Higher Education Policies for Female Retention in Computer Science

Vladimir Pavlov[1]

Supervisor(s): Fenia Aivaloglou[1]**, Shirley de Wit**[1]

[1]**EEMCS, Delft University of Technology, The Netherlands**

A Thesis Submitted to EEMCS Faculty Delft University of Technology,
In Partial Fulfilment of the Requirements
For the Bachelor of Computer Science and Engineering
June 23, 2024

Name of the student: Vladimir Pavlov
Final project course: CSE3000 Research Project
Thesis committee: Fenia Aivaloglou, Shirley de Wit, Gayane Vardoyan

Abstract

The underrepresentation of women in computer science (CS) programs is an important issue that needs to be addressed in order to promote gender inclusivity and innovation. The following study is a literature review of 42 papers published between 2005 and 2024. It investigates the effectiveness of different higher education policies and practices in retaining female students in computer science programs. Key areas of the paper include holistic admissions and bridge programs, anti-discrimination policies, support programs, and inclusive curriculum design, such as introducing practical context to education and adopting inclusive learning techniques. The research findings show that all these strategies enhance female retention in CS, by, for example, creating a sense of belongingness, increasing motivation and engagement, removing economic barriers, providing networking and career opportunities. A key takeaway of the paper is that each strategy has its own unique contributions and combining different policies strengthens and complements individual effects. Because of that, any party interested in applying these policies needs to carefully study the educational environment and then choose the most adequate set of measures.

1 Introduction

The underrepresentation of women in computer science is an important problem, as female students face higher attrition rates during their studies and in their subsequent careers [45]. Keeping women in the computer science industry is important for several reasons. First, a diverse workforce drives growth and innovation in the economy. Ensuring equal opportunity in profitable tech fields is crucial from an equality perspective [39]. In terms of society, increased female representation results in well-rounded, balanced products that reflect more various viewpoints [39]. Tackling this issue requires a thorough understanding of the causes of these disparities along with development of effective strategies for improving retention.

Research studies have already identified the causes of this issue. It has been documented that environmental and social factors are important in creating a sense of belonging for women in tech environments. This, in turn, increases retention and creates a coherent work environment [14]. In addition, female students need to have esteem for their skills and competence, as this is also a decisive factor in their retention and further specialization in computer science [2]. Identity-related factors and stereotype threats contribute to the attrition rates among women as well [13]. Other studies focus on effective institutional strategies. For example, support programs, inclusive curricula, and the establishment of women-centred tech communities have shown positive results in various case studies [36].

This paper is a literature review which aims to investigate the following research question: **"What are the effects of higher education policies aimed at reducing gender bias and stereotypes and how do these policies influence the overall academic and career outcomes for women in CS?"**. This investigation describes and evaluates various techniques designed to mitigate gender bias and stereotypes in post-secondary CS education. To provide an objective assessment, the paper provides empirical evidence upon implementation of these policies. In the discussion section, the paper offers interpretations of results, challenges in policy implementation, suggestions for policymakers, and describes possible limitations of the study.

2 Background Information

2.1 Evolution and Current State of Gender Disparities in CS

The role of women in CS has evolved dramatically over the past thirty years. Women were the leaders in the field, thanks to scientists such as Ada Lovelace and Grace Hopper, but around the mid-1980's the gender balance in CS started to skew quickly in favour of men. Several factors are responsible for that decline, including the invention of personal computing, which was marketed mainly to males, and the imposition of stereotypes in popular culture [1].

More recent data shows that of the bachelor's degrees awarded in CS in the US, about 20% of these are awarded to women, whereas they represent about 57% of all college students [45]. In the same way, there is also a lack of representation in CS industry. Only 26% of the computing workforce is comprised of women [53]. These statistics show a persistent gender gap that signifies underlying issues.

Furthermore, female students in CS are more likely to experience bias in academia and negative stereotypes which undermine their belonging and capabilities. Such an environment results in lesser self-confidence, which in turn leads to lower retention rates [12]. Also, the absence of female role models and mentors in academia and industry worsens the situation [15].

Addressing CS gender disparities is significant not only for equality reasons but also in terms of innovation and the ability to tackle new problems in the field. Many researches have shown the positive impacts of including different points of view in increasing creativity and effectiveness in creating solutions. Letting women have equal opportunities in technology careers is also one of the important considerations in social fairness and economic empowerment [19].

Many universities have implemented policies to support female CS students, including support programs, holistic admission, curriculum changes, etc to create more inclusive classroom environments. These efforts aim to provide female students with the resources and support needed to have equal opportunities in the field.

2.2 Related Literature Reviews

Female retention in CS has been the focus of many studies, which have examined a range of higher education policies aimed at addressing gender diversity. For instance, one study provided an overview of initiatives used to boost recruitment and improve retention among women in undergraduate CS courses. It categorized the measures into four groups: policy, pedagogy, influence & support, and promotion & engagement, and showed the diverse approaches taken to tackle the problem [8].

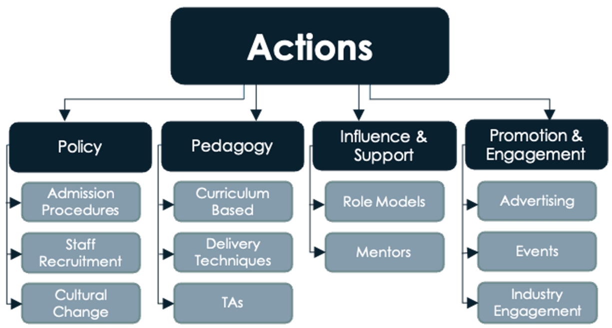

Figure 1: Categorization of measures [8].

This categorization allowed for the separation of related policies and led to a more precise and individualistic examination. The study describes the contribution and importance of measures within each category and concludes that there is no single solution and policies should be applied according to the situation [8].

Another related paper conducts a literature review, regarding the status of women in STEM for the period 2007-2017. This review covered areas such as recruitment, retention, barriers, and faculty issues. It identified stereotypes, biases, campus culture, classroom experiences, identity, and sense of belonging as significant factors affecting female students' experiences and retention in STEM fields [9].

3 Methodology

This literature review investigates existing research on higher education policies and practices that contribute to the retention of female students in CS studies and the effects of these policies. In the following section, we describe the steps taken to gather, analyze, and document relevant literature, ensuring the research is transparent and replicable.

3.1 Preliminary Setup & Research

This step served as a foundation for all subsequent research. First, three primary scientific databases were utilized: Scopus, Springer Link and JSTOR. The resources in these databases strongly emphasise high quality, all of them are peer-reviewed and there are plentiful articles, journals, books, etc. which are relevant to the research question on higher education policies affecting the retention of female CS students. Scopus is an extensive resource that contains academic journals across multiple disciplines, including education and social sciences. Springer Link also provides many resources regarding a wide range of subjects, making it relevant to the current study. Finally, JSTOR delivers a wide coverage of materials and is useful as it has thorough archival content which was used to identify possible historical trends. These databases were chosen to cover a wide range of perspectives that consider different stances regarding the subject.

In addition, this step involved identifying an initial set of query words and phrases that ensure breadth of the topic, such as: "female retention in computer science programmes", "gender bias in STEM education", "university policies for gender equality in STEM", "stereotypes in computer science" "women in technology education", "support programs for women in CS higher education", and "inclusive practices in STEM". The keywords were used in different combinations to maximize the retrieval of relevant articles.

This round of preliminary research produced over 75,000 query results within the three databases, as described in Figure 2. The query words used were broad enough to provide valuable insights, context about the gender disparities in CS and a starting point for researching various policies that mitigate this problem. This was done by scanning over titles and/or abstracts and recording recurring themes and policies.

3.2 Data Collection

The results from "Preliminary Setup & Research" were further refined in this step. This was achieved through the means of inclusion/exclusion criteria. The inclusion criteria included several requirements. This paper needs to include only studies carried out over the last 20 years in order to focus on recent trends. The referenced studies need to be in English language. An essential inclusion criterion is that all referenced papers need to be relevant to the exact research question and not just the topic of women in CS. This required narrowing down search criteria to the following phrases: "holistic admissions in CS degrees", "anti-discrimination policies in STEM and CS", "Mentorship programs for gender diversity in CS", "Scholarship programs in CS", "Effects of pair programming", "Project-based learning and its effects on female retention in CS", "Inclusive learning techniques in STEM and CS". Therefore, this was the final set of queries used when collecting data. In order to adhere to academic standards, the inclusion is also established on studies in peer-reviewed journals. Finally, the papers need to be empirical studies, and literature reviews that provide qualitative or quantitative data on the effectiveness of retention strategies. Exclusion criteria consist of studies that are irrelevant to the research question, non-academic sources, i.e. opinion materials, blog posts, non-peer-reviewed articles, and outdated research.

This step significantly reduced the amount of query results as it removed many papers which are irrelevant to the current research question.

3.3 Resource Overview and Analysis

The final step involved conducting "Resource Overview and Analysis". Titles and abstracts were reviewed to determine their relevance. Afterwards, the material was selected for complete review if it was pertinent. The selected articles were fully read to collect data and examine key information such as study objectives, methods, findings, and conclusions. Furthermore, the collected data was analyzed to identify common themes and patterns across the studies. This meant sorting papers according to theme relevance and the policy/ies they examined. In addition, the effectiveness of each policy was measured by examining the impact and result of each policy. This was done by looking into quantitative statistics and reports. Upon completing this step, 42 papers were selected and referenced in this study.

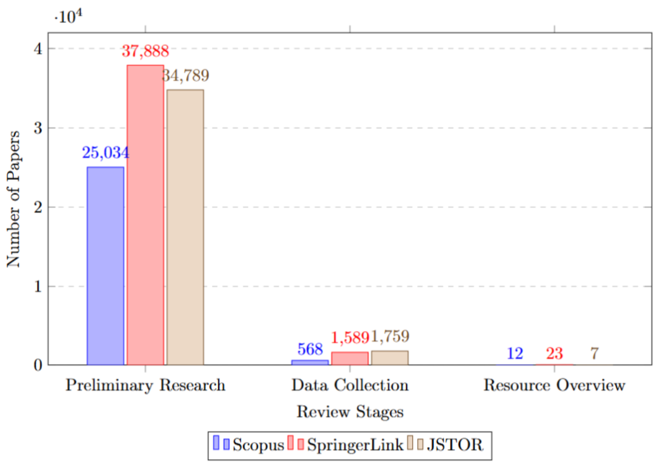

Figure 2: Number of papers per review stage.

3.4 Thematic Overview

Three core themes were identified after the examination of the papers. They are "university strategies for gender inclusivity", "pedagogy/curriculum design" and "engagement & support programs". The categories from Berry et al. shown in Figure 1 have been used as a starting point in theme classification and were a major inspiration for the above-mentioned themes. However, there is one key difference between the themes identified in the two papers. Berry et al. classify mentorship (role-model) guidance as a separate theme. Yet, the findings of this paper treat mentorship programs as a form of "engagement & support program". This is because it is often the case that such programs (mentorship programs, scholarships, etc.) are used together in combination. Each one has its own contributions and it is difficult to isolate the individual benefits and/or assign greater importance to one measure over the others, as it is context-dependent.

The papers referenced in the "Results" section are connected to one of the following categories. Figure 3 shows the paper distribution by theme. It is worth noting that there isn't any evidence of themes being underresearched, as there weren't major difficulties in finding resources about a field of interest.

3.5 Documentation

After completing the data collection and analysis, all information was summarized and all key insights were extracted. The paper presents the most common university policies to promote gender diversity and backs up the effectiveness of each of them with real-world data.

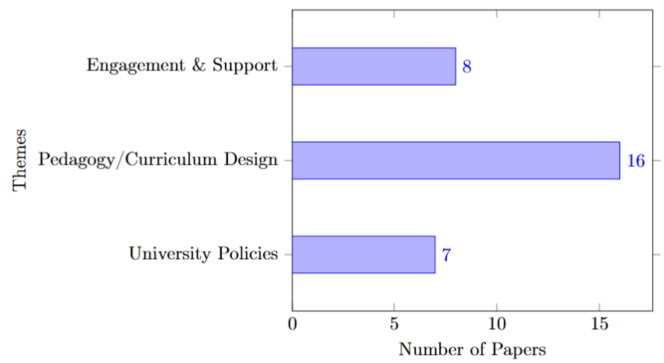

Figure 3: Paper distribution per theme

4 Results

This section documents various, well-established higher education policies and investigates their effectiveness. This section is divided into two parts. The first one reflects the following themes - "University strategies for gender inclusivity" and "Engagement and support programs". This is done as policies regarding these two themes are tightly interconnected and follow a direct approach when tackling gender disparities. More specifically, this includes gender-sensitive admission, anti-discrimination policies, support groups, etc. The second section looks into a more oblique, indirect approach which focuses on measures regarding the pedagogy and curriculum design of the study. This mainly includes creating a more inclusive environment and introducing practical context to education.

4.1 Policies for Mitigating Gender Bias & Stereotypes

Gender bias and stereotypes in CS education are significant impediments to the retention of female students. These biases appear in different forms, including curricular content, classroom settings, and institutional policies, often leading to a less inclusive and supportive environment for women. This section investigates ways of mitigating gender bias and stereotypes and brings out areas where further intervention may be necessary.

Research has shown that gender bias and stereotypes negatively affect female students' experiences and results in STEM fields, including Computer Science. For example, it has been found that stereotypes about gender and STEM capabilities can undermine women's confidence and interest in these fields, which in turn can lead to higher attrition rates [18]. Additionally, gender stereotypes in educational environments can lead to a sense of isolation and a decreased sense of belonging among female students [20]. There have been many institutional measures used to combat bias and stereotypes. These policies can be generally categorized into gender-sensitive admissions, anti-harassment policies, and support programs.

Holistic Admissions & Bridge Programs

Holistic admissions and bridge programs policies try to increase the number of female students entering CS programs.

This measure diversifies the class and prevents stereotypes and bias from forming and/or defining the students in the CS programme. This measure can be applied in several different ways. One way is by introducing holistic admissions processes. They consider a broader range of student qualities apart from standardized test scores. This includes considering extracurricular activities, work experiences, personal background, talents, etc. Such admission practices are essential as they can help mitigate the impact of gender biases inherent in traditional admissions criteria [40]. For example, the holistic approach to admissions at Carnegie Melon University proved to be very effective in diversifying the student population in CS courses. There has been a significant increase in first-year female students in recent years, as presented in the figure below.

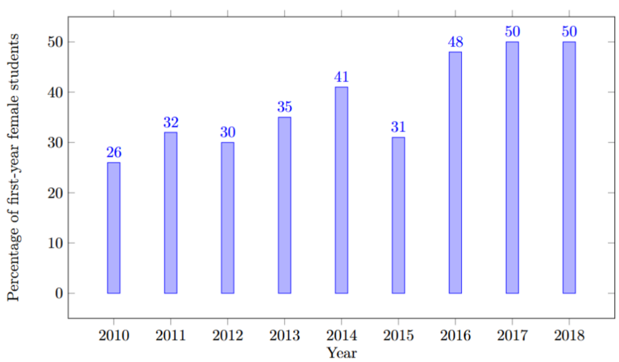

Figure 4: Share of first-year female undergraduate students at Carnegie Mellon University's School of Computer Science (2010-2018) [50]

Bridge programs are also beneficial in achieving greater gender diversity. They can be useful for women, who are less likely to have had prior exposure to CS before college as these programs often provide preparatory courses and experiences for incoming students [4].

One real-life example of such a measure is the CS Kickstart. This is an initiative at the University of California, Berkeley designed to attract and increase the retention of female students in CS by providing them with a foundation before they begin their undergraduate studies. Participants can follow preparatory CS courses, do hands-on projects and meet faculty and industry professionals. This practice acts as a bridge program as 33% of participants switch from other majors to computer science in the first year alone. Since its inception, the program has doubled the number of female CS majors at UC Berkeley [37].

Another example of a successful bridge program is "Girls Who Code". It is a multi-university initiative which aims to popularize CS among female students. It is present in many colleges throughout the US and through so-called "College Loops" provides networking, mentorship, and career development opportunities. It also allows students to connect with peers and professionals, attend tech conferences, and gain access to internships and job placements. As a result, the majority of program participants are more confident in their ability to pursue technical internships and jobs as a result of participating [31].

Anti-discrimination Policies

Another measure is the anti-discrimination policies. They are designed to protect students from gender-based discrimination and harassment, ensuring that all students have equal development opportunities and can learn in an inclusive environment. Such policies include report procedures, support for victims and protocols for enforcement. An example of such a measure is the Anti-discrimination policy adopted at UC Berkeley. It is a thorough document that includes various definitions of discrimination, both academically and socially. It contains clear step-by-step mechanisms for reporting and a section that describes the consequences of non-compliance to that policy [49]. Institutions with such anti-discrimination policies report higher levels of perceived safety and inclusivity among female students, which leads to higher retention rates [42].

Furthermore, systematic seminars for identifying and preventing discrimination have proven to create a more tolerant and peaceful university culture. This measure has a more preventative nature as it tries to tackle the root of the problem. These trainings aim to educate students, staff and faculty members about different types of discrimination including gender bias and discrimination, and how to identify and address such issues. One key component of the seminars that makes the participants actively engaged is the workshops. Interactive elements such as group discussions, role-play situations, or case studies help participants understand the practical side effects of discrimination and develop empathy by seeing issues from different perspectives [16]. For example, a study at Purdue University, shows that participation in diversity training improved faculty members' understanding of inclusion and microaggressions. Participants, especially women and minorities, reported a greater increase in satisfaction with their department affiliation, indicating that such training can enhance feelings of belonging and support [38]. Overall, educational institutions with such training programs report fewer incidents of discrimination and greater cooperation among students to report issues [47].

Support Groups & Measures

Mentorship, scholarships, development opportunities and other initiatives are applied as support programs by various institutions. For instance, financial support for female students in CS can remove economic barriers and encourage more women to pursue and succeed in these fields. It has been shown that scholarship programs have significantly increased the number of women enrolling and completing CS degrees [48]. In 2018, Middle Tennessee State University decided to implement a 5-year STEM scholarship to attract more students to their CS program, with a focus on making the student population more gender diverse. This financial support measure yielded positive results as scholars had better GPA grades and received five credits on average more per year than the rest of the students. In addition, the dropout rate of scholar students (15%) was significantly lower than that of regular students (37%) [26]. In addition, a study by The National Action Council for Minorities in Engineering

(NACME) Academic Scholarship Program at Arizona State University showed that providing scholarships to underrepresented students significantly improves retention rates. Female students in the program showed higher retention compared to the male students. This indicates that financial support can be an effective measure for retaining female students in CS [5].

In addition, introducing mentorship programs significantly increases the sense of belonging in the field and boosts students' confidence. Teaming students with mentors has been shown to benefit students as professionals share advice, experiences and guidance. Also, peer mentoring programs early in college significantly increase women's positive academic experiences and retention in engineering and CS [23]. In addition, mentorship reduces the stereotype threat, as female students can identify role models and look up to them [34].

Based on an interview study conducted at the University of North Carolina at Charlotte, female students who have participated in mentorship programs during their CS education listed mentors as people they saw as role models, people who boosted their confidence and received guidance from. Also, mentors helped them explore new professional places, exposed them to possible career opportunities and expanded their professional network [46]. Mentorship programs often include workshops. They usually focus on coding, project management, and leadership skills. Often, women in the CS industry or academia highlight the importance of such seminars and find them helpful in their professional development [27]. The table below represents a study at the University of Massachusetts Amherst which surveys STEM students who participated in a mentorship program. Mentees gave positive feedback and a reported symbiotic relationship with a mentor [23].

Mentee reports (7-point scales: 1 = not at all, 7 = very much)	Male mentors		Female mentors	
	Mean	SE	Mean	SE
Support received from mentor	4.69	0.28	4.92	0.25
Availability of mentor	5.04	0.25	4.96	0.26
Personal connection with mentor	4.35	0.28	4.69	0.22
Chemistry with mentor	4.86	0.27	5.12	0.23
Admire mentor	4.84	0.26	5.31	0.23
Can attain same level of success as mentor	4.86	0.27	5.40	0.22
Feel similar to mentor	4.24	0.26	4.83	0.22
Identify with mentor	4.51	0.27	5.10	0.21
Feel close to mentor (mentor-self overlap)	4.27	0.23	4.90	0.23

Table 1: Mentees' evaluations of mentoring relationships [23]

4.2 Policies Implemented in Pedagogy & Curriculum Design

Another key factor regarding female retention in CS programmes is the adequate structure of course curricula. Traditional CS curricula have often been criticised for not being inclusive enough or being unable to retain a diverse student body. Such course structures emphasize competitive and individualistic learning approaches which might discourage female students, as the latter tend to prefer a more collaborative and contextually relevant environment [41]. This section investigates the effective curriculum designs to make CS education more inclusive and supportive for female students.

Introducing Practical Context to Education

One possible way of making current curricula more relevant and inclusive is by incorporating real-world problems and applications. This includes project-based learning where students work together as a team and try to solve a real, practical problem. It has been documented that project-based learning increases students' motivation, provides sense to their work and generally enhances the learning process. Female students may find this helpful as they prefer a more sociable and collaborative learning environment [41]. Generally, tackling a common problem allows students to apply theoretical knowledge to practical projects, and develop technical skills simultaneously. Group work ensures students communicate, share ideas, and work collaboratively to solve a shared task. This enhances practical skills and other personal attributes that the CS industry deems important [22].

In addition, project-based learning increases the sense of responsibility among team members as it allows them to choose projects, set goals, and track progress. As a result, students become more independent, motivated and accountable. Adopting a project-based approach to education has been shown to enhance knowledge, collaborative and social skills, critical thinking, and exposure to real-world problem-solving [33]. One possible context of such projects is that certain coursework can be modelled in a way such that it solves a particular problem, both related to the university and not. For instance, this might include developing grading software, internal communication software, etc. or helping out local non-profit organizations and companies.

A college that successfully implemented such a policy is Harvey Mudd College. For a time interval of 7 years, between 2004 and 2011, this university has managed to increase female students in CS from 12% to 40%. This was achieved through a thorough curriculum redesign that included many practical projects that included real-world applications [3]. Such projects can also be in the form of internships or partnerships. Interactions with companies allow students to gain a lot of insights about the CS field and at the same time apply academic knowledge into practice. It has been documented that such practices effectively retain female students as they provide career opportunities and industry connections [29].

The positive effects of implementing project-based learning in STEM and CS disciplines can be observed in table 2. It reflects a survey among STEM students at the Howard Hughes Medical Institute. The table presents 1=strongly disagree to 5=strongly agree Likert scale on the following measures. In each one of the measures, students who participated in project-based learning felt more confident and capable, except for "relative cost", as some felt it overwhelming to manage large projects [6].

Collaborative and Inclusive Learning Environments

Collaboration and inclusivity in the learning environment provide students with ways they express themselves, increase engagement, as well as reduce the isolation that students sometimes face. Proper integration is essential, as students who feel isolated or left out have much higher chances of dropping out and/or performing unsatisfactorily [11]. Such practices can increase gender diversity and alter the CS class-

	No project-based			Project-based		
	N	*M*	*SD*	*N*	*M*	*SD*
1. STEM Self-efficacy	246	3.467	1.008	244	3.584	0.996
2. STEM Skills efficacy	245	3.805	0.639	238	4.062	0.583
3. Attainment value	245	3.959	0.903	241	4.083	0.864
4. Intrinsic value	243	3.542	1.062	242	3.668	0.982
5. Utility value	245	3.791	0.997	240	4.078	0.782
6. Relative cost	245	2.370	0.926	241	2.238	0.864
7. STEM Career aspirations	246	4.004	1.106	243	4.271	0.825

Table 2: Comparison of STEM metrics between no project-based and project-based learning

room into a more shared experience rather than individualistic as is often the case. Inclusive pedagogy can transform the classroom environment. An online professional development program involving over 200 participants showed that collaborative lesson planning and discussions significantly enhanced teachers' ability to implement inclusive teaching practices, thus improving the classroom environment for female students [32].

For instance, one method to achieve such a collaborative setting is through **pair programming**. It involves two students working together at one computer, writing code and completing a given task. Such activity includes active discussion, shared research of technology, teamwork, and most importantly common problem-solving. This enhances one's technical knowledge and coding skills, bonds students together, and develops soft skills [43]. This practice can create a more cohesive class and help maintain gender diversity and inclusivity, which in turn leads to increased retention of female students. Real-life assessment of this measure have been conducted at several universities through a single comparative study. The study design included controlled comparisons between sections of an introductory course where one group used pair programming and another group worked individually. Individual programming skills were assessed using lab assignments under exam conditions, and additional metrics such as written exam scores, homework, pre- and post-semester attitude surveys, and retention into subsequent courses [10].

For instance, at North Carolina State University, paired sections showed significantly higher rates of students receiving grades of C or higher compared to solo sections, and paired students performed better in later courses. At the University of California, Santa Cruz, paired sections had higher course completion rates in most semesters, and paired students were more likely to register for the next programming course. The University of Auckland study found that paired students received higher scores on individual programming projects. The Pondicherry Engineering College study reported significantly higher individual written test scores for paired students. Finally, the study shows that pair programming improves individual programming skills and enhances students' confidence and course completion rates without negatively impacting future solo programming performance. These findings also demonstrate that pair programming improves student outcomes and retention [10].

Another useful method is incorporating **classroom-style groups** in the learning process. This includes having lectures and labs in small, break-out groups with no more than 20 students. The key advantage of this practice is the personal attitude towards each one of the students. In smaller groups, the lecturer can adapt to the group dynamics and alter the teaching approach as needed. Also, the learning process is facilitated as students can discuss the material more openly and ask questions if needed. Being part of such classroom groups also increases the sense of belonging and keeps students motivated by creating an idea of common purpose [51]. One flaw of a large classroom environment is lack of communication among students and faculty. Breakout classes can mitigate this by allowing for more direct interaction and support from instructors and peers, which is crucial for building confidence and competence [51]. The implementation of breakout classes has been linked to creating a more supportive learning environment that addresses the specific needs of female students. At the Dublin Institute of Technology, adopting smaller class sizes and support groups led to a dramatic increase in first-year retention rates from 45% to 89% [44]. Such practices encourage students to be more tolerant, accepting and open-minded towards their fellows with whom they share common goals.

A third method for achieving a considerate learning environment is by adopting **inclusive teaching practices**. Inclusive teaching practices are educational strategies that appeal to different types of students, to their learning styles, backgrounds, and experiences. In the CS field, such a method is important for female retention as it is predominantly male domain. This, for instance, be achieved through culturally responsive teaching. This approach includes using culturally relevant examples and addressing different points of view. This increases the engagement with the study material as it is perceived as more relevant and results in better grades, improved motivation and retention [30]. Another inclusive teaching practice is the Deep Teaching style. This style emphasizes self-awareness, empathy, and creating a supportive classroom setting, which are crucial for improving the retention of female students in CS [24]. It has a strong emphasis on understanding one's self and the student in order to achieve mutual respect and understanding in the educational process. The model employs a sequential approach that begins with instructors reflecting on their own teaching practices and continues by developing empathy for students. This strengthens the bond between students and teachers and increases the sense of belonging, especially for those from an underrepresented group. By creating a supportive classroom environment, the Deep Teaching model enhances the retention of female students in CS programs, making them feel more welcomed and valued [24].

Another related technique for achieving inclusive teaching is the **Active Learning technique**. This technique relies on regular discussion, group tasks and projects. Students actively apply the learning material as opposed to passive listening to lectures. Such an approach leads to deeper understanding, higher participation, and has been documented to be particularly beneficial for underrepresented groups in

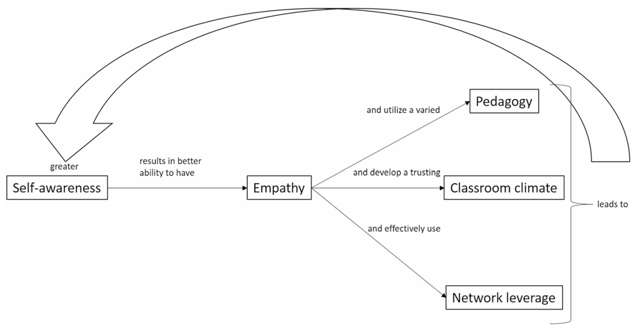

Figure 5: Flow of the classroom environment according to Deep Teaching model [24].

STEM [28]. Research has shown that active listening is crucial for women's educational and career success in the science and engineering fields. For example, a study involving an online educational simulation for female natural sciences and engineering students found that detailed feedback during active listening exercises improved participants' knowledge and skills. This demonstrates that active listening can help female students feel more understood and supported [7]. Additionally, active learning strategies that require active listening have been shown to significantly improve students' engagement and retention of course material. Methods like think-pair-share and minute papers have led to higher final exam scores and greater student satisfaction, by articulating their thoughts and listening to their peers [25]. Overall, active listening encourages effective communication, addresses individual concerns, and creates a supportive and inclusive learning environment. Thus plays an essential role in improving the retention of female students in CS programs.

5 Responsible Research

The following study was conducted with adherence to ethical standards and research integrity. The study relied on secondary data from peer-reviewed sources, as such it was ensured that all data collection processes included informed consent from participants. Also, information was analysed as objectively as possible, without bias towards specific policies or institutions. This was done to provide a balanced evaluation based on empirical evidence. All sources of data, models, and prior research received attribution utilizing citations. The methodology was described to allow transparency and reproducibility. This included information on the databases used, search terms, and criteria for inclusion and exclusion.

One key takeaway of the following study is realizing the importance of systematic documentation of used findings and resources. If I were to conduct the study once again, I would put additional emphasis on documenting all steps in data collection and filtering, so that each resource used can be backtracked via the query used. This allows for a more accurate methodology description and replication, which boosts the quality of the research.

It is important to note that ChatGPT was used to aid the following processes: chart creation in latex and brainstorming initial ideas and examples upon beginning the research. Any information provided by the LLM was double-checked in peer-reviewed sources.

6 Discussion

The study explored and evaluated the effectiveness of different higher education policies designed to retain female students in CS programs. It demonstrates that this problem requires a complex approach where a single policy is usually insufficient and a single measure only solves a specific aspect of the problem.

6.1 Interpretation of Policies' Results & Knowledge Gaps

All of the higher education policies described above try to enhance the well-being of female students. In other words, each measure contributes to one or more of the following: creating a sense of belongingness, decreasing isolation, creating a more collaborative/inclusive environment, identifying and addressing discrimination, having role models to look up to, being able to receive guidance/support, networking, etc. Existing research is relatively unambiguous as to the contribution of a specific measure. For example, many papers specify the similar benefits of holistic admissions and bridge programs, anti-discrimination policies, mentorship programs, collaborative classrooms, etc. This means that it can be established with certainty that each policy has its own effects contributing to female retention. It is also worth noting that these effects can differ quantitatively due to the context they are applied in.

This leads to the identification of several knowledge gaps within existing research. To begin with, most of the research regarding the subject matter is written in North America and Europe. This creates an informational limitation as all of the investigated data, results and policies might be irrelevant in other parts of the world. Not only that, there is a possibility that certain measures can backfire and actually produce negative effects for female students in CS and STEM in some parts of the world. Another knowledge gap in current research is the lack of data regarding the longitudinal impact of the policies [17]. Existing papers evaluate retention in terms of course completion, course grades and situational well-being. However, there is a lack of data explaining if these measures lead to the best professional outcomes, career development and satisfaction. It is also not well known if these measures lead to professional retention in the future or offer short-term solutions [8].

6.2 Suggestions for Policymakers

Certain institutions and policymakers can make use of this paper. The best way to utilize this document is to first identify gender disparities within one's university or higher education institution. This means identifying what are the possible causes of problems. One can start by answering the following questions: "are there students who feel left out?", "are some students discriminated?", "do all students receive equal opportunities in terms of learning and development?", "are there effective strategies to guide/support discriminated students or students from underrepresented groups?", "do students find the curriculum engaging and inclusive enough?", "are there ways for interested students, from underrepresented groups, to switch to CS utilizing bridge programs?", etc. After having a clear perception of the institution's problem, one can refer to the "Results" section. The interested party can investigate which measure he/she might need and what are the possible effects of the policy.

Moreover, policymakers are encouraged to implement a bundle of measures as the positive influence of one policy is enhanced and complemented by the effects of others. Suppose one wants to make the classroom environment more collaborative and inclusive, except for adopting inclusive teaching techniques, one can introduce anti-discrimination policies and training as well. Thus the effects of both measures are fortified. There is no single policy which can single-handedly increase female retention in STEM and CS, however with adequate problem identification and application of measures gender diversity can be achieved.

6.3 Challenges and Difficulties of Policy Implementation

An important aspect of these policies is the adoption process within a higher education institution. Some barriers are worth noting, especially when introducing change within large organisations that involve bureaucracy.

To begin with, one innate problem of these policies is that individual measures lack rigorous evaluation and measurement of outcomes. This is because it is difficult to determine the effectiveness of specific actions, often in the absence of control groups and clear metrics [8]. Many factors influence both causes and effects, such as university context, location, cultural background of students, etc. This makes it difficult to have a clear, objective measurement of each policy, which in turn complicates the decision about which is the most suitable measure for the situation.

Another obstacle is the possible cultural resistance within the institution. Research indicates that curricular and cultural factors can discourage female students from pursuing their computer science degrees. This indicates that tackling deeply entrenched bias and cultural norms requires a lot of institutional effort, however, it is needed in order to remove any stereotypes that impede gender inclusivity [52].

Resource barriers further impede the proper implementation of policies. It is often the case that effective measures require substantial financing and human resources. This means that institutions with smaller budgets and fewer resources would adopt such policies at a slower rate and/or not as effective as "richer" universities [35]. In addition, universities which lack managerial resources or have centralized decision-making are less competent in adopting new educational policies [21].

Understanding the challenges in policy adoption can lead to a better managerial process among interested parties and policymakers. For the implementation of measure/s to be as effective as possible, it is worth grasping any possible drawbacks beforehand.

6.4 Limitations

One significant limitation is the compressed timeframe. The paper was produced over 10 weeks, thus putting temporal constraints on the conducted analysis. As a male researcher, there is also a likelihood of not fully grasping the factors that hold for female retention, which may have led to bias in data interpretation and outcome conclusions. An additional problem arises in the analysis since some research has knowledge gaps. This means that some policies' effects are not investigated fully. Finally, the study could be affected by selection bias. The chosen literature and data sources can lack a general representation of the full spectrum of experiences related to female students in the CS programs.

7 Conclusions and Future Work

This study investigated the effectiveness of different higher education policies and practices in retaining female students in computer science programs. The primary research question focused on identifying successful strategies and understanding why these strategies promote female retention. The current paper focuses on two types of policies - direct and indirect. The former, having a more straightforward approach, includes holistic admission & bridge programs, anti-discrimination policies and support groups & measures. The latter, however, focuses more on curriculum design and what are the best ways to create a welcoming, inclusive and collaborative learning environment. Each one of these policies has its own specific contribution to increasing gender diversity.

For example, holistic admissions and bridge programs allow for a wider selection of candidates. Anti-discrimination policies and trainings promote inclusivity and help students identify and tackle forms of discrimination. Having support groups and measures, such as mentorship and scholarship programs, creates a sense of belongingness, increases well-being and removes possible economic barriers. Furthermore, the policies connected to curriculum design, such as introducing practical context to education and adopting collaborative/inclusive teaching techniques, all aim to promote a comprehensive learning environment which reaches and engages all students equally.

This paper can be of use to policymakers or people interested in gender diversity in CS. They can review various policies, their impact and efficiency. They are also encouraged to utilize more than one policy at the same time as effects complement and enhance each other.

In the future, one can investigate further techniques and document their efficiency and results. Any experimental or newly adopted policy is also worth examining and recording. Additionally, future research can also study how gender interacts with other social identities—such as race, socioeconomic status, and disability. This would create a more sophisticated analysis of the policies and would allow for a more custom-tailored approach to the problem of female retention in CS.

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