOUNTS, Engineering Encounters, West Point Bridge, Sea Perch, Flying Stars Model Aviation, Project CREATE, First Robotics, Odyssey of the Mind Competition, Orlando Science Center competitions. Science Olympiad, SECME Regional Competition and UCF Summer Camps.

c. We strive to communicate and cooperate with all other area STEM education entities and organizations, such as the Central Florida STEM Education Council, the Florida Engineering Education Conference, Florida Engineering Foundation" etc.", citation from [8], ends here.

In many studies related to closing the gender gap in STEM studies, one common finding is that men outnumber women in various STEM related employments. A recent article by Gjersoe in "The Guardian" of UK addresses the question: "Bridging the gender gap: why do so few girls study Stem subjects?" Gjersoe poses the questions given below in italics:

a. *Are girls biologically worse than boys at Stem subjects at school?* The answer in brief is NO.

b. Are gender gaps socially constructed? The answer in brief is YES.

c. Then why are there fewer women in Stem careers even in more gender-neutral countries? Citation from [9] begins here: *"Even in one of the most gender-neutral countries (*like Sweden, our comment*) in the world and despite the evidence of their own marks, girls still seem to be succumbing to the stereotype that girls aren't as capable in these subjects*" Citation from [9] ends here.

d. *Where do gender stereotypes come from?* Citation from [9] begins here: "*…findings suggest gendered notions of intelligence are picked up very early and start having an effect on the sorts of interests that girls pursue*". Citation from [9] ends here.

e. How can we attract more girls to STEM subjects at university? Citations from [9] begins here: "..One way to encourage girls is to use appropriate role models… a campaign to coincide with today's International Women's Day… send young female graduate Stem students into schools to talk to and inspire young teenage girls to consider pursuing STEM topics at A-level..young girls need individuals they are more likely to relate to if they are to be persuaded not to abandon their STEM potentials.." Citations from [9] ends here.

From these observations, Gjersoe points out that the strategy of attracting more girls to opt for education in STEM at university level must be focused on tackling the stereotypes girls are exposed to earlier in their primary, secondary schools and even in kindergartens.

This approach is in harmony with the "student in center and front" approach discussed in [7]. Melinda Gates in her book "The Moment of Lift" and various speeches and interviews emphasizes the importance of empowering women and girls by motivating them to get higher education and training in STEM. Most of the educators and philanthropists like Melinda Gates advocate early exposure to STEM, awareness of possibilities of interesting careers for women and girls in STEM related technology companies and the need for female educators and mentors. According to Melinda Bates, "empowered women transform societies" and "when we lift up women, we lift up humanity", [10]. Melinda Gates indicates also that girls with female STEM mentors remained in the engineering program and completed their studies.

With these current developments in the horizon, we need to look at the situation of applicants for education in STEM in some of the countries. According to the council of graduate schools, percentage of female students in total US graduate school enrolment in 2017 had the following values: 25.2% in Engineering, 32.1 % for Mathematical and Computer Sciences, 37.7 % for Physical and Earth Sciences. Interestingly, the percentage of female enrolment in Health and Medical Sciences according to the same source was 77.9%. According to National Science Foundation, National Center for Science and Engineering Statistics, the percentage of female students enrolling for a bachelor degree in the period 2004-2014 was 50.3%! However, in this statistics, Science and Engineering include the following disciplines: Agricultural Sciences, Biological Sciences, Computer Science, Earth/Atmospheric/Ocean Sciences, Engineering, Mathematics/Statistics, Physical Sciences, Psychology and Social Sciences! In the USA, the Council of Graduate School (CGS) has a category of studies under Health and Medical Sciences with fields such as Nursing, Kinesiology, Occupational Therapy, Health Sciences, etc. listed in "Taxonomy of Fields of Studies" of CGS, the female students outnumber the male students. This is partly addressed by groups dealing with STEMM (STEM and Medicine). These figures indicate also the problem of stereotypes discussed by Gjersoe above.

In Norway, the latest statistics indicates that the female students enrolling in ICT related studies for the coming semester starting in August is 28.8%, [11]. According to the Institution of Engineering and Technology (IET) of UK, the female workforce in engineering and technology is 9%. The UK has the lowest percentage of female workforce in engineering and technology in Europe with Latvia, Bulgaria and Cyprus having female workforce in these fields 30%. As an interesting current female population in Latvia is 54% with females outnumbering males!

As an overview of the status of females in various disciplines of studies and employment, a recent report from UNESCO, [12], gives the statistics shown in Fig. 1.

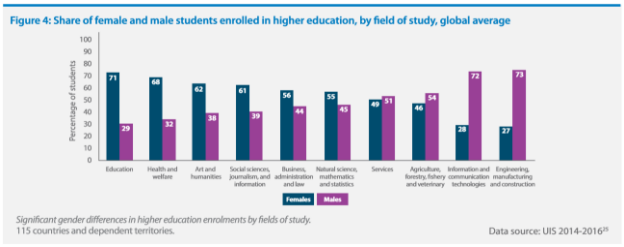


Fig. 1. Share of female and male students enrolled in higher education, by field of study, global average, from [12].

With females representing more than 50% of the population, the need for gender balance in the fields requiring STEM knowledge is obvious.

II. Industries Pushing for Gender Balance

Most of the industries promote gender balance and have own programs to promote employment of women in engineering fields, e.g. SIEMENS, BP, SHELL, EQUINOR, YARA, HYDRO etc. Visiting the websites of these firms and searching for gender balance will give some insight into the status of strategies suggested by these different companies. BP supported a study with the appropriate title "WOMEN IN ENGINEERING FIXING THE TALENT PIPELINE" , which addresses the following challenges involved in achieving gender balance in education and career paths for women in STEM, [13], citation from [13]starts here (*italics* our own comments):

1. Too few girls acquire the prerequisite qualifications in STEM subjects (*lack of mentoring and support*)

2. Addressing the unhelpful perception of STEM and engineering careers, among both girls and their families, as 'masculine' or 'brainy' (*formation of stereotypes in the formative years*)

3. Poor understanding of engineering careers and the engineering pathway (*lack of mentoring*)

4. The STEM ecosystem is fragmented, which increases the likelihood of duplication (citation from 13 ends here) (*need for cross-disciplinary and collaborative networks aimed at promoting the cause in schools, society and employers*)

These challenges are coupled to the ideas of formation of stereotypes in the formative years of young girls in their school and even-preschool days, as suggested by our comments given above with the four challenges above.

III. STEAM for STEM

According to the "STEM vs. STEAM: "The Gender Gap" report, parents of both male and female children equally report that their child's favourite STEAM subject in school is math (26 percent) or science (30 percent). It's when the school day ends that the differences emerge. Forty-one percent of the parents with boys surveyed said their children show the most interest in technology/computing activities outside of school, compared to 18 percent of parents with girls. Meanwhile, 45 percent of parents with girls report that their children show the most interest in art outside of school, compared to 10 percent of parents with boys." The results are reproduced in Fig. 2 and Fig. 3.

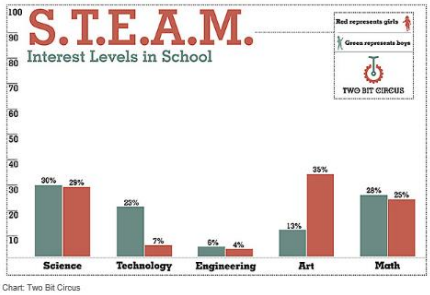


Fig. 2. In school levels of interest based on subjects, according to a study in the USA, [14].

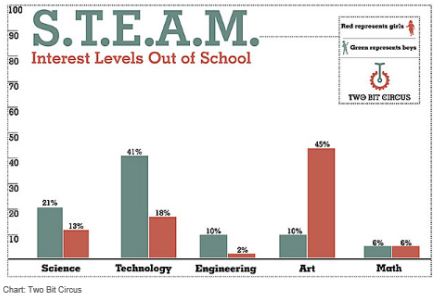


Fig. 3. Out of school levels of interest based on subjects according to a study made in the USA, [14].

These results can be specific for the schools or regions in the USA involved in the study cited in [14]. The authors of this paper do not know of any similar studies done elsewhere in the USA or in other parts of the world. However, there are some correlations to the challenges reported in [13] and discussed in Section II of this paper. In looking for the reasons for the lower levels of interest in STEM subjects among girls in school and out of school, one finds some correlation between the challenges mentioned in [13]. Including elements of art disciplines does motivate the feminine gender to show interest, develop innovative abilities, confidence and self-realization.

IV. Revisiting Biggs – Constructive Alignment

Seminal pedagogic work by the psychologist and pedagogue Biggs developed a model used by many in different stages of education, irrespective of the field. According to Biggs constructive alignment (CA) in teaching and learning is the continuous awareness of, "coherence between assessment, teaching strategies and intended learning outcomes in an educational programme". According to our opinion, this should be valid for the whole curricula and the learning period of an individual, irrespective of the gender. Awareness of this throughout the educational cycle of an individual (young or old) will probably eliminate the hurdles with the challenges discussed above and promote the achievement of gender balance, [15]. The webpage of Biggs, [15], has a plethora of interesting facts and resources for teachers, students and practitioners of any professions.

In a recent paper, [7], the effect of CA and the need for having the student "in center and front" was discussed. The

model discussed in [7] is somewhat modified and presented in Fig. 4. Coupling the outcomes of the study on STEAM from [14], and including the recent works and talks by women leaders in the field of technology, such as Melinda Gates, a suitable way of achieving the gender balance in STEM fields is through STEAM and continuous mentoring of female students, preferably by the same female person in the school days. This support among friends and family circles can eliminate the bias towards "stereotype" professions for females.

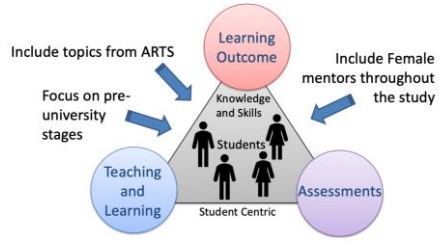


Fig. 4. Based on the study and our own experience, enhancement of Biggs model for achieving gender balance. Most issues are gender neutral, apart from inclusion of ARTS and continuous mentoring. The mentor should place the "female student in center and front". Adapted and modified version from [7].

V. General Observations

There are some general gender specific trends observed by us during the teaching of different topics in the field of electrical engineering, IT and Cybernetics. Without being "stamped" as stereotypic generalizations, it is found very often that, generally male students enjoy working with core-programming tasks.

"Art" is a key component in software engineering, involving developments of Graphical User Interfaces (GUI), web design, good code structure with dedicated documentation, and the female students become excellent software engineers as well. These aspects can be advantageous in the field of software engineering and system design, needing good overview and a sense for good design and overview.

Fig. 5 and Fig. 6 show the different disciplines involved in a modern industrial environment, whether is in the field of process-, energy- or manufacturing sector. Certainly, there have been in each sector some female employees working in STEM related tasks. Such female technologists can be used as "role models" in the schools. Such female technologists can also have some supporting mentor roles by interacting with schools.

Fig. 5. Disciplines covered by some of the industries cited in section II promoting gender balance. Female role models from these sectors are valuable in recruiting female students and for promoting gender balance, adapted from [16].

It is generally observed that female students tend to opt for design related studies in the STEM related studies.

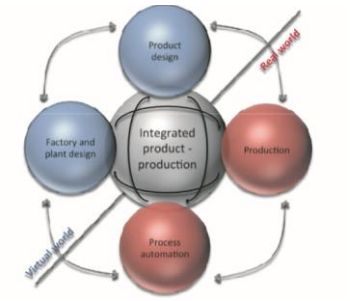


Fig. 6. Product development (both HW & SW) in both the "virtual" and "real" worlds, with. Design both HW&SW has elements of "ART" and is a good platform for obtaing gender balance in the technology sector, adapted from [17] & [18], as used in [16].

Some observations from software engineering activities from colleagues working in the industries covering the fields depicted in Fig. 5 are worth mentioning even if there is a chance for comments on falling into the trap of thinking in terms of stereotypes:

- Female students are very good at coding / programming!
- System Engineering involves considerable amount of programming. System Engineering involves planning, structuring and teamwork put into the system
- Programming is just one role (job option) in System Engineering. We have Project Managers, Designers, Architects, Testers, etc.
- Coding / Programming is a very small part of System Engineering
- Female students are good in planning well before implementing
- Female students are more systematic, structured and orderly than male students (in System Engineering everything is about working in a systematic and structured way)
- Girls think before shopping (equivalent to Requirements Analysis Design Before Coding)
- Female students do not hang up in details but see the whole (System / Software architecture, how do all software modules hang together)
- Girls have an eye for fashion, design, etc. (Software design and user experience are very important aspects in modern software systems)

These views are reflected in Fig. 7, which show the possible working areas for potential female employees after finishing a university education based on STEAM.

VI. Importance of Role Models

Many leading living and past scientists, both male and female, have already emphasized the importance of role models for motivating girls to follow curricula involving STEM in the

school. Reports of the lynching of the female scientist and astronomer Hypatia in her sixties in the Nile Delta of Alexandria around the year 415 AC is an example cited for the excellence of females in physics and astronomy.

Some personalities can motivate young girls to develop interest in careers needing expertise in STEM and complete their studies in these fields, e.g. female mathematicians, Grace Hopper serving during WW-II, Catherine Johnson, serving in NASA in the beginning years of the NASA space program, Fields medalist Miriam Mert Suhani and the renowned former environmental minister and current Chancellor of Germany Angela Merkel, with a PhD in particle physics. A recent publication, [19], related women in STEM has an interesting collection of leading personalities in science and can serve as a good source of motivations for females in schools and universities studying in STEM, in the spirit of the recent report from EU, [1].

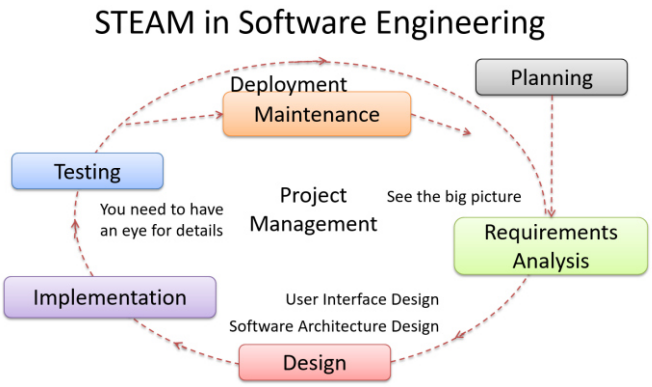


Fig. 7. STEAM in software engineering highlighting the potentials for involvement of females in diverse sectors shown in Fig. 5 and Fig. 6.

VII. Industrial IT and Automation

We take the example of Industrial IT and Automation, a topic covered in all the affiliations of the authors of this paper. The topics covered in such a curricular can contain the different "LEGO" modules, which in different combinations lead to a degree, qualifying the candidate, male or female, to launch into a career. Enhancing the curricula with elements of "ART" can help the female students in enhancing their outcomes in the context of the Biggs model shown in Fig. 4 above, as schematically illustrated in Fig. 8.

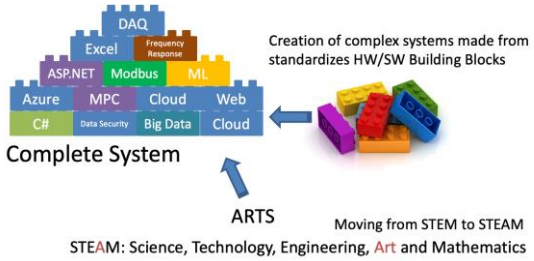


Fig. 8. Industrial IT and Automation as an example for STEAM for STEM for promoting gender balance in technological professions, adapted from [16].

As such, different tasks matching the innate talents of the female students or engineers can be allocated.

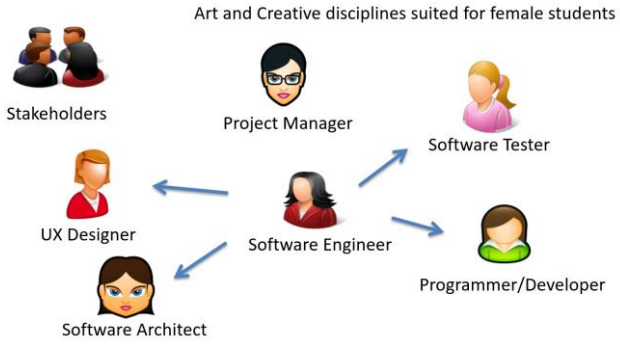


Fig. 9. Roles in software engineering during the studies and in employment. A typical Shad group

VIII. Examples for Inclusiveness and Diversity

According to [9], both genders perform similarly in most disciplines. Results from 100 investigations involving 3 million persons, meta-analysis of differences in performance in mathematics based on gender, indicate that girls outperformed boys in primary school. Further, these results show no difference in performance by the two groups in the secondary school. There were however some ambiguities in the case of the performance by both genders in complex problem solving with a slight bias towards male students. Interestingly, engagement in games by girls is being promoted in some educational sectors. A recent survey done by Entertainment Software Association of Canada indicates that among teen gamers in the age group 13-17, 47% are girls, indicating a good gender balance in gaming.

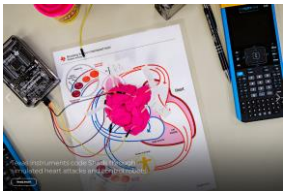
In Latvia, educational guidelines for the period 2014 – 2020 emphasize the importance of STEM in schools, colleges and universities. Different campaigns are going on Latvia for raising awareness of STEM and career opportunities on following an education in STEM. Recently, University of Latvia had a project "International Diploma for School Teachers in STEM Education / eSTEM", the aim of which was to determine the STEM situation in Latvia, to investigate STEM solutions in the world for adapting the best solution out of these to establish a modern STEM education in Latvia, [20-22]. This approach is followed by many nations within Europe and internationally. Similarly, in Germany international summer schools are being organized in the universities at university level.

In Canada, there is a 27 days hands-on program called Shad, with elements of Project Based Learning, involving group work, coding and entrepreneurship. As shown in Fig. 4, SHAD focuses on learning outcomes based on lectures, hands-on experience, PBL with group projects. The organizers focus on the development of individuals and the integration of participants in a community. Shad emphasizes that the learning outcomes and experiences in hands-on workshops addresses topics in STEAM.[According to David Johnston, the 28th Governor General of Canada, "Shad is an ingenious program that more Canadians need to know about. I wouldn't start a university today without experiential learning for every student. The reason is, it combines theory and practice." About thousand Canadian students in grades 10 and 11 participate in summer in nationwide STEAM and entrepreneurship programs addressing different topics. Michele Romanow, Forbes' top 100 Most Powerful Women, participant (called Shad!) in Shad 2003, states that she

reached her current position because of Shad. According to Shad, the focus areas during the summer Shad hands-on sessions are: STEAM and entrepreneurship-oriented labs, seminars and hands-on workshops, a team based hands-on design challenge (#STEAM4Good!), 27 days on-campus Live-in in campus residences thus giving the 10th and 11th graders a taste of university life, Shad-peers enabling meeting and group building of like minded 10th and 11th graders. Fig. 10 summarizes these ideas and aims of the Shad visions very well. STEAM is very clearly an all-pervasive theme in these Shad hands-on projects tackled by thousand 10th and 11th graders in Canada. Fig. 11 shows the Shad flag in front of the hall in McMaster University in Canada in June-July 2019.

Fig. 10 Shad- Summer school catering to Canadian and international pre-university students. STEAM as a major item among others such as project based learning (PBL), living, and working together, from [23].

(a) Shad gathering in McMaster University June-July 2019



(b)National Instruments supporting Shads with hand-on workshops through simulated heart attacks and control robots, Courtesy, Shad, [23].

(c) Shad Canada in McMaster University with an eager high-school student in the background

Fig. 11 STEAM & Entrepreunership program going on in McMaster University, Canada with an eager 10th grader looking at the program. A model for other countries?

National Instruments is one among many companies supporting the Shad course in recruiting youngsters of both genders to develop interest in STEAM and opt for education and career in STEAM. All the different topics shown in Fig. 6 to Fig. 9 above are in fact taken up in Shad. We have not seen similar national endeavors in any country belonging to EU.

Representatives from the Nuclear Waste Management Organization of Canada visited 12 out of 17 campuses in 2019 to teach Shads about Canada's measures for the safe, long-term nuclear management of used nuclear fuel (popularly known as nuclear waste).

IX. Conclusions

STEAM to STEM paradigm of [6] suggests that this observation can be utilized to strengthen the female students to continue their studies in education in STEM. In addition, the suggestions of Melinda Gates related to early exposure to STEM, STEM career awareness and female STEM mentors for girls in preschool and school are important to be taken up seriously by educationists.

There is a general awareness of the necessity of gender balance in the technologies based on STEM education. With the ever-increasing number of acronyms in the technological and educational sector, STEAM for STEM is becoming more and more a reality with changing curricula.

In the USA and Canada, as we have seen STEAM has replaced STEM and many preschool and even kindergarten activities specifically addresses STEAM as a way of achieving gender balance. After all Shad flags, flyers and webpages have this statement: "Shad is diverse and inclusive".

It is however interesting that some researchers are discussing separate courses for the genders, in selected subjects to improve performance. This is a completely different topic to be studied in further detail, [24].

Can EU countries collaborate and organize an event like Shad to address the issues taken up in the recent report from EU, [1] and the challenges discussed in [13]? It is high time that STEAM is given to STEM!

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