An exploration of unlearning of practicing civil engineers

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***Abstract*—This Research to Practice Work in Progress Paper presents an exploration of unlearning of practicing civil engineers. Unlearning is a necessary process to keep engineers abreast of ever-changing socio-technical and professional demands by replacing odd knowledge with a new one, which is coherent with their knowledge structures and practice contexts. This paper explores the unlearning of fundamental engineering concepts within 95 practicing civil engineers by investigating their performances on and attitudes towards Statics Concept Inventory. The analysis of their performances on the inventory revealed that many of them did not retain, use, and need this fundamental engineering concept in their practices. It appears that when engineers begin their professional careers, they also start giving up parts of their learned knowledge including many fundamental engineering concepts to acquire new knowledge suitable to their expertise and practice contexts of teams and organizations. (*Abstract*)**

***Keywords—unlearning, continued learning, lifelong learning, engineering education, civil engineering** (key words)*

I. INTRODUCTION

In many engineering disciplines, practicing engineers are increasingly being required to learn new practical techniques and methods to stay current in the fields and adapt to social changes to stay in business. Learning on the job after having formal education from colleges is not only encouraged but also mandated by many organizations and professional organizations. For examples, in the Civil Engineering Body of Knowledge for the 21st century, the American Society of Civil Engineers (ASCE) specifies "lifelong learning" as one of the 24 outcomes that anyone who seeks "entry into the practice of civil engineering at the professional level" needs to fulfill [1]. At Raytheon, all engineers must complete a minimum of 32 hours of continuing education annually via its "Individual Training Plan" program where they can take courses from the Raytheon Learning Institute or outside institutions [2]. The National Society of Professional Engineers supports mandatory continuing professional competency for licensed professional engineers described by the National Council of Examiners for Engineering and Surveying (NCEES) [3]. According to the NCEES Model Rule 2017 (section 240.30, p. 16), "every licensee is required to obtain the equivalent of 15 PDHs per annual renewal period," where PDH is the acronym for Professional Development Hour and defined as one contact hour of instruction or presentation [4]. ABET has estimated a seven-year life for a B.S. degree and emphasized lifelong learning as a critical skill to help engineers "keep up with the rapid changes in technology and stay abreast of current global and societal issues." Under ABET criteria for accrediting engineering programs for 2017 -2018, the outcome (i) of student outcomes requires institutions to prepare graduates to have "a recognition of the need for, and an ability to engage in lifelong learning" [5].

While the body of professional knowledge keeps growing, humans have limited cognitive resources [6, 7] to absorb from such enormous amount of changes. Human beings also tend to resist social changes as changing "attitudes or behavior is tantamount" and makes people "leaving the comfortable embrace of a social reality" in which they are a part [8]. An approach of solving these contradictions is unlearning because, under the contemporary view, this is a process of relinquishing obsolete knowledge from memory and the way of changing beliefs, methods, values, procedures, and routines [9]. Although unlearning phenomenon was mentioned in the Transactions of the ASCE in 1906 [10], few researchers have addressed this issue in the engineering education contexts since then. The purpose of this paper is to explore the unlearning process of 95 practicing civil engineers from various corporates in the US Pacific Northwest region. The study used Statics Concept Inventory and online survey to investigate whether practicing civil engineers retain and utilize the engineering statics knowledge in their practices. The study's results suggest that at the time engineers started their professional careers they might engage in unlearning what they learned during the college years including many fundamental engineering concepts and their unlearning is expertise dependent.

II. LITERATURE REVIEW

The unlearning phenomenon has been studied most in the learning contexts of corporate or organization [11, 12, 13], including academia [11, 14] and healthcare industry [15]. Unlearning in these contexts takes place at both individual and organizational levels and is conceptualized into three distinctive processes: individual unlearning, aggregated individual (or team) unlearning, and organizational unlearning

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[16,17]. Individual unlearning occurs depending on the contexts of the individual, team, and organization [16, 18] but organizational unlearning can occur without individual unlearning. For example, the organization may remove individuals who held key managerial roles but are slow or fail to adopt new practices to facilitate the individual unlearning [17].

A variety of definitions of unlearning exist in literature beside the one mentioned in [9] and introduced above. Other definitions include Hedberg's unlearning as "the process of reducing or eliminating pre-existing knowledge or habits" (as cited in [11]) and unlearning as "the deliberate undoing or reversal of what has been previously learned" [19]. Reference [16] synthesized definitions of unlearning from 35 studies and conceptualized unlearning as "a distinctive type of learning" that "involves a conscious process of choosing to give up, abandon, or stop using knowledge, values, or behaviours." They noted that unlearning does not necessarily involve "the permanent loss of knowledge" as individuals may reuse the previously abandoned or unlearned knowledge at some point later in their career lives.

Unlearning is linked to the concept of learning in educational psychology from at least two perspectives, constructivism, and socioculturalism. Under the constructivist' view, learners construct and assimilate new knowledge on the base of their pre-existing knowledge [20] and unlearning is the process to free up memory space in the cognitive resource memory [13, 17, 21, 22]. Under socioculturalism perspective, learning takes place in settings of collective social and cultural norms and identities [23] and unlearning is the process of changing beliefs, methods, routines, and practices [9, 11, 17, 21].

According to [13], unlearning is a prerequisite of learning and people need to unlearn the learned knowledge that they no longer rely on before they can learn new things. Based on this rationale, Kuhn (as cited in [13]) argued that old knowledge would not automatically be discarded unless they do not contribute to the production of reasonable results. Reference [21] considered unlearning as lifelong learning strategy because people unlearn "previous habits and behaviours in order to embrace changing technologies and processes." They noted that individual's prior knowledge, both explicit and implicit, values, and beliefs systems are obstacles of lifelong learning because many participants in their research "referred to their previous skills and behaviors before discussing the new ways of working."

III. Method and Results

Engineer participants were recruited for the study via the second authors' network of friends and coworkers on LinkedIn and snowball sampling. The participants were required to take the Statics Concept Inventories (SCI) test and a short survey via Surveymonkey.com. The SCI test is a set of 27 multiple-choice questions assessing learners on engineering statics conceptual knowledge such as free body diagram, statics equivalence, or equilibrium [24]. After each concept question, the engineers were asked to indicate whether they use and need to know the concept in their works. The responses for these statements were designed in the nine-point Likert scale with options ranging from "Strongly disagree" (= 1) to "Strongly agree" (= 9), and the middle position of the scale (= 5) indicates the "Neutral" option. Other intermediate options include "Somewhat disagree" (= 3) and "Somewhat agree" (= 7). The Cronbach's alpha coefficients for the "Use" and the "Need" of 27 questions is 0.995 and 0.996, respectively, suggesting that the statements have very high internal consistency.

Ninety-five engineer participants had valid entries from the survey, and their engineering experience varies from one month to forty-five years with the average years of experience is 10.74 (SD = 10.43, N = 95). Engineers' scores on the SCI test were compared to those of 1,372 students from 20 institutions using Mann-Whitney U test to explore whether engineers retain engineering statics knowledge in their practices. With students' average score of 47.7% (SD = 20.4%, mean rank = 744.05) compared to 40.6% (SD = 21.5%, mean rank = 588.90) for the engineers, students have a statistically significantly better conceptual knowledge in engineering statics than practicing civil engineers (U = 51385.5, z = -3.457, $p < 0.001$). In other words, if students' performance was taken as a reference point, the practicing civil engineers in this study did not retain the engineering statics knowledge in their practices.

Based on this finding, we are curious when practicing engineers start abandoning this knowledge in their careers and whether education levels and expertise impact this process. First, assuming all engineers worked right after college, we conducted correlations between engineers' years of experiences and their SCI test, "Use," and "Need" scores and found no correlations between these variables (Spearman's rho r = -0.03 and p = 0.80; r = -0.07 and p = 0.51, r = -0.09 and p = 0.40, respectively). This result reveals that the number of years of experience does not have a significant impact on engineers' SCI test, "Use," and "Need" scores.

Next, engineers were further split out in two groups; one group includes 13 engineers with less than two years' experience and the other includes 82 engineers with two or more years' experience, and their SCI and survey scores were compared each other. The p-values from the Mann-Whitney U test revealed that there were no statistically significant differences between the two groups regarding SCI test, "Use," and "Need" scores (p = 0.198, 0.212, and 0.263, respectively). Other comparisons with different splitting criteria such as engineers who have less than four years versus those who have four or more years' experience or bachelors' versus maters' degrees, all yield non statistically significant results (Table 1). That means engineers might stop using the learned engineering statics knowledge right after they start their professional careers, regardless of educational levels. This finding is aligned with a note in the Transactions of the ASCE [10], indicating that "everybody who has studied at a technical school" tended to be "chiefly engaged in unlearning the things learned there" "during the first year or two of practical work."

TABLE I
P-VALUES OF MANN-WHITNEY *U* TESTS FOR MEAN RANK COMPARISONS BETWEEN TWO GROUPS OF ENGINEERS

Classification methods	*N*	SCI	Use	Need
Years of experience				
a. Less than two years	13	0.198	0.212	0.263
Two years and more	82			
b. Less than four years	28	0.740	0.336	0.254
Four years and more	67			
c. Less than ten years	55	0.485	0.933	0.839
Ten years and more	40			
Education				
Bachelors [(1)]	60	0.472	0.114	0.080
Masters [(2)]	35			
Expertise				
Structural (STR)	31	0.000	0.000	0.000
Non-structural (non-STR)	64			

[(1)] One engineer reports high school education.

[(2)] One engineer reports a PhD degree.

Finally, engineers were split out in two groups depending on their expertise; one group includes 31 engineers in the structural engineering expertise (STR) and the other includes 64 engineers in other civil engineering specialties (non-STR) such as environmental engineering, geotechnical engineering, civil engineering, construction management, and water resources. The rationale for splitting engineers into these two groups stems from our observations from the preliminary analysis of engineers' surveys and the second author's experience in practicing and teaching civil engineering. It appears that structural engineers are more likely to retain and use engineering statics knowledge in their practices than other civil engineers. This remark was confirmed by our analysis (Table 1) where the STR engineers had a higher mean correct rate (M = 55.17%, SD = 21.9%; mean rank = 66.2) than the non-STR engineers (M = 33.5%, SD = 17.5%; mean rank = 39.2) on the SCI test, and the difference reached statistical significance (U = 429.5, z = -4.47, p < 0.001).

Figure 1 presents the scatter plots of the "Use" and "Need" distributions versus the SCI correct rate for the STR and non-STR engineers. The STR engineers have much higher average median values on both scales (6.44 for "Use" and 6.59 for "Need") than the non-STR engineers (1.98 for "Use" and 2.03 for "Need"), suggesting that many STR engineers considered the SCI concepts as parts of their working knowledge while the non-STR engineers did not. This finding is in accordance with a description of a typical structural design task reported in the literature [25], in which the SCI concepts are required along with other types of knowledge like the geometry of structure, structural analysis techniques, behavioral models, structural design codes, and heuristic and experimental knowledge during conceptual design.

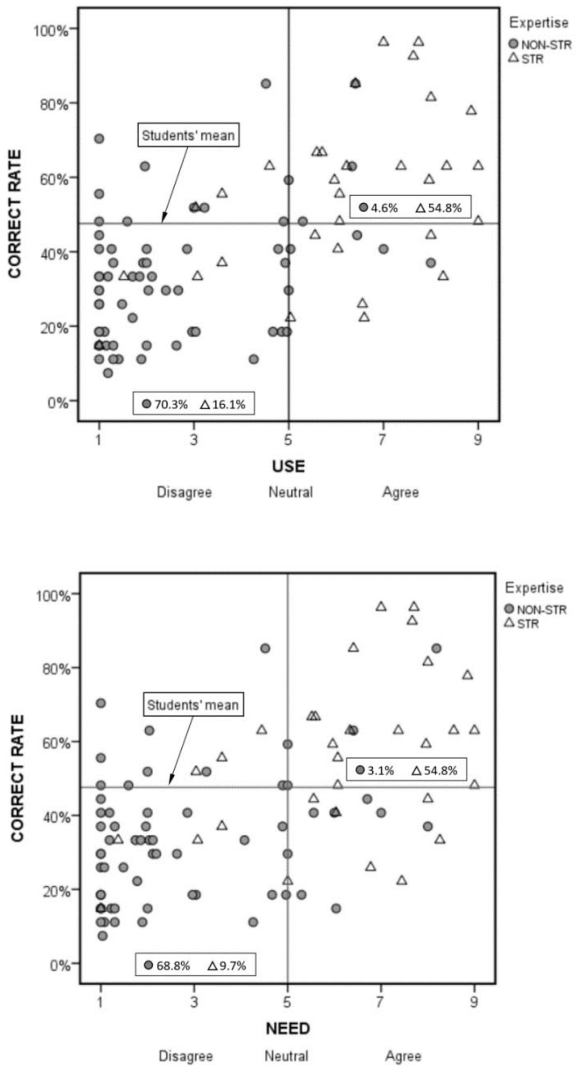

Figure 1. Scatter plots of "Use" and "Need" distributions versus the SCI correct rate for two engineer groups with students' mean and neutral response as references. All responses below "Neutral" (= 5) are lumped into "Disagree," while responses greater than that are lumped into "Agree" on both scales. The first and fourth quadrants in each plot are the areas of interested. The percentage numbers are calculated based on the sample sizes of STR and non-STR engineers in the study.

IV. CONCLUSIONS AND LIMITTATIONS

Quite often in many organizations, new employees need to learn how to apply their technical skills and expertise within the context of the organizations and are encouraged to unlearn the previous practices, knowledge, habits, assumptions as part of their onboarding processes [26, 27]. While all civil engineers had training in engineering statics during their undergraduate education, each may encounter very different working environments and contexts and choose to stop using, wholly or partly, this type of knowledge. Many engineers in this study explicitly indicated in the survey that they did not use and need specific engineering statics concepts in the practices and their low SCI test performances implicitly confirmed their statements. As per [16]'s description of unlearning, we might suggest that these engineers were experiencing the unlearning. Their unlearning of engineering statics knowledge might begin as early as the first month of their professional lives and vary depending on their expertise but educational levels. Structural engineers would be more

likely than civil engineers in other specialties to retain and use engineering statics knowledge in their practices.

This study has several limitations. First, the engineers in this study came from a small number of civil engineering corporates in the US Pacific Northwest where the geographical features may impact positively on the organizational practices and methods, and, eventually, individual unlearning processes. Second, although individual unlearning is generally associated with organizational unlearning and context changes, this study only addressed the individual unlearning of practicing civil engineers. Finally, the engineers might experience the unlearning of many types of engineering knowledge in their works, but the study focused primarily on the unlearning of engineering statics.

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