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A Theoretical Overview of Unlearning in Engineering

by
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Abstract

Unlearning is the deliberate undoing or reversal of what has been previously learned. This skill has been acknowledged in business and academia as being increasingly important for engineers in a highly changeable 21st century environment; additionally, industry have recently flagged a real-world skill deficit in graduates that can be remedied using the concept of unlearning. This paper shows that modern learning theories and engineering teaching initiatives implicitly rely on unlearning to successfully influence and appropriately prepare engineering students for industry.

Keywords

unlearning; engineering education; CDIO; conflict.

Introduction

"The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn."[2] Toffler's alarming view of the future, in his book: *Future Shock*, referred to the inevitable and imminent problem of 'information overload' that would stifle our existence. We now live in that future, and, contrary to his prediction, most would agree that technology has changed people's lives for the better[3]. However, his prediction regarding the ability to *unlearn* has gained ground, and is now quite relevant in the digital age. 'Unlearning' is the deliberate undoing or reversal of what has been previously learned. For example, one might want to unlearn a bad habit. Instinctively, one might believe that unlearning in education is a futile undertaking given that learning is the main goal of education; however, in the constantly changing environment that is the post-millennial world, unlearning has emerged as an important

1 BEng ME PgDip PhD, Department of Mechanical & Manufacturing Engineering, University of Dublin, Trinity College, Dublin, Ireland. Corresponding Author: mooneyrp@tcd.ie
2 Toffler, Alvin. *Future Shock* (Random House, 1970).
3 Isreal, Shel. "Future Shock: Why Alvin Toffler Was Wrong." *Forbes*, 2012. http://www.forbes.com/sites/shelisrael/2012/06/21/future-shock-why-alvin-toffler-was-wrong/#2715e4857a0b27d6ede26d45.

skill necessary for success in business[4] and academic teaching.[5]

During the past half-century, engineering education has shifted its focus towards teaching modern engineering science at the expense of teaching engineering practice. Consequently, industry have flagged the common complaint that graduates lack real-world skills and abilities necessary for real engineering situations. The engineering teaching methodology: Conceive Design Implement Operate (CDIO) aims to address this problem.[6] This paper discusses unlearning in the context of engineering education by linking together ideas, principles, and pedagogies of unlearning with CDIO, engineering industry, and conflict avoidance; pedagogics of unlearning are also discussed. Finally, key findings resulting from the discussion are summarised in the conclusion.

What is unlearning?

Cirnu[7] explains unlearning in the context of learning theory and from a corporate business point of view. To illustrate the concept of unlearning, Cirnu notably distinguishes *declarative* (know that) knowledge, i.e., explicit knowledge that can be expressed in declarative sentences, from *procedural* (knowing how) knowledge, i.e., implicit knowledge of actions required for a given task. Procedural knowledge is often tacit (in other words, difficult to communicate). Cirnu[8] points out that in a crisis situation, new (less stable) learning is habitually disregarded in favour of old (more stable) learning—even if it is flawed or misguided. The backwards bicycle[9] is used as an example of how challenging it is to unlearn procedural knowledge (neurally codified since one's first bicycle ride) even when declarative knowledge has advised to the contrary (knowledge that the bicycle has been modified in its mechanical operation). Knowledge, procedural or declarative, is a prerequisite for the unlearning process to occur, however, the former type can be considerably more difficult to omit or ignore by choice (i.e., to unlearn).

4 Cirnu, Carmen. "The Shifting Paradigm: Learning to Unlearn." *Internet Learning*, 2015. http://digitalcommons.apus.edu/internetlearning/vol4/iss1/8.
5 McWilliam, Erica. "Unlearning How to Teach." *Innovations in Education and Teaching International* 45, no. 3 (August 18, 2008): 263–69. doi:10.1080/14703290802176147.
6 Hugo, Ron, and Johan Malmqvist. "About CDIO," 2015. http://www.cdio.org/about.
7 Cirnu, "The Shifting Paradigm: Learning to Unlearn.", 126.
8 Ibid., 129.
9 Sandlin, Destin. "The Backwards Brain Bicycle." *SmarterEveryDay.com*, 2015. https://www.youtube.com/watch?v=MFzDaBzBlL0.

Why is unlearning important?

McWilliam[10] addresses the importance of unlearning in academic teaching. It is illustrated how teachers have unlearned their traditional role as *Sage-on-the-stage* (where one-way transmission of knowledge from educator to student occurs, and the focus is on the educator) in favour of a student-focused *Guide-by-the-side* approach. The latter approach aligns itself with contemporary learning methodologies, for example, constructivist theory, where the teacher is simply a facilitator of learning[11]. McWilliam argues that teachers must now unlearn the student-focused approach, and shift towards a *Meddler-in-the-middle* model that is characterised by mutual involvement of teacher and student in a more creative, experimental, and collaborative arrangement where error-making and tinkering is encouraged for the purposes of learning. This conjecture is justified by the state of the highly changeable 'fluid' social world of the 21st century where the transmissive culture of teaching is redundant amongst a wealth of freely available information (i.e., the Internet).[12] Unlearning is central to the success of both student and teacher under this approach, since the post-millennial social world—in which they are part—is often volatile and in a perpetual state of flux, the ability to adapt and creatively solve problems is therefore of increasing value.

Cirnu[13] points how the unlearning process takes place in, and is linked to, popular learning theories, thereby underlining its importance. In *behaviourist* theory, where learning occurs through passive stimulus-response sets, unlearning is characterised by removing reinforcements (positive or negative stimuli) and by the introduction of stimuli that strike an atypical response. In *constructivism* theory, learners use previous knowledge in an active manner to construct new ideas and concepts; here, unlearning is intrinsically linked with the 'previous knowledge' of the learner. In *cognitivist* theory, where learning is achieved through analogical reasoning in an interactive environment, unlearning is akin to Piaget's successive reformulation of knowledge structures.[14]

10 McWilliam, "Unlearning How to Teach.", 264.
11 King, Alison. "From Sage on the Stage to Guide on the Side." *College Teaching* 41, no. 1 (1993): 30–35. http://www.jstor.org/stable/27558571.
12 Bauman, Zigmunt. "Liquid Sociality." In *The Future of Social Theory*, edited by N. Gane, 17–46. London: Continuum, 2004.
13 Cirnu, "The Shifting Paradigm: Learning to Unlearn.", 128.
14 Lee, Virginia S. "Unlearning: A Critical Element in the Learning Process." *Essays on*

Unlearning in engineering education

The Conceive Design Implement Operate (CDIO™) initiative is an "innovative framework for producing the next generation of engineers."[15] Interestingly, the story of CDIO aligns it with the themes of unlearning introduced above. Traditionally, 20th century engineering students had plenty of hands-on practice. However, as the millennium approached scientific knowledge expanded rapidly and engineering education shifted towards teaching of modern engineering science at the expense of teaching engineering practice.[16] Subsequently, by the end of the 20th century, a common complaint emerged from industry: engineering graduates, while technically adept, lacked real-world skills and abilities necessary in real engineering situations. Consequently, through detailed feedback from industry and engagement with appropriate accreditation boards, a group of universities lead by MIT initiated an international collaboration that ultimately led to the CDIO initiative.[17] Under the CDIO initiative engineering graduates were expected to be able to: (i) Conceive, Design, Implement, and Operate (ii) complex value-added engineering systems, (iii) in a modern team-based environment, and students should be (iv) mature and thoughtful individuals. Two of the goals defined in the CDIO initiative were as follows.[18]

(1) Master a deeper working knowledge of technical fundamentals.

(2) Lead in the creation and operation of new products, processes, and systems.

Crawley, Brodeur, and Soderholm[19] explain how the first two goals have historically been in tension; where a traditional 'knowledge

Teaching Excellence Toward the Best in the Academy 14, no. 2 (2002). http://podnetwork.org/publications/02-03-essays/.
15 Hugo, Ron, and Johan Malmqvist. "About CDIO," 2015. http://www.cdio.org/about.
16 Crawley, Edward F., Doris R. Brodeur, and Diane H. Soderholm. "The Education of Future Aeronautical Engineers: Conceiving, Designing, Implementing and Operating." *Journal of Science Education and Technology* 17, no. 2 (April 12, 2008): 138–51. doi:10.1007/s10956-008-9088-4.
17 Berggren, Karl-Frederik, Doris Brodeur, Edward F. Crawley, Ingemar Ingemarsson, William T.G. Litant, Johan Malmqvist, and Sören Östlund. "CDIO: An International Initiative for Reforming Engineering Education." *World Transactions on Engineering and Technology Education* 2, no. 1 (2003): 49–52.
18 Ibid., 49.
19 Crawley et al. "Aeronautical", 143.

transmission' approach is applied to these goals the tension between technical fundamentals (goal 1) and professional skills (goal 2) intensifies. The CDIO approach relieves this tension by constructing sequences of integrated active learning experiences. Curricula are designed using mutually supporting disciplinary courses in a highly inter-woven fashion. The sequence of activities follows the conceive design implement operate acronym; instead of focussing mainly on learning the fundamentals and mathematics of engineering (e.g., conceiving and designing), students are exposed to hands-on learning experiences (e.g., implementing and operating) in the classroom and in modern workspace environments.

Constructivism learning theory is central to the CDIO initiative. The role of instructors is to facilitate the processing of new information to help students build meaningful connections with previous knowledge. Particular focus is given to *experiential* learning, for example, students participate in active learning tasks where individuals take on roles that simulate real engineering practices. Kolb[20] explains how experiential learning engages critical thinking, problem solving and decision making skills. Such learning experiences have a dual impact; technical fundamentals and practical skills are enriched in unison. Another benefit is that the learning experience itself provides a cognitive framework for learning the detailed abstractions that follow the technical fundamentals.[21] McWilliam's concept of the teacher as 'Meddler' agrees with this approach, by encouraging an experimental, error-making pedagogy where learning comes from creatively trying different things and failing frequently (until something works).[22] A simple example being: one cannot learn to juggle without dropping a ball.

Bennedsen and Christensen[23] state, "with CDIO comes a better conceptual understanding of the difficulties in changing long established approaches in for instance [*sic*] routine practices. Such changes involve unlearning". Their study reported on Danish higher education institutions that had implemented CDIO syllabi. One consensus among participants was that

20 Kolb, D.A. Experiential Learning: Experience as the Source of Learning and Development. (Englewood Cliffs, NJ: Prentice Hall, 1984).
21 Crawley et al. "Aeronautical", 141.
22 McWilliam, "Unlearning How to Teach.", 264.
23 Bennedsen, Jens, and Mette Birkedahl Christensen. "Key-Factors for a Successful CDIO Implementation in a Danish Context." In *8th International CDIO Conference*. Brisbane, 2012. http://www.cdio.org/files/document/file/key-factors_for_a_successful_cdio_implementation_in_a_danish_context_.pdf.

formal education often assumes that mere acknowledgement of the subject being taught is enough, whereas in reality, in real engineering practices, this level of knowledge is simply inadequate. CDIO syllabi outcomes tend to bridge this gap. One of five key-factors for the success of CDIO implementation was the idea of 'evolution, not revolution'; providing a common, more natural way to talk about engineering education. It is clear then that unlearning, adapting, and evolving harmoniously with industry is core to the CDIO initiative.

Unlearning in industry

CDIO was borne out of the need for graduate engineers to evolve with industry needs. As advances in technology proceeds at an ever increasing rate, and non-renewable energy resources diminish, engineers are being asked to solve increasingly more difficult problems. It follows that industry (i.e., real life, from a student's point of view) is now, more than ever, highly changeable and in a constant state of flux. The focus should be to help students learn how to change and adapt within their given environment, as opposed to simply achieving ones potential in an assumed stable environment. Unlearning is a key skill in respect of this objective.

The same is true for organisations themselves, at a corporate level. Tsang and Zahra[24] outline the importance of organisational unlearning; they distinguish learning from unlearning (in the organisational context), and continuous versus episodic change. They conclude that managing organisational unlearning will help senior executives to implement new strategies and initiatives successfully. Cirnu[25] discusses when unlearning is required in industry at the level of the individual; for example, when one must grasp a new initiative, embrace a new workplace culture, or adapt to the latest scientific theory. It is concluded that unlearning is a necessity rather than an option; and that the concept of unlearning is intrinsically linked to the concept of change.

A good example of a recent change in scientific theory, where unlearning has been central to the progression of the field, is in the discovery of the Higgs-Boson particle resulting from experiments carried out at the Large

24 Tsang, E. W.K., and S. A. Zahra. "Organizational Unlearning." *Human Relations* 61, no. 10 (October 1, 2008): 1435–62. doi:10.1177/0018726708095710.
25 Cirnu, "The Shifting Paradigm: Learning to Unlearn.", 130.

Hadron Collider at CERN, Switzerland.[26] Two mutually exclusive schools of thought dominated particle physics (with regard to the 'Standard Model') prior this discovery,[27] viz., the Super-symmetry and Multiverse theories. The measured mass of the particle discovered would disprove one or other of these theories; a measurement of around 115 GeV promoting the super-symmetry theory and 140 GeV promoting the multiverse theory. The actual measured mass of the discovered particle was somewhere in between at 126.0±0.4 GeV. While confirming the existence of the Higgs-Boson particle, this measurement endorsed neither theory fully, and has consequently prompted theory reformulation on both sides. Without the ability to unlearn, particle physicists would currently be stuck in the mud, since parties to both schools of thought must row back on aspects of their knowledge base.

Unlearning and conflict avoidance

Even now, in the 21st century engineering classroom with CDIO inspired syllabi and teaching methods, it is apparent that engineering students still want 'just enough' information to be delivered to them in a transmissive manner, so that they can do the minimum required to achieve the grade necessary to pass; and ultimately attain their desired qualification. Often there is a tendency to avoid asking questions in the classroom in order to: (i) prevent any embarrassment amongst peers (if the question itself is poor), (ii) not delay the class, (iii) not have to really think about what is being said, or finally (iv) to avoid any conflicting opinions regarding the content. Most often (in the author's experience), the students who have contradictory ideas to that which are being offered to them, eventually emerge as the brightest students with the most to offer in terms of constructive discussion.

A problem then exists; junior engineers have a tendency to avoid conflict, not voice their opinion, and be lead rather than question. Those engineers need to be trained how to unlearn prior knowledge, so that they can adapt, evolve and progress their career accordingly. Hayes[28] describes

26 Aad, G., T. Abajyan, B. Abbott, J. Abdallah, S. Abdel Khalek, A.A. Abdelalim, O. Abdinov, et al. "Observation of a New Particle in the Search for the Standard Model Higgs Boson with the ATLAS Detector at the LHC." *Physics Letters B* 716, no. 1 (September 2012): 1–29. doi:10.1016/j.physletb.2012.08.020.
27 Ibid.
28 Hayes, Jeff. "CPP Global Human Capital Report: Workplace Conflict and How Businesses

how conflict is an inevitable feature of working life in organisations, and when managed correctly leads to positive change. Unlearning can play a central role in the resolution of conflicts. A good example of this is described by Heffernan[29]; she recalls the discovery by physician and epidemiologist, Alice Stewart, regarding the dangers of x-raying pregnant women[30]. The medical establishment at the time failed to acknowledge this finding (avoiding the conflict), citing conventional wisdom; implicitly they were influenced by their view of themselves as people who helped, not harmed. Eventually, 25 years later, Stewart's work was recognised and the medical establishment were forced to unlearn their previous knowledge and abandon the practice of x-raying pregnant women. It is interesting to note that Stewart worked in a conflict ridden relationship with her statistician, George Kneale, whose primary objective was to disprove her theories to some degree of mathematical certainty; both parties, in contrast to the medical establishment, embraced conflict. Engineers (and it could be argued most other professions) should similarly embrace conflict in a way that effects a positive outcome. The ability to unlearn provides the basis for a wider, more adaptable, and robust individual in the face of conflict. The forgoing example shows how important it is, and how troublesome it can be, to unlearn, and how it is relates to conflict.

Teaching and unlearning

It is worthwhile to examine the 'pedagogics of unlearning'—the title of a recent conference hosted by Trinity College[31]—from the point of view of the experience of the author as an engineering educator, and by referencing two invited speakers of the conference: Deborah P. Britzman and Jacques Rancière.

Anecdotes are useful to grab the attention of undergraduate engineering students. Primarily, such students are mostly unaware what the 'real world' is like (in other words, they have no industry experience), and so

Can Harness It to Thrive," 2008. https://www.cpp.com/pdfs/CPP_Global_Human_Capital_Report_Workplace_Conflict.pdf.
29 Heffernan, Margaret. "Dare to Disagree." *TED Talks*, 2012. https://www.ted.com/talks/margaret_heffernan_dare_to_disagree/transcript?language=en#t-303202.
30 Stewart, Alice, Josefine Webb, Dawn Giles, and David Hewitt. "Malignant Disease in Childhood and Diagnostic Irradiation in Utero." *The Lancet* 268, no. 6940 (September 1, 1956): 447. doi:10.1016/S0140-6736(56)91923-7.
31 Dunne, Éamonn, Aidan Seery, and Michael O'Rourke. "Unlearning Conference Website," 2014. http://www.unlearningconf.com/.

they are attentive when a story based on experience is shared in order to elucidate a point. Secondly, and perhaps more interestingly, such an approach agrees with Britzman's thinking, that education is an emotional engagement; pedagogy leans upon a teacher's life and meaning is given by emotional links to actual experience[32]. Teachers and students are therefore co-dependant.

Rancière proposed in his book: *The Ignorant Schoolmaster*, the radical idea that all humans possess the same intelligence; the only difference being the extent to which they are willing to learn[33]. Rancière tells the story of a 19th century educator, Joseph Jacotot, who was tasked with teaching Flemish students to speak French when neither party understood the other's language. Astonishingly, Jacotot succeeded in bringing the students to a high-level of fluency using his 'emancipatory' methods of teaching (based on an assumption of equivalent intelligence). Rancière explains that "to teach what one doesn't know is to simply ask questions about what one doesn't know." This leads to the conclusion that everyone can teach anyone anything, even if they don't 'know' it in the first place. This is relevant and appropriate for modern engineering education where technologies are fast-changing (therefore a cycle of learning, unlearning and relearning inevitably follows technological advances); and a convivial yet collegial learning atmosphere is encouraged by industry *and* academia.

Conclusion

This paper introduces and explains the concept of unlearning generally and in the context of engineering. The importance of unlearning is illustrated with reference to learning theories. It is recommended that teachers should embrace a *meddler-in-the-middle* role—characterised by a creative, experimental, value adding approach—in order to prepare students for the highly changeable social world that is 21st century industry. Counterintuitively, error-making is encouraged with this approach to teaching; a good example (to justify the meddler approach) being that one cannot learn to juggle without dropping a ball.

A progressive engineering teaching initiative, CDIO™ (Conceive Design

32 Britzman, Deborah P. Practice Makes Practice: A Critical Study of Learning to Teach (SUNY Press, 1991).
33 Rancière, Jacques. *The Ignorant Schoolmaster Five Lessons in Intellectual Emancipation* (Stanford, California: Standford University Press, 1987).

Implement Operate),[34] is discussed and linked to unlearning with an example. Similarly, by examples, unlearning is connected to industry and the problem of conflict avoidance. Finally, some interesting pedagogics of unlearning theory are explained in the engineering education context.

A summary of key findings discussed in this paper are as follows: (i) Industry have recently flagged a 'real-world' skills deficit in engineering graduates, owing to a shift in focus towards engineering science education at the expense of engineering practice education. This is compounded by the rise of the millennial 'hand-held device' informed generation that have forgotten how to tinker and experiment for the purposes of learning. The CDIO initiative seeks to address this problem by implementing experiential learning activities into engineering curricula and by promoting creativity and innovation. Unlearning, as a skill, is implicitly required (or eventually attained) using this approach. (ii) At the individual level, new engineers in industry are faced with a highly changeable environment where unlearning skills will help them to adapt and change harmoniously with their environment. At the organisational level unlearning is a necessity, rather than an option; and it is intrinsically linked to the concept of change. (iii) Engineers (and more generally, people) tend to avoid conflict instinctively; however, conflict is unavoidable and should be embraced in order to achieve a positive outcome. The ability to unlearn provides the basis for a wider, more adaptable, and robust individual in the face of conflict. Finally, (iv) the pedagogics of unlearning inform teaching in an interesting and far-reaching way; for example, the idea that anyone can teach anything is supported by the concept of unlearning.

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34 Crawley et al. "Aeronautical", 141.

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