Self-Directed Learning Readiness among Engineering Students during Emergency Online Instruction

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***Abstract*—Work-In-Progress: In the early months of the COVID-19 pandemic, many higher education institutions in the United States rapidly transitioned to emergency online learning. At The Citadel, a residential military college with additional veteran/active duty and college transfer populations, undergraduate engineering courses before the pandemic were administered solely through face-to-face instruction. As such, changing modalities during the pandemic were a very new experience for our students. We hypothesized that students might develop improved self-directed learning readiness due to the need to manage learning in new and changing course modalities. In this study, we present changes in self-directed learning readiness among our undergraduate engineering students, as measured by the Self-Directed Learning Readiness Scale, at the beginning and end of emergency online instruction during the Spring 2020 semester. Generally, SDLRS scores increased during six weeks of emergency online instruction. However, juniors were the only academic class who did not experience gains in self-directed learning readiness. Interestingly, we earlier found that juniors experienced an increase in more cognitive load dimensions than other academic classes during the Spring 2020 semester. We are currently analyzing qualitative data and SDLRS scores collected in subsequent semesters to better understand the relationship between development of self-directed learning readiness and cognitive load.**

Keywords—Self-Directed Learning, Self-Directed Learning Readiness Scale, Cognitive Load

I. Introduction

The COVID-19 pandemic led to sudden and drastic changes in engineering education. Of note, many institutions rapidly transitioned to an online modality to provide continuity of instruction and ensure the well-being of campus stakeholders. Prior to the pandemic, undergraduate engineering courses at The Citadel were administered solely through face-to-face instruction; thus, the mandatory transformation to online instruction represented an unprecedented disruption to our model for student learning and development. In the physical sciences, LeChatelier's Principle describes that when a system at equilibrium is disrupted, the system transforms to establish a new equilibrium [1]. Given the disruption to our educational system, we hypothesized that students might experience elevated cognitive load as they learned to navigate and direct their own learning in new course modalities.

We are engaged in a longitudinal study to monitor undergraduate engineering students' cognitive load and self-directed learning readiness throughout the pandemic. Indeed, we previously [2] demonstrated that students experienced higher cognitive load during emergency online instruction, as compared to F2F instruction. We assessed cognitive load as workload via the NASA Task Load Index (TLX) [3], which requires participants to rate their workload across six dimensions: mental demand, physical demand, temporal demand, performance, effort, and frustration. We further found that sophomores and juniors may have experienced disproportionately higher cognitive load than other academic classes. We speculate that coursework heavy in the engineering sciences may explain the high load during the middle years.

In this work-in-progress, we will begin to explore the impact of modality on development of self-directed learning readiness. We have administered the rigorously-developed Self-Directed Learning Readiness Scale (SDLRS) [4] to Citadel students at key times before and after changes in modality. In this paper, we provide preliminary findings on changes that occurred during the Spring 2020 semester, perhaps as a result of emergency online learning. Using SDLRS data, we will address the following research questions: (1) To what extent, if any, did self-directed learning readiness change over the course of emergency online learning? (2) How did changes in self-directed learning readiness vary among academic classes? (3) Are there any preliminary connections between self-directed learning readiness and cognitive load? Ultimately, we hope to explore the interactions between cognitive load and self-directed learning readiness in different course modalities.

II. Theorectical Context

Knowles's Theory of Andragogy provides a framework for adult education, based on the premise that adults are self-directed learners [5]. Although definitions of self-direct learning abound, Knowles's is perhaps the most widely referenced [6]. He supports that self-directed learners assess their own needs, set goals, and seek strategies and solutions on their own [5].

Guglielmino also contributed significantly [7] to the study of self-directed learning through rigorous development and application of the Self-Directed Learning Readiness Scale (SDLRS) [4]. She describes that self-directed learning readiness

is a "process," whereas self-directed learning readiness is a "complex of personal attributes" [6]. In developing the SDLRS, she conducted a Delphi survey of experts and found that a self-directed learner is [4, pg. 73]:

"…one who exhibits initiative, independence, and persistence in learning; one who accepts responsibility for his or her own learning and views problems as challenges, not obstacles; one who is capable of self-discipline and has a high degree of curiosity; one who has a strong desire to learn or change and is self-confident; one who is able to use basic study skills, organize his or her time and set an appropriate pace for learning, and to develop a plan for completing work; one who enjoys learning and has a tendency to be goal-oriented."

The SDLRS has been widely applied in a variety of educational contexts and has been shown to produce reliable and valid results, despite a limited number of criticisms. Guglielmino herself conducted an extensive process to demonstrate the credibility of her instrument [8]. Delahaye and Choy [9] later reviewed the spectrum of studies evaluating the validity (content, construct, criterion-related) and reliability (internal consistency and test-retest) of the instrument and found that the SDLRS can be used with "acceptable confidence."

The SDLRS has been used to a limited extent in engineering education. Litinger and collaborators [10] conducted a cross-sectional study and showed no change in SDLRS scores across academic subgroups. They again found no change in SDLRS scores among mechanical and electrical engineering students engaged in a capstone design experience [11]. Miller, Sorby, and Clerck [12] used the SDLRS to track development of self-directed learning readiness among mechanical engineering students engaging in e-learning modules and found no significant changes with age or increased participation in the modules. Jiusto and DiBiasio [13] found no significant change in SDRS scores among a cohort of study abroad students. Consequently, we infer that self-directed learning readiness may be a difficult attribute to improve with traditional educational experiences.

Few studies have explored the relationship between self-directed learning and cognitive load. Cognitive load refers to the amount of working memory that is used during a particular task [14]. Cognitive Load Theory postulates that if cognitive load exceeds one's short-term processing capacity, then learning (assimilation of knowledge into long-term memory) cannot occur [14]. Uus, Seitlinger, and Ley [15] summarize that self-directed learning is subject to "human information processing constraints," which are "linked to individual memory functions." Uus and collaborators [15] found that working memory capacity does indeed impact the ability of middle-school aged students to engage in self-directed learning. Although they do not reference Cognitive Load Theory, Rutherford, Buschkuehl, Jaeggi, and Farkas [16] describe "self-regulated" learning as "cognitively demanding," due to the need for executive functions to "shift attention, inhibit distractors, and update information in working memory." Rutherford and collaborators [16] again found that cognitive capacity (executive functions) can either support or hinder "self-regulated" learning. Zulu, Haupt, and Tramontin [17] found no increased cognitive load due to self-directed learning among college-aged students, although their conceptualizations of the two constructs were somewhat narrow because they did not use standard instruments.

III. Study Methods

We are conducting a case study to analyze the impacts of pandemic-induced changes in engineering course modality on student experiences (i.e., cognitive load) and development (i.e., self-directed learning readiness). The current study focuses on the change in self-directed learning readiness during the early months of the pandemic (Spring 2020) when The Citadel mandated a rapid transition to emergency online instruction.

A. Survey Administration

We administered a survey to students twice during the Spring 2020 semester – during their first week of emergency online instruction and six weeks later after online completion of their engineering courses – to monitor their self-directed learning. We used the SDLRS to capture students' attitudes and skills related to readiness to manage learning. The SDLRS prompts students to use a five-point scale (1 = Almost never true of me; 5 = Almost always true of me) to reflect on their learning preferences and attitudes by answering 58 Likert-type items [4]. Both surveys were administered via Qualtrics, with additional open-ended questions to further capture student experiences related to self-directed learning.

B. Participants

We had 374 participants complete the SDLRS at the midterm and/or the final of the Spring 2020 semester. Most participants identified as white (78.9%) and male (93.6%). In addition, most participants were cadets engaging in a residential academic and military experience (82.6%). Remaining students were enrolled in our college transfer program (12.0%) or active duty/veteran students (5.3%). Most students were either mechanical (58.0%) or civil/construction (40.6) engineering students. Of the 374 participants, 208 completed the SDLRS during the midterm and final administrations.

C. Data Analysis

Student responses from each administration were used to compute an SDLRS score, based on a proprietary protocol [4]. SDLRS scores were categorized as Below Average (58-201), Average (202-226), or Above Average (227 – 290). Data, when disaggregated by academic class, were non-normal according to a significant Shapiro-Wilk test. As such, non-parametric tests were used for subsequent analysis. A significance level of 0.05 was used for all hypothesis testing.

The Kruskal-Wallis H test was used to examine differences in SDLRS scores by academic class prior to the pandemic [18]. Distributions of SDLRS scores were similar for all academic classes, as assessed by visual inspection of a boxplot. Analysis of SDLRS scores trends prior to the pandemic were important for contextualize subsequent changes in scores during emergency online instruction.

Wilcoxon-Signed Rank tests were used to examine changes in SDLRS scores between midterm and final survey administrations for each academic class [19]. The difference scores were approximately symmetrically distributed, as

visually determined by a histogram with superimposed normal curve. Effect size (r) was calculated as $z/n^{0.5}$. Effect sizes were classified according to Cohen's benchmarks – small: 0.10 – 0.29; medium: 0.30 – 0.49; large: 0.50 and greater.

IV. Results

Prior to the pandemic, self-directed learning readiness was similar across academic classes, as demonstrated by a non-significant Kruskal-Wallis H Test [$\chi^2(3) = 4.05$, $p = 0.256$]. Furthermore, SDLRS scores were within the "average" range both at the midterm and final of the Spring 2020 semester (Table I).

TABLE I. Differences in SDLRS Scores at Each the Midterm and Final of the Spring 2020 Semester.

	Academic Class				Kruskal Wallis Test	
	Fresh	***Soph***	***Junior***	***Senior***	**$\chi^2(3)$**	**p**
Midterm (N = 295)	219.5	220.0	214.0	220.0	4.05	0.256
Final (N = 287)	221.0	221.0	217.0	226.0	5.14	0.162

Generally, self-directed learning readiness increased over the six weeks of emergency online instruction. Of the 208 participants who completed both surveys, 57.2% reported higher SDLRS scores, as compared to 39.4% who reported lower SDLRS scores. With a small effect size, there was a statistically significant increase in the median SDLRS score before (Med = 220.0), as compared to after (Med = 223.0) emergency online instruction [$z = 3.05$, $p = 0.002$, $r = 0.21$].

The trend of increasing SDLRS scores was observed for most academic classes (Table II). For freshmen, sophomores, and seniors, over half of participants reported higher SDLRS after emergency online instruction. With a medium effect size, there was a statistically significant increase in the median SDLRS scores for freshmen ($Med_{mid} = 226.0$; $Med_{final} = 227.0$) and sophomores ($Med_{mid} = 220.0$; $Med_{final} = 223.0$). With a small effect size, there was a statistically significant increase in median SDLRS scores for seniors ($Med_{mid} = 222.5$; $M_{final} = 230.5$).

Juniors, however, were the only academic class to not show an increase in SDLRS score (Table II). In fact, equal percentages of juniors showed increases and decreases in SDLRS scores. There was not a statistically significant change in the median SDLRS score for juniors ($Med_{mid} = 213.0$; $Med_{final} = 211.0$).

TABLE II. Difference in SDLRS Scores between Midterm and Final within Each Academic Class.

	Pair Changes (%)		Wilcoxon Signed Rank Test		
	Pos.	**Neg.**	**$\chi^2(3)$**	**p**	**r**
Fresh (n = 23)	61.5	26.9	1.98	0.048	0.41
Soph (n = 46)	58.3	33.3	2.38	0.018	0.35
Junior (n = 61)	47.6	47.6	-0.14	0.889	-0.02
Senior (n = 78)	57.7	37.2	2.16	0.031	0.24

V. Discussion

A. Status of Self-Directed Learning Prior to the Pandemic

Prior to the pandemic, SDLRS scores were similar across academic classes (Table I), which is similar to previous work conducted by Litzinger and collaborators [10] at Pennsylvania State University. If SDLRS scores tended to increase due to academic experience, then it would be difficult to isolate the impacts of emergency remote instruction on self-directed learning readiness. However, if significant changes in SDLRS scores are not apparent across academic classes, then it is unlikely that SDLRS scores would normally tend to increase over the six-week study period (in the absence of a modality shift).

B. Changes in Self-Directed Learning during Emergency Online Instruction

While the effect size for the increase in SDLRS was small, the improvement in self-directed learning readiness was likely significant, given the short duration of emergency online instruction. Indeed, previous studies [10-13] showed typical engineering education experiences, including capstone design, to have little impact on SDLRS scores. As such, a statistically significant increase in self-directed learning readiness in only six weeks is quite notable.

C. Connections between Self-Directed Learning Readiness and Cognitive Load

Ultimately, we are seeking to understand the relationship between cognitive load and development of self-directed learning readiness. In our previous work, we discovered that juniors experienced increases in more cognitive load dimensions than any other academic class. Juniors were also the only sub-group who experienced an increase in mental demand with a large effect size. In the current study, juniors were unique among academic classes because they did not report improvements in self-directed learning readiness.

Our work is still in an early stage; however, we observe interesting co-variations between cognitive load experiences and development of self-directed learning readiness that warrant further investigation (Table 3). We hypothesize that freshmen and sophomores may have experienced manageable cognitive load during their engagement with the new frontier of emergency online instruction, which afforded them the opportunity to improve their self-directed learning readiness. Juniors, however, may have reached cognitive overload, as they experienced increases in four of the six cognitive load dimensions, including mental demand. In their overloaded state, they may not have successfully been able to adequately manage their own learning in the new online space, and thus did not report improvements in self-directed learning readiness. Seniors, on the other hand, experienced an increase in only one workload dimension (frustration) and little improvement in self-directed learning readiness. One feasible explanation is

that seniors were weeks away from graduation and did not fully engage in the new online experience; thus, they did not improve their self-directed learning skills. An alternative explanation might be that seniors were better prepared than less experienced academic sub-groups. However, we found self-directed learning readiness among seniors to be similar to other academic sub-groups prior to the pandemic.

TABLE III. PRELIMINARY COMPARISSON BETWEEN COGNITIVE LOAD AND SELF-DIRECTED LEARNING READINESS DURING EMERGENCY ONLINE INSTRUCTION

Academic Class	No. Increased Cognitive Load Dimensions (with med/large effect size) [2]	Effect Size for Increase in SDLRS score
Freshmen	2	Medium
Sophomore	3	Medium
Junior	4	None
Senior	1	Small

VI. CONCLUSIONS

A study was conducted to monitor changes in self-directed learning readiness among engineering students while engaging in emergency online instruction induced by the COVID-19 pandemic. Students completed the SDLRS, a rigorously-developed and widely-used instrument, within the first week of emergency online instruction and again six weeks later at the conclusion of the semester. The following conclusions were made based on the results:

1. Prior to the pandemic, self-directed learning readiness was similar across academic classes, which supports that SDLRS scores would not tend to naturally increase over the course of six weeks.
2. Freshmen, sophomores, and seniors experienced a significant increase in self-directed learning readiness, which is notable given that prior application of the SDLRS in engineering education contexts as shown scores to be static.
3. Juniors were the only academic class who did not show a change in self-directed learning readiness during emergency online instruction.
4. As prior work showed that juniors experienced an increase in more cognitive load dimensions than other academic classes, further exploration is needed on the relationship between cognitive load and development of self-directed learning readiness.

To contextualize our conclusions, we must also acknowledge our study's student sample. We have assessed SDLR and cognitive load for a very specific population of students – undergraduates enrolled in civil, construction, or mechanical engineering programs at a regional teaching college. Most participants were engaged in a residential military experience (i.e., cadets) and identified as white and male. As such, our preliminary findings of improved SDLR and potential covariation with increased cognitive load may not hold true across different demographic groups.

As this a work-in-progress, we are in the process of coding students' open-ended responses in order to identify aspects of self-directed learning readiness that students felt they developed versus were challenged by during Spring 2020. We also conducted focus groups during Summer 2020 and are examining themes related to self-directed learning and how they may have been related to experiences of cognitive (over)load. In addition, a subset of continuing students reflected on their learning experiences at the beginning and end of the Fall 2020 semester, and compared that semester with the previous spring semester. Among other questions, we will be exploring ways in which students felt prepared for online and hybrid learning during the fall as a result of their experiences with emergency online instruction, and whether there were again differences across class years or notable changes reported by a cohort.

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