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Board #14A: Work in Progress: Integrating Information and Data Literacy Skills into Biomedical Engineering Laboratory Courses

Mr. Alexander James Carroll, Vanderbilt University

Alex Carroll, MSLS, AHIP, is the Associate Director of the Science and Engineering Library (SEL) at Vanderbilt University. Alex leads the SEL's liaison program, designing and delivering services to support the research enterprise and the teaching mission of the School of Engineering and STEM academic units within the College of Arts and Science. He received his MSLS degree from the University of North Carolina at Chapel Hill's School of Information and Library Science, and his BA from James Madison University.

Alex is an Associate Editor of the Journal of the Medical Library Association (JMLA) and is a Distinguished member of MLA's Academy of Health Information Professionals (AHIP). His research interests include studying the information seeking behaviors and data practices of STEM researchers, designing library liaison services, and improving information literacy instruction for students in the sciences. His work in these areas has been recognized by the ALA Library Instruction Round Table with "Top Twenty" awards in 2018 and 2019, and by ASEE's Engineering Library Division with Best Publication Awards in 2020 and 2022.

Dr. Joshua Daniel Borycz, Vanderbilt University

At Vanderbilt University I help graduate and undergraduate students learn how to do research and succeed academically by introducing them to a range of tools, developing new tools, creating educational programs, and advocating for the use of library servi

Prof. Amanda R. Lowery, Vanderbilt University
Sheldon Salo, Vanderbilt University Library

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Background: Undergraduate engineering programs train students to develop, conduct, and interpret experiments, as well as foster an ability to acquire and apply new knowledge as needed [1]. While engineering educators recognize the importance of equipping students with the ability to find and synthesize technical information, limited classroom time inhibits instructors' ability to teach students these skills [2], [3]. Engineering librarians are well-suited to partner with engineering educators in designing instructional interventions that promote development of these skills [4]. Senior design courses have been identified within the literature as rich opportunities for integrating information literacy instruction into the biomedical engineering (BME) curriculum [5]. While single interventions within senior design courses are helpful, students may experience greater benefits from a holistic information literacy training program that is scaffolded across the undergraduate curriculum [6], [7].

Purpose: We explored whether laboratory courses were an effective context for integrating information literacy throughout the undergraduate BME curricula. We scaffolded instructional interventions across the undergraduate curriculum, anticipating that after participation in this information literacy program, students would demonstrate an increased understanding of the breadth of technical information sources available.

Instructional Methods: Students at Vanderbilt University completed a required BME laboratory course as a sequential series of one credit courses in their sophomore (BME 2900W), junior (BME 3900W), and senior (BME 4901) years. In addition to gaining expertise in conducting experiments methods, collecting data, and interpreting findings, students were expected to demonstrate progressive growth in their ability to write laboratory reports that placed their results in context with previously published primary literature.

Engineering librarians provided guest lectures in this three-course sequence, introducing information sources and how to access them. In BME 2900W, librarians demonstrated how to find experimental protocols, engineering handbooks, and methods papers. In BME 3900W, students learned how to find patents and review articles. In BME 4901W, librarians provided an overview of managing research data, including best practices for organizing files and designing machine-readable tabular data.

Methods: Beginning in the Spring 2022 semester, we initiated a longitudinal assessment of this information literacy program. Students completed pre-tests prior to each of the interventions that established their baseline knowledge, while also tracking skills gained and retained between each course. Following their completion of BME 4901, student also completed an identical post-test. The first cohort of students that experienced the full training sequence matriculated through the program in the Fall 2023 Semester. Data collection will continue into the Spring 2025 semester.

The pre-tests and post-test, which included a mix of objective and open response questions, are available on the Open Science Framework [8]. This protocol was reviewed by the Vanderbilt University Institutional Review Board and was approved as a Quality Improvement project (IRB #232075).

The survey responses to the multiple-choice questions from each class were recorded in a spreadsheet with response identifiers, course information, and answers. The Analysis of Variance (ANOVA) method was used to compare the proportion of correct answers from each BME class (2900W, 3900W, 4901W) to the objective questions in these tests. The Tukey Honest Significant Difference (TukeyHSD) test was performed to make pairwise comparisons between individual variables. These were computed using the *stats* package in R-4.3.1.

Preliminary Results: Table 1 reports results from student performance on nine objective questions. Q3-Q7 asked students to identify sources of information to consult when completing different tasks. Q8-Q11 asked students to identify which library-licensed resources to utilize when searching for different types of technical literature documents. Q12 asked students to describe what type of document the acronym “IMRAD” applies to.

Table 1: Percentage of students who correctly answered each question. Correct response to each question was patents, research articles, experimental protocols, review articles, handbooks, Derwent Innovations Index, Web of Science, Cold Spring Harbor, AccessScience, and Journal Articles

Test (n)	**Q3: Intel property**	**Q4: Exp findings**	**Q5: Exp methods**	**Q6: Crit summaries**	**Q7: Overviews**	**Q8: Patents**	**Q9: Articles**	**Q10: Exp Protocols**	**Q11: Handbooks**	**Q12: IMRAD**
2900 Pre (93)	83.9%	88.2%	92.5%	71.0%	55.9%	80.6%	77.4%	26.9%	31.2%	24.7%
3900 Pre (99)	91.9%	97.0%	94.9%	78.8%	60.6%	84.8%	82.8%	57.6%	55.5%	25.3%
4901 Pre (26)	100.0%	100.0%	100.0%	100.0%	65.4%	96.2%	88.5%	73.1%	46.2%	15.4%
4901 Post (19)	100.0%	94.7%	89.5%	84.7%	73.7%	100.0%	84.2%	78.9%	63.2%	31.6%

Figure 1 shows the proportion of correct responses divided by class, question, and topic. The pre- and post-test results for BME 4901 from Table 1 were combined because the content taught in this course (research data management) was not covered in the multiple-choice questions analyzed in this work. The ANOVA results indicate a significant increase in the number of correct responses to all test questions within each successive course (Mean square = 4.6; F-statistic = 22.4; p-value<0.001). The ANOVA results for course and question interaction term indicated a significant difference for questions across courses (Mean square = 0.43; F-statistic = 2.80; p-value<0.001). Since questions 1 to 7 each address resource types, 8 to 11 address tool knowledge, and 12 is on article structure, these questions were combined into the topic categories Resource, Tool, and Reading for comparison. ANOVA results for the course and topic interaction term showed a significant difference for topics across courses (Mean square = 0.63; F-statistic = 3.64; p<0.01). Table 2 shows the significant TukeyHSD pairwise results for each individual question and topic compared across courses.

Table 2: Difference in mean correct response rate between questions and topics in each course that have statistically significant results from TukeyHSD.

Course	**Q6**	**Q10**	**Q11**	**Resource**	**Tool**
2900-3900	-	0.307***	0.244**	-	0.162***
2900-4901	0.268*	0.487***	-	0.137**	0.243***

*p<0.05, **p<0.01, ***p<0.001

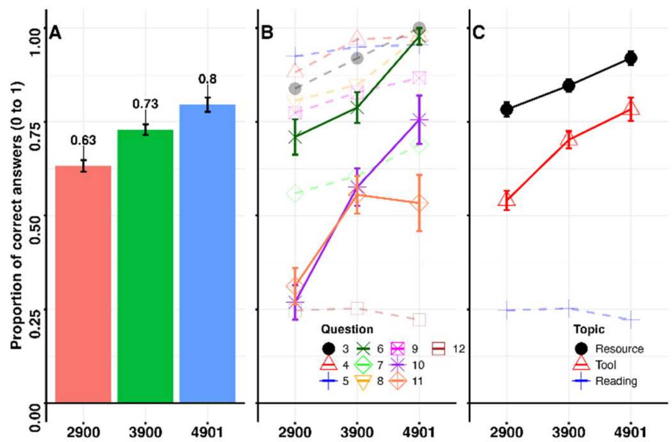

Figure 1: Proportion of correct responses for (A) all questions combined, (B) individual multiple-choice questions, and (C) topics covered by the questions (Resource: 1-7, Tool: 8-11, Reading: 12) for each BME class. All results in A are statistically significant. For B and C, the solid lines indicate statistical significance ($p<0.05$). The error bars show the standard error for each point.

Discussion: These results show that information literacy instruction can have a lasting impact on student outcomes. Figure 1A demonstrates an overall increase in knowledge on research information. The test questions indicated that most BME students were already familiar with patents, research articles, and protocols (Q3, Q4, and Q5), as well as the Derwent Innovation Index and Web of Science (Q8 and Q9) (Figure 1B), which all had correct response rates of over 75% in the BME 2900W pre-tests. The instructional focus on the importance of review articles for understanding fields and connecting to important journal articles helped students increase their familiarity with this resource type (Q6). While most students in 2900W had not heard of Cold Spring Harbor (Q10) or AccessScience (Q11), after attending a didactic on how to use these tools, students remembered the types of information they could be used to find. Overall, the students' knowledge of research tools and research types increased significantly after each session (Figure 1C).

At Vanderbilt University, laboratory courses presented a unique instance where undergraduate students were expected to find and synthesize primary and secondary literature, and that learning was scaffolding over time. Moreover, students expect active learning within laboratory courses, which facilitated the inclusion of hands-on learning components. Educators at other institutions may find that lecture-based courses in the engineering curriculum could benefit equally from information literacy instruction. However, the degradation of some students' recall of information sources following the 4901 post-test (where specific information tools were not addressed) may highlight the importance of continued refresher training on these topics.

Future Work: The objective questions in these tests do not measure how well students can use technical literature; rather, they test recognition of resource types, tools, and article structure. At the 2024 Annual Meeting, we plan to share preliminary data from a sentiment analysis of a random sample of open response questions from students who completed all four tests. The text responses from students may reveal more improvement in student research workflows and confidence levels. In future work, we also plan to assess a random sample of students' laboratory reports using rubrics to measure student achievement of learning outcomes and citation analysis to measure extent of information use [9], [10], [11], [12]. The complete rubric can be viewed online on the Open Science Framework [13].

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