SEFI Journal of Engineering Education Advancement
Vol. 2, No. 1, 2025, pp. 80-100, ISSN 3006-6301
DOI : 10.62492/sefijeea.v1i1.31

Lifelong learning - a new conceptual framework, and the role of an undergraduate engineering education

Franz Newland[a,1], Hossam Sadek[b],

[a] **University of Ottawa, Faculty of Engineering, Canada**
[b] **York University-Lassonde School of Engineering, Canada**

ABSTRACT

Lifelong learning is used extensively within education and specifically within engineering education, but is not well-defined, which makes it hard for learning organizations to clarify how they are supporting the lifelong learner. The few existing frameworks do not consider the time horizons of learning activity, do not include "life-wide" learning and do not explicitly differentiate between learning for professional and societal needs. This paper therefore proposes a new conceptual framework of lifelong learning which breaks it into three phases: a long-term "career- and life-focussed" learning phase, a medium-term "programme of learning" phase, and a real-time phase for monitoring and adjusting learning as it happens. The paper uses the framework to consider how the authors' undergraduate engineering programs currently develop these facets and proposes how this framework could develop this further. Although the proposed framework was developed for engineering, and engineering education specifically, it is intended to be taken up more widely. The framework will support the individual learner achieve greater intentionality as they develop their learning skills throughout their life and will support learning institutions to articulate the intended learning skills around lifelong learning more precisely.

KEYWORDS

Lifelong learning, metacognition, self-directed learning, self-regulated learning.

PUBLICATION

Submitted:
23rd December 2024

Accepted after revision:
24th March 2025

[1] Corresponding Author : Franz Newland, School of Engineering Design & Teaching Innovatio, University of Ottawa, 200 Lees Block E, Ottawa, Ontario K1N 6N5, Canada

Introduction

Lifelong learning is widely recognized as a crucial component of graduate employability, career progression, and workplace learning. Engineering educators have emphasized the importance of lifelong learning as an outcome of undergraduate programmes since the 1960s (Shuman, Besterfield-Sacre, and McGourty 2005), and this emphasis has only grown more critical in light of the rapid pace of technological change. Additionally, a significant number of engineering graduates switch careers multiple times or pursue careers outside of engineering, making lifelong learning essential for their continued success (Ro 2011). The construct has a solid history and rationale, and is underpinned by a substantial body of literature, however the term 'lifelong learning' is now used quite inconsistently in educational circles, as detailed later in this paper, and would therefore benefit from a clearer framework.

The authors set out to review common frameworks of lifelong learning in engineering in Canada, as part of their own, and their programs' continuous improvement. To acquire the skills for lifelong learning for the engineering profession, there is an expectation that undergraduate engineering programs provide specific instruction in the skills needed. The authors looked at frameworks of lifelong learning for higher education from a literature review, with the intention that this might help inform better integration of this skill into the authors' curricula. The review, however, highlighted a lack of a common language to describe the attributes of these skills. This created challenges to using any of the existing frameworks of lifelong learning for curricular improvement. Although organizations responsible for accrediting engineering education worldwide have a largely unified high-level definition of the need for lifelong learning, creating a common framework of characteristics and indicators has proven to be challenging. " *Because there is no single widely agreed upon definition […] or break down of lifelong learning characteristics, universities identify their own list of indicators for accreditation*" (Saxe, Mahmoud, and Razavinia 2022), resulting in a lack of consensus across institutions. Van den Broeck et al. (2022) capture that "*Literature about LLL is […] scarce in engineering education*". This lack of agreement on a common definition or framework is not unique to engineering education, but rather a generic challenge. It is accepted that "*In spite of the considerable attention paid to this issue, lifelong learning strategies are not fully understood*" (Qalehsari, Khaghanizadeh, and Ebadi 2017). Laal (2011) also points to the need for a framework of lifelong learning for all disciplines. Aspin and Chapman (2000) state that "a more comprehensive analysis of all the various dimensions and features of the nature, aims and purposes of policies for `realizing a lifelong approach to learning for all' will have to be tackled, and a more wide-ranging set of justifications addressing the differences in those aims and purposes more clearly articulated and provided."

Lifelong learning is defined as the twelfth engineering "graduate attribute" by the Canadian Engineering Accreditation Board (CEAB), as a graduate's "*ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge*". Other accreditation organizations such as the Accreditation Board for Engineering and Technology (ABET), the European Network for Accreditation of Engineering Education (ENAEE) or others, and engineering education organizations and societies such as the US National Research Council's Board on Engineering Education (National Research Council 1995), The National Academies (National Academy of Engineering 2004), or the American Society for Engineering Education (Dowell, Baum, and McTague 1994), assert that students must develop the skills and attitudes that foster continuous learning in order to succeed in our

accelerating global environment. Accrediting organizations place emphasis on lifelong learning because it is deemed essential for the ongoing professional growth of practicing engineers. Whilst this paper focuses on engineering and engineering education in a Canadian context, the Washington Accord ensures a certain degree of consistency across many international engineering education contexts, where the "*accreditation processes of each signatory's country are monitored every 3-6 years to ensure they maintain their comparability with all member signatories*" ("The Washington Accord | Engineers Canada," n.d.). ENAEE includes the "*ability to recognise the need for and to engage in independent life-long learning;" and the "ability to follow developments in science and technology*" as part of its lifelong learning attribute ("EUR-ACE® Framework Standards and Guidelines," n.d.).

Not many past studies have performed reviews of frameworks of lifelong learning against engineering curricula. The European University Enterprise/ Education/ Employability Databases Organization System (EUEDOS) has taken steps to provide better integration between the future engineer's learning, and the practitioner's lifelong learning, by introducing "*an integral 3-phase roadmap for implementing an effective and pragmatic delivery, of a technological model able to interleave and render an individual's employment and academic profile, as inter-nested to his/her life-through education*" (Mylonas and Bouyouris 2007). Another study, by KU Leuven and their consortium partners (Beagon et al. 2022), that mapped five lifelong learning attributes from Cruz et al (2019) to six engineering programs in Finland, Belgium and Ireland, is of direct relevance to this current analysis. In that study, a quantitative review of learning outcomes was performed, flagging "*only one of the five competencies [relating to locating and scrutinizing information] was adequately addressed*". Similarly, Saxe, Mahmoud, and Razavinia (2022) propose a framework focussed on the teaching design of lifelong learning in engineering education, to ensure alignment between outcomes, instructional strategies and assessment, recognition of lifelong learning as "*the overarching graduate attribute (GA) that is directly relevant to each of the other 11 attributes.*", and incorporating the instructors' own lifelong learning commitments. Self-regulated learning and metacognitive awareness are skills areas that are commonly recognized, including in Saxe, Mahmoud and Razavinia (2022), as required skills for successful higher educational learning. There is nonetheless still a dominant narrative in undergraduate degrees that the learner has transitioned from a directed learning space (K-12) to one where the student is expected to work out on their own how to manage their learning. No support is provided for the learner to go through that transition, ignoring the fact that managing one's learning is a skill that itself needs developing.

The authors have both fulfilled the roles of "graduate attributes lead" and undergraduate program director for their respective programs during periods of program accreditation review and have reviewed each of the graduate attributes extensively in their own and other programs. For ongoing graduate attribute and curricular improvement processes, the authors regularly evaluate the learning activities and assessment tools related to graduate attribute 12, lifelong learning, per the Canadian Engineering Accreditation Board, in two of the engineering programmes at their home institution. Whilst sufficient to meet accreditation requirements, the authors have been keen to develop more scaffolded framing for this learning. The learning tools and opportunities that have been identified as relevant to the lifelong learning graduate attribute within the authors' programs are captured in Table 1, which maps tools to different types of lifelong learning skill and indicator. The indicators of lifelong learning currently used at the authors' home institution for all engineering programs broadly cover the following two areas: 1) Identifying gaps in one's knowledge, skills and abilities and 2) Developing professional goals and plans for continual learning.

ISSN 3006-6301, Vol. 1 (No. 1) 2025

Table 1: Learning tools identified relating to lifelong learning in the authors' two home engineering programs.

Tool	Detail / Implementation	Related graduate attribute
"Exam wrappers"	Reviewing exam performance and learning factors (Stephan, Stephan, and Miller 2020), (Lovett 2013). Used in one of the programmes	1
Learning motivation	Students review why they chose to study Engineering, and learning motivations are discussed with peers.	2
Introducing reflection strategies	Learners are given some reflection strategies and assignments (such as "What? So what? Now what?").	1,2
Use of reflection in project-based learning	Learners in team project settings are asked to identify project motivations and reflect on team motivations, identify gaps in knowledge and spaces for self-instruction within this. They are also asked to reflect on project learning journey and success/challenges.	1,2
Self-directed project learning	Planning for a successful project – to address holes in personal and team knowledge to complete a project, students engage in self-directed learning activities (e.g. through optional hand-skill, machine shop and other workshops, or for digital badges)	1,2
Experiential Education (EE) opportunities	These give students access to a diverse range of learning spaces, but do not always include any learning-related reflection.	2
Career events	Activities looking at the nature of engineering careers - Career events, invited industry guest speakers, visits to companies, students create a LinkedIn profile, and they may engage in the optional co-op programme.	2
Learning journey reflections	Students consider what brought them to engineering, what the different engineering streams are, and are encouraged to attend different club, industry, and university events. There are also activities to support the learner in their selection of their engineering programme of choice.	2
Professional learning contexts	Learners reflect on the role and need for CPD, develop very early ideas of a personal CPD plan, reflect on lifelong learning, including considering any preferred opportunities for lifelong learning, and identify learning opportunities that fit personal learning preferences	1,2

There is some alignment between the tools used and the indicators, however assessment is generally indirect. Using reflection to measure identification of gaps in knowledge (a posteriori) is not directly measuring identifying gaps. Self-directed learning within a class is still within a class and is not a measure of finding relevant sources of learning or motivation for taking a learning opportunity, with evaluation of the learning being limited. Reflections on continuous professional development and selection of learning program are not actually assessing adaptability or developing professional standing. As stated by Saxe, Mahmoud, and Razavinia (2022), "*there is an overall lack of assessments that can measure lifelong learning propensity in students […], and very few published assessments*

that measure students' motivation and attitudes towards lifelong learning". It is interesting to note that some of the best institutional assessment tools for lifelong learning currently are self-assessment questionnaires such as those captured by Chen, Lord, and Mcgaughey (2013).

With regards to instruction, at the level of individual learning activity there is currently no formal instruction on self-regulated learning and metacognition making much of this left to individual instructors' choice, with no systematic activity. Activities for self-directed learning are not explicitly framed as such and/or may not be valued within the formal learning structure. In the authors' two programs, curricular and extracurricular activities and co-op possibilities also have the potential to help students develop professional goals and plans for continual learning, supported by mandatory student advising each year, however there is no specific reflection on learning needs in these spaces, and how they are being achieved.

At a broad societal level, there are several expectations around undergraduate engineering education regarding preparing students for the requirements of continuing professional development. Universities are assessed on the rate of graduate employment, so supporting students during their studies to quickly find paths into employment on graduation is aligned with university performance indicators. These expectations and measurements are not explicitly tied to the attribute of lifelong learning within the authors' programs.

The authors argue that universities may give students the space to learn how to learn, however our observation is they only sometimes provide the tools or support to achieve this, it is unclear for many faculty how exactly to make these skills more explicit, and universities need to be better at contextualizing these metacognitive skills to help the learner understand their learning processes. This paper will therefore explore the terminology around lifelong learning and highlight the overlaps and inconsistencies in the literature, and gaps in the definition. The paper then proposes a new three-phase lifelong-learning framework, developed inductively from the authors' challenges around the Canadian graduate attribute for engineering education, and deductively from a literature review of lifelong learning in different contexts. The paper then considers the possible roles of engineering education institutes in developing the skills defined in the proposed conceptual framework, recognizing that not all facets of lifelong learning may be able to be acquired during an undergraduate learning experience.

It is important to provide the positionality of the authors, acknowledging racial, gender and colonial biases and experiences that will result in blind spots in developing this new conceptual framework of lifelong learning. The authors are both self-identifying cisgender males with relatively traditional engineering education backgrounds. One undertook their higher education in Canada and the other in Europe. One identifies as predominantly white European and the other as from Egypt, and both have immigrated to Canada as adults. One of the authors had extensive industry experience before re-entering academia, and both have mostly been tenured teaching-focussed faculty with extensive past responsibilities in curricular development and programme improvements. Neither required any accommodations during their pre-undergraduate and undergraduate learning.

In addition, in creating a new conceptual framework with terms that have been used pervasively, there will be some dissonance between the proposed use of specific terms and their use in some existing literature, especially in light of the contradictory use seen in some literature. The goal is not to prescribe terminology, but rather to better identify the parts that can make up the purpose of a learning attribute in learners.

Method

The literature was sourced from Scopus Database. The initial search string, "lifelong learning AND engineering AND graduate attribute," focused on accreditation requirements related directly to lifelong learning. However, this search yielded a limited number of articles (17 articles), with most emphasizing pedagogical activities and assessment methods rather than conceptual frameworks. To broaden the scope, the search was expanded to "lifelong learning AND engineering." A preliminary review of titles, abstracts, and keywords from the most cited articles revealed that the term "lifelong learning" is well-recognized in academic discourse and often used in connection with other related terms. Consequently, additional searches were conducted using the following terms in combination with "Lifelong learning": self-directed learning, self-regulated, metacognition, and goal setting. These searches were limited to engineering education journals, conference proceedings, and content within titles, abstracts, or keyword. Given that lifelong learning, self-regulation, and metacognition are extensively researched in disciplines such as education and psychology, the search scope was then expanded accordingly. To develop a more comprehensive understanding of the lifelong learning landscape, additional searches included broader literature on lifelong learning within engineering (beyond the field of engineering education) and extended to relevant studies outside the engineering domain. The inclusion criteria for this expanded search focused on articles where the title or abstract clearly suggested that the study offered conceptual frameworks related to lifelong learning or its alternative terms.

A number of articles (e.g. Kirby et al. 2010; Dawe et al. 2021; Cruz, Saunders-Smits, and Groen 2019) provide detailed reviews of the numerous studies that have investigated the attributes of lifelong learning. These studies can be broadly classified into those that focus on practical implementations of teaching practices, course interventions, and assessments to promote students' specific skills that are linked to lifelong learning, and those that aim to develop a better understanding of what lifelong learning is and its attributes/indicators or to create a programme-wide framework for implementation. In particular, Dawe et al. (2021) performed a focused review of lifelong learning within the Canadian engineering education context. The researchers examined 17 Canadian institutions and categorized the graduate attribute indicators into three main categories. The first category was knowledge indicators, which include knowledge of engineering information sources, skills, and self-awareness (metacognitive knowledge). The second category was skill indicators, encompassing self-directed learning skills, application skills, and the ability to adapt learning strategies to new conditions. Finally, the third category was attitude indicators, which refer to the individual's attitude towards lifelong learning. The second of these levels is further detailed by Stolk et al. (2008) : "*Individuals become self-directing through mastery of a broad range of skills, attitudes, and knowledge that enables construction of understandings and management processes for their thoughts, motivations, actions, and interactions with their learning environment.*". They go on to say that "*In addition to masters of learning processes, self-directed learners are self-starters, with intention to develop and conceptions of themselves as highly capable learners*".

According to Knapper and Cropley (2000), lifelong learners are active learners who plan and assess knowledge rather than waiting for others to prepare it for them. They can learn in formal and informal settings from their peers, teachers, and mentors. They can apply their knowledge to different contexts and are astute users of different learning strategies for unique situations. The authors believe these attributes of a lifelong learner can be developed through the skills, competencies and knowledges of a lifelong developmental continuum.

A common method for classifying lifelong learning characteristics is to divide them into two domains: cognitive and affective (Besser et al. 2022; Al-Masoud, Naoumov, and Kirstukas 2013; Mourtos 2003). On the one hand, the cognitive domain encompasses skills such as identifying, explaining, and acquiring new knowledge, as well as developing attitudes that support ongoing learning. On the other hand, the affective domain focuses on the individual's recognition of the need for lifelong learning and active participation in opportunities that facilitate this. In other words, lifelong learners must not only possess cognitive abilities but also exhibit a willingness and motivation to continuously develop themselves. Knapper and Cropley (2000) proposed a framework that has been the focus of several investigations, which includes five characteristics: goal setting, knowledge application, self-direction/self-evaluation, locating information beyond the classroom, and adapting to new learning situations. Based on these 5 characteristics, Kirby et al. (2010) developed a 14-item survey to measure students' disposition to engage in lifelong learning. Another study (Uzunboylu and Hürsen 2011) distinguished six subscales: self-management competencies, learning how to learn competencies, initiative and entrepreneur competencies, competencies of acquiring information, digital competencies, and decision-taking competencies. Dunlap and Grabinger (2003) identified three main themes for lifelong learning: Self-regulated learning, Metacognitive awareness, and Disposition toward lifelong learning. In a critical review conducted by Cruz, et al. (2019), the authors identified 18 characteristics of lifelong learning that could be grouped into five main categories: Reflection, Acquiring, Learning, Initiating, and Participating. The most frequently reported characteristics were self-reflection (mentioned in 17 studies), locating and scrutinizing information (mentioned in 16 studies), willingness, motivation, and curiosity to learn (mentioned in 11 studies), creating a learning plan (mentioned in 10 studies), and self-monitoring (mentioned in 6 studies).

Several studies of lifelong learning have focused on self-regulated learning and/or metacognitive awareness as the main characteristics, and some have even equated these two concepts with lifelong learning itself. In general, previous studies suggest that teaching methods which prioritize academic rigor, critical analysis, reflection, and diverse peer interactions have a beneficial influence on the cultivation of lifelong learning skills (Mayhew, Wolniak, and Pascarella 2008; Lord et al. 2012).

Considering the broader literature on lifelong learning in engineering acknowledges that a key driver is the regulatory imperative for engineering graduates and practicing engineers to engage in this skill. Engineers Canada, as the representative of all provincial engineering regulatory bodies nationally and internationally, considers professional development as a crucial aspect of its work. They establish a clear connection between an engineer's ethical responsibilities towards safeguarding the public interest and the implementation of mandatory continuing professional development requirements ("Public Guideline on the Practice of Engineering in Canada" 2012). Continuous professional development encompasses:

> *"the planned acquisition of knowledge and skills, continued practice in each member's areas of competence, and the development of personal qualities necessary for the execution of professional and technical duties throughout a member's professional life. It encompasses both technical and nontechnical skills."* ("Engineers Nova Scotia Continuing Professional Development Policy" 2017).

In the present day, engineers operate within a constantly evolving and innovative environment. In order to confront this challenge and maintain competitiveness in their fields, technical professionals must possess expertise in their subject matter, possess exceptional problem-solving abilities, collaborate effectively within teams, and commit to lifelong learning ("2023 Accreditation Criteria and Procedures" 2023). Similarly the Engineering Council in the UK notes that "*All Engineering Council*

registrants make a commitment to maintain and enhance their competence. In practice, this means undertaking Continuing Professional Development (CPD)" ("Engineering Council," n.d.). In the US, "*NSPE proactively encourages its members to engage in lifelong learning and the evolution of engineering education to ensure the profession evolves in an ethical, sustainable manner*" ("Education | National Society of Professional Engineers," n.d.). Similar definitions have been found in jurisdictions around the world, identifying the following attributes of lifelong learning as essential to the engineering practitioner:

- Planning one's lifelong learning, for both knowledge and skills
- Practicing in one's area of competence, requiring ongoing review
- Personal development both in technical and non-technical areas
- Learning that is ongoing throughout the professional life of the practitioner

Interestingly, there are remarkably few papers that address how professionals can identify and undertake relevant activities – there is an expectation that the practitioner is able to find such opportunities independently or through their employer.

As a final step, it was important to consider the societal framing for lifelong learning, outside engineering, to ensure the engineering scope was not missing any remaining attributes. Indeed the origins of the term lifelong learning are as a translation of the original 'éducation permanente', an expression coined by Edgar Faure in his seminal work *Learning to Be* (Faure et al. 1972), for the United Nations Educational, Scientific and Cultural Organization (UNESCO). UNESCO, which operates the Institute for Lifelong Learning (UIL), adopted the notion of lifelong learning as a driver for the 4th sustainable development goal, as well as recognizing its importance to the other sixteen goals ("Our Mission | Institute for Lifelong Learning," n.d.). Learning is an inevitable human activity from birth to old age, and provision of lifelong educational opportunities is essential for the realization of human potential and the spread of human rights and democratic ideals, concepts that are also echoed by Laal (2011). An important underlying concern for Faure and his colleagues was the provision of equal opportunity, leading to self-fulfilment, which in his view could only be brought about through political and educational structures that would encourage learning throughout a person's lifetime (Faure et al. 1972).

A major goal for the proponents of lifelong learning was to gain recognition for the idea that learning is a deliberate and inevitable human activity that merits both encouragement and study by experts. As highlighted by Martínez-Mediano and Lord (2012), international organizations have long emphasized the significance of lifelong learning (LLL) for active participants in the knowledge-based economy. The term "lifelong learning" was popularized within the context of economic advancement and societal progress (Faure et al. 1972; Delores 1996). Education, democratization and self-actualization were seen as interlinked concepts (Dewey 1930). The European Union declared 1996 as the "year of lifelong learning" ("European Year of Lifelong Learning (1996) | EUR-Lex," n.d.), while the Organization for Economic Cooperation and Development (OECD) highlighted the importance of lifelong learning for both economic development and equity, particularly in developing nations (OECD 2007). Similarly, Latvia's recent six-year experiment into intentional lifelong learning opportunities identified a number of equity-related gains through this intentionality ("Adult Education Project Comes to a Close," n.d.), which echoes other work that emphasizes how post-traditional learners in particular are more commonly from equity-deserving groups (e.g. "The Post-Traditional Learners Manifesto Revisited: Aligning Postsecondary Education with Real Life for Adult Student Success | VOCEDplus, the International Tertiary Education and Research Database," n.d.).

Not only should learning be lifelong, it should also be 'life-wide' in the sense that learning cannot be confined to formal educational institutions, but rather is seen to take place in a wide variety of settings (Laal 2011) - including non-formal learning in the workplace, within voluntary associations (Dobson 1982), and informal learning in social and recreational contexts (Tuijnman and Boström 2002). In these broader educational framings, lifelong learning includes a person's "generic ability to guide their own learning throughout their lives and in the wide variety of situations they will encounter after leaving formal education" (Kirby et al. 2010).

Meeting the goals of self-actualization, democratization, being better citizens, spreading human rights, rising to the changing needs of professions, maintaining competency and validating learning inside and outside formal learning settings may seem challenging to reconcile. This review identified a strong desire for a common framework for lifelong learning, in particular in light of inconsistent interpretation of the meaning of the term. In undergraduate settings, the challenge of teaching a set of skills intended to serve the learner throughout their life often results in a framing of lifelong learning focussed more on short-term learning skills – metacognition, reflection and some level of self-direction, whilst acknowledging the directed nature of learning in institutions. A few frameworks focus on approaches to scaffold learning, supporting those who are trying to support the learner in acquiring lifelong learning practices, but these are typically focussed on a sector of learner, for example the undergraduate or those in employment. Whilst a few frameworks are identified in the literature, and the frameworks do have a large degree of consistency and overlap, none specifically consider the time horizon of learning activity, where for example metacognition is primarily focussed on recognizing learning as it is happening, whereas planning for future learning needs may be something requiring a timescale of a few years. Similarly, there are no frameworks that explicitly consider all learning, including learning outside formal settings, despite the sense of "life-wide" learning used by Kirby et al. (2010) and Laal (2011) being broadly recognized. The differences between the need to maintain professional competency and the needs from society as a whole for us all to engage in lifelong learning are also not captured in the existing frameworks in ways that allow the learner to connect their learning to multiple possible higher goals. Missing these time references and higher levels of purpose and consideration for lifelong learning in analyses of the traits and characteristics of the lifelong learner can make it hard to map the higher goals of lifelong learning to specific, measurable characteristics that can be supported in the lifelong learner, in a consistent way across their life.

Results

Having reviewed all the existing literature and identified the apparent inconsistencies, overlaps and gaps, this work proposes a new conceptual framework addressing these issues, following Parahoo (2006) who state that a "conceptual framework draws on concepts from various theories and findings to guide the study". Similarly, Adrienko et al. (2011) state a conceptual framework is appropriate when "Tasks are distinguished according to the type of information they target and according to the level of analysis". The initial context for developing a conceptual framework is the engineering graduate attribute related to "lifelong learning" (GA12 in a Canadian context), within an undergraduate engineering education. The framework has also been developed with Ontario's "Undergraduate Degree Level Expectations" (UDLEs) in mind ("Appendix 2: OCAV's Undergraduate and Graduate Degree Level Expectations," n.d.), which are applicable to any undergraduate learning in any university discipline (not just engineering education), and the framework has also been designed with international and life-long learning in mind.

The proposed conceptual framework follows a timeline model, shown in Figure 1, with a real-time phase, when engaging in the learning itself, that focuses on real-time reflection on the learning process, a middle phase, on selection of a learning opportunity, that focuses on autonomy of managing the learning, and a long-term phase, focussing on the ability to articulate one's current learning state, possible learning needs, learning contexts that can fill the gap, and selecting a learning opportunity. Depending on the learner and the framing for learning, it may be appropriate to consider this framework from left to right or the reverse – the starting point is less important than the multiple phases. The key characteristics of each phase are now detailed.

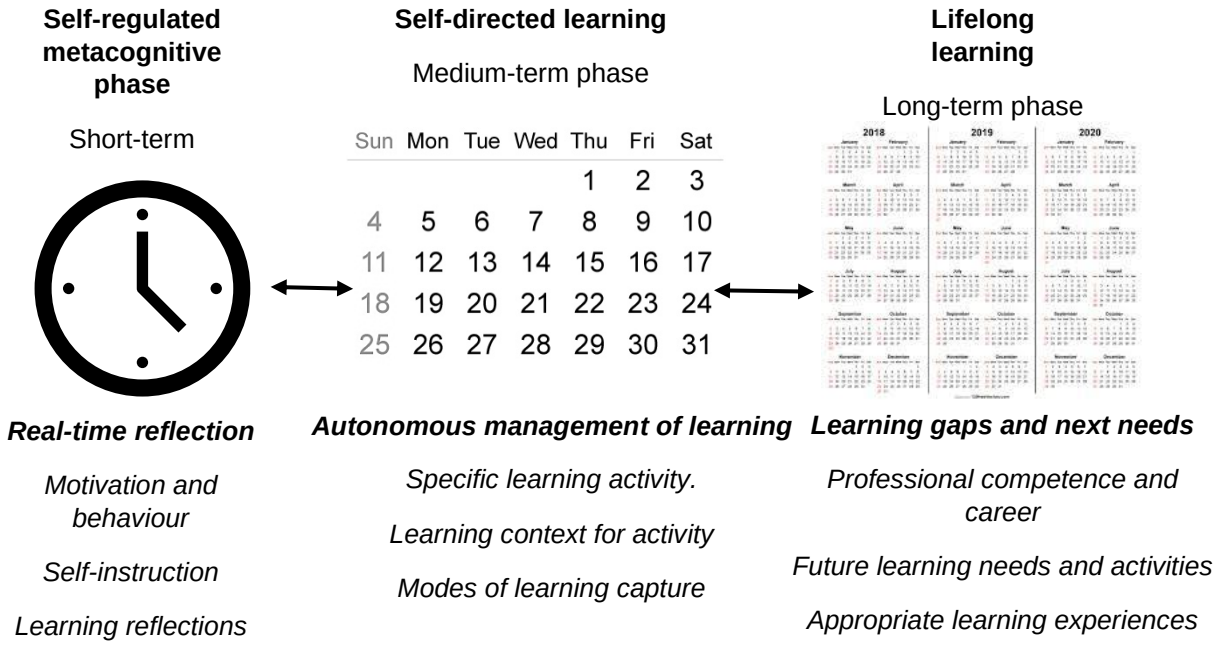

Figure 1: Timeline model of the proposed conceptual framework for lifelong learning

Self-regulated and Metacognitive learning phase (short-term learning horizon)

The elements of learning assigned to the short-term phase relate to managing the learning process itself, in real-time. This encompasses understanding, articulating, and regulating motivations for learning and behaviours in learning, as well as monitoring and controlling the learning itself. For learning behaviours, it encompasses both self-regulation and regulation of the efforts assigned to learning. This also encompasses the exercise of self-instruction and self-reflection. In terms of university learning, this can be considered as specific learning activities within a course or club activity etc. such as a lecture, an exam or assignment or a club event.

Self-directed learning phase (medium-term learning horizon)

The middle phase has been labelled as the self-directed learning phase. In this labelling, it is important to distinguish between self-directed learning and self-regulated learning, as also considered by Uz and Uzun (2018). The self-directed learning phase's focus is on the direction and autonomy of learning choices. The elements of learning assigned to the middle phase primarily relate to the detailed planning for, and reflection on, a specific learning activity once it has been identified and selected. The activity may start with defining and planning the specific learning task and identifying how it can meet the specific outcomes required and goals sought. It includes developing and using strategies for self-directed learning through modelling, training and/or practice. This requires the learner to understand, monitor and change/control the physical and emotional contexts of learning, and the institutional,

curricular, learning process and personal contexts of learning. At the end of learning, this phase includes reacting to, and reflecting on, the learning, recognizing how to ascribe cause to learning performance, and noting emotional reactions to performance and adjusting motivation beliefs accordingly. In terms of university learning, this can be considered as the learner activities around preparing for and reviewing a course or a club or related activity for a given purpose.

In addition, we have assigned development of different learning portfolios at this specific learning activity phase. Although it could be argued such portfolios would make most sense at the lifelong learning phase, we have chosen to attribute them at the middle phase where the long-term phase focuses more on career planning, and this phase focuses more on capturing the artifacts of a specific learning activity. Part of portfolio development includes recognition of different portfolio styles: action-oriented portfolios which may help with awareness of what the learner can do, meaning-oriented, which may help make sense of/understand learning processes, and self-authorship portfolios which may expose assumptions, biases, misconceptions, beliefs, or values of the learner.

Lifelong learning phase (long-term learning horizon)

The elements of learning assigned to the long-term phase primarily relate to the processes of identifying what learning may be needed, where to find opportunities for such learning, how to select the most appropriate opportunity, and how to get the most from it. In terms of university learning, this can be considered as the programme-level learning and the activities available at the university while students complete the programme.

Identifying learning needs includes awareness of requirements for maintaining professional competence, continuous professional development, awareness of career path and learning steps to achieve it and maintaining learning resilience within and outside the profession. It also encompasses emerging learning needs from society - and therefore encompasses learning for the individual, the profession, and society. Finally, it encompasses the concept of continuities and discontinuities of learning - growth in a given area of expertise (e.g. keeping up with the latest methods and knowledge in thermodynamics modelling), as well as awareness of new and emerging disciplines, contexts and factors that may not grow out of existing expertise (e.g. learning about how AI may be being used to create a system digital twin, requiring radical rethinking of some traditional modelling approaches).

One additional element to the long-term phase is its role to frame and connect all learning activity – all the graduate attributes of engineering for example - for the learner to use this phase to identify their personal profile across all the attributes that make them a competent engineer, and to identify their aspirational engineering profile.

Using the facets of each phase, a possible set of progressive indicators of each element of the proposed learning conceptual framework is shown in Table 2. This framework captures the common elements from other frameworks, but makes the time focus of different lifelong learning activity more explicit. The framework tries to capture learning in any and all contexts, including learning outside formal settings, through each of the learning phases. The framework similarly provides for learning that relates to multiple higher purposes, whether personal, professional or societal. The progression of indicators broadly relates to standard cognitive models and learners would nominally develop these from left to right. There is no specific direction vertically (learners may start from real-time learning facets, or long-term learning facets, or jump around as they engage in learning).

Table 2: Proposed lifelong learning conceptual framework and possible progressive indicators for it.

Facet	Progression of indicators		
	Conceptualize	**Develop**	**Use**
Articulate and control learning motivation and behaviour (Short-term phase)	Identify current learning motivations and behaviours.	Recognize how different personal learning behaviours and motivations affect success	Actively track and articulate learning motivations and behaviours across all learning
Demonstrate self-instruction (Short-term phase)	Recognize spaces of self-instruction, nature of autonomy and control over self-learning	Document an example of self-instruction	Show ongoing self-instruction praxis
React to and reflect on learning (Short-term phase)	Recognize different learning reflection strategies	Articulate reactions to different learning activities and performance	Demonstrate ongoing reflexive practice to all learning
Define and plan a specific learning activity. **(Medium-term phase)**	Predict personal learning expected from a learning activity	Plan for success from learning – develop a set of learning steps for a given learning activity	Articulate the specific learning and learning planning for all already planned learning activities.
Understand and change learning context for a given learning activity (Medium-term phase)	Understand influences and contexts on successful learning.	Describe successful learning contexts and identify differences with current context	Identify necessary changes in learning context and make substantive changes to achieve them
Use different modes of learning capture. **(Medium-term phase)**	Understand different learning awareness types: action-/meaning-oriented, self-authorship - and how they can be captured in portfolios or other tools	Develop examples of each learning narrative and articulate value proposition of each to personal learning	Show ongoing learning narrative engagement in action-oriented, meaning-oriented, and self-authorship learning awareness, across all learning opportunities
Prepare to meet professional competence and	Understand requirements for continuous professional	Develop a CPD plan and review mechanism, consider career paths and	Demonstrate ongoing CPD, identify

Facet	Progression of indicators		
	Conceptualize	**Develop**	**Use**
achieve future career goals (Long-term phase)	development (CPD). Identify possible future career goals	skills, and personal interest and motivation	knowledge/skill areas required of a career goal
Articulate future learning needs and activity types to achieve them (Long-term phase)	Describe learning contexts that have been successful	Define personal requirements for an ideal learning experience	Identify current state of learning and next learning needs to achieve plan and adapt to new contexts
Find and select appropriate learning experiences including in non-academic spaces (Long-term phase)	Recognize different opportunities for learning.	Describe personal pros and cons of different learning opportunities.	Select and engage in a learning experience, identify learning opportunities to meet next needs
Develop learning across personal, professional, and societal activities (Long-term phase)	Recognize and map learning across all personal, professional, and societal activities	Assess learning interconnections between domains of activity	Actively seek ways in which multiple types of learning attribute are addressed in each learning activity

Discussion

The proposed conceptual framework for lifelong learning is designed to remain relevant throughout a learner's lifetime. This study, however, was inspired by a desire to improve how lifelong learning skills are developed in undergraduate engineering education, where such skills are a required graduate attribute for accredited engineering programs worldwide. We now consider how this framework could be used to improve curricular decisions around lifelong learning in undergraduate engineering education programs, by looking at the tools currently used in the authors' programs, and considering possible paths for greater intentionality. It is also important to note that some facets of lifelong learning—particularly those related to self-directed learning—may be more effectively cultivated outside formal education settings, where structured instruction typically guides the learner.

Interestingly, the lifelong learning phase (long-term phase) is the most extensively represented in the tools currently used to assess learning in the authors' programs (namely tools that map to indicator 2 in Table 1). This is largely due to accreditation requirements, which emphasize continuous professional development in the engineering profession. Undergraduate engineering programmes routinely have a dedicated course looking at professionalism, and guest speakers are often invited to discuss future

careers and the future work of the engineering practitioner, which supports the longer-term phase of lifelong learning.

It is not required for undergraduate engineering programmes to have a dedicated course or formal training in self-directed learning, self-regulated learning, or metacognition. Self-directed learning (the middle phase) appears to be the least represented in the learning tools used by the authors' two programs today, and is not explicitly called out in the programs' two lifelong learning attributes. While students do engage in some self-directed learning, these opportunities are not explicitly recognized or framed as such. Similarly, while there are activities that encourage metacognitive approaches, little is done to help students explicitly connect these activities to underlying models of self-regulated learning and metacognition. Without this connection, students may struggle to recognize how and where their learning strategies are effective or ineffective. A key challenge in fostering self-directed learning within undergraduate engineering programs lies in the balance between structured learning and autonomy. However, the primary issue is not necessarily the absence of opportunities for self-directed learning but rather the lack of intentionality in making these opportunities visible to students. Addressing this does not require extensive curricular changes or additional activities. Instead, it requires stakeholders to explicitly highlight existing opportunities where students can engage with their learning process, reflect on how they learn, and take greater ownership of their educational journey. By making these moments more intentional and regularly integrating them into the curriculum, students can develop a stronger sense of control over their learning.

Specific suggestions on how to bring intentionality to lifelong learning in the authors' programs are now provided for each phase of the model. There are many opportunities to work across the phases as well. The suggestions below are intended to help shift from a learning space that has activities linked to lifelong learning, to one where the intentionality of those activities can be raised and exposed to the learner, to help them navigate their own learning management journeys. In addition, they make more explicit the ways students can shape their learning outside the curriculum, in co-op, clubs, etc., and value this learning equally with curricular learning.

Lifelong learning phase

Getting learners to look closely at competence and learning needed for specific career paths of interest is an existing activity at the lifelong learning phase. Looking at typical continuous professional development activities required in those career paths, and more broadly learning opportunities readily available in society (e.g. through libraries) could be used to help students prepare mechanisms and approaches for post-graduation learning needs. Connecting current students to alumni could help specifically share experiences of learning relevance, learning motivation, key skills, and knowledges. Higher-level courses could be taught by professionals in industry, who support the teaching as a small part of their work or as part of their own continuous development. Opportunities for students to try different learning activities could therefore include:

- Connecting students to relevant professional organizations or associations and/or opportunities to attend conferences or events. These can often be achieved for free or at low cost to student members, especially as event volunteers.
- Intentionally pointing students to curated learning spaces outside of academia such as LinkedIn learning, company-specific or tool-specific training, relevant clubs outside campus, public library facilities and courses outside the university.
- Valuing learning experiences that exist outside the university-created curriculum, which are critical to longer-term learning development.

Universities could equally consider providing ongoing learning support throughout a learner's life. Reflections on learning needs after an undergraduate degree are typically instigated by the individual lifelong learner or provided by an employer by way of improving the employee's performance. Universities could offer a an annual review of alumni learning goals and needs, both related to current career and non-career development. This could be offered as a service to industry, for employers, or directly to alumni, potentially in exchange for alumni support for undergraduate student activities and events, addressing the multiple needs of society, professions, organizations and of the individual learner. Faculty would require training to support alumni in this way, and there may need to be tools to support the alumni learner track their learning goals and achievements and track volunteer hours for the University, for example, in exchange for such lifelong learning support.

Self-Directed Learning phase

Self-directed learning would benefit from explicit instruction about what it is. Student advising activities play a vital role in helping students self-direct their learning journeys currently. Some advising activities could undertake small adjustments to provide more explicit exposure of the self-directed learning phase, including specific conversations around the semester's learning goals in and out of the classroom, reviewing their achievement and capturing this in a learning portfolio. This could equally be developed for example as a multi-year course run for one day per semester over the duration of the programme of study. Such a course could be used to give students support for building learning portfolios, for planning their learning for each semester, completing reflections on each completed semester, and for articulating learning goals and achievements. Running this as a faculty-wide or university-wide "learning day" could give the opportunity to create a broader learning culture across the organization, get learner feedback on programmes and provide feedback on initiatives to improve learning, and give other community stakeholders such as faculty and staff an opportunity to engage in their own lifelong learning activities. The student advising role could include considering learning from engagements in clubs or committees, etc. as well as core and complementary course selections. To increase student autonomy over their learning, programs could give them much greater agency over what their learning looked like. For example, the programs could allow:

- mixing classes across institutions, potentially worldwide, which could help students select a learning modality that worked best for them such as taking a lab-based course in thermodynamics from institution A or a community-based experiential education course in thermodynamics from institution B (noting the need for accreditation processes to be supportive of such an approach, however),
- giving students choices of timing (in the day or the year) for their learning opportunities, such as taking a summer in-person lab course or taking an evening course from a different institution if their own only offered daytime ones, and/or
- providing pathways to recognizing non-curricular learning - for example allowing students to choose to learn project management or thermodynamics from a co-op or workplace experience and demonstrate it through on-the-job documentation and review.

Self-regulated and Metacognitive Learning phase

At the real-time phase, a key need is for explicit instruction on what learning is, learning methodologies/techniques, reflection models and reflection types. In addition, there is a need to give learners opportunities to compare the effectiveness of different learning activities for different goals; for example, to learn machine shop skills within a class lab, within a club-organized training session

and through a co-op training session, and then reflect on which was most successful and what made it so.

Recognizing what constitutes a learning activity and the diversity of activities that learners are engaging in is a necessary first step. Regular in-course reflections could be used to highlight different metacognitive approaches used in each course. Reflections across the learning journey (e.g. per semester) on learning success (habits, approaches, …) could be built into student advising sessions or the previously mentioned one-day-per-semester learning course that is spread out across a degree. The reflections could include considering how success or failure can affect a learner's motivations, and how to change those reactions if unhelpful for learning.

Courses and extra-curricular activities could be provided with the equivalent of a "food nutrition label" for every learning opportunity. For example, Figure 2 could illustrate the learning activity for a voluntary leadership role, which may involve 10% of the recommended daily dose of writing down work, 20% of use of presentation skills, 25% of hand-skills and 10% of risk management, whereas a specific course or another learning activity might involve a different set of metacognitive ingredients.

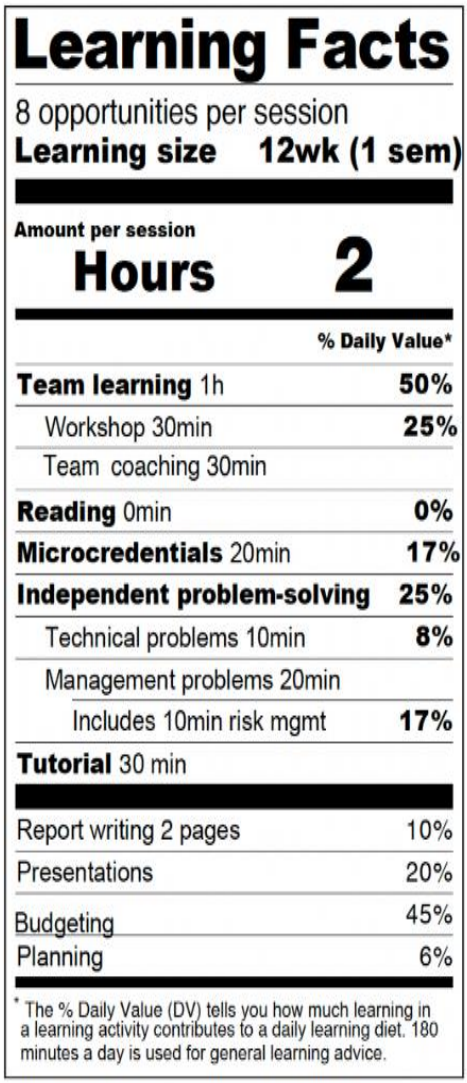

Figure 2: Example "learning nutrition label" to help learners identify the nature of lifelong learning they will experience in a learning activity.

With such labels, it would then be easier for faculty and others supporting learning to put in place scaffolded metacognitive supports.

Future directions for the conceptual framework

The conceptual framework presented is focussed on lifelong learning; however, the authors recognize that learning happens within an environmental, organizational, and societal landscape. The learner has their own internalized competencies and external expressions of that learning, however their need to learn to navigate and seek support for their learning may depend on: their own internalized competencies and external expressions of that learning, however their need to learn to navigate and seek support for their learning may depend on:

- The learning environments they can interact with and the values and purposes of those environments.
- The organizational values and cultures around lifelong learning for each of the organizations, institutions, or collectives the lifelong learner may engage with, which can encourage or hinder metacognition for example and
- The broader, overarching societal values and framing of lifelong learning that can scaffold and support learners and can identify learning environments explicitly or not.

This paper does not explore the possible variations in environment, organizations, and societal framing. A future extension of this conceptual framework will aim to encompass these extra phases, to capture the possible variations in learning environments, organizational learning cultures and societal framing of lifelong learning.

Conclusions

Life-long learning is a widely used term but is assigned a wide variety of meanings in the literature, making it difficult to navigate exactly what skills, capabilities and competencies are built into the term. To help provide greater clarity around the purposes of lifelong learning, a learning framework is proposed and has been presented, that tries to capture needs from engineering education, engineering more broadly, and societal motivations for lifelong learning. This conceptual framework has three phases - a short-term “self-regulated and metacognitive” phase, focussed on achieving, regulating, and reflecting on an individual learning activity, a medium-term “self-directed” learning phase focussed on a specific programme of learning in the near-term, and a longer-term “lifelong learning” phase helping the learner consider alignment between their longer-term learning goals and professional and societal higher purposes. It is hoped that by providing a phased conceptual framework, learners and learning spaces can be more precise and intentional about their specific learning purpose at a given time.

The framework provided is intended to support learning throughout the learner’s lifetime, and to support those engaging in any engineering education better articulate their role in supporting the lifelong learner. The authors have mapped the conceptual framework to their undergraduate engineering programmes, to assess the potential of the framework for informing learning design. They have identified that the framework has generally good coverage in undergraduate learning, but the activities that are undertaken within the existing programme are generally not done with much programme-level intention, and students may therefore miss the learning underpinnings of the related

activities. Also, the self-directed learning phase is least present in the undergraduate engineering degree structures reviewed. The paper provides possible ways to implement the underlying intentionality and expose the learning at all phases within an undergraduate degree journey, both within and outside the classroom.

In closing, it is important to reiterate the authors' positionality relative to this work, and the biases and blind spots this will naturally engender, and to acknowledge that this proposed new learning framework exists within, and is affected by, a specific societal and organizational context. The proposed conceptual framework is focussed on the lifelong learner themselves and their internalized competencies and external expressions of that learning. Future work is needed on the broader learning context, to identify the interactions and effects of the larger context on the framework for the learner themselves.

Declaration of Interest

No conflict of interest.

Notes on Contributors

Dr. Franz Newland has been an Associate Professor at the School of Engineering Design and Teaching Innovation at the University of Ottawa since Summer 2024. This work relates to a collaboration that started whilst he was an Associate Professor (Teaching Stream) in Earth and Space Science and Engineering at York University. Prior to starting at York in 2015, he had the chance to work in Space Engineering in industry in Europe and Canada over a couple of decades. His research interests started from space mission design, spacecraft operations and orbital mechanics, and have now spread into multidisciplinary learning, engineering education and lifelong learning. He is a member of several professional organizations, including the Canadian Engineering Education Association (CEEA), and the American Society for Engineering Education (ASEE), and he is an Associate Fellow of the American Institute of Aeronautics and Astronautics and Member of the Royal Aeronautical Society.

Dr. Hossam Sadek is an Associate Professor (Teaching Stream) in the Department of Mechanical Engineering at the Lassonde School of Engineering. He earned both his Master's and Ph.D. degrees in Mechanical Engineering from McMaster University in 2004 and 2009, respectively. Dr. Sadek has extensive teaching experience in a wide range of undergraduate courses. He has played a key role in undergraduate program development and continuous improvement. From 2015 to 2018, he served as the Graduate Attribute Lead, and from 2018 to 2022, he was the Undergraduate Program Director for Mechanical Engineering. Dr. Sadek is actively involved in the engineering education community. He is a member of several professional organizations, including the Graduate Attribute Professional Network, the Canadian Engineering Education Association (CEEA), and the American Society for Engineering Education (ASEE). His research focuses on engineering education, with current interests in lifelong learning, capstone design courses, and student reflections.

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