frontiers | Frontiers in Education

TYPE Mini Review
PUBLISHED 04 September 2025
DOI 10.3389/feduc.2025.1598369

Check for updates

OPEN ACCESS

EDITED BY
Pilar Gema Rodríguez Ortega,
University of Cordoba, Spain

REVIEWED BY
Miloš Krstić,
University of Nis, Serbia

*CORRESPONDENCE
Claudia Patricia Ovalle Ramirez
✉ covallera@gmail.com

RECEIVED 28 April 2025
ACCEPTED 05 August 2025
PUBLISHED 04 September 2025

CITATION
Ramirez CPO (2025) Female engagement in STEM through hybrid programs (Ireland TUD-model).
Front. Educ. 10:1598369.
doi: 10.3389/feduc.2025.1598369

Female engagement in STEM through hybrid programs (Ireland TUD-model)

Claudia Patricia Ovalle Ramirez*

Department of Psychology, University of Antioquia, Medellín, Colombia

Purpose: The article describes factors that may boost female participation in STEM undergraduate programs and a model applied at TUD (Technical University Dublin).
Design/methodology/approach: It presents a case study in Higher Education involving an ecosystem that fosters the involvement of females in one STEM hybrid undergraduate program in Ireland.
Findings: The successful program implemented by TUD was based on empirical research that demonstrates that females do not lack skills but have a diverse profile of abilities. Therefore, females need undergraduate hybrid programs designed to attract them and develop their multiple skills, involving not only Engineering but also practical training in fields such as Medicine, Management and World Languages.
Conclusion: The "Infrastructures of Inclusion" such as hybrid programs and high impact practices (academic, social, institutional), are relevant for involving a higher proportion of females in STEM fields such as Computer Science.
Practical implications: Future research may evaluate the impact of hybrid programs in STEM to boost female participation in other countries.
Research limitations: The research is limited to one geographical area (Dublin, Ireland).
Originality/value: This article contributes to inform interested researchers with one model hosted at TUD Dublin.

KEYWORDS

STEM, female participation, inclusion, education system, undergraduate program, engineering

Introduction

Educational research on gap closure has focused on typical individual variables (i.e., student academic abilities, motivation, and student engagement with their career) (Zapata et al., 2018). Currently, research focuses on high-impact institutional practices for the success of vulnerable students, also called "inclusion infrastructures" (Strum et al., 2011; Strum, 2007, 2006).

These practices include offering relevant programs, public engagement for teaching (i.e., faculty engaged scholarship), learning (i.e., student civic engagement), and fostering faculty and administrative diversity (Strum et al., 2011; Strum, 2006). Offering relevant programs refers to training opportunities that meet environmental, economic, and social needs (Tett et al., 2017; Ulriksen et al., 2017). The relevance of higher education programs also refers to student satisfaction with the choice of institution and university programs. Public engagement for teaching ("faculty engaged scholarship") refers to how postsecondary institutions serve communities through their missions, context-relevant academic output, and empowerment of the community (Masanche, 2020). Involvement for learning ("student civic engagement"), implies the construction of subjectivities through actions such as participation in service-learning that strengthen the civic contribution on the part of vulnerable or excluded students (Barnett, 2018; Hellwege, 2019). Also, fostering faculty and administrative diversity helps teaching methodologies and curricula to be perceived as more relevant when the student shares the same culture and interests of the teacher and administrators (Munday et al., 2019); it also decreases negative impacts such as the risk of stereotyping and lack of a sense of belonging (Benitez et al., 2017) and eliminates selection biases in the admission of minority students (Schmaling et al., 2015).

> Because higher education institutions have their own culture and leadership (Klempin and Karp, 2018), there may be a wide range of inclusion practices that favor the success of vulnerable and minority students in STEM, such as women. These practices indicate the way Universities should approach women's participation in higher education.

Conceptual framework

In Europe, The Parliament's report on female STEM education and employment (FEMM Committee, 2020) emphasizes the importance of creating "enabling environments" respecting individual choice to facilitate women's enrollment in STEM (Science, Technology, Engineering and Mathematics) and work fields such as AI and cybersecurity.

Likewise, the most recent systematic review of support programs for STEM degrees (Pearson et al., 2022), points out that the persistence and retention of low-income, first-generation, and underrepresented students depends on a few critical components: active recruitment and admission non-conditional on grades or standardized tests (i.e., instead future academic development potential is determined); academic support (i.e., mentoring from faculty and seniors, research from the beginning, meeting with role models, GRE preparation, target academic interventions, and transition summer bridge programs); social supports (i.e., peer interaction through living accommodation on campus); financial support (specific financial support and incentives); and involvement/engagement (i.e., avoiding stereotype threat, preventing conforming to traditional gender stereotypes, etc.). Among these factors, the two that show major impact are the practice of research (from the beginning in laboratories with knowledgeable mentors) and the training of faculty and administrators (i.e., investing in continuous training of mentors).

A successful example of the inclusion of women in STEM is the *Biology Scholars Program* (BSP) at Cornell University (United States), which closes the wide gap between URM (underrepresented) and non-URM students in terms of GPA and graduation rates (Ballen and Mason, 2017). This is possible thanks to an "inclusion infrastructure" that consists of academic monitoring and support through small study groups (2-h study group during sophomore year), leadership development, early interaction with faculty (seminars on research and ongoing research in laboratories from the start), career and professional development (visits to graduate and medical school) and a sense of community developed by the program among URM students.

In the USA, female engagement in STEM is centered around the "hidden engines of the economy" such as e-health, cloud services, programming, and software/hardware development, Females have been attracted by articulating the needs of employers with the educational offer in STEM in innovative fields (Sanchez, 2023).

OTH Regensburg in Germany has also implemented STEM programs: Bachelor of Medical Information Technology and Bachelor of Business Information Technology. The programs take seven semesters (terms) each including three intensive components: two theoretical (basic and core computing) and one practical (clinical applications and practice in hospital/companies). The modality is dual, closer to industries, and more attractive to females because the programs include applied learning in a second non-STEM field (OTH Regensburg, 2024).

In Ireland, the need to provide personalized training and upskilling for vulnerable groups living in households with low work intensity has also been suggested (Council of the European Union, 2019; Osnabruck Declaration, 2020). These recommendations involve the technical higher education system and its ability to develop infrastructures of inclusion for females. For example, the creation of new higher educational programs to engage and motivate women in non-traditional areas, such as Computer Science, intertwined with Medicine, Business, or Psychology.

Paradoxically, according to Stoet and Geary (2018), countries with elevated levels of gender equality have the largest STEM gaps in secondary and tertiary education. The gap between boys' science achievement and girls' reading achievement shows sex differences in academic strengths and attitudes toward science, and this is correlated (but not causal) with the STEM graduation gap between genres.

Tinto (2025) indicated that factors engaging students in higher education involve not only cognitive but also non-cognitive aspects. It is not just academics but also psychological (individual skill profile, motivation, etc.) and social factors (acculturation, building communities of practice) that must be intervened to close the gender gap. This will lead to improved retention and performance of female students to contribute to societal goals such as *The Global Sustainable Development Goal 4* (Quality Education: *European female workforce increases in qualified IA and cybersecurity fields*) and *Goal 5* (Gender equality: *Growth and innovation in STEM*).

Recent psychological research has revealed persistent gender disparities in STEM fields and explored several factors influencing women's participation. Among others:

1. Impact of female role models: exposure to female STEM teachers in secondary education increases the likelihood of women enrolling in tertiary STEM programs, but it does not entirely bridge the gender gap (Dulce-Salcedo et al., 2022)
2. Motivational dynamics: female students show strong interest in STEM despite challenges in male-dominated environments (Dökme et al., 2022; Slattery et al., 2023)
3. Socioeconomic and cultural factors: both socioeconomic background and gender influence access to STEM education. This highlights the intersectional barriers (gender and SES) not addressed by higher education (Boyle et al., 2024)
4. Entrepreneurship in STEM: female graduates with STEM degrees face greater challenges in entrepreneurship, with certain educational strategies potentially mitigating this gender gap (Piva and Rovelli, 2022). In a cluster of 31 European countries for the period 2013–2018, the gender gap in entrepreneurship could be explained by the gender gap in educational outcomes, and systems with higher levels of education did not improve the level of female entrepreneurship (Gaweł and Krstić, 2021)

5. Global and cultural contexts: broader studies from India and Nepal discuss cultural, societal, and institutional challenges impacting women's participation in STEM, emphasizing the need for supportive environments (Nandi et al., 2023)

These studies collectively highlight the complex interplay of motivation, role models, socioeconomic factors, and cultural barriers in shaping female participation in STEM education. This research underscores the ongoing need for targeted interventions to address these challenges from both institutional and higher education systems. The present study introduces the model used at TUD (Technical University Dublin) which can boost the female participation in STEM based on evidence to engage women in STEM.

A case study at TUD (technical university Dublin) to close the gap in female enrollment and success in STEM

Former proposals by the School of Computing at the Dublin Institute of Technology (DIT), Ireland, under a "Computer Science for All" (CS4All) initiative, implemented structural reforms at the faculty level to address recruitment and retention issues of female undergraduate computer science (CS) students by providing female mentors and networking. This intervention was extended to a more focused curriculum and the development of programs to delve into female students' interests.

For example, the international computer science (ICS) bachelor's degree, allows learning a new language while developing a career in computer science, and overseas work placement or an "Erasmus" scholarship component. The program has achieved a dramatic improvement in female retention, increasing from 45 to 89% in first-year progression rates. The progression rate from first year to second year on Computer Science (CS) undergraduate degrees averaged 45%, and TUD's BSc in Computer Science Program started with just 10% female enrollment in the first year.

In 2020, the percentage of female students in TUD (Technical University) Dublin's Computer Science International degree was 42% because of accessible role models and gender balance among staff and students (ESTeEM: Equality in Science & Technology by Engaged Education Mentoring). These initiatives, under female academics such as Dr. Susan McKeever (head of the Computer Science Department), have led to stable system changes across and outside of TU Dublin. For example, the INGENIC group (Irish Network for Gender Equality at National 3rd Level Institutions for Computing) consists of representatives from seventeen different third-level institutes across Ireland, including TUD. INGENIC fosters the right learning environment to increase the intake and retention of female students.

Dublin has a particular ecosystem that fosters gender balance and parity in Computer Science, as the interconnected niche may influence and inspire women to access and thrive in STEM careers. Dublin is home to several STEM organizations based on computing sciences that are devoted to female access and permanency: Coding Grace, HER+Data, R-Ladies, Women of Wearables, Women who Code, Ladies that UX, Django Girls, Pyladies, Lovelace Space, Womenhack, Lesbians who Tech, Block W Women, in Animation Rails, Girls Gamecraft Teenturn, STEM Women, Cyber Women, Ireland Girl, Geek Dinners, Women in AI Ireland, PhaseInnovate, and Women in Machine Learning and Data Science (IDA-Foreign Investment Consultants, 2024).

This high impact on higher female numbers enrollment was related to a series of evidence-based interventions focused on retention, such as developing critical skills, close attendance monitoring, incentives to participate in practical work, assessment and grades turning, and building a culture of participation. In addition, practices such as recruitment through innovative "hybrid" programs offering an additional learning domain such as "World Languages" and female student contingent experiences (immediate feedback, supportive network of accessible role models and mentors for both staff and students, avoiding student isolation, setting up free coding courses for non-tech and high school level female students, early practical experience). These practices together are "carrots" (motivators) for improved female recruitment, which may lead to wider social and cultural change across the nation favoring female STEM participation.

Based on the following evidence, it can be assumed that hybrid programs can attract females to STEM+:

- Among males and females of comparably high math aptitude, females are also likely to outperform males in verbal ability (Park et al., 2008; Wang et al., 2013). This may allow females greater flexibility in career choice than males and, therefore, more opportunity to consider both STEM and non-STEM fields (Ceci and Williams, 2010; Wang et al., 2013) leading them to want programs that cover more than just technology. This is the "expectancy–value" theory, which recognizes the motivation produced by the value assigned by females to potential outcomes of higher education and the importance of considering their choices, desires and capacities when designing STEM programs for their education.
- According to Ertl and Hartmann (2019), "not all STEM fields are equal, even on a finer level." For example, gender differences regarding realistic and social interests do not decrease in all STEM-L subjects (STEM programs with a low female proportion). This calls for the creation of courses and bachelor's programs that consider both realistic (e.g., computer science) and social interests to promote female engagement and spark motivation and persistence.
- Another theoretical position encompasses intersectionality, the product of gender in interaction with race, ses, disability, etc. (Boyle et al., 2024) called for system-level intervention and the prioritization of females in STEM to prevent and diminish the effects of cumulative disadvantage due to these intersections.
- In TUD (Technical University of Dublin) trends in the success of hybrid computing programs have been observed. TUD's Comp Sci degree together with languages, also called "Computer Science International," consistently came out best on the gender balance of all computing programs in the university. This is explained by McKeever and Deirdre (2018)[1]. The initiative achieved 42% enrollment and persistence of females in STEM[2].

1 https://arxiv.org/abs/2110.06090

2 https://irishtechnews.ie/female-intake-computer-science-degrees-tu-dublin/

- The European Unión Committee acknowledges the importance of a focus on the supply side (the needs and desires) of women regarding their own choices in higher education. The EU also proposed initiatives to include women in IA and cybersecurity through innovative higher education programs structured in a non-standardized male-oriented fashion.
- Recently, the concept of "leaky pipeline in STEM" has been reviewed and modified to give voice to the differences between females and their trajectories which cannot copy male's in STEM trajectories (Miller and Wai, 2015).

Conclusion

There is unexplored potential for new and creative infrastructures of inclusion in STEM to impact female trajectories within developed and underdeveloped nations. A starting point is the creation of Bachelor and Associate programs that allow women to develop their multiple talents, for example, combining their realistic and social interests. Abandoning a cookie-cutter program design philosophy when it comes to the creation of new STEM programs may substantially increase female participation. This has been evidenced by TUD's 42% female enrollment in the Computer Science International program. This infrastructure of inclusion also has incredible leadership under an amazing scholar, Mrs. Susan McKeever.

Author contributions

CR: Writing – review & editing, Writing – original draft.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Ballen, C. J., and Mason, N. A. (2017). Longitudinal analysis of a diversity support program in biology: a national call for further assessment. *Bioscience* 67, 367–373. doi: 10.1093/biosci/biw187

Barnett, L. (2018). Service-learning as a tool for increasing political efficacy and civic engagement at a Hispanic-serving institution. *Citizens. Soc. Econ. Educ.* 17, 151–167. doi: 10.1177/2047173418809707

Benitez, M., James, M., Joshua, K., Perfetti, L., and Vick, S. B. (2017). "Someone who looks like me": promoting the success of students of color by promoting the success of Faculty of Color. *Liberal Educ.* 103:n2. Available at: https://eric.ed.gov/?id=EJ1150813

Boyle, N., McGettrick, R., and O'Sullivan, K. (2024). "I just want to annoy him now and say, look, I can do STEM too!": a qualitative investigation into the attitudes and engagement of female students in STEM education in Ireland. *Int. J. Adolesc. Youth* 29:2387082. doi: 10.1080/02673843.2024.2387082

Ceci, S. J., and Williams, W. M. (2010). Sex differences in math-intensive fields. *Curr. Dir. Psychol. Sci.* 19, 275–279. doi: 10.1177/0963721410383241

Council of the European Union (2019). Council opinion on the 2019 stability Programme of Ireland

Dökme, İ., Açıksöz, A., and Koyunlu Ünlü, Z. (2022). Investigation of STEM fields motivation among female students in science education colleges. *IJ Stem Ed* 9:8. doi: 10.1186/s40594-022-00326-2

Dulce-Salcedo, O. V., Maldonado, D., and Sánchez, F. (2022). Is the proportion of female STEM teachers in secondary education related to women's enrollment in tertiary education STEM programs? *Int. J. Educ. Dev.* 91:102591. doi: 10.1016/j.ijedudev.2022.102591

Ertl, B., and Hartmann, F. G. (2019). The interest profiles and interest congruence of male and female students in STEM and non-STEM fields. *Front. Psychol.* 10, 1–18. doi: 10.3389/fpsyg.2019.00897

FEMM Committee. (2020). Education and employment of women in science, technology, and the digital economy, including AI and its influence on gender equality. The policy department for citizen's rights and constitutional affairs directorate general for internal policies. PE 651.042

Gaweł, A., and Krstić, M. (2021). Gender gaps in entrepreneurship and education levels from the perspective of clusters of European countries. *J. Dev. Entrep.* 26:2150024. doi: 10.1142/S1084946721500242

Hellwege, J. M. (2019). Left to their own devices: a student-centered approach to civic engagement. *J. Polit. Sci. Educ.* 15, 474–497. doi: 10.1080/15512169.2018.1500917

IDA-Foreign Investment Consultants (2024) Report on women in STEM

Klempin, S., and Karp, M. M. (2018). Leadership for transformative change: lessons from technology-mediated reform in broad-access colleges. *J. High. Educ.* 89, 81–105. doi: 10.1080/00221546.2017.1341754

Masanche, N. Faculty members' conceptualization of community-engaged scholarship: applying Michael Burawoy's framework. J. High. Educ. Outreach Engagem., (2020), 1, 73–97. Available online at: https://openjournals.libs.uga.edu/jheoe/article/view/1599

McKeever, S., and Deirdre, L. (2018). Addressing the recruitment and retention of female students in computer science at third level. doi: 10.48550/arXiv.2110.06090

Miller, D. I., and Wai, J. (2015). The bachelor's to Ph.D. STEM pipeline no longer leaks more women than men: a 30-year analysis. *Front. Psychol.* 6, 1–10. doi: 10.3389/fpsyg.2015.00037

Munday, N., Rachel, A., and Mahzar, A. (2019). Increasing diversity of faculty and administrators in the Virginia Community college system. *Inquiry* 22, 1–20. Available at: https://commons.vccs.edu/inquiry/vol22/iss1/4

Nandi, A., Sahoo, S., Haberland, N., and Ngô, T. D. (2023). A glass ceiling at the playhouse? Gender gaps in public and private preschool enrollment in India. *Int. J. Educ. Dev.* 103:102905. doi: 10.1016/j.ijedudev.2023.102905

Osnabruck Declaration. (2020). On vocational and training as enabler of recovery and just transitions to digital and green economies.

OTH Regensburg (2024). Studieren and der at OTH Regensburg. Available at: https://www.oth-regensburg.de/suche/?tx_solr%5Bq%5D=Studieren+an+der+at+OTH+Regensburg

Park, G., Lubinski, D., and Benbow, C. P. (2008). Ability differences among people who have commensurate degrees matter for scientific creativity. *Psychol. Sci.* 19, 957–961. doi: 10.1111/j.1467-9280.2008.02182.x

Pearson, J., Giacumo, L. A., Farid, A., and Sadegh, M. (2022). A systematic multiple studies review of low-income, first-generation, and underrepresented, STEM-degree support programs: emerging evidence-based models and recommendations. *Educ. Sci.* 12:333. doi: 10.3390/educsci12050333

Piva, E., and Rovelli, P. (2022). Mind the gender gap: the impact of university education on the entrepreneurial entry of female and male STEM graduates. *Small Bus. Econ.* 59, 143–161. doi: 10.1007/s11187-021-00525-1

Sanchez, O. (2023). Five community colleges tweak their offerings to match the local job market [WWW Document]. The Hechinger Report. Available online at: http://hechingerreport.org/five-community-colleges-tweak-their-offerings-to-match-the-local-job-market/ (accessed 3.19.25).

Schmaling, K. B., Trevino, A. Y., Lind, J. R., Blume, A. W., and Baker, D. L. (2015). Diversity statements: how faculty applicants address diversity. *J. Divers. High. Educ.* 8, 213–224. doi: 10.1037/a0038549

Slattery, O., Prendergast, M., and Riordáin, M. N. (2023). Navigating a male dominated domain: experiences of female STEM students in higher education in Ireland. *Ir. Educ. Stud.* 42, 861–880. doi: 10.1080/03323315.2023.2261418

Stoet, G., and Geary, D. C. (2018). The gender-equality paradox in science, technology, engineering, and mathematics education. *Psychol. Sci.* 29, 581–593. doi: 10.1177/0956797617741719

Strum, S. P. The architecture of inclusion: Advancing workplace equity in higher education. Syracuse University. (2006).

Strum, S. P. The architecture of inclusion: Interdisciplinary insights on pursuing institutional citizenship. Syracuse University (2007).

Strum, S., Eatman, T., Saltmarch, J., and Bush, A. (2011). Full participation: Building the architecture for diversity and community engagement in higher education. Syracuse: Imagining America. Available at: https://surface.syr.edu/cgi/viewcontent.cgi?article=1001&context=ia

Tett, L., Cree, V. E., and Christie, H. (2017). From further to higher education: transition as an on-going process. *High. Educ.* 73, 389–406. doi: 10.1007/s10734-016-0101-1

Tinto, V. (2025). Student persistence through a different lens. *J. Coll. Stud. Retent. Res. Theory Pract.* 26:959. doi: 10.1177/15210251241249158

Ulriksen, L., Holmegaard, H. T., and Madsen, L. M. (2017). Making sense of curriculum—the transition into science and engineering university programmes. *High. Educ.* 73, 423–440. doi: 10.1007/s10734-016-0099-4

Wang, M.-T., Eccles, J. S., and Kenny, S. (2013). Not lack of ability but more choice: individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychol. Sci.* 24, 770–775. doi: 10.1177/0956797612458937

Zapata, G., Leihy, P., and Theurillat, D. (2018). Compromiso estudiantil en educación superior: adaptación y validación de un cuestionario de evaluación en universidades chilenas. *Calidad en la Educación*. 48, 204–250. doi: 10.31619/caledu.n48.482