

TU Dublin Research Scholarship Programme
First Time Supervisor Award Application Form

Title of the Project	Supporting Diversity in STEM by Enhancing Problem-Based Learning (PBL) Practices
Name of the Applicant	Professor Shannon Chance, PhD, SFHEA

1. Proposed Project Details [25 marks]

1.1 Project Proposal

Research Centre/Institute (if applicable)	CREATE research group
Project Title:	Supporting Diversity in STEM by Enhancing Problem-Based Learning (PBL) Practices
Area Please tick one area that best fits your research project.	Society, Culture & Enterprise
School/Department Please indicate the School/Department for student registration	Discipline: Engineering Education Research Currently within the School of Multidisciplinary Technologies in the College of Engineering and Built Environment
Please indicate which award this project is for, e.g., MPhil, PhD, etc.	PhD
<p>Project Abstract</p> <p>Across engineering in Ireland, skills shortages represent “a major concern” and “barrier” to growth, and “the continuing gender gap requires greater attention and action”.¹ Addressing shortfalls and increasing diversity requires shifting the culture of science, technology, engineering, and maths (STEM) and STEM learning – it must start with understanding the experiences of the students who enrol in STEM. The proposed mixed methods study involves phenomenological analysis of 71 existing interview transcripts, complemented by a quantitative survey of STEM students to identify patterns across TU Dublin. These longitudinal data provide a unique window into students' experience of engineering and the active, inquiry-driven, Problem-Based Learning (PBL) used at TU Dublin. Analysis of these valuable data is urgently needed, with objectives to: Distil lessons from interviews and surveys to improve attraction, delivery, and retention in engineering and STEM education and employment; Assess the degree to which PBL pedagogies support women in engineering; Describe how women experience PBL in engineering at TU Dublin; Identify positive and negative aspects of the PBL experience; Make full use of the existing longitudinal interview data via in-depth analysis; Extend the value and generalizability of the findings via a quantitative survey; and Assess data for gender, ethnic, and intersectional dimensions.</p>	
<p>Research Question</p> <p><i>What challenges do women face with collaborative, peer-to-peer and Problem Based Learning while studying engineering and other STEM courses at university, and how do they deal with these challenges?</i></p>	
<p>Detailed Project Description</p> <p>In 2020, Irish firms aimed to hire 5,152 engineers but 91% of engineering leaders listed skills shortages as “a major concern” and “barrier” to growth.¹ In Ireland today, more students are choosing STEM studies at second level, but many don’t continue into STEM higher education and “the continuing gender gap requires greater attention and action – in Ireland and internationally”¹.</p>	

'Pipeline' or 'conversion' rates – persistence to graduation and into STEM careers of students who do enrol – are an issue. Globally, half of all students starting in engineering exit the major within a year² and in Ireland “drop-out rates in some third-level STEM courses [are] hitting 80%”³. Moreover, most who graduate in engineering are male; in Ireland, men account for over 80% of all graduates in engineering, manufacturing and construction⁴. Today's culture of engineering study and work is largely shaped by males, and this may discourage some prospective applicants from joining the field.

Prior research suggests experiential, Problem-Based Learning (PBL) increases student engagement and helps address reasons women avoid STEM subjects^{5, 6, 7}. Yet, task allocation and peer evaluation in teams continue to reflect gender bias, even when students do not recognize inequity^{8, 9}. Time and project management, group coordination, and communications often fall to women – and often go unrecognized¹⁰. Such dynamics can influence students' perception of how they fit, if they belong, and whether they should stay in engineering. Engineering culture is often described as “chilly” to those who don't fit the engineering stereotype¹¹. Women who experience an unwelcoming environment have shown less commitment to stay in STEM programs than those who feel accepted¹². Although women who enter STEM courses are typically high achievers with strong self-confidence, their experiences can cause significant drops in their confidence levels, especially in their first two years¹³. A US study found female participants felt dismissed, ignored, and unacknowledged when working in small groups of men in both work and academic settings¹⁴. Profanity, semi-sexual double entendre, and violent metaphors used by male faculty and students in engineering classrooms, although typically not intended to offend, contribute to a chilly climate¹⁵.

PBL, which inherently involves group work, is promoted at TU Dublin by the Learning, Teaching and Technology Centre (LTTC), and so it is important to assess how well the pedagogy is working here. This study will investigate women's experiences with PBL and other forms of collaborative peer-to-peer learning in engineering at TU Dublin, compare and contrast this with experiences of women from other engineering schools in Europe, and assess how the PBL experience changed over time for the Dublin-based women. This will be assessed via qualitative, phenomenological analysis of existing interview data. Findings will be extended via a survey of women in STEM at TU Dublin.

Addressing shortfalls and increasing diversity requires shifting the culture of STEM and STEM learning – it must start with understanding the experiences of STEM students. The First Time Supervisor (FTS applicant) has amassed a valuable, longitudinal dataset to help answer the **research question**: *What challenges do women face with collaborative, peer-to-peer and Problem Based Learning while studying engineering and other STEM courses at university, and how do they deal with these challenges?*

Phenomenological interviews collected 2015-2019 via the applicant's two MSCA fellowships^{16, 17}, provide insight regarding the experiences of diverse female students (see Figure 1).

Methodologies. The proposed two-part mixed-methods study involves qualitative and quantitative components. Ethics clearance will be sought for each phase, as the second phase will be built upon findings of the first.

In the **first phase**, extensive qualitative, phenomenological analysis of 71 existing interview transcripts will be conducted to assess how women have experienced PBL and other forms of

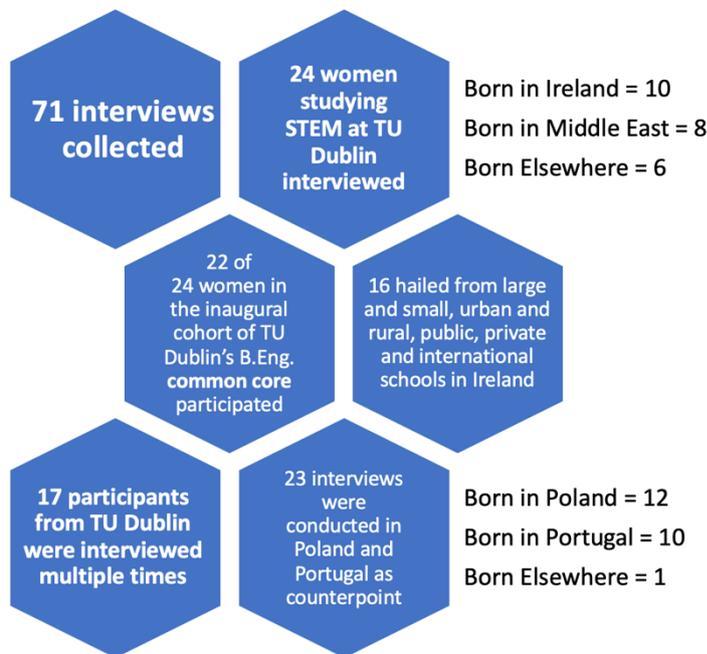


Figure 1: Composition of the existing dataset

collaborative learning (e.g., studying with peers in- and outside class) at TU Dublin across their four years of engineering studies and in other institutions in Portugal and Poland. The TU Dublin sample studied using formal PBL methods as part of their B.Eng. degree programs, starting from day one of their course – they include 24 of the 26 women on the inaugural cohort of TU Dublin's common core engineering programme. These students completed their course in 2019 when the final set of interviews were conducted — analysis of these data is urgently needed. Additional interview data, collected in Poland and Portugal, provide a counterpoint to help assess the degree to which findings are localized to TU Dublin, versus representative of women's

experiences in PBL and collaborative learning more broadly. Phenomenology helps researchers investigate structures of consciousness and explore how specific phenomena are experienced from the first-person point of view. Van Manen's interpretive, hermeneutic method will be used for analyzing interview data.¹⁸ TU Dublin has expertise in this: Brian Bowe and Rob Howard have supervised these using phenomenological methods^{19, 20, 21} as well as closely related phenomenographical methods^{22, 23, 24}. As 33 prior doctoral theses using phenomenology in EER had sample sizes of 7-28 participants, this is an ambitious study, feasible explicitly because the qualitative data have already been collected and checked for accuracy.²⁵

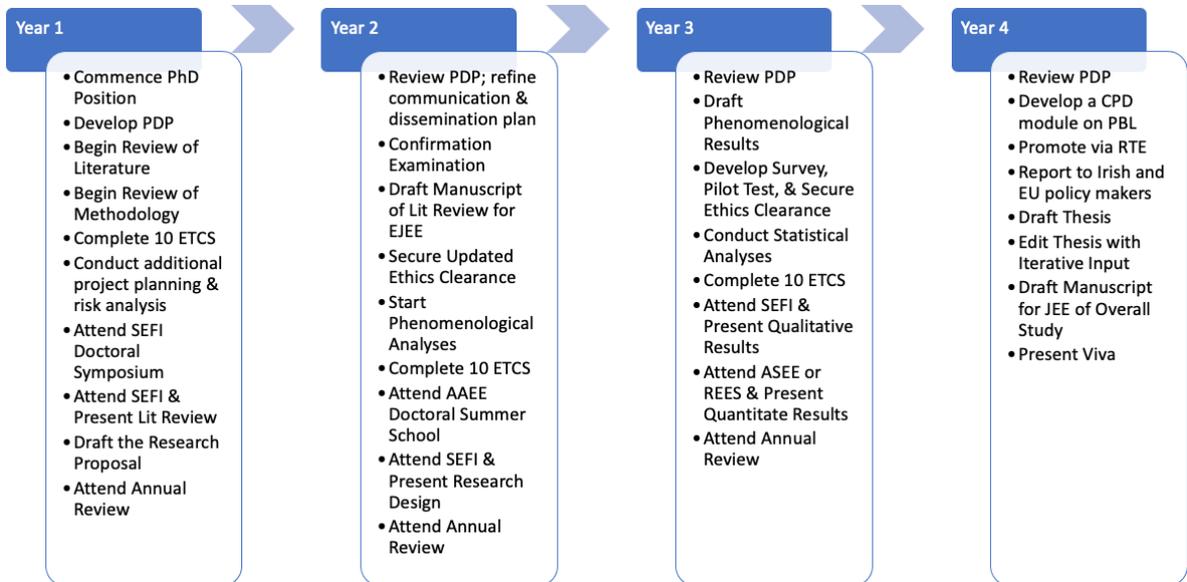
In the **second phase**, a widescale survey will be conducted with women studying on four or more STEM courses that involve PBL across TU Dublin to assess the degree to which the qualitative findings hold true more broadly. Survey questions will be based on analysis from the phenomenological phase and piloted before use. Preliminary analyses conducted by the applicant indicate that many women in the engineering sample at TU Dublin had to adjust to working on teams with male students for the first time, as they came from single-sex schools. Many felt they had less preparation to start engineering than their male counterparts because their secondary schools provided limited access to physics and other engineering-related courses. The survey will provide a broader, and more current, perspective on these topics, to see if these barriers were experienced by many women in STEM at TU Dublin and assess what this might imply for Irish education policy. Specific sources of stress will be distilled from the interviews, and the follow-up survey will help assess how widespread these challenges have been. Thus, the follow-up survey will allow the PhD researcher to confirm and extend findings of the phenomenological phase.

Objectives of the study are to:

- Distil lessons from interviews and surveys to improve attraction, delivery, and retention in engineering and STEM education and employment
- Assess the degree to which PBL pedagogies support women in engineering
- Describe how women experience PBL in engineering at TU Dublin
- Identify positive and negative aspects of the PBL experience
- Make full use of the existing longitudinal interview data via in-depth analysis
- Extend the value and generalizability of the findings via a quantitative survey
- Assess data for gender, ethnic, and intersectional dimensions

Workplan (Figure 2). Upon arrival, the PhD researcher will be provided longitudinal data and guided in career planning, literature review, and target methodologies (Year 1) as a foundation for phenomenological analysis (Y2) and collection and analysis of survey data to achieve generalizability (Y3). The researcher will take part in the Graduate Research School’s structured PhD programme, annual Doctoral Symposia provided by the European Society for Engineering Education (SEFI), summer schools of the Australasian Association for Engineering Education (AAEE) or similar, and online workshops organized by the Research in Engineering Education Network (REEN) and other leading organizations for engineering education research (EER). The research will be disseminated via SEFI, regional symposia, and either the American Society for Engineering Education (ASEE) or REEN’s Symposium (REES) and journal articles, submitted to the *European Journal of Engineering Education* (EJEE) and *Journal of Engineering Education* (JEE).

Figure 2: Work Programme including Timeline, Ethical Considerations, Methods, and Dissemination



Feasibility, limitations and risks. The level of funding available, the existence of an extensive dataset, high-quality mentoring from the FTS applicant^{26, 27, 28}, and the supervising team’s track records help ensure this project can be completed on time²⁹. The sample size, considered large for qualitative research, will facilitate transferability but not generalizability; to address this limitation we propose rigorous methodologies and inclusion of a survey. Possible risks include a low return of surveys (however, ample qualitative data exist to make completion of a thesis viable) and Brian

Bowe’s timetable (however, Rob Howard represents a viable backup). A primary risk is that the interview data will grow stale if they are not analyzed soon.

Originality. A longitudinal dataset of this depth is extremely rare in EER, and it presents unique opportunities. Using phenomenology is an innovative approach to study this topic³⁰ and having an extensive pre-existing dataset will allow time to extend qualitative findings via a wide-scale survey. Prior work of similar nature is US-based and quantitative in nature^{5, 31}, tracking *what* happens (e.g., patterns of enrolment and retention), but failing to identify *what* keeps them engaged in the field or compels them to leave. The stressors they face and the *why* behind departures remains unclear so a deeper, more qualitative, study is needed. In early interviews, TU Dublin students reported some unique factors – a high proportion of single-sex schools, difficulty registering for physics in some schools – that warrant follow-up^{32, 33}.

1.2 Proposed First Time Supervisor

First Time Supervisor Name	Professor Shannon Chance
Email	shannon.chance@tudublin.ie
Title of Highest Degree Obtained and Institution E.g. PhD in Chemical Engineering at Dublin Institute of Technology	PhD in Higher Education (Policy, Planning and Leadership) at William and Mary, a public research university in Williamsburg, Virginia.
Date of Conferral	May 2010
Research Experience	
<p>The researcher will receive <u>excellent support</u> from the supervisors, Shannon Chance and Brian Bowe, who are widely published in engineering education research and have used phenomenology^{34, 35, 36, 37, 38, 39, 40, 41} and advanced statistical analyses^{42, 43}. Both are active in, and founders of, TU Dublin’s CREATE research group.</p> <p>Shannon has diverse <u>transdisciplinary experience</u>^{44, 45}. She holds a PhD in Higher Education and is a Senior Fellow of the (UK) Higher Education Academy. She previously held a tenured post as Full Professor of Architecture in the USA; she holds current credentials as an Architect and LEED Accredited Professional.</p> <p>As documented in her CV,⁴⁶ her 32 <u>externally funded awards</u> include a Fulbright Fellowship (€40k), two MSCA fellowships (€259k, €183k), and a current consulting contract for curriculum development (bringing €297k into TU Dublin over three years).</p> <p>In addition to her permanent Lecturing post at TU Dublin, she holds appointments as <u>Visiting Professor</u> at both University College London (where she is actively engaged with the UCL Centre for Engineering Education) and London South Bank University (LSBU).</p>	

She chairs the global Research in Engineering Education Network (REEN)⁴⁷ which organizes symposia, online workshops, special focus journal issues, and capacity-building initiatives. She is Associate Editor of IEEE Transactions on Education, Editorial Board member of the *European Journal of Engineering Education*, and maintains three educational blogs^{48, 49, 50}.

Shannon has served as Lead Editor for special issues of IEEE Transactions on (1) sociocultural diversity and (2) student development regarding identity and epistemology, and a forthcoming issue (3) of the *Australasian Journal of Engineering Education* on ethics in engineering education and practice.

She has published 9 book chapters, 17 peer reviewed journal articles, and 65 peer-reviewed conference papers. Her Google Scholar h-index equals 9, with 280 citations of her work listed—high for social sciences.⁵¹ She has also produced 7 invited publications and delivered workshops and seminars in 16 different countries.

She is acknowledged as an enthusiastic, conscientious mentor^{26, 27, 28} and the resources she has created to help researchers learn research planning, grant writing, and final report writing have been viewed by thousands of researchers from around the world²⁶. Her blog post “Example SOC proposal for MSCA IF: Abstract and Evaluation” has been viewed 2677 times since it was posted on August 3, 2020. The “Final Report of my MSCA Individual Fellowship”, posted March 6, 2020, has been viewed 1447 times. Overall, her research blog has welcomed 59.9k visitors, accruing 172.9k views since she initiated it as a Fulbright to DIT in August 2012.

She is a founding member of TU Dublin’s RoboSlam outreach team, providing PBL education on robotics and electronics to children across Ireland.⁵²

Although she has supervised many Level 9 thesis students to completion and is the second supervisor to one PhD researcher at LSBU who is nearing completion, she has not supervised a PhD at TU Dublin. The Graduate School has confirmed her eligibility at the FTS level. Receiving this funding will allow her to contribute locally.

1.3 Proposed Advisory Supervisor

Advisory Supervisor Name	Professor Brian Bowe
Email	brian.bowe@tudublin.ie

2. Strategic Alignment [25 marks]

To achieve the UN SDGs⁵³, Engineers Ireland sees a tremendous need for people "with the right engineering skills for sustainable development" particularly regarding “Water, Energy, Sustainable Infrastructure and Innovation”⁵⁴.

This study supports Engineers Ireland’s new accreditation standards regarding “coverage of equality, diversity and inclusion in professional practice, teamwork and communication”.⁵⁵

It addresses Ireland’s “need to increase the uptake of STEM subjects and to enhance STEM learning for learners of all backgrounds, abilities and gender, with a particular focus on uptake by females” expressed in its STEM Education Policy Statement 2017-2026⁵⁶.

It supports the National Gender Strategy⁵⁷ objective to “Advance the Physical and Mental Health and Wellbeing of Women and Girls”.

Regarding Irish policies for Gender Balance in STEM, this study contributes knowledge “about critical barriers to girls’ participation in STEM education and STEM learning, while also highlighting effective interventions to increase participation of girls in STEM”⁵⁸.

It supports Ireland’s Innovation 2020⁵⁹ strategies:

- Education for innovation (by refining innovative PBL pedagogies), and
- Innovating with the EU and the wider world (by integrating “inter-disciplinary research”⁵⁹, perspectives from Poland and Portugal, and engagement with EER networks local to global).

Ireland’s Department of Education⁶⁰ recommends “a cross-disciplinary approach” to addressing these issues, and this project uses social science methods to study technical subjects, bridging AHSS (arts, humanities, social sciences) with STEM.

Understanding what attracts women to engineering will help support the four pillars of Ireland’s STEM EDUCATION POLICY STATEMENT: 2017-2026⁶¹:

- 1) “Nurture learner engagement and participation”
- 2) build “robust relationships between schools and HEIs, research agencies, ... media and government agencies”, as per our dissemination plan.
- 3) “Support STEM education practice”
- 4) “Use evidence to support STEM education”

This project supports TU Dublin’s core value of inclusion and mission for:

- Excellence in student-centred learning (focusing on student experience and learning)
- Impact-focused research to excite students and staff, and benefit our communities, society and the economy (public communication, graduate attributes for industry)
- Co-creation of teaching, learning and research through dynamic collaboration⁶²

The project supports TU Dublin Strategic Intent 2030 for access, diversity, and improved student experience. With Intent “underpinned by the key SDG goal of ‘Quality Education’”⁶³, this proposal supports SDG4 (quality education, target 4.3)⁶⁴, SDG5 (gender equality, target 5.1)⁶⁵, and SDG10 (reducing inequalities, target 10.2)⁶⁶ as well as TU Dublin’s:

- People pillar with Strategic Objectives to transform “learning opportunities and experience for all” including those who represent minorities in their fields and grow recognition of TU Dublin “as an exemplar in equality, diversity and inclusion”.
- Partnership pillar regarding internationalization (over half of our TU Dublin sample group was born outside Ireland and we have interviewed participants from other corners of Europe as well), strategic partnerships (with EER organizations near and far), and building “the TU Dublin brand” (at home and abroad, in STEM education and EER).

- Sustainability pillar (by better supporting engineering students, whose decisions will directly affect society, the environment, and the economy) because **sustainable development is not possible without the involvement of engineers!**

3. Contribution to research capacity and capability building [25 marks]

This research will increase Irish competitiveness in STEM by helping more effectively support students – particularly diverse engineering students.

This project will extend TU Dublin’s soft infrastructure for supporting PBL and enhance its research capacity and standing, nationally and internationally.

The study will support TU Dublin’s integration into the European University of Technology (EUt+) (including efforts to bridge ethics and technology). The researcher will work alongside the FTS in her work leading REEN, organizing events for SEFI (including its Ethics and EDI groups) and the Marie Curie Alumni Association’s EDI group, and contributing to EUt+ (via the TU Dublin-led EthiCo project, which the FTS is already supporting).

This project will tie into Athena SWAN initiatives to support diversity and support TU Dublin’s EDI Directorate (providing data, in-depth interpretation, and reporting via EDI blogs).

It will build upon LTTC strategies (regarding PBL and staff development). The researcher and FTS applicant will develop a CPD on PBL that can be included in LTTC publications and courses. The researcher will volunteer to speak at events organized by TU Dublin’s REIS Team to help others seeking grants for education research. The researcher will attend researcher development programmes – hosted by REIS, LTTC, the Irish Research Council, and Horizon Europe – and contribute to the discussion.

Building capability, this funding will support one early career researcher to produce a quality thesis; earn a PhD; disseminate findings via conferences and journals; develop and deliver a CPD module on PBL; establish a network and positive reputation in EER. The researcher will learn exemplary qualitative and quantitative research skills from global leaders in EER.

The researcher and FTS applicant will benefit from and contribute to TU Dublin and its CREATE research group (with approximately two dozen members), UCL’s Centre for Engineering Education (CEE, a sister organization to TU Dublin’s CREATE research group, also with two dozen members)⁶⁷, and the UK-Ireland EER Network (EERN). The researcher will participate in symposia and present preliminary and final work for feedback from all of these groups.

Such activities will enhance the networks, synergies, research skills, effective collaboration, and research-informed teaching of members in CREATE⁶⁸, CEE⁶⁹, and EERN. These are valuable connections: UCL is a world-leading research university; its Institute of Education (IOE), which co-directs CEE alongside UCL’s Faculty of Engineering, ranks #1 in the world for education research⁷⁰. Closer ties with UCL, CEE, and IOE can be of huge benefit to TU Dublin, CREATE, and LTTC.

This project will expand CREATE's success in educational research and funding. The researcher and other CREATE members will learn from the FTS applicant's knowledge and past achievements in grant writing and project management (see above). The FTS supervisor is likely to submit proposals under Horizon Europe (e.g., Doctoral Training Network); experience generated via this FTS award will help support those applications (allowing the FTS applicant to demonstrate effective PhD supervision). The researcher, FTS applicant, and TU Dublin will benefit from any funds awarded.

4. Dissemination Plans and Impact [25 marks]

Dissemination will include communicating to the public via blog posts^{71, 72}, social media^{73, 74} RTÉ Brainstorm, and Irish and EU policymakers. This will build recognition of TU Dublin's strength in PBL and activities in EDI, which can aid the recruitment of diverse students and staff.

Academic dissemination will include a written thesis and five or more conference papers published with:

- European Society for Engineering Education (SEFI)
- UK-Ireland EERN
- (travel funds permitting) either the American Society for Engineering Education (ASEE) or REEN's Research in Engineering Education Symposium (REES)

We will produce at least two manuscripts, targeted toward:

- 1) *European Journal of Engineering Education*, Impact Factor 1.5, h-index 26, SJR 0.463
- 2) *Journal of Engineering Education*, Impact Factor 2.638, with 2019 Journal Citation Reports from Clarivate Analytics of 42/263 across Education and Educational Research, 7/42 across Education (Scientific Disciplines), and 30/91 across Engineering (Multidisciplinary).

We will pursue Plan S Open Access publishing⁷⁵. Already, both journals provide Green Open Access, and TU Dublin can obtain Gold Open Access with EJEE via its consortium.

Conference and journal manuscripts will be posted on Arrow.

We will disseminate findings locally (via CREATE, LTTC⁷⁶, and our EDI Directorate⁷⁷), regionally (via the UK-Ireland EER Network⁷⁸ and UCL's CEE), Europe-wide (SEFI⁷⁹, EUt+⁸⁰), and globally (REES, ASEE) – via symposia, conferences, and newsletters – with our CPD module/workshop on PBL offered to each group, online or face-to-face.

Impacts will include production of a PhD; expanding publication and supervision skills of the FTS; applying research-informed techniques to teaching practice; bringing benefits of the existing dataset to the public realm; increasing national/public recognition of PBL and EDI at TU Dublin and helping meet our strategic goals for accessibility to all students.

The PBL CPD and discussions of results will influence teaching practice by providing teachers (locally, regionally, internationally) with empirically backed recommendations. The existing interview data are of extremely high value to TU Dublin and its learning and teaching (LTTC) initiatives. The data are also of high value to STEM education beyond TU Dublin – there will be many national and international applications of the findings. This study of pedagogies helps deliver graduate attributes needed for industry (e.g., better teamwork, communication, creativity, critical thinking by students). This matters locally and internationally, as the skills gap for

engineers is wider than Ireland⁸¹. The EU has already invested in collecting the data; bringing findings to the EU will raise TU Dublin's profile internationally via this research.

Irish and European education policy may be influenced by findings (e.g., improved access to physics and pre-engineering for girls, as our preliminary analysis recommend^{32, 33}).

Students in courses taught by members of EER organizations and networks, and readers of the publications produced, will benefit directly from knowledge generated in this study, and targeted advice for enhanced teaching. Engineers have huge potential to impact almost all SDGs, and this is why the world needs diverse, well-equipped engineers.

This broad range of activities will prove doable and effective, based on the FTS applicant's track record.

5. Applicant Declaration

I declare that the information provided by me in this application is true to the best of my knowledge and judgement.

I confirm that I have attached evidence of employment with TU Dublin beyond the duration of the project to this application.

I have consulted with the relevant Head of School/Department and declare that, should my application be successful, provision can be made within the School/Department for the required training, facilities and resources including equipment, travel funding and consumables required for the proposed research programme.

Applicant Signature

6. Advisory Supervisory Declaration

I declare that I fully support the applicant and will act as advisory supervisor if the application is successful.

Advisory Supervisor Signature

References

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- ¹ Engineers Ireland. (2020). *Engineering 2020: A barometer of the profession in Ireland*.
<https://www.engineersireland.ie/LinkClick.aspx?fileticket=QIJmhwkgSs%3D&portalid=0&resourceView=1>
- ² Mills, J.E. (2011). Reflections on the past, present and future of women in engineering. *Australasian Journal of Eng. Educ.*, 17(3), 139-146.
- ³ O'Brien, C. (March 29, 2021). 'Drop-out rates in some third-level STEM courses hitting 80%'. *The Irish Times*. <https://www.irishtimes.com/news/education/drop-out-rates-in-some-third-level-stem-courses-hitting-80-1.4522466>
- ⁴ Turcinovic, P. (2013). EU knowledge triangle: 'Renaissance or ocean of papers?' *Donald School Journal of Ultrasound in Obstetrics and Gynecology*, 7(3), 272-277.
- ⁵ Boedeker, P., Nite, S., Capraro, R. M., & Capraro, M. M. (2015, October). Women in STEM: The impact of STEM PBL implementation on performance, attrition, and course choice of women. In *2015 IEEE Frontiers in Education Conference (FIE)* (pp. 1-8). IEEE.
- ⁶ Marra, R.M., Rodgers, K.A., Shen, D., & Bogue, B. (2012). Leaving engineering: A multi-year single institution study. *Journal of Engineering Education*, 101(1), 6-27.
- ⁷ Kokkelenberg, E.C., & Sinha, E. (2010). Who succeeds in STEM studies? An analysis of Binghamton University undergraduate students. *Economics Of Education Review*, 29(6), 935-946.
- ⁸ Fowler, R. R., & Su, M. P. (2018). Gendered risks of team-based learning: A model of inequitable task allocation in Project-Based Learning. *IEEE Transactions on Education*, 61(4), 312-318.
- ⁹ Hirshfield, L. J. (2018). Equal but not equitable: Self-reported data obscures gendered differences in project teams. *IEEE Transactions on Education*, 61(4), 305-311.
- ¹⁰ Neumann, M. D., Lathem, S. A., & Fitzgerald-Riker, M. (2016). Resisting cultural expectations: Women remaining as civil and environment engineering majors. *Journal of Women and Minorities in Science and Engineering*, 22(2).
- ¹¹ Wyer, M., (2003). Intending to stay: Images of scientists, attitudes toward women, and gender as influences on persistence among science and engineering majors, *J. Women Min. Sci. Eng.*, (9),1, 1716.
- ¹² Wyer, M., (2003). Intending to stay: Images of scientists, attitudes toward women, and gender as influences on persistence among science and engineering majors, *J. Women Min. Sci. Eng.*, (9), 1, 1716.
- ¹³ Brainard, S.G. and Carlin, L., (1998). A six-year longitudinal study of undergraduate women in engineering and science, *J. Eng. Educ*, (87),4, 369 - 375
- ¹⁴ Wilkins-Yel, K. G., Simpson, A., & Sparks, P. D. (2019). Persisting despite the odds: Resilience and coping among women in engineering. *Journal of Women and Minorities in Science and Engineering*, 25(4).
- ¹⁵ Tonso, K. (1996). "The Impact of Cultural Norms on Women," *Journal of Engineering Education*, (85), 3, 217–225.
- ¹⁶ European Commission. (2016). Re-Engineering Europe's STEM Pipeline.
<https://cordis.europa.eu/project/id/629388>
- ¹⁷ European Commission. (2019). Designing Engineers: Harnessing the Power of Design Projects to Spur Cognitive and Epistemological Development of STEM Students.
<https://cordis.europa.eu/project/id/747069>
- ¹⁸ van Manen, M., *Researching lived experience* 1997, Ontario, Canada: The Athlone Press.
- ¹⁹ Chari, D. (2014). *What is nanoscience?'*-A hermeneutic phenomenological study of nanoscience researchers' experiences.
- ²⁰ Sloan, A. (2015) *A Phenomenological Study of Computer Science Lecturers: Lived Experiences of Curriculum Design*, Doctoral Thesis, Technological University Dublin. doi:10.21427/D7QC75

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- ²¹ Bates, E. (2011). How do Apprentice Painters and Decorators on the Irish Standards Based Apprenticeship Experience their Learning? Dissertation. Technological University Dublin.
- ²² Beagon, U. (2021) A Phenomenographic Study of Academics Teaching on Engineering Programmes in Ireland: Conceptions of Professional Skills and Approaches to Teaching Professional Skills, Doctoral Thesis, TU Dublin, 2021, DOI:10.21427/K4MD-2571
- ²³ Irving, P. (2010). A Phenomenographic Study of Introductory Physics Students: Approaches to their Learning and Perceptions of their Learning Environment in a Physics Problem-Based Learning Environment. Doctoral Thesis. Technological University Dublin. doi:10.21427/D7K888
- ²⁴ Walsh, Laura. (2009). *A phenomenographic study of introductory physics students: approaches to problem solving and conceptualisation of knowledge*. Technological University Dublin. doi:10.21427/D73598
- ²⁵ CHANCE, S., & Direito, I. (2018). Identification and preliminary review of doctoral theses in engineering education that have used phenomenological methods. In *Proceedings of the 46th SEFI Annual Conference 2018. Creativity, innovation and entrepreneurship for engineering education excellence. Societe Europeenne pour la Formation des Ingenieurs (SEFI)*. Copenhagen, Denmark. http://discovery.ucl.ac.uk/10062437/1/Chance_SEFI%202018-ShannonChance-final%20paper-submitted.pdf
- ²⁶ CHANCE, S. (2021). An Editor's Job is ... sometimes a success! Ireland By Chance. <https://shannonchance.net/2021/04/19/an-editors-job-is-sometimes-a-success/>
- ²⁷ CHANCE, S. (2021). A new doc is born: Dr Diana Adela Martin. Ireland By Chance. <https://shannonchance.net/2020/12/17/diana-adela-martin/>
- ²⁸ CHANCE, S. (2019). Meet emerging research star: Carlos Mora. Ireland By Chance. <https://shannonchance.net/2019/11/15/meet-emerging-research-star-carlos-mora/>
- ²⁹ CHANCE, S. (2021). Résumé & CV. Ireland By Chance. <https://shannonchance.net/shannons-cv/>
- ³⁰ CHANCE, S., & Direito, I. (2018). Identification and preliminary review of doctoral theses in engineering education that have used phenomenological methods. In *Proceedings of the 46th SEFI Annual Conference 2018. Creativity, innovation and entrepreneurship for engineering education excellence. Societe Europeenne pour la Formation des Ingenieurs (SEFI)*. Copenhagen, Denmark. http://discovery.ucl.ac.uk/10062437/1/Chance_SEFI%202018-ShannonChance-final%20paper-submitted.pdf
- ³¹ LaForce, M., Noble, E., & Blackwell, C. (2017). Problem-based learning (PBL) and student interest in STEM careers: The roles of motivation and ability beliefs. *Education Sciences*, 7(4), 92.
- ³² CHANCE, S. M., Bowe, B. & Duffy, G. (2016). Policy Implications of Irish Women's Experiences in STEM Education. *Association for the Study of Higher Education (ASHE) conference in Columbus, Ohio*.
- ³³ CHANCE, S. M., Eddy, P., & Bowe, B. (2016). Implications for education policy: A comparative study of women's experiences in engineering and physics education in Ireland and Poland. Joint conference of Irish Social Sciences Platform (ISSP) and National Economic and Social Council (NESC) in Dublin.
- ³⁴ CHANCE, S. M., Duffy, G., & Bowe, B. (2019). Comparing grounded theory and phenomenology as methods to understand lived experience of engineering educators implementing Problem-Based Learning. *European Journal of Engineering Education*, <https://doi.org/10.1080/03043797.2019.1607826>
- ³⁵ CHANCE, S. M., Duffy, G. & Bowe, B. (2016). A phenomenological study of lecturers' experiences using Problem-Based Learning to transform engineering education. American Educational Research Association (AERA) conference.
- ³⁶ Chance, S., Bowe, B. (2015) Influence of Collaborative Learning on Women's Experiences of Engineering Education. Research in Engineering Education Society (REES). Dublin, Ireland. Jan. 2015. <https://arrow.tudublin.ie/cgi/viewcontent.cgi?article=1012&context=engschelecon>

- ³⁷ CHANCE, S. M., & BOWE, B. (2014). To stay or leave? A plan for using phenomenology to explore gender and the role of experiential learning in engineering. *Proceedings of the 42st Conference of the European Society for Engineering Education (SEFI)*. Birmingham, UK.
<https://arrow.tudublin.ie/engscheleart/231/>
- ³⁸ CHANCE, S., & DIREITO, I. (2018, October). Identification and preliminary review of doctoral theses in engineering education that have used phenomenological methods. In *Proceedings of the 46th SEFI Annual Conference 2018. Creativity, innovation and entrepreneurship for engineering education excellence. Societe Europeenne pour la Formation des Ingenieurs (SEFI)*. Copenhagen, Denmark. http://discovery.ucl.ac.uk/10062437/1/Chance_SEFI%202018-ShannonChance-final%20paper-submitted.pdf
- ³⁹ CHANCE, S. M. & WILLIAMS, W. (2018). Preliminary findings of a phenomenological study of Middle Eastern women's experiences studying engineering in Ireland. *American Society for Engineering Education (ASEE) conference in Salt Lake City, Utah*.
<https://arrow.tudublin.ie/engschcivcon/108/>
- ⁴⁰ CHANCE, S. M., & WILLIAMS, B. (2016). *A phenomenological study of women's experiences of receiving family support when studying STEM subjects at technical institutes in Ireland and Portugal*. European Society for Engineering Education (SEFI) conference in Tampere, Finland.
<https://comum.rcaap.pt/handle/10400.26/15118>
- ⁴¹ DUFFY, G., BURKE, T., CHANCE, S., BOWE, B., & HOWARD, R. (2013). Student Experiences of a Project-Based Learning Module. *Proceedings of the 41st SEFI Annual Conference*, Leuven, Belgium.
<https://arrow.tudublin.ie/cgi/viewcontent.cgi?article=1058&context=engschececon>
- ⁴² CHANCE, S. M. (2010). University leadership in energy and environmental design: How postsecondary institutions use the LEED® green building rating system. PhD dissertation, The College of William and Mary (Williamsburg, Virginia).
- ⁴³ CHANCE, S. M. (2012). Planning for environmental sustainability: Learning from LEED and the USGBC. *Planning for Higher Education*, 41(1). <https://arrow.tudublin.ie/engscheleart2/96/>
- ⁴⁴ CHANCE, S. M. (2012). About Shannon. Ireland By Chance. <https://shannonchance.net/about-2/>
- ⁴⁵ CHANCE, S. M. (2012). Curriculum Vitae of Shannon Chance. Ireland By Chance.
<https://www.dropbox.com/s/yxd6r9ryzcbxpqx/curriculum%20vita%20chance%20cv%20april%202021.pdf?dl=0>
- ⁴⁶ CHANCE, S. M. (2021). CURRICULUM VITA Chance CV April 2021.
<https://www.dropbox.com/s/yxd6r9ryzcbxpqx/curriculum%20vita%20chance%20cv%20april%202021.pdf?dl=0>
- ⁴⁷ Research in Engineering Education Network. (2021). Home. <https://reen.co/>
- ⁴⁸ Ireland By Chance. (2021). Home. www.IrelandByChance.com
- ⁴⁹ Research in Engineering Education Network. (2021). Blog. <https://reen.co/blog/>
- ⁵⁰ RoboSlam: Robot Building for Beginners. (n.d.). Blog. <https://roboslam.wordpress.com/blog/>
- ⁵¹ Google Scholar. (2021). Shannon Chance.
<https://scholar.google.com/citations?user=hw7us9AAAAAJ&hl=en>
- ⁵² Burke, T., Berry, D., CHANCE, S., & DUIGNAN, F. (n.d.). RoboSlam: Robot Building for Beginners.
www.Roboslam.com
- ⁵³ United Nations Department of Economic and Social Affairs. (n.d.). The 17 Goals.
<https://sdgs.un.org/goals>
- ⁵⁴ Engineers Ireland. (2020). *Engineering 2020: A barometer of the profession in Ireland*.
<https://www.engineersireland.ie/LinkClick.aspx?fileticket=QIJmhwkgSs%3D&portalid=0&resourceView=1>
- ⁵⁵ Engineers Ireland. (January 2021). Accreditation Criteria.
https://www.engineersireland.ie/LinkClick.aspx?fileticket=Mz3SCck_uRg%3D&portalid=0&resourceView=1

-
- ⁵⁶ Government of Ireland. (2021). Gender Balance in STEM. <https://www.gov.ie/en/policy-information/4d40d5-stem-education-policy/#gender-balance-in-stem>
- ⁵⁷ Department of Justice and Equality. (2017). National Strategy for Women and Girls 2017-2020. [http://www.justice.ie/en/JELR/National Strategy for Women and Girls 2017 - 2020.pdf/Files/National Strategy for Women and Girls 2017 - 2020.pdf](http://www.justice.ie/en/JELR/National%20Strategy%20for%20Women%20and%20Girls%202017%20-%202020.pdf/Files/National%20Strategy%20for%20Women%20and%20Girls%202017%20-%202020.pdf)
- ⁵⁸ Goos, M., Ryan, V., Lane, C., Leahy, K., Walsh, G., O’Connell, T., ... & Nizar, A. (2020). Review of Literature to Identify a Set of Effective Interventions for Addressing Gender Balance in STEM in Early Years, Primary and Post-Primary Education Settings. <https://assets.gov.ie/96986/f05f7b2f-e175-442e-85e9-4a2264391843.pdf>
- ⁵⁹ Interdepartmental Committee on Science, Technology and Innovation. (2015). *Innovation 2020: Ireland's Strategy for Research and Development, Science and Technology*. <https://enterprise.gov.ie/en/Publications/Publication-files/Innovation-2020.pdf>
- ⁶⁰ Government of Ireland. (2021). STEM Education Policy. <https://www.gov.ie/en/policy-information/4d40d5-stem-education-policy/>
- ⁶¹ Government of Ireland. (2017). STEM Education Policy Statement 2017-2026. <https://assets.gov.ie/43627/06a5face02ae4ecd921334833a4687ac.pdf>
- ⁶² TU Dublin. (2021). About Us. <https://www.tudublin.ie/connect/giving-to-the-university/about-us/>
- ⁶³ TU Dublin. Strategic Intent 2030: *Realising Infinite Possibilities*. <https://www.tudublin.ie/explore/about-the-university/strategicplan/2030/>
- ⁶⁴ Ordnance Survey Ireland. (2019). Sustainable Development Goal 4. <https://irelandsdg.geohive.ie/pages/goal4>
- ⁶⁵ Ordnance Survey Ireland. (2019). Sustainable Development Goal 5. <https://irelandsdg.geohive.ie/pages/goal5>
- ⁶⁶ Ordnance Survey Ireland. (2019). Sustainable Development Goal 10. <https://irelandsdg.geohive.ie/pages/goal10>
- ⁶⁷ TU Dublin. (n.d.). CREATE – Contributions to Research in Engineering & Applied *Technology Education*. <https://www.dit.ie/create/>
- ⁶⁸ TU Dublin. (n.d.). CREATE - Research Group Members. <https://www.dit.ie/create/researchers/>
- ⁶⁹ University College London. (2021). UCL Centre for Engineering Education. <https://www.ucl.ac.uk/centre-for-engineering-education/>
- ⁷⁰ University College London. (3 March 2021). UCL named as one of the world’s best universities to study. <https://www.ucl.ac.uk/news/2021/mar/ucl-named-one-worlds-best-universities-study#:~:text=UCL%20has%20been%20named%20as,world's%20most%20consulted%20university%20ranking.>
- ⁷¹ Research in Engineering Education Network. (2021). Blog. <https://reen.co/blog/>
- ⁷² CHANCE, S. (2021). Home. www.IrelandByChance.com
- ⁷³ Research in Engineering Education Network. (2021). <https://www.linkedin.com/groups/8537067/>
- ⁷⁴ REEN Board. (2021). <https://twitter.com/BoardReen>
- ⁷⁵ Van Norden, R. (2020). Open-access Plan S to allow publishing in any journal. <https://www.nature.com/articles/d41586-020-02134-6>
- ⁷⁶ CHANCE, S. M., Eddy, P. L., Duffy, G., Bowe, B., & Harvey, J. (2013). Policies that enhance learning and teaching. *Proceedings of the World Academy of Science, Engineering and Technology; International Conference on Higher Education*. Paris, France. <http://eprints.teachingandlearning.ie/1983/>
- ⁷⁷ CHANCE, S., Williams, B., & Direito, I. (2020, December 1). Project based learning: a tool for gender inclusion and enhanced team learning. Technological University Dublin blog for Diversity Equity and Inclusion. <https://sway.office.com/fjc0aQKqkWotCl2J?ref=email&loc=play>
- ⁷⁸ Royal Academy of Engineering. (n.d.). About EERN. <https://hefocus.raeng.org.uk/eern-home/>

- ⁷⁹ CHANCE, S., Williams, B., & Direito, I. (2020). Tackling gender inclusion of Middle East students in engineering education with Project-Based Learning. *SEFI Newsletter*.
<https://www.sefi.be/2020/12/14/tackling-gender-inclusion-of-middle-east-students-in-engineering-education-with-project-based-learning/>
- ⁸⁰ TU Dublin. (2020). TU Dublin colleague leads on development of ECT Lab+.
<https://www.dit.ie/update/28-09-20/tudublincolleagueleadsondevelopmentofectlab>
- ⁸¹ European Commission. (2020). Analysis of shortage and surplus occupations.
<http://www.regionalskills.ie/regions/midwest/images-folder/skill-shortage-and-surpluses-in-europe-2020.pdf>