

Organizational Patterns for Increasing Gender Diversity in Computer Science Education

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Increasing gender diversity of the student population in computer science education and keeping it more balanced requires activities and efforts in various areas (such as staff training, curriculum development, advertisements) and on different management levels (individual, small teams, department, university). While all of these are important, there are some overlapping organizational aspects that can be found in most reports on efforts that succeeded in increasing the gender diversity.

In this paper we present four patterns that address these organizational aspects: ACTION GROUP, MALE PARTICIPATION, NETWORKING OPPORTUNITIES, and MENTORING.

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1. INTRODUCTION

Computer Science (CS) is still not a gender-diverse field, it is male-dominated. The situation in Computer Science Education is not much better. In the Netherlands, only 4-5% of the CS students are female [Dienst Uitvoering Onderwijs 2014]. Compared with other countries it is a small fraction. For example, in Germany there are on average 20% of the CS students female [Dpa 2013]. At Carnegie Mellon University (CMU) in the US, women comprised 40% of Computer Science majors among incoming first-year students in 2014 [Byron Spice 2014]. The female enrollment at CMU has long exceeded national averages in the US.

Many different reasons why few women participate in CS were identified, such as geek culture, gender stereotypes, lack of female role models, or lack of support for females when choosing a CS career [Barker and Aspray 2006; Cohoon and Aspray 2008; Hill et al. 2009; Ashcraft and Blithe 2009; Lagesen 2011]. According to a new Northwestern University

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study the Netherlands have the strongest stereotypes regarding the association of science with genders, it is more with men than with women. The study included data from nearly 350,000 people in 66 nations [Miller et al. 2015].

Increasing gender diversity of the student population in computer science education and keeping it more balanced requires activities and efforts in various areas (such as staff training, curriculum development, advertisements) and on different management levels (individual, small teams, department, university). More balanced means in the ideal case fifty-fifty, but it is good to start with aiming at reaching a critical mass for creating supportive peer communities [Louvrier 2015]. This critical mass (most often defined with appr. 30%) can also be used as initial target when applying these patterns, even though a diversity that reflects the society should be the ultimate goal.

In earlier work we described practices that address some of the above mentioned reasons using *design patterns* as format [Bartilla and Köppe 2015; Köppe and Bartilla 2014], a brief summary of these patterns is given in the appendix.

Architect Christopher Alexander [Alexander et al. 1977] and colleagues defined patterns as a formulae that “describes a problem which occurs over and over again, and then the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice”. Patterns have since been described and applied in many different fields, including software design, organizational development, and also in education. Especially educational patterns span different levels of educational actions [Baumgartner 2011], ranging from small teacher-student interactions (like QUESTION BOOMERANG [Köppe and Schalken-Pinkster 2013]) up to curriculum development and didactical strategies of whole institutions (like NEW PEDAGOGY FOR NEW PARADIGMS [Pedagogical Patterns Editorial Board 2012]). Most patterns described in the educational domain cover lower levels of educational actions.

In most reports on efforts that succeeded in increasing the gender diversity of the student population in computer science education, there are some overlapping organizational practices. In this paper we present four patterns at the organizational level that form the core of some of these practices. The patterns are summarized in Table I.

Pattern Name	Summary
ACTION GROUP	Form a sound group of people who all have the same goal of improving the diversity, are committed to the activities on longer terms, and represent a strong force/unit(?).
MALE PARTICIPATION	Involve males in all your activities in order to prevent people from seeing them as "women-only".
NETWORKING OPPORTUNITIES	Explicitly provide networking opportunities for female students.
MENTORING	Use female role models as mentors for female students.

Table I. : Proposed Patterns

All of these patterns should be combined with the more general “Fearless Change” patterns for introducing change in companies [Manns and Rising 2005]. Even though most of the patterns are likely applicable in a broader context too, we decided to scope our work to addressing the gender imbalance in computer science education.

The patterns were mined from literature and are based on research findings and descriptions of good/best practices. The literature will be referenced in the example sections of the patterns.

The pattern descriptions use an adapted version of the format used by Alexander et al. [Alexander et al. 1977]. Each pattern starts with a short description of the context, followed by three diamonds as a section separator. In the second part, the problem (in bold) and the forces, which shape the problem and explain why it is hard to solve, are described, followed by another three diamonds. The third part offers the solution (again in bold) and both positive and negative consequences of the pattern application which are part of the resulting context. We also provide advice for the implementation of the pattern. As last part examples of the pattern application are given. These also provide the rationale for the pattern and therefore might also include additional literature references.

References to other related patterns are made explicit by writing the names of these patterns in SMALL CAPS. A summary of all referenced patterns can be found in the appendix.

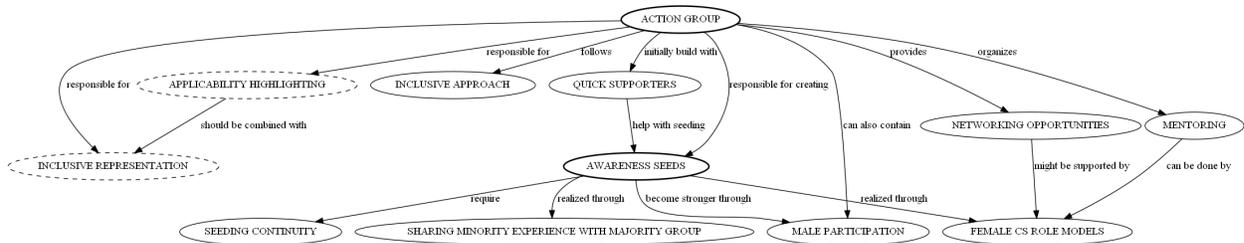


Fig. 1: Pattern relations

Some Words On Diversity

We are aware of the fact that diversity of course comprises much more than just the difference between males and females. There are more genders than just male and female. And of course not all males (and not all females) are the same too, there's a huge variety of different persons with different attributes, interests, backgrounds etc. We therefore believe that it is of importance to increase the diversity in computer science education (and actually the whole society) with respect to *all* these differences and variants.

As stated earlier, in the Netherlands the percentage of female students in computer science is about 4-5%. We therefore focus in our work on addressing this imbalance first. We believe that increasing the diversity of males and females in CS education also supports the creation of an environment where other underrepresented groups (with whatever background or orientation) might find it easier to be just a happy and motivated computer science student.

2. TOWARDS A PATTERN LANGUAGE

In earlier work we described patterns that address various aspects of increasing gender diversity in computer science education [Bartilla and Köppe 2015; Köppe and Bartilla 2014]. Table II gives a summary of these patterns.

Pattern Name	SUMMARY
APPLICABILITY HIGHLIGHTING	Don't focus only on the technical aspects of computer science in the external representation, but also equivalently include aspects of applicability.
INCLUSIVE REPRESENTATION	When using pictures of students for advertising material, mix both male and female students and show both in a variety of contexts.
INCLUSIVE APPROACH	Activities that are focused on increasing students' retention—by creating an "being-at-home" feeling, also known as "academic binding"—should address female students primarily as computer science students and not primarily as females.
AWARENESS SEEDS	Plant seeds that create awareness of why gender diversity in the student population is desired so that people come to action.
SEEDING CONTINUITY	Don't stop after initial activities, continue with planting awareness seeds on a regular and recurring base.
FEMALE CS ROLE MODELS	Expose everyone to females computer scientists as role models so that the image of the discipline can change.
QUICK SUPPORTERS	Start with recruiting supporters from the group which is already aware of the undesired gender imbalance and the issues related to it.
SHARING MINORITY EXPERIENCE WITH MAJORITY GROUP	Let majority members experience or learn about what it means to belong to the minority.

Table II. : Summaries of referenced patterns

Together with the patterns described in this work, these patterns form the beginning of a pattern language. Their inter-relatedness is shown in Figure 1.

As can be seen, two patterns **ACTION GROUP** and **AWARENESS SEEDS** (highlighted in bold) are central elements in the language so far, most other patterns help with realizing these (**AWARENESS SEEDS**) or are enabled by them (**ACTION GROUP**). While most patterns are more process-oriented, **APPLICABILITY HIGHLIGHTING** and **INCLUSIVE REPRESENTATION** (shown with dashed border) address aspects of what should be taken into account for advertisement activities intended for increasing enrollment of female students.

We intend to expand the pattern language in future work, also introducing categories for the patterns and providing scenarios of applications of pattern combinations.

3. THE PATTERNS

PATTERN: ACTION GROUP

There is a homogeneous CS student population of mainly male students at your higher educational institution (such as a university or a university of applied sciences). There is the intention of increasing the gender diversity of the student population at your institution with the goal of reaching a critical mass of female students as new status quo. There are various people—staff, management, students—who are interested in helping hereby.



The organizational structure (or hierarchy) of educational organizations is mainly intended for supporting the primary processes of education, these processes are the drivers for the structure and have the highest priority. Such structure often offers less support for other processes and activities that can help to increase gender diversity.

People think that the organizational structure is open to everyone, but the small numbers of female students show that this is not true.

Even if there is a possibility in the structure for the coordination of such processes and activities that can help to increase gender diversity, there is often not much time available for them and they are seen as organizational overhead. People don't attach importance to it, which also negatively influences the resources (time, money) made available for it.

Activities of individuals, even when done with the best intentions, are energy-consuming for these individuals and likely do not have long-lasting effects.

Bottom-up (or "grass roots") activities that do not have support by management are likely to run dry in a short time. They won't find their way into institutional policies and management won't provide money and/or time additional to the regular work.

On the other hand, top-down missions of management that are not backed by the staff do not have a high chance of success in long terms either. Such an approach has something artificial, it is not grown out of a necessity, but imposed from above so people will stay resistant. It can also be a sign that management does not see the need for this topic.

Both ways miss the creation of a broad acceptance throughout all institutional levels and have therefore a high chance of failure.



Therefore: form a group of people who all align on the goal of improving the gender diversity of the student population as a first step. This group should also be committed to the activities on longer terms, and have the authority to make changes.

The most important function of such a group is to combine forces with support from—and in cooperation with—management. An important precondition for this solution is the commitment at all levels of the organization to increase the gender diversity of the student population. If this is not the case, then this commitment should be created first through various AWARENESS SEEDS and probably an CORPORATE ANGEL and/or LOCAL SPONSOR [Manns and Rising 2005]. When setting up such action group and starting with initiating activities, most patterns for fearless change might be helpful [Manns and Rising 2005]. It would for example be good to create a GROUP IDENTITY [Manns and Rising 2005].

The final goal for such a group is to have a diverse student population. This vision can be realized through some intermediary steps. Initially the group should consist of mainly female lecturers and staff, because they function as contact persons for the students. Women should be preferred at this point because of a possible identification by the female students. They also often know the student's situation from their own experience. Female students should be included because they are the group of interest/concern. In this way, female students get ownership and control over the activities. The female students should be involved because of being competent CS students and not only because they are women (the unique characteristic) as the only starting point (see also INCLUSIVE APPROACH). The next step could

be to set up a network by including the students, other institutions (other universities, companies, or secondary schools) and male/female colleagues and students (see also QUICK SUPPORTERS and MALE PARTICIPATION). This would enlarge the support and improve the continuity. Others can then participate and play different roles in the network, dependent on their role in the institution. There are constantly active supporters and others can help on request. Female role models from outside the institution could also become members of the action group in a later step.

The agenda arises from the interests of the network, but is also defined by the management. This way a long-term support of the management is guaranteed. The main objective 'more gender diversity' is leading for all activities. However, the management may have different interests such as financing the group and its activities, using it for promotional or political reasons, or for improving the student enrollment and retention in general. Involved students also want to have fun and build a professional network for later.

The activities should be evaluated regularly to expand successful strategies and improve or cancel less effective strategies. It is also a possibility to enlarge visibility by reviews/reports which are publicly available. These can for example be put on a website (as also described in E-FORUM [Manns and Rising 2005]), presented at conferences, or distributed in local newspapers.

The aim is that involvement from continuously participating students and lecturers does not only have to be voluntary. Students could get credits or even money as a student assistant. Staff members get time for it. That values their work and also enables continuity of activities.

There should be a working cycle of newcomer female students, active networking students and alumni. In this way, knowledge and information could be shared and time and energy used effectively. Most likely it will be necessary to have a support group for a long time because students leave the higher education system. New students must be integrated in the group. For this it needs reliable structures in the background to monitor the beginning students up to alumni who engage as role-models, provide a professional network, and advocate the idea from the network outside of the organization.

It is good to have a core group which is responsible for organizing regular meetings and thinking of next activities. The group should be visible at the institution and the members of this core group should get (some) time for their tasks. Outside of this core group a larger group can be formed with members who occasionally take over tasks and also supporters of the group who are not directly involved in the activities, but occasionally help with organizational issues or simply express their appreciation of what the group does.

To increase the visibility of the group and also the commitment of the members, the group should get a memorable name.

Positive consequences are that activities are organized and executed by multiple people, which helps with distributing the work. It naturally helps with distributing AWARENESS SEEDS in the organization. Being a member of such a group also likely leads to a higher commitment and the visibility of the underrepresented group increases.

On the other hand, people outside of this group might get the feeling that there is too much attention focused on that group, especially if they don't see the need for it. This can lead to envy and be counterproductive. AWARENESS SEEDS and an INCLUSIVE APPROACH likely help to lower the chance of this consequence.

People also could get the feeling that because of the existence of such an action group enough is being done on improving diversity and that further support is not needed. It furthermore could happen that students have the feeling that they are missionized and therefore don't want to participate. Using AWARENESS SEEDS in combination with a mix of bottom-up and top-down activities might help here.

Such a support group formed the core of the activities at the NTNU [Sørensen et al. 2011].

At Carnegie Mellon University (CMU) they also successfully formed a community of women in the School of Computer Science called Women@SCS [Frieze and Blum 2002; Fisher and Margolis 2002]. They "have found it essential to have a core group of activist students at the helm", which is also an example for an ACTION GROUP. That such a group especially in long terms can be successful has been shown in a series of studies at CMU [Frieze and Quesenberry 2013].

PATTERN: MALE PARTICIPATION

In order to get broader support and organizational help, you want more people to participate in activities that are intended for increasing the gender diversity at your institution.



People—men and women—may see the activities as a women-only issue and might not feel connected to them.

People more easily understand the problems and issues which alike people have. It is hard to think of what someone else thinks and feels in general, but it can be even harder if this person has another background, is of another gender, or comes from another culture.

Gender uniformity in computer science education seems to negatively affect mainly the minority: the female students. But it also has negative effects on the male students—they keep the stereotypes and unconsciously reproduce them—and in the long term on society where gender equality forms an important value.

The structure of power—who is determining what is the standard and be seen as normal—is usually dominated by the majority, often in an unconscious and invisible way. This is another reason why it is hard to change the situation.



Therefore: explicitly have males—mainly faculty and staff, but later on students too—participate in the activities too.

The males should offer support for the activities and also should be willing to do so. Forcing people to become involved might be counter-productive, they should become convinced of the need for support through various AWARENESS SEEDS. Even though it's good to have males involved, e.g. in the ACTION GROUP, the leading organizational roles should be held by females in order to also have them being FEMALE ROLE MODELS. Having males involved might also open the access to their networks for the female participants.

Having males—as members of the majority in computer science education, both teachers and students—participating in the activities helps with communicating that this is not a women-only issue, but of importance for everyone. This way the chance of breaking the (unconscious and/or undesired) reproduction of stereotypes can be increased.

Applying this pattern will help with convincing other men (hereby creating an EARLY MAJORITY [Manns and Rising 2005]), as these men can function as EVANGELISTS [Manns and Rising 2005] and are also a source of AWARENESS SEEDS. Start with QUICK SUPPORTERS in order to get enough male participants in your ACTION GROUP. Such QUICK SUPPORTERS can be found by observing their attitude towards gender diversity during discussions on the topic. They can be asked directly to participate and become involved in some activities.

Involving more men likely leads to a broader support, especially at the levels of power where men still form the majority such as higher management. These males can also function as strong AWARENESS SEEDS for their male peers, as some of these peers are likely easier convinced of the importance of the topic by them as by females.

Involving males also can have negative effects, as there is a chance that they become too dominant and hereby reproduce the structure of power that the activities intend to change. It is therefore important to have most leading organizational roles held by females.

The National Center for Women & Information Technology (NCWIT) did research on the role male advocates and allies play in increasing gender diversity through creating an open and friendly environment for everyone. They published a brochure that helps males becoming involved in promoting gender diversity in technology workplaces [Ashcraft et al. 2013]. This approach is applicable too in computer science education institutions.

PATTERN: NETWORKING OPPORTUNITIES

There are a few female students in your computer science cohort, but they form a minority.



Minority groups such as female CS students miss opportunities for their careers if they don't have access to networks of peers and professionals, but this access does not come naturally to these minority groups in CS.

People naturally tend to build relations (and a network) with alike people, a mechanism called *homosocial cooptation* [Meuser 2004]. This makes it harder for members of a minority—female CS students—to build the same extensive set of relations with others than it is for members of the majority—male CS students. This not only counts for the students themselves, but also for the relations between students-teachers and students-workforce, where too a gender imbalance is still present.

Members of the majority take these networking opportunities for granted as they come nearly naturally, which makes it harder for them to realize the importance of giving minority members the same opportunities.



Therefore: provide networking opportunities for female CS students, either explicitly or as part of other events.

These networking opportunities are ideally part of the work of the ACTION GROUP. They can range from small informal meetings to larger official events and do not need to be explicitly called networking events. Especially in places where the imbalance is big, it would be good to make a start with minority members only. At a later time, or at places with a less tremendous imbalance, the opportunity could also involve a balanced number of majority members. In that case it is important to ensure that these do not dominate the event or meeting.

People are different, and so are female CS students, not all of them might like to network extensively. These networking opportunities shouldn't therefore be forced on the students, but offered as a chance they otherwise would miss or could only create with difficulties. If necessary, students could also be taught about why networking is important and how to network and make use of networks.

A good idea is to make use of existing networking structures and of FEMALE ROLE MODELS. One can set up a local ACM-Women chapter¹ or host events of self-organized groups of female programmers such as Rails Girls² or PyLadies³. Especially these latter examples demonstrate that it might be fruitful to support female students in creating such networking opportunities themselves (and in their own ways and preferences) instead of organizing them for the students. This will create a higher commitment to the activities and also foster a closer relation with the ACTION GROUP. In other words, you can take the students to an event that is organized by another organization (such as the Grace Hopper Celebration or small conferences on Gender & STEM) or you can have your students organize such an event themselves where they can invite guest speakers, present their own work, and have informal discussions on CS-related topics. It is always a good idea to DO FOOD [Manns and Rising 2005], as eating together creates great opportunities for talking with others in an informal atmosphere.

It is important that women eventually need to become part of the bigger networks, so that their positions are strengthened and they get broader access to job opportunities etc. Just being in small, women-only type of networks, will not do much except the feel-good/support effect. These local small networks should therefore eventually become connected with the bigger networks.

By providing networking opportunities for female CS students, they will get the chance to benefit from the positive aspects of networking such as peer support, project opportunities, or higher chances in job applications.

¹<https://women.acm.org/chapter>

²<http://railsgirls.com>

³<http://www.pyladies.com>

As with all activities directed at women mainly, such networking opportunities could too create a feeling of being not of relevance for the majority. It is therefore important to accompany these networking efforts with various AWARENESS SEEDS. Explicitly calling all these events “networking opportunities for women” might be experienced as an overkill by the female students (even though these events *are* networking opportunities) and might not attract them anymore. It is therefore important to not emphasize too much the aspect of networking for the female students, but to let this (intentionally) happen during all sorts of events.

A good opportunity for networking is the Grace Hopper Celebration, organized yearly by the Anita Borg Institute⁴.

One important aspect of the success of Women@SCS at the CMU is that they provide an opportunity for networking [Frieze and Quesenberry 2013]. Networking is an important aspect for finding a place in a community and creating work opportunities. Such networking often happens automatically during members of the majority—male CS students—while members of the minority—female CS students and other minorities—are excluded from such networks through various mechanisms such as homosocial cooptation [Bartilla 2014]. It is therefore necessary to create such networking facilities for minority groups as well.

⁴<http://ghc.anitaborg.org>

PATTERN: MENTORING

There are a few female students in your computer science cohort, but they form a minority.



Female students often drop out in problematic times and situations, as they struggle with finding their way in a male-dominated environment and often suffer from a lower self-confidence and higher need for proving themselves.

Female students often find themselves as the only ones in larger groups of students, so most of their classmates are male. And even if there are other female students, these often have the same problems with finding their place in the group. Having FEMALE ROLE MODELS—such as occasional female lecturers for technical subjects—shows them that it is possible to find a place in this environment, but does not help them in concrete situations or if they have concrete problems and questions. There is no "natural" network which provides help in such situations.



Therefore: provide mentors for female students. These mentors are counterparts in good and bad times.

Mentoring means that someone with more experience is connected to someone with less experience and is about encouraging and supporting (female) students who already are studying computer science. The mentor guides and supports the mentee during a shorter or longer period.

Mentors can be female (then they also can function as FEMALE ROLE MODEL), but male too (which might offer the students better access to larger networks the male mentor is already part of). A mentor can support the students with advice based on her own experience. The goal is to keep the female student enrolled, but also to help with the transition towards the work environment. Such a mentor also can serve as a first step towards building a network [Friedman 2014].

The role of mentor can be ideally fulfilled by either female students in higher semesters, by female lecturers, or by female experts from the work field. However, it is important that the role is fulfilled by people with good mentoring skills and an interest in mentoring a female student. Just assigning someone as mentor who is not able or willing to do it does not work. If not enough female mentors are available, it will also work with skilled and willing male mentors.

Finding mentors is not easy, as most people don't have enough time available for such tasks. However, people who are seeing the importance of this often are also willing to offer support (including the necessary time) as mentor. Important is that they become committed to mentoring on long terms in order to guarantee continuation. Mentors can be found in the networks of involved people (such as the ACTION GROUP), but there are also organizations such as ACM Women, the National Center for Women & Information Technology (NCWIT), or VHTO in the Netherlands, which provide a database of potential mentors.

If applied, this pattern offers good support for female students during the first semesters and increases the chance that they finish the study. It also shows them where they are able to, as the mentor is a senior.

Some students might feel uncomfortable or overwhelmed with getting such a special attention. This is especially because research has shown that most female students don't want to be treated special and just want to be a part of the whole [Bartilla 2014].

Even though all students would likely benefit from having mentors, it is especially important for female students to get such kind of support because of the often present lower self-confidence and the additional effort the female students have to take to find their position in the group.

VHTO, the national expertise office in the Netherlands for girls and women in STEM, organizes Mentoring Circles for female students in the transition from education to employment (including self-employment) [VHTO 2016].

Mentoring plays another role in the success of female CS students. Moshe Vardi names it as important in his Communications of the ACM column [Vardi 2015].

4. CONCLUSION

In this paper we presented 4 patterns that address the issue of increasing student gender diversity in higher education on an organizational level. These patterns should be applied in combination with the earlier defined patterns [Köppe and Bartilla 2014; Bartilla and Köppe 2015].

In future work we will identify more patterns that address other aspects of increasing gender diversity in CS education as well such as equal treatment, staff diversity, or increasing self-efficacy of beginning female students.

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APPENDIX

Summary of Referenced Patterns

Table III gives summaries of all fearless change patterns that were referenced in this work (adapted from [Manns and Rising 2005]).

Pattern Name	SUMMARY
ASK FOR HELP	Since the task of introducing a new idea into an organization is a big job, look for people and resources to help your efforts.
CORPORATE ANGEL	To help align the innovation with the goals of the organization, get support from a high-level executive.
DO FOOD	Make an ordinary gathering a special event by including food.
E-FORUM	Set up an electronic bulletin board, distribution list, listserve, or writeable Web site for those who want to hear more.
EARLY MAJORITY	To create commitment to the new idea in the organization, you must convince the majority.
EVANGELIST	To begin to introduce the new idea into your organization, do everything you can to share your passion for it.
GROUP IDENTITY	Give the change effort an identity to help people recognize that it exists.
LOCAL SPONSOR	Ask for help from first-line management. When your boss supports the tasks you are doing to introduce the new idea, you can be even more effective.

Table III. : Summary of referenced patterns