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Design of a Professional Development Framework in Teaching and Learning for Engineering Educators

O. McConnell, C. MacMahon, J. Harvey

***Abstract*—** Ireland's National Professional Development Framework for Those who Teach in Higher Education, aims to provide guidance and leadership in the planning, developing and engaging in professional development practices. A series of pilot projects have been initiated to help explore the framework's likely utility and acceptance by educators and their institutions. These projects require engagement with staff in the interpretation and adaption of the framework within their working contexts.

The purpose of this paper is to outline the development of one such project with engineering educators at three Institutes of Technology seeking designation as a technological university. The initiative aims to gain traction in the acceptance of the framework with the engineering education community by linking core and discipline-specific teaching and learning competencies with professional development activities most valued by engineering educators.

Informed by three strands of literature: professional development in higher education; engineering education; and teaching and learning training provisions, the project begins with a survey of all those involved in teaching and learning in engineering across the three institutes. Based on engagement with key stakeholders, subsequent qualitative research informs the contextualization of the national framework for discipline-specific and institutional piloting.

The paper concludes by exploring engineering educator perceptions of the national framework's utility based on their engagement with the pilot process. Feedback from the pilot indicates that there is a significant gap between the professional development needs of engineering educators and the current professional development provision in teaching and learning.

***Keywords*—** Engineering Education, Pilot, Professional Development Framework, Teaching and Learning.

I. Introduction

"... if we teach today as we taught yesterday, we rob our children of tomorrow, John Dewey" [1].

Ireland's National Professional Development Framework, NPDF, in teaching and learning [2] follows similar strategic initiatives [3] aimed at empowering educators to plan, reflect on and recognise their professional development, guiding them through their selected career paths in higher education.

The NPDF was designed to be highly malleable to different institutional contexts and academic disciplines. The challenge with its implementation is in gaining traction with key stakeholder groups most likely to use it, including teaching and learning professionals, academic managers, administrative support staff and, most importantly, educators themselves.

Pilot projects can yield insight into the NPDF's acceptability. Proponents of professional development advocate that teaching is a skill that can be enhanced with guided practice and directed feedback [4], [5]. This paper's philosophical positioning rests on a belief that initiatives focused on professionalising teaching [6] are an imperative.

For professionalisation to gain traction, professional development initiatives must be congruent with the notion of teaching and learning being held on a parity of esteem with research and community engagement. One such project aims to adapt the framework for engineering educators at three institutes seeking to merge as a technological university. In the pursuit of transformation, tension has surfaced between a narrow perspective of teaching and learning and the broader reality of the role of engineering educators whereby teaching competency is inextricably linked to maintaining professional currency. Hence, the project serves as a useful lens through which to examine the NPDF's reduction to practice.

Having outlined the context to this research, the paper proceeds as follows: section 2 briefly outlines the initial development of the NPDF in teaching and learning for higher education in Ireland; section 3 discusses engineering education competencies and challenges within engineering educators' community of practice; section 4 summarizes teaching and learning training provisions currently available across the sector; section 5 describes the process to design and pilot a practical and applied version of the NPDF for engineering educators; and section 6 concludes with a discussion of the design process and its outcomes.

II. Professional Development in Teaching and Learning in Higher Education

A. Background to the NPDF

In developing the framework, the National Forum for the Enhancement of Teaching and Learning undertook a comprehensive consultation and mapping of professional development pathways [7]. The synthesising of a diverse range of activities and supporting models assisted in the conceptualisation of how professional development is defined across Ireland's higher education sector [8.] The NPDF offers a typology that categorises professional development into four types: collaborative non-accredited, unstructured non-accredited, structured non-accredited and accredited. It found a

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common desire to provide certified pedagogical training, aligned to [9], for those embarking on their teaching careers in higher education.

B. Key Features of the Framework

The framework identifies underpinning values of inclusivity, authenticity, scholarship, learner-focus and collaboration. It emphasises the need for continuous evidence-based reflection [10] and responsiveness to change [11]. Finally, many models also highlight stage of career as a key aspect, taking into account early, middle and later careers [e.g. 3]. It identified five domains for consideration – self, communication and dialogue, knowledge, skills, and digital capacity. Engagement with key actors, such as students and educators, is essential to sustainable implementation.

C. Challenges to Implementation

Implementation of the NPDF requires supporting processes. This cross-institute initiative aims to align engineering educator professional development priorities to the NPDF [12] at Dublin Institute of Technology (DIT), Institute of Technology Blanchardstown (ITB) and Institute of Technology Tallaght (ITT). Further intended to be malleable to other disciplines, the framework is, in essence, a pilot adaptation of the national framework. It aims to identify core and discipline-specific competencies, to map activities to the NPDF typology and to identify gaps for training opportunities to be created. Desimone [13, p.6] states that "the content focus" is key to designing effective professional development. Evidence indicates a positive correlation between content focus and teacher knowledge, improved pedagogy and higher student achievement [14]-[16]. Custer and Daugherty, [17] note that effective professional development for engineering educators is oriented toward engaging participants in problem solving and encouraging familiarisation with the processes of engineering design and methods.

III. Engineering Education

A. Core Competencies for Teaching and Learning

DIT's MA, MSc and PGDip provisions are informed by required knowledge and skills for teaching in higher education, so a great deal is known about the core competencies required for effective teaching in higher education. A snapshot of accredited professional development in Ireland [18] identified 68 teaching and learning programmes from 23 institutions, the majority at NQF Level 9. Some institutions encouraged staff to participate through fee waiver and time off, whereas others have made it mandatory for new staff to undertake pedagogical training. A snapshot of non-accredited provision identifies five categories [19]: pedagogy, curriculum design, assessment, academic development and digital capacity. In this context, teaching and learning moves beyond understanding what makes a good teacher to other domains, such as how adults learn [e.g. 20], how students process information [e.g. 21], or how prior knowledge influences learning [e.g. 22]. However, many non-accredited activities are not currently recognised in a formal way. So, the NPDF seeks to address this.

B. Discipline-specific Competencies in Engineering Education

Engineering today is characterised by a greater diversity of demands made on professional engineers. There is a concern that the education system for producing new generations of engineers is failing to keep pace [23]. Content and pedagogy are also level dependent. Whilst at a vocational level they are instructional and hands-on, at a professional level they lean towards interdisciplinarity, social agency, design and problem-solving [24]. Research training focuses on design science [25]. To address these challenges, engineering educators have begun sharing their teaching and learning techniques [26]-[29].

Loucks-Horsley et al [30] outline the ideal characteristics for professional development in STEM. They suggest that it should articulate a clear metaphor for effective classroom learning, provide educators with opportunities to broaden their experience, be congruent with andragogic principles [31], build community of practices [32] and prepare educators for leadership roles. Fink et al. [33] explored the challenges of becoming a professional engineering educator, citing reports calling for reform [34]-[36]. They advocated for integrated curricula, addressing multiple learning styles, a focus on employability skills and an emphasis on socio-economic responsibility. Calling for reforms to be rooted in educational research and cognitive science [37], they remind us that students should remain the focus [38], [39].

C. Remaining Challenges in Engineering Education

More importantly, reforms stress the importance of institutional support for educators to create innovative pedagogy and curriculum. Yet, challenges in engineering education remain [40]. Accreditation panels continually emphasise fundamentals, engineering design, more material at the forefront of engineering, instruction in employability skills, training in critical thinking, problem-solving and proficiency in ethics and social agency. This list of desirables cannot be met using the siloed approach to educating engineers in a crowded curriculum that has predominated over the past century. Whilst the literature is replete with methods for integrating curriculum, such as problem-based learning, they have had only a marginal impact on mainstream engineering education.

IV. Teaching and Learning Training Provisions

A. Strategic Prioritisation of Professional Development

Aligned with the implementation plan of the Technological University for Dublin Alliance, institutional strategies focus on empowering "staff to fulfil their potential within a ... stimulating environment, with learning and development opportunities that are flexible, relevant and accessible within an engaged, innovative, diverse and high performing workforce" [41, p.3]. This is to be achieved by promoting an ethos whereby all staff are encouraged to pursue development opportunities, so that at least 90% of academic staff hold a masters and 45% a doctoral qualification. Financial support has been provided for staff pursuing these qualifications across the three institutions.

B. Alignment of Professional Development to Teaching and Learning

Whilst this implementation plan says little about professional development in teaching and learning, there are known provisions. For example, DIT's Learning Teaching and Technology Centre offers an MA in Higher Education, an MSc in Applied eLearning, a PG Diploma and modules for continuous professional development. Tallaght offers a Certificate in Learning & Teaching and related workshops. Similarly, ITB offers support and related training. Yet, whilst worthwhile initiatives, teaching and learning provision within the institutions has its challenges. Contrary to the rhetoric of teaching and learning being core business, a resource-based analysis of the institutional strategies suggests that it is a low priority. With few tenured opportunities for working in teaching and learning [42], it has little representation at senior management. There is also concern that the practitioners will be replaced by a classroom bound generation of PhD educators in pursuit of TU designation.

V. Designing a Professional Development Framework in Teaching and Learning for Engineering Educators

A. Designing the Framework and Aligning to the NPDF

Through a process of consultation, the project included a survey of all those involved in teaching and learning in engineering across the three institutes. To assist with contextualizing the NPDF for discipline-specific and institutional piloting, further consultation with important stakeholders was undertaken through qualitative enquiry.

Based on this research and the literature review, a draft competency framework was developed and refined through an open consultation process with key stakeholders. A pilot process was initiated to mimic how this competency framework could be used and aligned to requests made by engineering educators for professional development in teaching and learning activities or training. A panel consisting of representatives from HR, teaching and learning experts and academic management reviewed these submissions. They were tasked to prioritise the allocation of funding based on a set of criteria including alignment to the competency framework and department priorities, value for time and money, and enhancement value in teaching and learning.

B. Key Survey Findings

An electronic survey elicited responses related to: familiarity with the NPDF; engagement with professional development in teaching and learning; perceptions of teaching competence (see Table I); and professional development activities. Three sections: [i] background information, [ii] professional experience and [iii] professional development in teaching and learning, required respondents to rate their values and needs according to a 4-point Likert-type scale. Forwarded to over 300 colleagues, data was elicited from 121 respondents (≈ 40% participation rate). The majority of respondents had 11-20+ years' experience working in higher education with previous time spent in industry.

Regarding the NPDF, 76% of respondents were not familiar or had low familiarity with the framework, and only 51% considered it relevant. 69% of respondents reported a high level of engagement with professional development in teaching and learning and 86% considered engagement important.

Respondents ranked the significance of five factors regarding professional development in teaching and learning as follows (highest to lowest): relevance of the topic, collaboration with colleagues, delivery by a teaching and learning expert, delivery by an expert from industry, receiving an accredited award.

51% of the respondents hold no qualification in teaching and learning, 81% a masters or doctoral qualification and 44% are not a member of a professional engineering body.

TABLE I
ATTRIBUTES OF A GREAT ENGINEERING EDUCATOR

What makes a great engineering educator?	Average
Competent in their own discipline, for example in engineering fundamentals and problem solving	4.3
Active researcher who maintains currency	2.7
Networks effectively in their discipline	2.6
Effective teacher	4.7
Understands the role of engineering education in society	3.2
Demonstrates strong skills as an engineer and is a good role model for students	3.9

Relative scores in a ranking 1-6, (1 the most important... 2, 3, 4, 5 ... 6 the least important)

Respondents were asked to rate their most valued teaching and learning professional development activities (see Table II). The top five were: engaging in informal dialogue with colleagues on how to enhance teaching, engaging in self-study, mentoring students, attending workshops/ seminars and exchanging teaching materials with colleagues.

TABLE II
MOST VALUED PROFESSIONAL DEVELOPMENT ACTIVITIES

Responses	No	Low	Mod.	High	Average
Engaging in informal dialogue with your colleagues on how to enhance your teaching	0%	10%	33%	57%	3.5
Engaging in self-study	1%	14%	36%	49%	3.3
Mentoring students	1%	13%	38%	48%	3.3

4-point Likert-type scale

The professional development needs, both for teaching and learning in general and discipline-specific, were varied. With 15 options needed by respondents, the top five general teaching and learning professional development needs were: digital skills for teaching, student assessment practices and feedback, universal design (designs for accessibility), curriculum design and development, and different learning styles of students.

Out of 11 options for professional development needs in teaching and learning specific to engineering, the top five responses included: problem-based learning, data analysis, contemporary issues in engineering, design processes and employability skills (initiative, teamwork, communication,

resilience, creativity).

To ascertain potential motivation to engage in professional development respondents rated on a sliding scale the perceived impact of teaching and learning professional development: confidence in their role (59/100), job satisfaction (56/100), career progression (36/100) and job security (23/100).

C. Key Student Focus Group Findings

Focus groups took place across the three institutes and 27 students shared their insights. They were asked to identify competencies across three domains: educator, engineer and engineering educator. Responses were mapped to three competency domains: [i] pedagogical: teaching practice, [ii] content: engineering knowledge and [iii] pedagogical-content: relating engineering practices to teaching and learning.

Students had little difficulty identifying general teaching competency domains. Approachability and flexibility of their lecturers was highly valued, mirrored by engineering educators as they themselves ranked mentoring students as the joint second most valued professional development activity. The more allusive and less familiar domains of engineer and engineering educator proved more challenging to define.

In the domain of engineering educator, the students found it difficult to identify competencies, but stressed the importance of authenticity, i.e. that educators are also experts in their own field, so they can relate everyday examples to classroom problems, strengthening the argument that maintaining professional currency as an engineer is a vital component of teaching excellence. Digital capacity was deemed important by students (rated as the highest need by educators), as they discussed the requirement for engineering educators to be proficient in the digital learning space.

D. Key Interview Findings

Interviews with academic managers (n=8) sought to understand how the current administrative system functions regarding professional development in teaching and learning. Analysis of the transcripts revealed a differing landscape across the three institutes in terms of support mechanisms, funding and policy. Some departments had designated budgets, whilst others were wary to ask educators about their professional development needs, using funds from departmental resources on an ad hoc basis. This lack of open engagement was evident in the survey as 53.6% of engineering educators had not engaged in a conversation about professional development in teaching and learning with their academic manager.

Teaching and learning is considered an intrinsic part of the institutes of technology identity, confirmed by academic managers, echoed by engineering educators in the survey and by students in the focus groups. Given the failing public sector performance management development system (PMDS) as a model for supporting professional development in higher education, academic managers highlighted the need for an alternative system of promoting, recording and recognising professional development activities of academic staff outside of the HR domain. Academic managers stressed the importance that the adapted NPDF needed to be a practical guide, easy to use and relevant to different academic career stage.

The different research activities highlighted some areas of divergence and convergence across the key stakeholder groups (see Table III) regarding perceptions of professional development in teaching and learning.

TABLE III
SUMMARY OF KEY STAKEHOLDER PERSPECTIVES

Professional development in teaching and learning PD in T&L	**Engineering educators**	**Students**	**Academic managers**	**Divergence or convergence**
Importance	86% considered important	Some evidence	T&L seen as core function, but 54% of engineering educators have not had a conversation about their PD with management	Divergence
Top significant factor	Relevance of topic	Importance of role-model	20.5% of engineering educators said no support	Divergence
Most valued	Collegial engagement	Ability to network and communicate	Some evidence of opportunities to network	Convergence
Top general need	Digital skills for teaching	Student expectation evident	Recognised a need for training	Convergence
Top engineering-specific need	Problem-based learning	Need complex theories to be simplified through real-world examples	Applied approach to teaching and learning for the student cohort	Convergence
Motivation to engage	Personal as not seen linked to career progression	Maintaining professional currency valued	No link currently for activities to different career stages	Divergence

VI. DESIGNING A DRAFT COMPETENCY FRAMEWORK

A. Theoretical Framework

The theoretical underpinning guiding the design of the competency framework is the implicit dual professional identity of engineering educators. Some argue that they are educators and the adjective ‘engineering’ describes what type. Others point out that they are educating for entry into a profession and are, hence, engineers who happen to be educating. Irrespective of which lens, engineering educators inevitably seek to develop inextricably linked competencies as an engineer and educator.

Hence, two streams of theoretical work inform the development of the framework. The first recognises the need

for engineering educators to translate their engineering knowledge into pedagogically powerful structures that are adaptive to varying student learning needs [43]. The second recognises a need for engineering educators to remain professionally current through research, consultancy and engagement in communities of practice that seek to solve engineering and engineering education problems [44].

B. Design, Consultation, Redesign

Guided by the literature review, the qualitative research findings and the theoretical underpinning, a competency framework was drafted. Key to the success of the framework's acceptability and expediency is the involvement of and consultation with key stakeholders. An open consultation workshop was advertised on Eventbrite and subsequently attended by participants from the three institutes and the wider education community (n=16). The purpose of the interactive workshop was to deconstruct and reconstruct the three domains [43]: pedagogical (teaching practice), content (engineering knowledge) and pedagogical-content (relating engineering practices to teaching and learning) to engage in collegial discussion and to further refine the draft.

VII. Piloting the Process

With the draft competency framework developed, the next step involved simulating a process, which could be aligned to the NPDF. Engineering educators across the three institutes were invited to complete a request for funding for professional development in teaching and learning. The request criteria included an overview of the training or activity, how it aligns to the competency framework domains, estimated cost and number of participants.

Submitted forms were reviewed by a by a panel consisting of representatives from HR, teaching and learning experts and academic management. They were tasked to prioritise the allocation of funding based on a set of criteria including alignment to the competency framework and department priorities, value for time and money, and enhancement value in teaching and learning.

In total 17 requests for funding were submitted, with the majority aligned to the content and pedagogical-content domains of the competency framework, with only 2 applications in the pedagogical domain. In the context of the pilot process, the nature of the requests highlighted a desire for professional development activities focused on maintaining professional currency as an engineer, thereby strengthening their engineering educator identity as a role model for students.

VIII. Conclusion

Students clearly voiced the importance that engineering educators should be authentic role models, versed in the real-world of engineering and possessing the ability to break down complex problems using tangible applicable examples. As seen in the literature, Desimone [13] agreed that content focus is key in the design of effective professional development. Both students and engineering educators recognised the concept of dual identity – being an effective teacher and a role model as an engineer – hence the importance of providing support for engineering educators in professional development that reaches further than just the well-defined pedagogical domain.

The literature indicated a positive correlation between content focus and teacher knowledge, improved pedagogy and higher student achievement [14]-[16]. Recognising the importance of the content domain and the pedagogical-content domain is central to the success of the adaption of the NPDF at discipline level. Thus, whilst serviced very well by the current teaching and learning provision, which is focused narrowly on pedagogical training, professional development in teaching and learning requires a broadening to more comprehensively address the needs expressed by engineering educators.

Furthermore, this research highlighted the diverse range of competencies and the differing range of professional development activities needed and valued by engineering educators. The adapted NPDF needs to be flexible enough to respond to these diverse needs and to provide guidance on recommended activities linked to stages in career development.

In designing this development framework in teaching and learning for engineering educators, convergent and divergent views have surfaced. The future success of the frameworks' utility pivots on finding a common ground between the needs of all key stakeholders, articulating a clear policy and providing support to ensure policy becomes practice.

References

[1] NFTL, *A Conceptual Model for the Professional Development of those in Irish Higher Education*. Dublin, Ireland: National Forum for Enhancement of Teaching and Learning in Higher Education, 2015. Retrieved from https://www.teachingandlearning.ie/wp-content/uploads/2015/12/A-Model-of-PD-for-HE-Dec2015.pdf

[2] NFTL, *National Professional Development Framework for All Staff Who Teach in Higher Education*. Dublin, Ireland: National Forum for Enhancement of Teaching and Learning in Higher Education, 2016. Retrieved from https://www.teachingandlearning.ie/wp-content/uploads/2016/09/PD-Framework-FINAL.pdf

[3] UKPSF, *The UK Professional Standards Framework for Teaching and Supporting Learning in Higher Education*. Heslington, UK: Higher Education Academy, 2011.

[4] K. A. Ericsson, R. T. Krampe and C. Tesch-Römer, "The role of deliberate practice in the acquisition of expert performance", *Psychological Review*, vol. 100, no. 3, pp. 363–369, 1993.

[5] D. C. T Berliner, "The nature of expertise in teaching,*" In F.K. Oser(Edx.), Effective and Responsible Teaching: The New Synthesis*, San Faranciso, CA: Jossey Bass, 1992, pp. 227–248.

[6] P.F. Conway and R. Murphy, "A rising tide meets a perfect storm: new accountabilities in teaching in Ireland", *Irish Educational Studies*, vol. 32, no. 1, pp.11-36, 2013.

[7] T. Maguire, *Mapping Professional Development Pathways for those who teach in Irish Higher Education: Where are we now and where do we want to go?*. Dublin, Ireland : National Froum for the Enhancement of Teaching and Learning, 2015.

[8] T. Maguire, *A Conceptual Model for the Professional Development of those who Teach in Irish Higher Education.* Dublin, Ireland: National Froum for the Enancement of Teaching and Leanring, 2016.

[9] EC, *Improving the Quality of Teaching and Learning in Europe's Higher Education Institutions*. Brussels, Belgium: European Commission, 2013.

[10] H. Timperley, *Realizing the Power of Professional Learning*. Berkshire: McGraw-Hill, 2011.

[11] L. Darling-Hammond and J. Bransford, *Preparing Teachers for a Changing World: What Teachers Should Learn and Be Able To Do*. San Francisco, CA: John Wiley & Sons, 2007.

[12] J. Harvey, B. Nolan and M. Keane, *Developing a Professional Development Framework to Promote, Acknowledge and Evidence Teaching*

and Learning Professional Development Activities for Staff at a Disciplinary Level: Proposal Application. Dublin Institute of Technology, Institute of Technology Blanchardstown, Institute of Technology Tallaght, Ireland, 2016.
[13] L. M. Desimone, "Improving impact studies of teachers' professional development: toward better conceptualizations and measures" *Educational Researcher*, vol. 38, no. 3, pp. 181-199, 2009.
[14] T. R. Guskey, "Results-oriented professional development: in search of an optimal mix of effective practices", *Journal of Staff Development*, vol. 51, no. 1, pp. 42-50, 1994.
[15] H. Borko, "Professional development and teacher learning: mapping the terrain*", Educational Researcher*, vol. 33, no. 8, pp. 3–15, 2004.
[16] R. K Blank, N. de las Alas and C. Smith, *Analysis of the quality of professional development programs for mathematics and science teachers: Findings from a cross-state study*, Washington, DC: Council of Chief State School Officers, 2007.
[17] R. L. Custer and J. Daugherty, "Professional development for teachers of engineering: research and related activities", *The Bridge*, vol. 39, no. 3, pp.18, 2009.
[18] T. Maguire, T, E. Tan and N. Rushe, *A Snapshot of Accredited Professional Development Provision in Irish Higher Education*. Dublin, Ireland: National Forum for the Enhancement of Teaching and Learning in Higher Education, 2015.
[19] N. Kenny, K. Young and L. Guilfoyle, *A Snapshot of Non-Accredited Continuing Professional Development for those who Teach in Irish Higher Education*. Dublin, Ireland: National Forum for the Enhancement of Teaching and Learning in Higher Education, 2015.
[20] D. A. Kolb, *Experiential learning: Experience as the Source of Learning and Development*. New York: FT Press, 2014.
[21] J. E. Zull, *The Art of Changing the Brain: Enriching Teaching by Exploring the Biology of Learning*. Sterling, Virginia: Stylus Publishing, 2002.
[22] J. R. Anderson, *Cognitive Psychology and its Implications*. H Freeman/Times Books/Henry Holt & Co., 2005.
[23] G. R. Davies, P. J. Goodhew, G. E. Kirk, D. A. Nethercot, H. Norie, J. F. Roulston, M. Shears, J. C. Shelton and M. J. Wither, *Educating Engineers for the 21st Century*. London: The Royal Academy of Engineering, 2007.
[24] J. D. Donna, "A model for professional development to promote engineering design as an integrative pedagogy within stem education", *Journal of Pre-College Engineering Education Research*, vol. 2, no. 2, pp. 11-17, 2012.
[25] N. Cross, "Designerly ways of knowing: design discipline versus design science*", Design Issues*, vol. 17, no. 3, pp. 49–55, 2001.
[26] M. Prince, "Does active learning work? a review of the research", *Journal of Engineering Education*, vol. 93, no. 3, pp. 223–231, 2004.
[27] T. J. Moore and M.A. Hjalmarson, "Developing measures of roughness: Problem solving as a method to document student thinking in engineering", *International Journal of Engineering Education*, vol. 26, no. 4, pp. 820, 2010.
[28] O. V. Shipulina, D. H. Smith and P. Liljedahl, "Bringing reality into calculus classrooms: Mathematizing a real-life problem simulated in a virtual environment", *International Journal of Engineering Pedagogy*, vol. 3, no. 1, pp. 56–66, 2013.
[29] P. N. Meter, C.M. Firetto, S. Turns, T.A. Litzinger and C.E. Cameron, "Improving students' conceptual reasoning by prompting cognitive operations", *Journal of Engineering Education*, vol. 105, no. 2, pp. 245–277, 2016.
[30] S. Loucks-Horsley, K. Styles and P. Hewson, "Principles of effective professional development for mathematics and science education", *NISE Brief*, vol. 1, no. 1, 1996.
[31] M. S. Knowles, *Andragogy in action: applying principles of adult learning*. San Farancisco, CA: Jossey-Bass, 1984.
[32] R. DuFour and R. Eaker, *Professional Learning Communities at Work: Best Practices for enhancing Student Achievement*. Bloomington, IL: National Education Service, 2008.
[33] L. D. Fink, S. Ambrose and D. Wheeler, "Becoming a professional engineering educator: A new role for a new era", Journ*al of Engineering Education*, vol. 94, no. 1, pp. 185–194, 2005.
[34] M. D. George and S. Bragg, *Shaping the Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*. DIANE Publishing, 1996.
[35] B. E. Seely, "The other re-engineering of engineering education", *Journal of Engineering Education*, vol. 88, no. 3, pp. 285–294, 1999.
[36] W. M. Phillips, G. D. Peterson and K. B. Aberle, "Quality assurance for engineering education in a changing world", *International Journal of Engineering Education*, vol. 16, no. 2, pp. 97, 2000.
[37] M. W. Matlin, *Cognition*. Forth William, TX: Harcout Brace Jovanovich, 1989.
[38] E. L. Boyer, *Scholarship Revistied: Priorities of the Professoriate*. Princeton, NJ: The Carnegie Foundation for the Advancement of Teaching, 1990.
[39] C. J. King, "Restructuring engineering education: why, how and when?", *Journal of Engineering Education*, vol. 101, no. 1, pp. 1–5, 2012.
[40] R. M. Felder, D. R. Woods, J. E. Stice and A. Rugarcia, "The future of engineering education II. Teaching methods that work", *Chemical Engineering Education*, vol. 34, no. 1, pp. 26-39, 2000.
[41] DIT, *DIT Strategic Plan to 2019: Towards TU4Dublin*. Dublin, Ireland: Dublin Institute of Technology, 2017.
[42] J. Mercille and E. Murphy, "The neoliberalization of Irish higher education under austerity", *Critical Sociology*, vol. 43, no. 3, pp. 371-387, 2017.
[43] L. Shulman, "Knowledge and teaching: foundations of the new reform", *Harvard Educational Review*, vol. 57, no. 1, pp. 1–22, 1987.
[44] L. D. Fink, S. Ambrose and D. Wheeler, "Becoming a professional engineering educator: A new role for a new era", *Journal of Engineering Education*, vol. 94, no. 1, pp.185-194, 2005