



## **Experiences and Struggles of Female STEM Students: Insights from a Women-Only STEM Program**

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### **Abstract**

*In many STEM fields, especially computer science and engineering, women are vastly outnumbered in undergraduate education. This becomes even more noticeable in further education and the workforce. The gender difference is the most pronounced in high-level positions, a phenomenon often referred to as the 'leaky pipeline' [1; 2]. While the underrepresentation of women in STEM is often investigated starting at a very young age on topics such as spatial knowledge, learning methods, and stereotypes [3], university education is a critical time when female students will become familiar with many of the struggles faced by women in STEM, and ultimately decide to drop out of their studies or not.*

*In this paper, questionnaire results are analyzed from an annual German women-only STEM summer school (informatica femminile Baden-Württemberg) targeted at computer science students and professionals, and an annual winter school (meccanica femminile) targeted at female mechanical and electrical engineering students and professionals. These results provide important insights regarding female STEM students including motivation, discrimination, dropout and retention, and the importance of a mono-educational environment. By providing insight into the struggles female STEM students face, their reasoning for potentially dropping out or leaving the field becomes much clearer, as do potential solutions to help with these issues.*

**Keywords:** *Mono-Education; Women in STEM-studies; Dropout of female STEM-students*

### **1. Introduction**

In Germany, female students make up just 21.8% of first-year computer science students, and 26.3% of first-year students in technical subjects including mechanical engineering, process engineering, electrical engineering, and information technology as of 2018 [4].

The process leading to the underrepresentation of women in STEM has been coined as the 'leaky pipeline'. This phenomenon starts before higher education when many young or high school-age girls decide to not pursue STEM. The decision against STEM may result from a multitude of reasons, such as gender-specialized parenting [5], lack of confidence in STEM subjects [3], and general stereotypes & implicit bias [1]. The pipeline continues throughout higher education where many women will drop out of their STEM studies. Finally, the 'leaky pipeline' persists after higher education, as many female STEM graduates leave their job or pursue different career paths.

Another issue that exists for women in STEM is discrimination. It is difficult to quantify the discrimination faced by women in STEM as it cannot be studied in a controlled environment and is often quite discreet, but it has been considered one of the factors causing the under-representation of women in STEM by researchers [2]. Some forms of discrimination faced by women in STEM include isolation, lower recognition of accomplishments, reduced chances of receiving a job or promotion, social microaggressions, and more [1]. A form of discrimination that female university students are very susceptible to is sexual discrimination [6].

Heublein et al. [7] state in their paper about the development of dropout rates in Germany that, while the dropout rate between male and female STEM students is not extremely different, the dropout rate for female engineering students and female mathematics / natural science students is higher than the general female bachelor's degree student dropout rate. This demonstrates that women in STEM are still more likely to drop out than the standard female university student [7].

Even if the dropout rates of male and female students in STEM may not be so different, the dropout rates of women in STEM are more critical: women in STEM are already vastly underrepresented in specific fields. Also, there is already such an effort to attract young girls to study STEM in the first place, that the loss of one of these students due to dropout is especially hard to recuperate from [3].



And if one wants to increase the proportion of women in the long term, not only must the dropout be replaced, but another, additional woman must be attracted to study the STEM topic.

As groups with higher performance anxiety are “predicted to be at the greatest risk of attrition from STEM majors” [8] it is worth considering the impact that stereotypes, discrimination, and other factors may have on the female STEM student experience and dropout rates. This is a critical part of the ‘leaky pipeline’, so the understanding of why women in STEM are dropping out of their studies and how to retain them is of great importance.

## 2. Methodology

Netzwerk F.I.T (Netzwerk Frauen.Innovation.Technik / Network Women.Innovation.Technology) Baden-Württemberg is an initiative of Furtwangen University. It is funded by the State Baden-Württemberg Ministry of Science, Research and the Arts to increase the proportion, reduce the dropout rate and provide support for female students in STEM. The Netzwerk F.I.T hosts two educational events per year, each a week-long, these being a winter school *meccanica femminile* (mf) targeting female students and engineers in the subjects of mechanical and electrical engineering, and a summer school *informatica femminile BW* (if) targeting female students and professionals in the subjects of IT and computer science. These events are offered exclusively to women, providing a mono-educational environment where all lecturers and participants are female. The focus of these events is on technical skills development courses, professional development courses, and networking opportunities. These events offer a protected space to talk about gender-specific experiences in male-dominated study programs. One goal is to encourage participants in their choice of study and provide them with support.

At the end of each event, participants are asked to complete an event questionnaire. This includes several questions regarding their experiences as female STEM students. These questionnaires provide important insights regarding the student’s motivation to pursue a STEM field, their experiences with discrimination, whether or not they have considered dropping out of their studies, and their feelings towards the mono-educational environment.

It should be noted that though the event’s target audience are female STEM university students, some of the participants, and subsequently questionnaire respondents, have already completed their studies or are students who have started their career. Also, as some participants may attend the events several times, there may be individuals whose responses are considered more than once. Furthermore, it must be considered that the questionnaire was not originally designed for a social science study, but as an accompanying evaluation of the events for monitoring purposes.

## 3. Results of the questionnaire

The following section includes relevant questions and responses from participants of the events *informatica femminile BW* (if) and *meccanica femminile* (mf). The presented questionnaire data is from 2018 to 2022. Participants belong to one of the following three groups: Students, professionals, or women who do both at the same time (study/work). This information on status can be omitted by the respondent in the questionnaire.

### 3.1 “Why did you decide to study a STEM subject?”

Participants were asked about the importance of various motivations for their decision to study a STEM subject. Responses are on a Likert scale of 1 (= strongly disagree) to 5 (= strongly agree). The average mean score for each response was determined (if & mf participants 2018-2022). The most important motivation for studying a STEM subject is the item ‘Interested in study content’ with a mean value of 4.72, that is 95.54% of the responding participants agreed (value 4) or strongly agreed (value 5) to this (Fig. 1).

Furthermore, it is very surprising that ‘Role models’ are so rarely selected as a motivation for taking up a subject in the STEM field. At first glance, this contradicts the assumption that role models are so important for young girls when choosing a career and therefore must be highlighted and given prominence. The results rather suggest that the young women study a STEM subject despite the lack of role models or that the female students themselves are not aware of the lack of motivating role models.



Why did you decide to study a STEM subject? Events 2018 to 2022  
Mean and Standard Deviation  
5=strongly agree to 1=strongly disagree

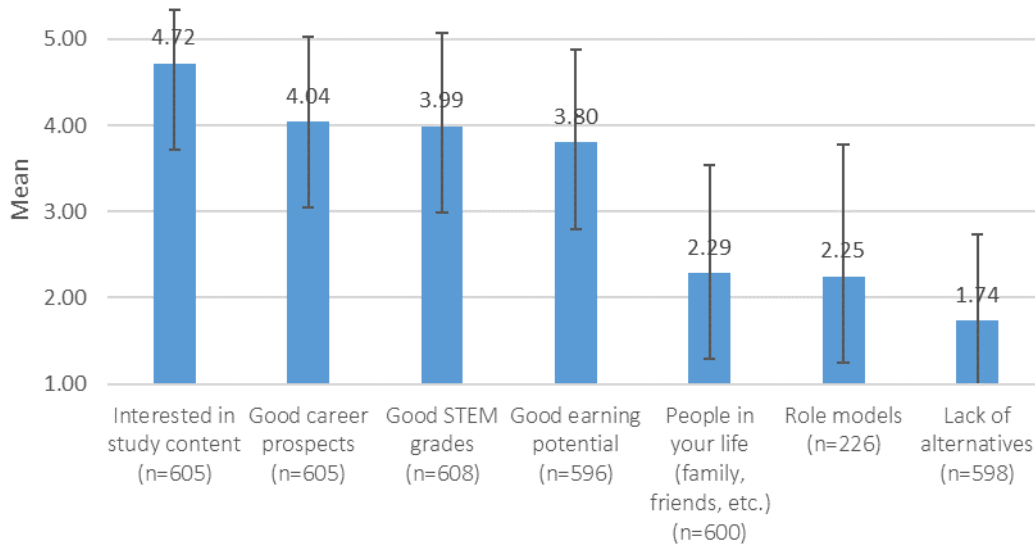


Fig 1. Mean and Standard Deviation of various motivations in decision to study a STEM subject. Events 2018 to 2022

### 3.2 “Have you experienced discrimination and / or negative experiences in your studies or profession?”

Participants were asked if they have experienced discrimination or similar negative experiences in their studies or profession. The average percentage of participants of the events if & mf 2018 to 2022, who report specific forms of discrimination, can be found depicted graphically in figure 2.

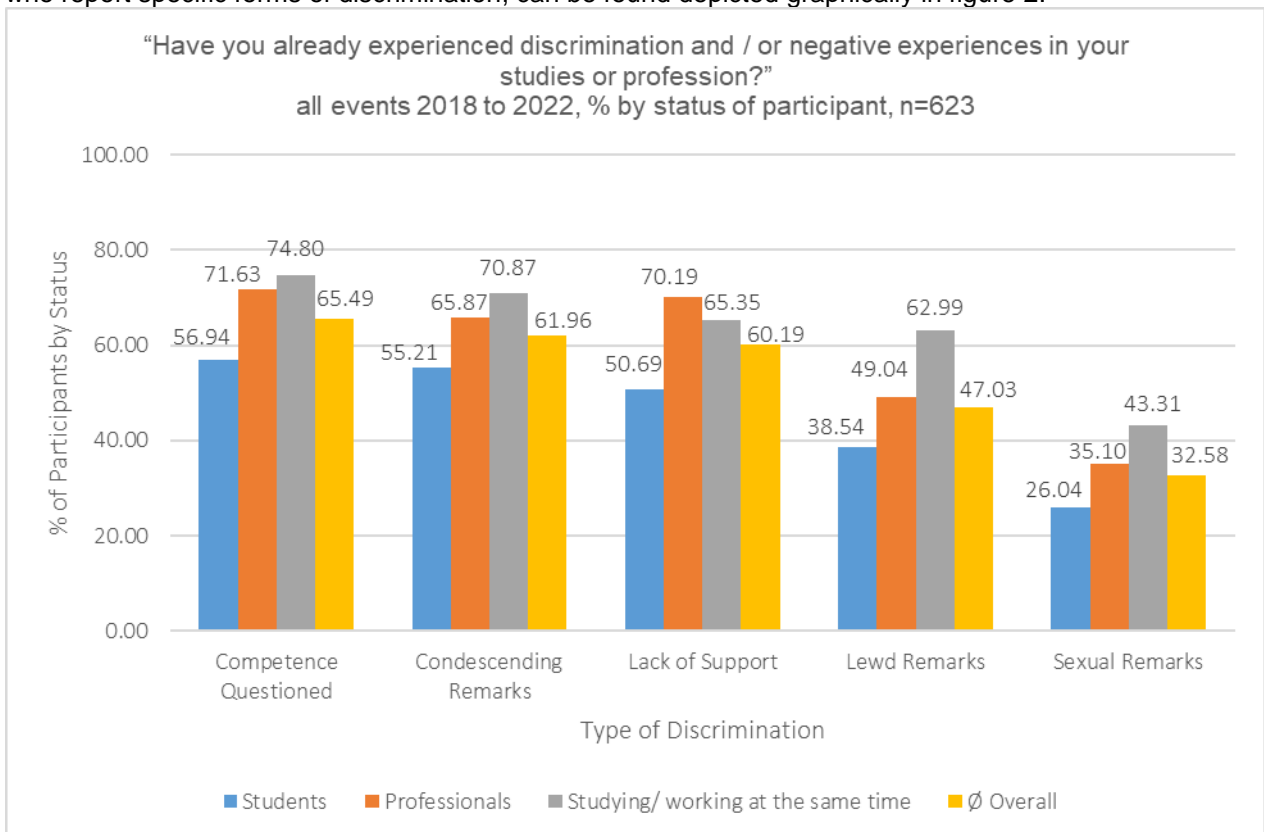


Fig. 2. Participants and Discrimination. All events 2018 to 2022, in % by status of participant, n=623



It can be noted that a high proportion of the respondents have experienced negative experiences or forms of discrimination. This applies in particular to competence being questioned (overall 65.49%), condescending remarks (61.96%) and lack of support (60.19%). Also, lewd remarks and sexual remarks were also selected at an alarmingly high level. It should be noted that there are considerable differences in the proportions depending on the status of the respondents. The student participants always have the lowest number of responses. For example, while 56.94% of the students have experienced 'competence questioned', the professional participants responded with 71.63%, and the group of participants who are 'studying/working at the same time', have experienced this kind of discrimination at a percentage as high as 74.80%. In the case of the item 'Sexual Remarks', 26.04% of the students have experienced this, while 35.10% of the professionals and 43.31% of the participants who are 'studying/working at the same time' have experienced this. There are two possible explanations for these figures and discrepancies between the groups. On the one hand, it may be that the female students have had less experience overall (professional life is still ahead of them). Professional life might be even more competitive than a student's life at university; discrimination might be a toxic outgrowth of competition. On the other hand, it is also possible that certain forms of discrimination are not recognized (yet) by the participants who are students. The answers are based on a self-assessment of experiences by the participants.

### 3.3 "Have you ever seriously considered dropping out of your studies?"

Participants were asked if they had ever seriously considered dropping out of their studies. Participants who are not currently studying or have not studied at all, did not answer this question.

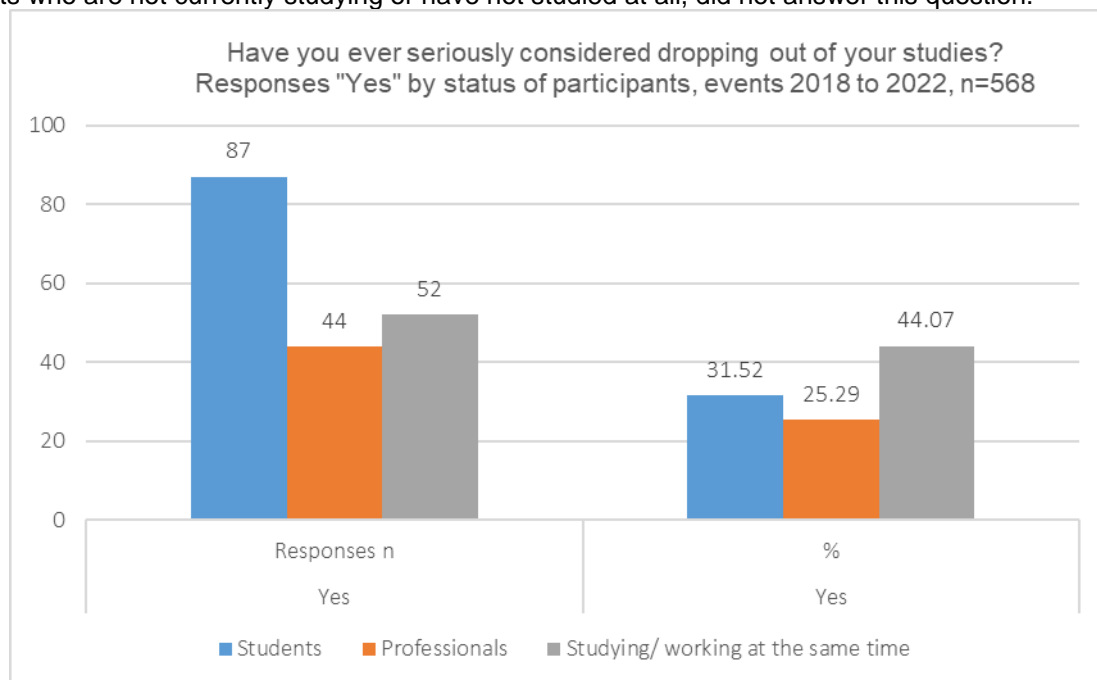


Fig. 3. "Have You Ever Seriously Considered Dropping out of Your Studies?" Responses 'Yes' by status of participants, events 2018 to 2022, n=568

From 2018 to 2022, an average of 32% of participants have considered dropping out of their studies at some point (participants 2018-2022, valid n=568). Once again, we see some differences in the proportions when considering the status of the participant in more detail (Fig. 3). The highest percentage overall shows the group 'Studying/working at the same time' (44.07% 'Yes'), whereas the 'Professionals' group has the lowest figure (25.29%). At first glance, it may seem surprising that professionals have the lowest numbers. However, this may be due to the fact that the years as a student are over, and some time may have passed, so that the difficulties encountered from that time may be suppressed in retrospect, a so-called memory recall error. Additionally, in general the professionals have already finished their studies successfully. The portion of former students who dropped out of their studies would not be attending these events as a professional, and therefore the results from the 'Professionals' group is biased. In contrast, the female students and the group of those studying and working at the same time experience everyday student life at the time of the survey and give a different



perspective. It should be noted here that the participants who study and work at the same time think the most about dropping out. This can probably be explained, among other things, by the added pressure of both studying and working.

### 3.4 “If yes, how important were the following reasons?”

Participants who had responded ‘yes’ to having considered dropping out, were then asked about their level of agreement to various reasons for dropping out. Responses are on a Likert scale of 1 (strongly disagree) to 5 (strongly agree). The average mean score for each response was determined and is as follows (events 2018 to 2022, descending order):

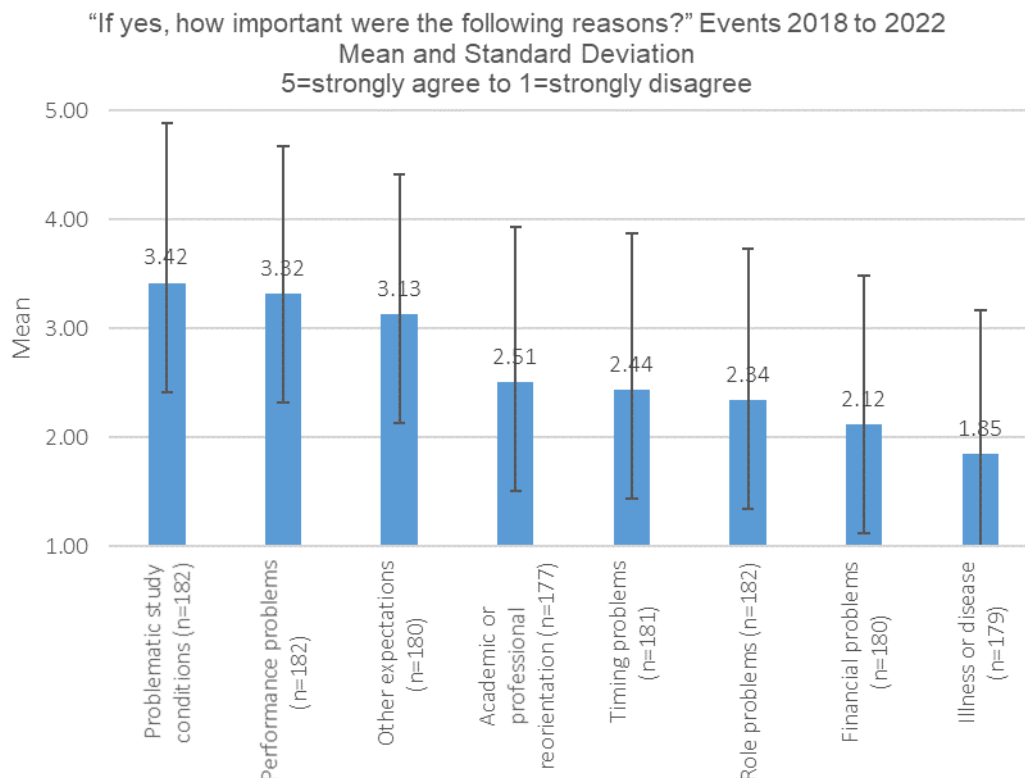


Fig. 4. “If yes, how important were the following reasons?” Events 2018 to 2022, Mean and Standard Deviation, Likert scale 5=strongly agree to 1=strongly disagree

The problem areas that were most frequently selected by the participants are ‘Problematic study conditions’ (59.89% selected agree and strongly agree, mean=3.42, SD=1.47), ‘Performance problems’ (54.40% selected agree and strongly agree, mean=3.32, SD=1.35) and ‘Other expectations regarding the study program’ (46.67% selected agree and strongly agree, mean=3.13, SD=1.28). These problems reflect a wide area of expectations, performance, and motivation which are typical reasons for drop out of studies. Interestingly, financial problems do not play a major role, while other studies show that financial problems are very often cited as a reason [9]. Also, ‘Role problems (as a woman in a male dominated field)’ is not selected as a main factor when thinking seriously about dropping out of one’s studies. This seems to be in sharp contrast to the results in figure 2, where e.g., 56.94% of the students answered that their competence was questioned. Possible reasons might be that young females might misinterpret some forms of discrimination as due to their own behavior instead of being aware of a role problem. For example, the item ‘competence questioned’ might be associated by the student herself as being due to not feeling competent, therefore not behaving competently and finding the problem in her own personality. Part of mentoring literature advises women to behave in a way that they seem to be more competent, suggesting that they can solve the problem themselves through self-regulation [10].

### 3.5 “What made you decide to continue after all?”

Participants who had responded ‘yes’ to having considered dropping out, were then asked about what made them decide against dropping out. Responses are on a Likert scale of 1 (strongly disagree) to 5



(strongly agree) to a suggested reason. The average mean score for each response was determined and is summarized in the following table (events 2018 to 2022, descending order):

Table 1. Reasons to continue with their studies

	n	Mean	SD
Interested in study content	178	4.31	0.84
Good career prospects	178	3.75	1.17
Good earning potential	174	3.55	1.30
People in your life (family, friends, etc.)	175	3.27	1.44
Good STEM grades	174	3.01	1.26
Lack of alternatives	174	2.68	1.46
Participation in if / mf events	163	2.36	1.58
Role models	77	1.79	1.36

Response Likert scale: Strongly agree = 5 to strongly disagree = 1

The reason for continuing studies that the most participants strongly agreed to is the interest in study content. That was also the motivation to study STEM in the first place. Interestingly, the item 'Role models' is the least mentioned (n=77) and with a mean of 1.79 this suggests a minor importance of role models as a reason to continue. It is possible that this reflects the fact that role models are missing (therefore they cannot have major influence).

Of particular interest to the organizers of the events were the answers as to whether the events themselves explicitly contributed to participants refraining from dropping out of their studies. Therefore, the response behavior to the corresponding item is summarized in the following table in more detail.

Table 2. Importance of Events mf and if (2018 to 2022)

	n	%
Strongly disagree	83	50.92
Disagree	13	7.98
Undecided	17	10.43
Agree	25	15.34
Strongly agree	25	15.34

Response Likert scale: Strongly agree = 5 to strongly disagree = 1  
n=163 · Mean=2.36 · SD=1.58

Of the participants who considered dropping out, an average of 30.68% (strongly) agree that their participation in Netzwerk F.I.T's events, if or mf, is one of the reasons that influenced their decision to continue with their studies (2018-2022). However, for more than 50% of the participants who seriously considered to drop out, these events did not play a role at all.

### 3.6 "In your opinion, are there differences in terms of learning culture between mono-educational and co-educational courses?"

Participants were asked about their opinion on the differences in learning culture between co-educational courses, a study scenario with a mix of genders, or mono-educational courses, a study scenario with one gender which is - in this case - female.

Table 3. "In your opinion, are there differences in terms of learning culture between mono-educational and co-educational courses?" events 2018 to 2022, by Status of Participant, n=617

	Overall		By status of participant					
			Student		Professional		Study/ work	
	n	%	n	%	n	%	n	%
Yes	416	67.42	171	60.00	146	71.22	99	77.95
No	201	32.58	114	40.00	59	28.78	28	22.05

An average of 67.42% of participants responded that 'yes', there are differences between the learning culture of mono-educational and co-educational courses (2018-2022, valid n=617). However, students selected 'yes' only by 60.00%, compared to 77.95% for students with a job.



Participants had the possibility to give free-text answers about differences in learning cultures. The answers revealed insecure self-perceptions in male-dominated groups. The women see themselves under critical scrutiny, expect criticism or putting themselves in vulnerable positions; they have to define their role in the group. These quotes reflect a high level of unease and at the same time, the quotes hint on the systemic dimension of discrimination.

#### **4. Discussion & Conclusion**

Overall, this data proves valuable for understanding female STEM students' struggles, motivations, and general experiences.

Approximately a third (32%) of participants report considering dropping out of their studies. The most common reasons for considering dropping out are problematic study conditions and performance problems.

In regard to discrimination, two thirds of the participants have at least experienced some form of discrimination on average. The most common forms of discrimination are a questioning of competence and general condescending remarks, however even the most unreported form of discrimination in this questionnaire, sexual remarks, has been reportedly experienced by an average of about 33% of the participants. It should also be noted that the category 'sexual remarks' may include sexual discrimination ranging from verbal harassment to sexual assault.

Participant's decision to ultimately continue with STEM studies are most highly associated with their overall interest in the study content, the good career prospects, the good earning potential, and the people in their life such as family members or friends. These answers are very similar to the responses from students reporting their motivation for initially choosing to study a STEM subject.

When asking about co-educational courses versus mono-educational courses, an average of 67% of participants believe that there is a difference between the two education styles. Participants were prompted to describe these differences, and the custom responses generally describe more feelings of confidence, being taken seriously, and more open conversations amongst women.

The preceding data effectively demonstrates experiences and struggles of female STEM students that are often difficult to quantify. For example, while literature cites 'performance problems' or 'performance reasons' as the most common reason for dropping out [9; 11], the questionnaire results show that 'problematic study conditions' are just as, or even more important than performance problems. The exact meaning of 'Problematic study conditions' could include a multitude of factors, but it is reasonable to consider that the struggles that come with being a female STEM student contribute to such problematic study conditions. Having one's competence questioned, being subjected to condescending remarks, or just generally feeling outcast in the STEM community due to being a minority can reinforce negative stereotypes and lead to a lack of confidence and generally unpleasant study conditions. By recalling the previously discussed impacts of stereotype threat [8; 12] and sexual assault [6], and considering that over two thirds of participants have experienced discrimination, and nearly half of the participants have experienced discrimination of a sexual manner, it is possible to consider that such discrimination contributes to the problematic study conditions and therefore to the dropout rates of female STEM students.

The results of this study and research also provide solutions to combat the negatives that come with being a woman in STEM, especially for students. A 'general interest in STEM subjects' is the highest motivator for female students to pursue STEM, as well as the most important factor for them to continue their studies after considering dropping out. Additionally, two third of participants believe that there is a difference between mono-educational and co-educational study programs. Based on these findings, it's obvious that it is of great importance to provide experiences for female STEM students that renew and cultivate their interest in their field of choice. Also, it seems to be beneficial to provide spaces where women in STEM can be amongst other women to cultivate their confidence and allow themselves to be vulnerable. Therefore, mono-educational events such as if & mf that provide educational opportunities amongst other women are critical to retaining women in STEM.

#### **5. Acknowledgement**

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