On enrolling more female students in science and engineering

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Many people hold this truth to be self-evident that universities should enroll more female students in science and engineering; the main question then being how. Typical arguments include possible benefits to women, possible benefits to the economy, and the unfairness of the current female under-representation. However, when clearly stated and scrutinized these arguments in fact lead to the conclusion that there should be more women in scientific disciplines in higher education in the sense that we should expect more women (which various kinds of discrimination may prevent), not that we should actively enroll more women. Outreach programs towards high school students may therefore be logically incompatible with the arguments supposed to justify them. They should purport to allow women to graduate in a field congruent with her abilities and desires, rather than try to draw as many of them to scientific disciplines as possible: one cannot try to 'recruit' as many female students as possible while claiming to help them choose more freely.

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INTRODUCTION — RAISING A HORSE FROM THE DEAD

Far fewer women than men study science and engineering. It is often argued that women would benefit from graduating in a scientific discipline, due to higher salaries and the possibility to help others. Having more female engineers would also be beneficial to the economy because of the increasing need for engineers and of the positive impact of diversity on designs. Another argument is that this under-representation of women is unfair. Everyone then focuses on how to enroll more women in scientific disciplines.

In most articles on the subject,[a] justifications for enrolling more female students are relegated to the introduction (i.e. the least important and least original part of the article). Some provide no justification at all or very vague ones, such as "for a variety of practical and moral reasons" [1]. The closest authors get to presenting arguments is naming them: they mention the name of an argument —rather than the argument itself—, say that it has been widely used (probably implying that it must therefore be valid), and move on. They for instance say "a lot of people argue for diversity in terms of fairness [...] but that's not my argument" [2], "fairness is one answer, but certainly not the only one" [3], or "aside from the obvious issues of access, fairness and equity" [4] without ever actually making these arguments explicit. Yet, such words do not imply the existence (let alone the validity) of arguments any more than dragons exist because the word 'dragon' does. In fact, everyone is so convinced that asking why universities should enroll more female students in science and engineering would be beating a dead horse that nobody checked that the horse was dead.

They would reply that their arguments need not be made explicit because they are obvious. Also 'obvious' is the revolution of the sun around the earth. Mathematician and philosopher Alfred North Whitehead said that "it requires a very unusual mind to undertake the analysis of the obvious." Such a mind should not be very unusual amongst scientists and engineers. They should be able and willing to "undertake the analysis of the obvious." In the present context, this requires a precise study of these justifications, even (or especially) when they seem obvious. The least this will take is to state arguments

[a] By 'the subject' I mean whether universities should strive to enroll more female students in scientific fields, not why few women actually enroll in science and engineering. In other words, the present article is about questions of policy and prescription, not an empirical description.

explicitly and clearly rather than glibly allude to them. Vague allusions would not be acceptable in scientific journals and there is no reason to lower our standards when writing articles of a different kind.

The objective of WISEST [5] at the University of Alberta is "to investigate the reasons why few young women are choosing careers in the sciences and engineering [and] to take action to alter the situation." This means trying to solve a problem before one is even sure that it exists at all. Yet, science and engineering have been successful in part because one first understands phenomena before using that knowledge for specific purposes. One would expect scientists to apply the high standards of science to the issue at hand — understanding should precede action. If an argument justifies a higher enrollment only under certain conditions then the actions one takes cannot contradict these conditions, lest the policy be literally unjustified. As with a mathematical theorem, if the assumptions under which the argument was obtained do not hold, neither does the conclusion. Therefore, one cannot decorrelate justification and action.

Several kinds of arguments are often mentioned. While more arguments may strengthen one's position, it also means a greater probability that they be mutually exclusive. For instance, some argue that a greater female enrollment in science and engineering is good for the economy —but not necessarily for the women themselves—, whereas to others it is a matter of freedom of choice. While each of these arguments might justify a greater female enrollment, they are obviously incompatible. The purpose of this article is to analyze the arguments most commonly invoked to justify a greater female enrollment in science and engineering. In particular, one must make sure that they are self-consistent, that they do entail what they are supposed to prove, and that they are not incompatible.

MUTUAL ATTRACTION

Motivating the economy

As science and technology play an ever-increasing role in society and economy, the number of science and engineering graduates must increase; and since females and minorities are under-represented they offer great potential sources of engineers [2, 4, 6–18]. Furthermore, more women in engineering would be good because of the greater variety of designs which more diverse teams could invent [2, 3, 6–8]. Likewise, "diversity in the community of scientists, because it increases the disparity of viewpoints from which hypotheses are derived and tested, is necessary both for discovering truth and avoiding error" [19]. One must be careful not to confuse such factual statements with metaphysical ones [20] — for instance, "ASEE believes that diversity enriches the educational experience and improves the practice of engineering" [21] mixes matters of belief and of fact.

These arguments seem altruistic since women can *contribute* to the economy: "More compelling arguments have been raised that recognize the direct benefits that female participation is likely to have upon these fields" [8]. But compelling for whom? These arguments may indeed efficiently motivate science and engineering to attract women, but is this sufficient? Even if the "imperative to educate math and science professionals is immediate and unconditional" [16], can it justify everything? In essence, these arguments treat women as mere pawns to be transferred from one department to another for the sake of the economy. But then one must be consistent and favor anything which contributes to the economy. For instance, if child labor and child pornography can benefit the economy, one should demand that they be legalized. Clearly, benefits to the economy are not sufficient — an argument relying on them must show that they are more important than any possible negative consequence. One cannot claim economic benefits in the 'pro' column and neglect to inspect the 'con' column. Such an argument is invalid unless it is shown that the benefits are greater than the drawbacks. And this has not been done (or even attempted) so far.

Even if the advantages were greater than the drawbacks, there would remain the question of whether one can force somebody to do something for the benefit of others. From a Kantian viewpoint, this is wrong because one should never treat people merely as means, but always as ends. To utilitarians, good means maximizing the happiness of the greatest number; if women do not want to become scientists or engineers, having more of them in the field will decrease their happiness while increasing that of others

only marginally. From either viewpoint these economic arguments must be rejected if women do not want to study science and engineering, i.e. they are not valid justifications on their own.

There are several ways out of this problem. One may ignore the issue altogether; this is ever popular yet not quite satisfying. One may stand by the premise of efficacy maximization and accept its logical consequences; this is self-consistent but quite appalling. One may claim that there exist particular cases; but a rule with too many exceptions is no rule at all. One may provide a refined argument which does not endorse child labor and child pornography; but this path is at best narrow and it may not even exist. Finally, one may acknowledge that the fact that science and engineering should want to attract women does not imply that there *has to* be more women in science and engineering: what women want is crucial.

Motivating women

"The compensation in science-related fields is often higher than that of other fields. By not participating in science-related fields, women are barred from the economic rewards of these fields" [8]. Sullivan *et al.* [4] make it clear early that engineering means money by paying high school girls to attend their summer engineering workshop. However, if money were all that matters, why would there be engineering schools at all, given that engineering professors could earn more in industry? Apparently, women do not pick a field trying to maximize their income either: "clearly, if monetary incentives were enough, current starting salaries would have already fixed the problem" [2].

Women are more likely to stress interpersonal factors (e.g. helping others), whereas men tend to value money and status more [22, 23]. Would engineering allow women to help others? The former president of the U.S. National Academy of Engineering argues that engineering does have a positive impact on society and provides an opportunity to help others [2]. Let us assume for the sake of argument that he is right. What does this argument actually prove? It shows that women are mistaken if they choose not to study science and engineering because they believe that it will not allow them to help others. That is, such an argument shows that women should want to major in scientific disciplines. It does not show that there has to be more women in science and engineering.

Weaknesses of the argument by mutual attraction

We must first notice that taken in isolation demographics, better designs, higher salaries, and helping others all fail to justify anything. It is necessary that both women and the economy have an interest in an increased female enrollment, i.e. it is necessary to invoke these arguments together. Although having only one argument is not as satisfying as having four, it can be sufficient. But is this argument really satisfactory?

Do women want to marry science? They do. Does science want to marry women? It does. But if they decide not to marry, does one have a good reason to marry them against their will? As Appiah [24, p. xii] points out, "my life's shape is up to me [...], even if I make a life that is less good than a life I could have made. All of us could, no doubt, have made better lives than we have: but that is no reason for others to attempt to force these better lives upon us. Thoughtful friends, benevolent sages, anxious relatives will rightly offer us both assistance and advice as to how to proceed. But it will *be* advice, not coercion, that they justly offer." In essence, this argument by mutual attraction tells us what to *expect* but does not provide us with any justification to make it happen if it does not spontaneously take place. In other words, 'more women should be enrolled' does not imply 'we should enroll more women.' One must notice that 'should' denotes an expectation in the first sentence but a decision in the second: these two statements, however similar they may seem, are actually very different. This 'argument' is in fact an expression of surprise rather than a justification for actively increasing female enrollment.

Since the needs of the economy and the possibility to help others are not universal, neither is the win-win situation. For instance, it is doubtful that *all* engineers have a positive impact on society: do weapons of war and buggy operating systems help others? Even if it is because of a small minority, the

claim that engineering has a positive impact on society collapses: only certain jobs would be motivating, not any engineering job. Moreover, the need for engineers is not eternal (demand may decrease due to recession, outsourcing, etc.) and engineers from all fields are not wanted everywhere all the time. The question 'should there be more women in engineering?' is thus meaningless: there are as many questions as fields, times, places, etc. You can justify all female enrollment some of the time, and some female enrollment all the time, but you cannot justify all female enrollment all the time. What looked like a justification for a greater female enrollment in science and engineering is in fact career counseling.

Those arguing in favor of a greater female enrollment in scientific fields typically fail to notice that these extra female students must come from somewhere. But whence? If more female physicists means fewer female physicians, this is not necessarily an improvement (it may be bad for the population as a whole, it may be bad for female representation in medicine, etc.). The question of women in science and engineering cannot be addressed in a vacuum: indirect effects also matter. What is needed is a global rather than a partial solution — that more female physicists would be good is irrelevant if more female physicians would be even better. (In mathematical terms: one needs to use differentials rather than partial derivatives.) Further, one cannot argue that more women should graduate in science without thereby arguing that fewer women should graduate in other fields. This requires to argue that science is somehow superior to other fields — that science has a lot to offer is irrelevant, what matters is what it has to offer that others do not offer. That is to say, one must get one's hands dirty and compare fields.

Since people other than women undoubtedly bring new ideas (which can lead to new designs) the focus on women seems arbitrary — one should seek to hire anybody who can contribute original ideas [20, 25]. Moreover, foreigners (possibly hired due to the lack of local engineers) are definitely one such category. The low enrollment in engineering schools is therefore beneficial to society since it leads to more creative designs through the hiring of foreign engineers. This is another example of incompatible arguments: if diversity is crucial then low overall enrollment in scientific fields is a solution, not a problem.

FAIRNESS

Under-representation: statistical viewpoint

It is typically taken for granted that, since women are under-represented in science and engineering, their enrollment should be increased [4, 12–17, 26–30]:

(1) Women are under-represented.

(2) Their enrollment ought to be increased.

(3) They are not under-represented any more. QED.

It is important to notice that under-representation is of a statistical nature (lower proportion of women than in the overall population), it is neither good nor bad *per se*. Consequently, women cannot be "woefully underrepresented" [31] and, despite what Chubin *et al.* [15] believe, "improving" or "promoting" the number of women does not have any meaning. Likewise, the claim of Baum [12] that "the numbers speak for themselves, demonstrating a significant problem in recruiting and retaining women" is ventriloquism. Moreover, if under-representation were wrong in itself then the under-representation of women in prison would imply that we should 'enroll' more female inmates [32].

According to Nozick [33, p. 232], "it depends upon how the distribution came about. Some processes yielding these results would be legitimate, and the various parties would be entitled to their respective holdings. If these distributional facts *did* arise by a legitimate process, then they themselves are legitimate." Even though he was referring to a different kind of distribution, the main idea —the result is legitimate if the way it came about is— also applies to female enrollment. Why should there not be more women in jail? Because the process leading to the result of few female inmates is legitimate (women commit fewer crimes). The question is then whether the process leading to a low female enrollment in scientific disciplines is legitimate. But this question is wholly different from under-representation. Clearly, one cannot simply say without any explanation that because there are few women in science

and engineering there ought to be more (saying that there are *too few* women would already assume that there ought to be more). As David Hume famously pointed out, one must be very careful when trying to derive an 'ought' from an 'is.'

Under-representation: ethical viewpoint

Under-representation taken in this crude statistical sense is obvious but does not in itself justify to increase female enrollment. Instead we should define under-representation by changing the reference from the average population to the situation in a perfectly fair world, i.e. a world devoid of prejudice, discrimination, and other biases. Women are then said to be under-represented if the level of female enrollment in the actual world is lower than what it would be in a perfectly fair world. This new definition is less straightforward than comparing enrollment to the proportion of women in the overall population (in particular this ethical under-representation cannot be measured numerically) but it can link under-representation to unfairness, which the latter cannot do. In particular, it does not justify an increase of the number of female inmates, which is obviously an improvement.

One speaks of equal opportunity when people who have equivalent abilities and who perform an equivalent amount of work reach equivalent results. In a perfectly fair world, men and women would obviously have equal opportunities. What about the real world? The low enrollment of females in science and engineering indicates that they do not reach similar results. But do men and women have similar abilities? Moreover, there can be unfairness only if women who want to study science are barred from the field, not if low enrollment springs from low interest. One must therefore examine both the abilities and motivations of women compared to men.

Sexual differences in abilities and occupational interests

Due to the greater variability of males compared to females, men are over-represented at the top [34] and at the bottom of intellectual ability, e.g. four times as many boys as girls are dyslexic [35]. Moreover, men and women have different strengths: women typically have better verbal skills and men mathematical and spatial abilities; this difference is (at least in part) hormonal and has been observed in non-human species [36]. Men and women do not differ only in terms of abilities, they also make different choices. On Holland's vocational interest test, women score higher on the 'artistic' and 'social' dimensions and men on the 'investigative' and 'realistic' (relevant to science and engineering) dimensions [37]. Lips [38] also found that among upper level university students "women reported more ability for and identification with the arts, communication, and social sciences; men reported more ability for and identification with mathematics, science, technology, and business." Part of the difference is biological: many sex-differentiated behaviors appear at an early age when children are unable to identify sexes [39, 40] and sexual differences of taste have been found in non-human species [41]. Part of the difference is due to socialization: parents, teachers, and the students themselves typically have lower expectations in math for girls compared to boys [42, 43].

While social biases would not exist in a perfectly fair world, biological differences would. Hence, all one can conclude is that the fair level of enrollment is above the current figure (which is too low due to social biases) but below 50% (innate differences prevent this). While this conclusion seems anticlimactic, any claim beyond this (e.g. that the fair level of enrollment is close to 50%) would be mere opinion, as it would *assume* that one of the two contributions dominates. For instance Gates [27] claims that "institutions that award fewer than about 40% of bachelor's degrees [in physics] to women should be actively investigating to find out why" but does not explain where this number comes from. Many authors enjoy providing ample references showing how few girls are in scientific disciplines but they do not seem to notice that such statistics do not in any way imply that there should be 50% (or 40% or any other equally arbitrary number) of female students in science and engineering.[b]

[b] Many authors talk of a "leaky pipeline" —i.e. the fact that the older the girl the less interested she is in science and

Fairness and freedom of choice

The ethical definition of under-representation is an improvement but does not suffice. If all women studied science then obviously there would be no under-representation. Yet, this would be far from ideal since it would require forcing many women to study science against their will. Indeed, under-representation —even defined ethically— is intrinsically asymmetric: it can see when there is too little but is blind to cases of too much. A symmetric criterion would say that women should be neither barred from nor forced to the field. One can notice that this is not based on averages but on individuals. In effect, this means giving up the superfluous concept of under-representation altogether. We will simply say that fairness exists when all women can graduate in a field congruent with their abilities and desires. One must also notice that enrollment numbers too are irrelevant, since they take women to be indistinguishable. They may be useful to draw our attention to a problem but one must eventually give them up to focus on the actual problem [20]. Should there be more women in science and engineering? No. There should only be more women in science and engineering who want to be in these fields.

IMPLICATIONS FOR OUTREACH PROGRAMS

As we have seen, many people argue that there should be more female students in science and engineering. The next step they take is to try and increase female enrollment in these fields. A popular solution takes the form of outreach programs towards high school girls, giving them a more hands-on experience of science and engineering [4, 8–10, 12, 13, 28, 29, 44]. (Some start earlier: "I am convinced that elementary school is not too early to start building the foundation for an engineering education" [45]).

The more the better

Outreach programs are considered 'recruitment' and their success is measured in terms of number of participants who eventually enroll in science and engineering [3, 4, 6–15, 28–30]. Clearly, this equates more with better: the purpose is to get as many women as possible to scientific fields, independently of what these women want. In effect, it treats them as statistics rather than as individuals. Bean counters may parade as grand liberators, but even when the rhetoric mentions a free career choice —e.g. "women pursuing their *interests* in science" [44, emphasis added]—, success is measured in terms of numbers.

One must keep in mind that the reason why outreach programs were created in the first place was that the number of female students in science and engineering was artificially low, due to the impossibility for girls to freely choose a career in these fields. But outreach programs tend towards the opposite extreme: an impossibility for girls to freely choose *against* a career in science or engineering. It would certainly be paradoxical to trample their right to a free choice in order to enforce it. Sharing one's love for science and trying to cancel out a negative bias are very different from preaching the science gospel and actively converting girls. Manipulating a girl towards science is not any more acceptable than manipulating her away from it. "All forms of tampering with human beings, getting at them, shaping them against their will to your own pattern, all thought control and conditioning is, therefore, a denial of that in men which makes them men and their values ultimate" [46].

Some insist that many outreach programs are voluntary. Yet, one cannot say that outreach is justified because girls cannot choose freely their career and that outreach cannot be an issue because the girls freely choose to attend. Either girls can choose freely and outreach is pointless or girls are

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engineering— and want to get rid of this 'leak' (see for instance Widnall [18]). Yet they tend to forget that this is a simile, not an argument. One can also say that a difference between girls in elementary school and in high school is that the latter have breasts. Can one infer that this difference is due to social pressure? Should one try to put an end to this phenomenon?

not free to choose and outreach can indeed create a new servitude. In either case, outreach programs shortchange girls.

Who makes the choice?

Some will also counter that none of the authors cited actually argued that women should be forced into science and engineering. Yet, none argued that women should *not* be forced into these disciplines either. Neither do they at any time explain how they try to prevent this from happening. The question of freedom of choice thus seems morally neutral to them (while the claim may not be explicit, it is embodied in their actions). Since they do not see freedom of choice as relevant, they cannot take it into account.

Empirical studies show that "people form enduring interests in activities in which they view themselves to be self-efficacious" yet "people may rely more on perceived than tested abilities in formulating their interests" [47]. By showing girls that they can be successful in science or engineering, one does not expunge past influences to increase their freedom of choice. Rather one generates a new influence, this time in favor of the scientific disciplines. It is not possible to erase social biases, one can only overwrite them: outreach is bound to tamper with the girls' interests and manipulate girls towards scientific fields.

Take three girls. Tell the first one how rewarding science is and show her that she can be a successful scientist. Do the same with the other two girls and medicine and law. What will happen? The first girl will graduate in science, the second in medicine, and the third in law. Does the outcome correlate with what the girls want? Not at all. It correlates with the viewpoint that they have heard. *We* are the ones making a decision by choosing what information we give them.

Reinventing outreach

While the idea that more is better is clearly mistaken, finding a practical replacement is not straightforward: obviously, assessing the match between a (possibly unexpressed) preference and a career is more difficult than assessing enrollment. Just as obviously, one should never set a goal just based on how easily success can be evaluated.

Were we to tell girls all they need to know about the many alternatives (science, engineering, art, business, journalism, law, medicine, staying at home, teaching, etc.), they may be able to make a personal informed choice. Those who believe that science and engineering have mostly an image problem (e.g. Wulf [2]) would expect this to solve the problem since, even if competing choices are also presented in a fair way, science and engineering would benefit the most. If they are right then the issue of low female enrollment can be resolved without trampling the rights of the girls to choose freely. (One can notice that this is not science and engineering outreach anymore, but rather fair and neutral career counseling.)

Strictly speaking, the fact that none of the arguments supposed to justify a greater female enrollment actually does does not prove that outreach programs are an error. What it does show is that no valid argument has been offered, which justifies outreach programs in their current form. One may either revise programs to make them consistent with what justifies them (i.e. make them justified) or one may propose a new argument proving their validity. In any case, one cannot continue programs devoid of rational justification.

CONCLUSION

Many in science and engineering hold this truth to be self-evident, that there should be more women in the field. I considered several commonly proposed justifications: higher salaries, the possibility to help others, the increasing need for engineers, and the positive impact of diversity. When made explicit and seriously scrutinized, they in fact show that there should be a mutual attraction between women

and scientific fields, i.e. there should be more women in scientific disciplines in the sense that we should expect more women. These arguments do not show that we should actively enroll more women: they do not justify 'recruitment.'

Many claim that women are under-represented in science and engineering and that, out of fairness, their enrollment should be increased. Yet, under-representation is statistical in nature, it is neither right nor wrong. Upon trying to redefine it to make it an ethical concept, I obtained a criterion that does not mention under-representation or enrollment numbers and simply states that all women should be allowed to graduate in a field congruent with their abilities and desires.

As currently conceived, outreach means trying to sell our product (science and engineering) to as many potential female customers as possible. It does not aim at empowering women to choose freely any more than any other sales pitch does. Since drawing always more women to science and engineering violates their right to choose a career freely, a change of mindset —a 'paradigm shift'— from increasing enrollment to increasing freedom is necessary. Since presently outreach is incompatible with its justifications, programs have to be modified to be really justified (or better arguments must be proposed to justify the programs in their current form). Of course, this is easier said than done: trying to allow women to choose a field freely would be a moral dream but also a practical nightmare. Nevertheless, one cannot go on undisturbed on a path which is plainly the wrong one.

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