Should there be more women in science and engineering?

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Many people hold this truth to be self-evident, that there should be more female students in science and engineering. We first examine four usual arguments: higher salaries, the possibility to help others, the positive impact of diversity on designs, and the increasing need for engineers. These indicate that there ought to be a mutual attraction between women and scientific fields, so that there should be more women in these fields inasmuch as women are motivated to graduate in science and engineering. Another common argument is that women are under-represented in scientific fields. Yet under-representation is morally neutral and cannot by itself be a justification. Focusing on ethics rather than statistics, we conclude that every woman should be allowed to graduate in a field congruent with her abilities and desires. This is similar to the result of mutual attraction. Outreach programs towards K–12 girls must therefore purport to allow them to choose a field freely, rather than try to draw as many of them to scientific disciplines as possible. At the very minimum, this will require an evaluation of the impact of outreach and a change of mindset.

Keywords: female students, gender equity, higher education, university, ethics, policy, outreach programs, minority students

I. RAISING A HORSE FROM THE DEAD

The idea that there should be more female students in science and engineering and the consequent policies are so important, are discussed so much, and can affect so deeply the lives of so many people that one would expect them to have strong foundations. In fact, everyone is so convinced that asking whether there should be more women in science and engineering would be beating a dead horse that nobody checked whether the horse was dead.

Precise arguments are unnecessary: there should be more female students in scientific fields "for a variety of practical and moral reasons" (Felder et al., 1995). The closest that 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." (Wulf, 1998), "fairness is one answer, but certainly not the only one." (Gosink, 2001), or "aside from the obvious issues of access, fairness and equity" (Sullivan et al., 2003) 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.

These authors would probably reply that these arguments do not really need to be made explicit because they are obvious. It is also obvious that the sun revolves around the earth. Since what seems obvious may turn out to be false, arguments have to be stated explicitly and convincingly rather than glibly alluded to (this must be done at least once, then one can rely on what is from then on a genuine argument without repeating the whole of it). When authors try to make their arguments explicit (the exception rather than the rule) the result can be incoherent, e.g. "with the predicted shortage of engineers by the year 2000, employers cannot be satisfied with anything less than the very best engineers available" (Zywno et al., 1999). One must make sure that the arguments are self-consistent, compatible with one another, and do entail what they are supposed to prove. This requires to present them explicitly.

Several kinds of arguments are mentioned. Having several independent arguments may strengthen one's position. Unfortunately, more arguments also means a greater probability that they be mutually exclusive. For instance, some argue that a greater female enrollment in science and engineering is supposed to be good for the fields —but not necessarily for the women

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themselves—, while others claim that female enrollment in science and engineering is a matter of freedom of choice. While each of these arguments might justify a greater female enrollment, they are obviously incompatible. As long as reasons are taken in isolation, they might seem convincing. When they are considered together, on the other hand, one starts noticing such inconsistencies. Part of the point of this article is to look under the rug, pick up mutually exclusive arguments and see to what extent they can be reconciled. Like in movies where a man has several lovers it gets interesting only when the lovers meet one another. Let us see if our incompatible arguments will plot a revenge against the cheating idea that there should be more women in science and engineering.

II. MUTUAL ATTRACTION

A. Motivating science and engineering

As technology plays an ever-increasing role in society and economy, the number of engineering graduates must increase and since females and minorities are under-represented they offer great potential sources of engineers (Baum, 1990; Brainard & Carlin, 1998; Chen et al., 1996; Cuny & Aspray, 2000; Moskal, 2000; Rockland et al., 2002; Sullivan et al., 2003; Wulf, 1998; Zywno et al., 1999). Furthermore, more women in science and engineering would be good because of the greater variety of designs which more diverse teams could invent (Cuny & Aspray, 2000; Gosink, 2001; Moskal, 2000; Wulf, 1998).

These arguments seem altruistic since women can *contribute* to the economy: "More compelling arguments [than a higher income] have been raised that recognize the direct benefits that female participation is likely to have upon these fields." (Moskal, 2000). But compelling for whom? These arguments may efficiently motivate science and engineering to attract women, but this is not sufficient. In essence, these arguments treat women as mere pawns to be transferred from one department to another based on some external reason (e.g. the economy). Can one force somebody to do something for the sake of others? According to Immanuel Kant (1785), 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 (Bentham, 1789; Mill, 1871). If women do not want to become engineers, having more of them in the field will decrease their happiness while increasing that of others only marginally.

These economic arguments achieve the great fit of getting to agree (against them) ethical views which seldom do so: be it from a Kantian or a utilitarian viewpoint, these arguments must be rejected if women do not want to study science and engineering, i.e. they are not valid justifications on their own. 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.

B. Motivating women

A common argument is that "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." (Moskal, 2000). Sullivan et al. (2003) 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" (Wulf, 1998).

Studies show that women are more likely to stress interpersonal factors (e.g. helping others), whereas men tend to value money and status more (Eccles, 1994; Morgan et al., 2001). Would engineering allow women to help others? The 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 (Wulf, 1998). Let us assume for the sake of argument that he is right. What does this argument actually prove? It shows that women are wrong if they choose not to study 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 engineering. Which does not imply that there *has to* be more women in engineering.

C. Three shortcomings of the argument by mutual attraction

We must first notice that taken in isolation contributions to the economy, higher salaries, and helping others all fail to justify anything. It is necessary that both women and the fields 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 engineering? They do. Does engineering want to marry women? It does. But what if they do not decide to have a relationship? One may be disappointed and one may try to convince them that they are making a mistake. But one has no good reason to marry them against their will (even if one is convinced that their will is mistaken). In essence, this justification by mutual attraction tells us what to expect ('there should be more women in science and engineering' here means that one would expect to find more women in these fields) but does not provide us with any justification to make it happen if it does not spontaneously take place. One can only be a spectator, perhaps an advisor but not a *deus ex machina*: one can try to show women that engineering would be great for them but one must then let them make their own decision. Many will see this impossibility to intervene as a shortcoming of this argument.

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. Yes, there should be more women. But only in some fields of engineering. Only at some times. Only in some places. 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.

D. Efficacy as an argument

For the sake of precision, we must point out that the argument by improved design is not quite identical to that of the need for more engineers in that better designs may directly improve people's lives. Nevertheless, for this argument to have any strength, one must describe what the precise benefits would be and in what women would bring them about — that a design is bad does not imply that women would have necessarily done better. A general rule such as 'on average, more feminine teams create better designs' may theoretically be induced from such examples beyond reasonable doubt. But this requires more than a few isolated examples (and it requires to look for cases of better designs by men, since these too should be taken into account in the average). Clearly, the positive impact of women on designs has not been satisfactorily established so far (which does not mean that the argument is intrinsically invalid).

One should notice that women are not the only ones who can contribute to diverse designs. Foreigners (possibly hired due to the lack of local engineers) undoubtedly bring new ideas, which can lead to new designs. The low enrollment in engineering schools is therefore beneficial to society since it leads to better designs. This is another example of incompatible arguments: if diversity is crucial then low overall enrollment in scientific fields is a solution, not a problem.

Some argue that one needs more female engineers independently of what women want. Whether this is correct or not, one must at the very least be consistent and apply the same rule to all possible contributions to the economy. If child labor and child pornography can benefit the economy, should they be legalized? Also, why not directly draft the best students to science and engineering instead of allowing them to choose? In order to avoid these extreme consequences, one needs to provide an argument which *unconditionally* shows that there should be more women in engineering without endorsing child labor and child pornography. This path is at best narrow and it may not even exist. In the absence of such a rebuttal, we must acknowledge that the interests of engineering cannot, in themselves, unconditionally justify a greater female enrollment in the field.

Any argument based on efficacy (what is good for the economy, what leads to better designs) may have consequences abhorrent to its proponents, e.g. endorsement of child labor and child pornography. 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 will never get wide approval. One may claim that there exist particular cases but a rule with too many exceptions is not a rule at all. Finally, one may look for an argument of a completely different nature, which would not have the dreadful consequences of efficacy.

III. FAIRNESS

The argument by mutual attraction examined in the previous section turned out to be much weaker than its proponents believe. However, all hope is not lost: there still are possible objective arguments to consider, for instance fairness and diversity.

A. Diversity

The argument of diversity is widely used to justify a greater enrollment of minorities in universities: "affirmative action policies are justified because they ensure the creation of the racially and ethnically diverse student bodies essential to providing the best possible educational environment for students, white and minority alike." (Gurin et al., 2002) If students do not have a chance to come in contact with minorities, they will have a more limited view on many intellectual and social subjects because they miss a "wide exposure to the ideas and mores of students as diverse as this Nation of many peoples" (Powell, 1978). However, this argument cannot be applied to the under-representation of women since both sexes are typically present in one's family and schools are generally coeducational: although everybody one knows may be from the same social class, race, religion, etc. one has always lived in a 'sexually diverse' environment (Correll, 2001). Increasing female enrollment in universities would therefore not have the same beneficial consequence as increasing minority enrollment.

B. A tautology?

Since diversity fails to justify an increase in female enrollment, we turn to fairness as a possible justification. Typically, one just utters the word 'fairness' and expects everybody to bow. There seems to be no need to clarify what one means by 'fair' nor in what a higher female enrollment would be fair. Yet, the existence of rather idiosyncratic interpretations (e.g. to Moskal (2000) fair means "economic rewards" — as in 'a *fair* share of the booty'?) shows that the meaning of the word is not self-evident. Many people use 'fair' in a very loose way, as a synonym of 'moral' or 'good'. In this case, it has no precise meaning, just a vague positive value: 'we should do what is fair' then means 'we should do what is good', i.e. 'we should do what we should do'. This tautology is obviously of no help to decide what we should concretely do.

C. The superiority of science and engineering

Another way to construe fairness is to say that science and engineering being superiorly good, everybody should 'have a piece.' This is true for instance of freedom, justice, education, etc. Yet, this requires that these fields be indeed superior. Based on some criteria they may be, but then one needs to show that these criteria are intrinsically superior to any other, with the risk of an infinite regression. Moreover, most fields are probably convinced of their own superiority (like most religions are convinced that they are the one true religion) and there is no reason to assume that science and engineering are right and everybody else is wrong.

Sullivan et al. (2003) claim that "all citizens should be equipped with knowledge and experience to make informed choices on issues involving technology." This argument may justify enrollment in one engineering class, but should one really pursue a degree in engineering in order to equip oneself with the knowledge and the experience required to choose the right MP3 player? Is it not

more important to learn foreign languages on small planets or law in countries ruled by lawyers? The superior need for generalized scientific and technological education is not striking.

No demonstration of the superiority of scientific disciplines has been provided. The burden of proof is on those who hold that fields are not equally acceptable career choices. Until such a proof is provided, we must assume all fields equal.[1] "We should not be sending these young women the message that they are less worthy human beings, less valuable to our civilization, lazy or low in status, if they choose to be teachers rather than mathematicians, journalists rather than physicists, lawyers rather than engineers." (Kleinfeld, 1999).

D. 'Is' or 'ought'?

As a matter of fact, "while women make up over 50% of the college-age population in the U.S., they represent a small minority among engineering students" (Chen et al., 1996). Yet, does it really imply that it is "critically important that the causes for the low enrollment and high attrition rates of female engineering students be identified and eliminated" (Chen et al., 1996)? This claim relies on the simplest (and most common) of arguments based on under-representation: having no argument at all (Anderson & Northwood, 2002; Baum, 1990; Brainard & Carlin, 1998; Chen et al., 1996; Morgan et al., 2001; Sullivan et al., 2003; Zywno et al., 1999). (1) Women are under-represented. (2) Their enrollment ought to be increased. (3) They are not under-represented any more. QED.

Yet, under-representation is of a statistical nature (lower proportion of women than in the overall population), it is neither good nor bad *per se*. The claim that "The numbers speak for themselves, demonstrating a significant problem in recruiting and retaining women." (Baum, 1990) is just ventriloquism. If under-representation were wrong in itself then the under-representation of women in prison would imply that there should be more female inmates: the numbers speak for themselves, demonstrating a significant problem in recruiting and retaining female inmates. It should now be obvious that 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 (1739–40) pointed out, one must be very careful when trying to derive an 'ought' from an 'is'. If one means to equate under-representation and unfairness, a link between the two must be provided explicitly.

E. Under-representation as unfairness

Under-representation taken in this crude statistical sense is obvious but irrelevant. Some, such as Cuny & Aspray (2000), seem to vaguely see that the problem cannot be purely statistical as "underrepresentation translates into a *loss of opportunity* for individuals" (my emphasis), yet they do not grasp the implications since they still aim for "an effort by all departments to increase the total number of women." For under-representation to be a valid argument, it indeed must be (re)defined to be ethical, rather than statistical, in nature.

We use as reference 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 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

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[1] This is a second major difference compared to affirmative action (the first was that female students cannot contribute to diversity the way minorities do): while a college education and a college degree are better than no higher education, science and engineering are not intrinsically superior to other fields. Due to these crucial differences, arguments in favor or against affirmative action cannot *a priori* be assumed to apply equally well to the case of women in science and engineering, and *vice versa*.

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. We must therefore examine both the abilities and motivations of women compared to men.[2]

F. Sexual differences in abilities and occupational interests

Due to the greater variability of males compared to females, men are over-represented at the top (Hedges & Nowell, 1995) and at the bottom of intellectual ability, e.g. four times as many boys as girls are dyslexic (Kleinfeld, 1998). 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 (Browne, 2005).

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" (relevant to math and natural sciences) and "realistic" (relevant to engineering) dimensions (Kaufman & McLean, 1998). Part of the difference is biological: many sex-differentiated behaviors appear at an early age when children are unable to identify sexes (Connellan et al., 2000; Serbin et al., 2001) and sexual differences of taste have been found in other species (Alexander & Hines, 2002). Part of the difference is due to socialization: parents (Jacobs & Eccles, 1985), teachers (NSF, 1994), and the students themselves (Hyde et al., 1990) typically have lower expectations in math for girls compared to boys.

While social biases would not exist in a perfectly fair world, biological differences would. Hence, all we 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.

G. Women are individuals

The crude statistical definition of under-representation, which uses the overall population as reference, is a mere description: it carries no moral value and can therefore not be an argument. We had to redefine under-representation in order to root it in ethics. This is an improvement but does not suffice. If all women studied science then obviously there would be no under-representation. However, this would be far from ideal since it would require to force many women to study science against their will. Indeed, under-representation —even redefined 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. Satisfaction of this criterion will put an end to under-representation but without the shortcomings of the latter.

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[2] Some argue that the important question is in fact not 'why should there be more women in science and engineering?' but rather 'why are there few women in science and engineering?'. Yet, if one had the answer to the latter, one would wonder what one should *do* based on this knowledge. In essence, one would ask if there should be more women in science and engineering. Therefore 'why are there few women in science and engineering?' is of a secondary importance and matters only inasmuch as it can shed some light on why there should be more women.

H. Fairness and freedom of choice

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. Once again, the proposed justification fails to *unconditionally* prove that there should be more women in scientific fields. In fact, it proves that there should *not* be more women in science and engineering in all cases.

In Sec. II, we concluded that the mutual attraction between women and scientific fields would work only inasmuch as women are motivated to graduate in these fields. In the present section, we showed that all women willing and able to study science and engineering should be allowed to and that others should not be forced to. These two viewpoints —one based on efficacy and the other on fairness— lead to surprisingly similar conclusions. (A third approach, based on 'common sense', would give the same result.) We can therefore be confident that our conclusion that every woman should be allowed to graduate in a field congruent with her abilities and desires is robust. This conclusion has never been explicitly derived before. We did find a good reason to increase female enrollment in science and engineering. But it applies only under precise conditions and it was more demanding than merely mentioning 'under-representation' or 'fairness'.[3]

IV. OUTREACH PROGRAMS AND FREEDOM OF CHOICE

A. The fair expectations

What does 'should' exactly mean in 'there *should* be more women in science and engineering'? Let us consider a simple analogy. We had two bottles of champagne and drank one, therefore there should be one left. Here 'should' obviously has to do with a rational expectation based on the circumstances: it would not be immoral if it turned out that no champagne was left, it would be illogical. If expectation and reality clash, something must be wrong with the premise: maybe we drank the second bottle or we had only one bottle to begin with. It would be silly to say that since there should remain a bottle and none is to be found, we should go buy another one to solve the problem. This would be solving the wrong problem.

Likewise, 'based on fairness, there should be more women in science and engineering' means that one expected more women. Since there is a discrepancy between expectation and reality, something must be wrong with the premise (fairness). Increasing female enrollment for its own sake would be like buying another bottle to replace the missing one: it would solve the wrong problem. In other words, the fact that there should be more women in science and engineering does not necessarily imply that one should increase female enrollment. The only logical solution is thus to deal with the unfairness directly. Policies aiming at increasing the number of women in science and engineering typically include some form of outreach program towards K–12 girls. Acting early seems necessary, but is it sufficient?

B. Kant on outreach

Zywno et al. (1999) found that 57% of the surveyed girls who had attended their summer camp and were currently enrolled at a university were in engineering and 35% in other science-related fields. This proves that outreach programs are wrong. At least Kant (1785) would so argue. Indeed, according to his categorical imperative, one should follow only those rules which could consistently be made universal laws. If outreach programs were universal laws, under 10% of women would major in non-scientific fields. This would create an even greater disorder than the problem one meant to solve, as it would necessarily lead to dreadful manpower shortages in some

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[3] Some will probably claim that the arguments studied here are misrepresentations. This may be true. However, since the reasons for an increased female enrollment are numerous, self-evident, compelling, etc., it is nearly impossible to find explicitly and clearly laid out justifications in the literature. In order to evaluate the validity of these arguments, we had to make them explicit and clarify them. This sometimes borders on the mind-reading —for instance, is a greater income supposed to be a matter of fairness (Moskal, 2000) or of motivation (Wulf, 1998)?—, which may look like misrepresentation.

fields. However, this argument relies on very large enrollment numbers, i.e. on a dramatic 'success' of outreach. We will now turn to viewpoints which do not require such a strong assumption.

C. The more the better

Measuring success in terms of number of participants who eventually enroll in science and engineering *de facto* equates more with better. Calling outreach programs a "successful recruitment strategy" (Zywno et al., 1999) when female enrollment is high or more generally seeing outreach as 'recruitment' (Anderson & Northwood, 2002; Baum, 1990; Brainard & Carlin, 1998; Cuny & Aspray, 2000; Gosink, 2001; Moskal, 2000; Rockland et al., 2002; Sullivan et al., 2003) clearly means that the purpose is to get as many women as possible to scientific fields. Even when the rhetoric mentions a free career choice, the actual goal is to increase enrollment numbers: Muller & Pavone (1997) talk of "a commitment to increase the number of women pursuing their *interests* in science" (my emphasis) yet measure success in terms of numbers ("percentage of women in Dartmouth's graduating class who were science majors rose from 12% to 25%. The proportion of women represented among engineering majors rose to 25%.")

The idea that more is better relies on the crude statistical concept of under-representation which was dismissed in Sec. III. Using a more adequate criterion, we found only reasons to increase the number of women enrolled in science and engineering who want to be in these fields. This is an important theoretical improvement but it leads to a major practical problem: obviously, assessing the match between a (possibly unexpressed) preference and a career is far more difficult than assessing enrollment. Just as obviously, one should never set a goal just based on how easily success can be evaluated.

D. Freedom of choice

In any case, one cannot cut corners and assume that in fact every girl unknowingly wants to become an engineer 'deep down'. One must keep in mind that the reason why outreach programs were created in the first place was that the number of females in science and engineering was artificially low, due to the impossibility for girls to freely choose a career in these fields. However, outreach programs seem to lead to 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 engineering 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.

Some may counter that none of the authors cited actually argued that women should be forced into science and engineering. Yet, none of the authors argued that women should *not* be forced into these disciplines either. Nor do they at any time explain how they try to prevent this from happening. It thus seems that the question of freedom of choice is morally neutral to them (while the claim may not be explicit, it is embodied in their actions). Since freedom of choice is not seen as relevant, it cannot be taken into account when designing the programs.

Some insist that many outreach programs are voluntary. Yet, one cannot say that outreach is justified because girls cannot choose freely and that outreach cannot be an issue because the girls freely choose to attend. This is obviously inconsistent since it would require that girls be both free and not free. Either girls can choose freely and outreach is pointless or girls are not free to choose and outreach can indeed create a new servitude. In either case, outreach programs shortchange girls.

E. Giving up outreach?

One may agree that the importance given to numbers may *theoretically* drive outreach programs to 'recruit' as many girls as possible, yet be skeptical that they actually do or ever will. In fact, studies show that there is a correlation between feeling competent in a discipline and interest in this discipline (Lent et al., 1994; White, 1959). One of the main goals of outreach programs is to undo the possible social biases mentioned in Sec. III.F by showing girls that they can be

successful in science and engineering. Outreach thereby tampers with the girls' interests and (probably unconsciously) manipulates girls towards scientific fields. By trying to delete social biases, these programs *ipso facto* create a new bias. They do not free women, they merely change the nature of their servitude.

While a change of mindset (a 'paradigm shift') from increasing enrollment numbers to increasing freedom of choice is both necessary and possible, it does not seem possible not to influence the girls by increasing their feelings of competence (this is similar to quantum systems, where one cannot read without writing). Should outreach programs stop right away then? Not necessarily. Although flawed, they might still be better than doing nothing. In any case, it is necessary to evaluate their negative effects and to reduce them so that benefits clearly outweigh risks on freedom of choice. How to achieve this is not obvious. It is not even clear whether it is possible at all. What is clear is that one cannot go on undisturbed on a path which appears to be the wrong one.

V. CONCLUSION

Many in science and engineering hold this truth to be self-evident, that there should be more women in the field. We considered several commonly proposed justifications: higher salaries, the possibility to help others, the increasing need for engineers, and the impact of diversity on new designs. When made explicit and seriously scrutinized, they in fact show that there should be a mutual attraction between women and scientific fields. This attraction is not universal so that there should be more women in science and engineering only inasmuch as women actually want to graduate in these fields.

Disappointed by the weakness of this argument, we looked for a possible objective justification. 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. We therefore redefined it to make it an ethical concept. Although an improvement, this still had a shortcoming: its asymmetry. We finally settled on a criterion which did not mention under-representation and simply states that all women should be allowed to graduate in a field congruent with their abilities and desires. This conclusion is similar to that obtained from mutual attraction.

Since freedom of choice sets a limit on the extent of the increase of the female enrollment in science and engineering the goal of outreach programs must be clarified. Trying to allow women to choose a field freely would be a moral dream but a practical nightmare, whereas drawing always more women to science and engineering violates the right of the students to choose a career freely. Since outreach programs cannot logically trample this right in order to enforce it, they need to make sure that their advantages clearly overweigh their drawbacks.

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