Student Outcomes in an Concentrated Chemistry Laboratory Course for Online Students

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Subject / Problem

To meet the needs of a greater diversity of students, higher education has begun to innovate in instructional delivery models. Students with commitments to family, earning a living, wellness, and other lifestyle-needs demand flexibility and variety in how and when they access learning and information (George-Walker & Keeffe, 2010). As a result, the number of online education programs in U.S. higher education is rising. By fall 2016, 6,359,121 students were taking at least one online course, representing 31.6% of all students (Seaman, Allen, & Seaman 2018). These students were fairly evenly split between those taking both online and non-online courses (3,356,041) and those taking exclusively online courses (3,003,080) (Seaman, et al., 2018).

Online learning increases access to higher education by accommodating a greater diversity of student lifestyles, and bringing opportunity to learners for whom time-bound and place-bound education are impossible. But the growth in online programs has led to questions and research about quality. Most of this research has been at the course level, comparing outcomes in online, face-to-face, and blended (combination of face-to-face and online) formats. Allen, Mabry, Mattrey, Bourhis, Titsworth, and Burrell's (2004) meta-analysis (N=71,731) of quantitative studies comparing academic performance found that online students "slightly outperformed" students in conventional on-campus programs. Kahue, Stephens, Leach, and Zepke (2013) found that online students were as satisfied with the online learning environment as conventional on-campus students. However, student and faculty's conflicting perceptions of online programs pose barriers. Jaggars (2014) reported that many college students were reluctant to enroll in fully online programs because they wanted to maintain a connection to the people and location of the campus and have greater connection with the instructor. Allen and Seaman (2012) reported that 67% of professors perceived learning outcomes for online courses to be inferior or somewhat inferior to those for comparable face-to-face courses.

In this study, we take a different approach to the issue of quality in online learning, with a focus on accommodating the diverse needs of students in a fully online biochemistry degree program. Laboratory courses have traditionally posed barriers for online learners since experiences equivalent to on-campus labs are difficult to achieve at distance. To provide opportunity for students to overcome this barrier, we developed and studied a concentrated face-to-face organic chemistry laboratory course conducted over 3.5 days in the summer. Conventional students take their organic chemistry laboratory course in a 14-week traditional semester. To evaluate the effectiveness of this concentrated laboratory course, we conducted a quasi-experiment comparing outcomes (content knowledge, science identity, and self-efficacy) of students ($n = 27$) in the 3.5 day concentrated laboratory with those of students ($n = 190$) in the conventional 14 week course. For this study, we assumed an equivalency theory conceptual framework with time as the primary organizing construct (Norberg, Dzuiban, Moskal, 2011).

Based on equivalency theory (Simonson Scholosser & Hanson, 1999; Simonson, Smaldino, Albright, & Zvacek, 2011), learning outcomes can be the same despite differences in course format. The goal of equivalency theory is to provide learners with experiences of equal value despite differences in format. Equivalency theory suggests that course formats can be flexible and convenient without compromising rigor and learning. Equivalency theory also prioritizes providing a collection of experiences that are most suitable for each student or student group. This leads to an important question for equivalency theory not previously studied: Can learning outcomes be equivalent when the span of days for meeting face-to-face is dramatically reduced?

Design / Procedure

The focus of this study was to examine the outcomes of a time-based-strategy for equivalent learning in a fully online degree program in order to increase opportunities for a greater diversity of students to earn a biochemistry degree. We employed a quasi-experiment design. Our research questions were:

1.) Are there significant differences in assessments of content knowledge between students who participated in a 3.5 day concentrated course and those in a conventional 14 week course?
2.) Are there significant differences in assessments of student identification with science between those in a 3.5 day concentrated course and those in a conventional 14 week course?
3.) Are there significant differences in assessments of motivational factors between students who participated in a 3.5 day concentrated course and those in a conventional 14 week course?

Participants and Context. The students included in this study were enrolled in general organic chemistry laboratory courses at a large public university is the US southwest. Students enrolled in the conventional degree program took the course in the spring 2018 semester. These students performed 10 laboratory experiments in a 3 hour time period, one experiment per week over the course of the semester. In addition to the experimental work, the students were required to watch a 30 minute pre-laboratory video and to submit graded pre-laboratory and post-laboratory exercises designed to assess comprehension. The students also wrote reports in the style of an academic publication for two of the laboratory experiments.

Students in the online degree program took the concentrated 3.5 day laboratory course in summer 2018. The students performed all but one of experiments that were part of the conventional semester-long course. The omitted one was not a traditional experiment, but a molecular model-building exercise in support of the parallel lecture course. This experiment was not needed for the online students since they had already completed their lecture course in the previous semester. In all other ways, the experiments, the time allotted to each experiment, and the associated materials and assessments were essentially identical to those in the conventional course. The concentrated course started at 8AM on a Sunday morning and ended at noon the following Wednesday. The students performed experiments during the day and completed the pre- and post-laboratory activities in the evenings. The online students submitted their reports after they returned home, but within 2 weeks of the end of the laboratory part of the course.

The demographics of the two student populations were different. For example, the average age of the students in the conventional degree program in 2018 was 21 years, compared to 26 years for the students in the online program. 51% of the conventional population were women compared to 66% of the online students. The percentage of the conventional population that was African American was 4%, compared to 12% in the online population.

Assessment of Outcomes. Students in the concentrated and conventional laboratory courses were invited to complete a survey at the end of the course. The survey had three sections designed to address the three research questions. In addition to content knowledge we questioned how the course design might influence student affective factors. Development of science identity is often considered an important contributor to success in college science courses, particularly for underrepresented populations (Chang et al., 2011). Laboratory courses may be particularly important in this context since it is suggested that science identity is promoted when students participate in practical science settings (Carlone & Johnson, 2007). Student motivation, and self-efficacy in particular, is often found to correlate strongly with performance in college-level science, consistent with learning theories that connect self-determination and self-efficacy with self-regulation (Pintrich, 2004). We felt it was important, therefore, to monitor how a large alteration to the laboratory course structure might influence these important affective factors.

To assess content knowledge, ten of the survey questions focused on course content and concepts. The questions were multiple choice and the scores from this section were normalized to percentage of the maximum possible points. To assess science identity we used a published instrument that has been tested for reliability in the context of undergraduate STEM majors (Williams & George-Jackson, 2014). To assess motivation, the Science Motivation Questionnaire II (SMQ-II) was included in our survey. SMQ-II has been tested for reliability and validity in the context of undergraduate science and nonscience majors (Glynn et al., 2011). SMQ-II assesses five different motivation factors, intrinsic motivation, career motivation, self-determination, self-efficacy and grade motivation.

Analysis and Findings

27 of the 30 students in the concentrated course and 190 out of 240 in the conventional course completed the surveys. The mean scores (*M*) and standard deviations (*SD*) for content knowledge, science identity and the five motivation factors are summarized in Table 1. The mean scores were larger for the online students in the concentrated 3.5 day course in all of the assessments. Differences between the conventional and concentrated course students were analyzed using t-tests and Hedge's *g* for effect size.

In content knowledge, science identity and all of the motivation factors, the higher scores for the online students were statistically significant (the relevant statistics are summarized in Table 1). The differences in content knowledge and science identity had moderate to large effect sizes ($0.5 < g < 0.8$). Large effect sizes were found for intrinsic motivation and self-determination ($g > 0.8$), the effect sizes for the other factors were again medium to large ($0.5 < g < 0.8$).

Although they cannot be generalized, the findings strongly support the proposal that for these online students in this concentrated course, the assessed outcomes were at least equivalent, if not better, than those of conventional students in their lab course, not only for content knowledge, but also for important affective factors. These findings are at odds with the suggestion of Lyall and Patti (2010) that online students in "residential" concentrated laboratory chemistry courses at an Australian university "felt confused" by the experience. The results are, however, in general agreement with the conclusion of a review of studies that compared traditional and nontraditional laboratory courses, that student learning achievement is equal or higher in the nontraditional courses, although these studies mainly focused on content knowledge (Brinson, 2015).

Content Knowledge, Science Identity and Motivations Scores for Students in Conventional versus Concentrated Organic Chemistry Laboratory Courses [a]

	Conventional (n = 190)		*Concentrated (n = 27)*				
	M	*SD*	*M*	*SD*	*t*	*sig.*	*g*
Content Knowledge	59.3	15.0	70.0	11.4	3.57	<.001	0.73
Science Identity	63.6	19.3	76.9	14.0	3.46	<.001	0.71
Motivations							
Intrinsic Motivation[b]	68.2	16.1	85.9	10.2	7.78	<.001	1.14
Career Motivation	66.1	20.4	80.9	16.2	3.62	<.001	0.74
Self-Determination[b]	70.4	16.4	89.1	9.71	8.44	<.001	1.18
Self-Efficacy	75.6	16.6	86.7	11.9	3.35	<.001	0.69
Grade Motivation[b]	82.8	13.8	90.7	8.96	3.96	<.001	0.59

[a] *M* = mean score, *SD* = standard deviation, *t* = t score, *sig* = significance, *g* = Hedge's g value, small effect = 0.2, medium effect = 0.5, large effect = 0.8. [b] Equal variances assumed except for these three factors.

This study does not provide evidence for the underlying reasons for these results, however, some potential factors can be readily identified. Specifically, the 3.5 day format is more immersive than the traditional course. Compared to conventional students who complete one experiment per week, online students in an afternoon lab might use what they just learned in the morning lab, facilitating the connection concepts between experiments. Alternatively, the online population includes more older and returning students, and so it may not be surprising if they were more highly motivated, resulting in better learning outcomes and laboratory experiences.

Contribution to Science Education and NARST Members

This work directly addresses a theme of the 2020 NARST conference, "Science Education across Places and Contexts", and NARST's goal of "helping all learners achieve science literacy". Online education can provide opportunity and access to learning for students who might otherwise be excluded from postsecondary education, and rapid growth in online education is projected to continue (Ginder, Kelly-Reid, & Mann, 2017). How to deliver valid laboratory courses to online students is often considered a key confounding issue for designers of science degree programs (Reeves & Kimbrough, 2004). Our findings have implications for hypotheses about how to improve access to important laboratory science courses for these online students. This study also supports the utility of equivalency theory in guiding course and program design.

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