INTERVENTION DESIGN AND TEACHING PRACTICE FOR ENHANCING ENGINEERING SKILLS IN READING RESEARCH ARTICLES

M. Vilchez
Department of Fluid Mechanics, Universitat Politecnica de Catalunya
Terrassa, Spain
0009-0008-0472-4221

M. Vlasov
Department of Statistics and Operational Research, Universitat Politecnica de Catalunya
Barcelona, Spain

M. Torrent
Department of Fluid Mechanics, Universitat Politecnica de Catalunya
Terrassa, Spain
0000-0002-3054-8267

L. Rodero-de-Lamo
Department of Statistics and Operational Research, Universitat Politecnica de Catalunya
Barcelona, Spain
0000-0002-8794-7541

P.J. Gamez-Montero [1]
Department of Fluid Mechanics, Universitat Politecnica de Catalunya
Terrassa, Spain
0000-0002-5168-3521

[1] *Corresponding Author*
P.J. Gamez-Montero
pedro.javier.gamez@upc.edu

***Conference Key Areas**: 3. Teaching technical knowledge in and across engineering disciplines; 11. Engineering skills, professional skills, and transversal skills*
***Keywords**: undergraduate research, research argumentation, engineering skills, technical knowledge, fluid mechanics*

ABSTRACT

The constant drive to improve engineering education's pedagogy stems from its crucial role in serving society. The practice of reading research articles is an academic strategy to keep up with the rapid advancement of the information and competencies required of today's engineers. Proficiency in this skill is difficult to attain, and unfortunately, this valuable capacity is often overlooked and not included in the curriculum for undergraduate students, which results in a loss of knowledge and a wasted opportunity. This article presents a practical case in an undergraduate Fluid Technology course, a teaching intervention designed for enhancing engineering students' skills in reading research articles carried out over a period of four months, within the boundaries of the course context. The first aim was to assess the progression of the students' ability to read research articles. The second aim was to elucidate student perceptions and conceptual cognition of their 'Capability', 'Ability', 'Skills' and 'Background' before and after the teaching practice. The teaching encompasses the reading assignments and post/out-of-class activities, the warm-up readings, two in-house ad-hoc lectures, the pre- and post-test readings and the pre- and post-questionnaires. The students' perception of self-improvement, as well as the positive shift in grades, are both reflected in the satisfactory results of the tests and questionnaires. This innovative educational research is readily adaptable to other cases and has potential for educating responsible engineers, thinking and understanding like engineers.

1 INTRODUCTION

Engineering education has always been fundamental to serving society and educating responsible engineers. To do this, it must be adaptable enough to adjust to the many different global forces that exist today and will exist in the future. Nonetheless, there are concerns about whether engineering practice will be able to keep up with the rapid advancement of the information, skills, abilities, competences, and attitudes that today's engineering demands (Lohmann 2008; Bubou et al. 2017). Engineering in higher education needs to adapt quickly in order to provide students with strong, astute, and perceptive engineering practice for the problems that lie ahead.

Reading scientific articles is one academic strategy used for improving engineering education: a transversal competency especially appropriate to be integrated in the context of a technical course. Students can greatly benefit from learning this ability in both their academic and professional careers. The relationship between a student's academic reading skills and success in education, even during the first year of an undergraduate course, proves it even more advantageous (Hermida 2009). The present work offers an effective method for reading scientific articles, developing analytical skills by questioning the content, and a scaffolded teaching strategy for not overloading students. A teaching intervention design for reading primary literature is given, based on a real case in practice in a compulsory undergraduate Fluid Technology course given by the Department of Fluid Mechanics at the School of Industrial, Aerospace, and Audiovisual Engineering of Terrassa (Spain), part of the Universitat Politècnica de Catalunya (UPC).

1.1 Primary literature on undergraduate education

An increasing amount of research has been carried out during the last 20 years, with an emphasis on how research experiences help students and how teaching and research are linked in higher education. Griffiths proposed ground-breaking methods that linked teaching with research (Griffiths 2004), and Healey's later work consolidated a comprehensive framework based on the research-based approach (Healey 2005).

Successful comprehension of primary literature is difficult since these are official documents that scientists use to communicate their research to each other. In light of mastering these techniques, students will be empowered to take responsibility for their own understanding, increasing excitement and motivation, which will lead to higher-quality learning results (Fernandez 2021, Yeong 2014). Research-based learning in engineering courses is particularly essential when it comes to motivation because most students do not learn through the study of primary scientific literature in high school science courses. Furthermore, via the production, relevance, and exploitation of digital resources, primary literature is influencing the social and cultural aspects of academic domains (Fry and Talja 2007). Nevertheless, there is no set criterion by which to judge a paper's significance or applicability at the time of publication.

Studies have been conducted on how teachers and researchers read primary literature and how they incorporate information from the articles into their professional knowledge, as research knowledge and primary literature serve as the foundation for the academic community (Bartels 2003). Other studies have focused on secondary sources and how teachers of scientific literature can use popular texts and popular genres (Parkinson and Adendorff 2004).

1.2 Research-based learning and engineering education

A strong grounding in many engineering techniques can be obtained through undergraduate research training. It has been demonstrated that it enhances students' comprehension and capacity to communicate primary scientific findings, giving them a competitive edge over their peers (Kozeracki et al. 2006). Discipline-based education research documents the most recent advances in the knowledge of how engineering and scientific students learn as well as how the syllabus is designed and teaching methods are employed (Benson et al. 2010; Singer and Smith 2013).

Curricula and teaching methods are evolving to guarantee innovative advances in engineering students' comprehension and learning. Therefore, in order to meet the problems of the twenty-first century, engineering education must strengthen the link between teaching and research. The method by which engineering educators conceptualise research and scholarship must be taken into consideration in order to effectively encourage and perform active learning and foster the development of the linkage between teaching and research (Brew 2003). It is essential that engineering educators take part in research-based programs, active learning, the overall teaching-research nexus, and employ current neuroscience knowledge as teaching methodology to enhance and make the lecture successful (Sanchez-Carracedo et al. 2021).

1.3 Course design using primary literature as an academic tool

Knowing how to read research articles is a skill that is often overlooked in university curricula. Most academics and research professionals have actually learned this skill through self-teaching (Greenhalgh 2014). As an additional component of their work, engineering educators study an extensive number of research publications. Unexpectedly, this talent is not taught frequently, especially not to undergraduate students, which results in an excessive amount of knowledge and effort wasted (Finelli and Froyd 2019).

The current initiative aims to provide methods for reading and useful frameworks for evaluating journal articles within the core of an engineering course while being guided and supervised by instructors. Conceptual comprehension is given priority over rote memorization in the assessment system in order to promote this kind of learning. Unlike traditional lecture-style training, which is teacher-centered, active learning involves all students participating in the learning process. It promotes an atmosphere that supports independent thought outside of traditional classroom settings and knowledge that is confident in oneself. Passivity and inaction are definitely not workable or feasible options. Integrating knowledge through problem-solving and case studies is one approach to accomplishing this, as opposed to just absorbing it. By doing that, it keeps pupils from becoming more demotivated and encourages a deeper comprehension of the topics at hand.

2 METHODOLOGY

2.1 Course context

Fluid technology is a compulsory course programmed each semester and encompasses two periods of six weeks each, with twelve sessions in total. The course typically has 70–80 students, between 21 and 24 years old, and all have to enrol in the subject. The students are proficient in both official languages, Spanish and Catalan. The textbooks and slides are written in Spanish, the lectures are taught in Catalan, and the assignments are in English. The course material, activities, and assignments were stored on the teaching support platform ATENEA (Moodle) on servers at the UPC.

The course is 4.5 ECTS, with 6 hours of teaching per two weeks, and its schedule is planned before each semester, sent to students one week in advance, and explained in the introductory lecture of the first week. In total, the teaching intervention encompasses the following:

- **Lectures and applications**, a variety of learning activities and problem-solving exercises [100 minutes per week]
- **Practice seminars**, including learning computer activities. [110 minutes per two weeks]
- **Self-study**. Pre/out-of-class activities (slides, short textbook-style readings, course-related short online videos, problem statements and resolution [90 min/week]) and post/out-of-class activities (online computer-based multiple-choice individual quizzes [90 min/week]). The total time scheduled represents 66% of self-study hours.

2.2 Intervention design and teaching practice

The teaching practice brings new perspectives to the engineering undergraduate course. The instructor, at the beginning of the intervention, informs the students and outlines the course regarding all programmed pre-, post-, and in- and out-of-class activities.

1. **The lectures on Reading Primary Literature** (RPL). The teaching practice is supported by two lectures to address how to identify the ‘anatomy’ of the paper, research questions and hypotheses, research argumentation, contents, and results in research articles.
2. **The reading assignments and the post/out-of-class activities**. Figure 1 shows the intervention program. The two lectures, RPL (1/2) and RPL (2/2) of 50 minutes each, are conveniently scheduled in the timeline with the reading assignments as post/out-of-class activities.
3. **The warm-up readings**. The designed progressive approach for a successful implementation of the intervention based on warm-up readings is depicted in Figure 1: 1st, 3rd and 4th, parts one and two. These warm-up readings accompany the students without overloading them, matching syllabus-related concepts and avoiding discouraging them during the intervention, especially at the beginning and before the RPL lectures.
4. **The test readings and the pre- and post-test**. The first aim of the intervention is to assess the student’s ability to read research articles; in fact, to measure the progression of this ability. Two test readings are planned to measure the effectiveness of the teaching practice: pre-test reading, 2nd, and

post-test reading, 5th, Figure 1. The two articles were selected with attention, as different contents and syllabus-related concepts were used to generate the pre- and post-test questions.

5. **The pre- and post-questionnaires and SEEQ survey**. The second aim of the intervention is to elucidate student perceptions and conceptual cognition of their ‘Capability’, ‘Ability’, ‘Skills’ and ‘Background’ to read and critique primary literature before (pre-questionnaire) and after (post-questionnaire) the teaching practice (see Figure 1). Finally, the Student Evaluation of Educational Quality (SEEQ) survey is carried out to obtain perceptions, not only of the RPL intervention, but of the entire course.

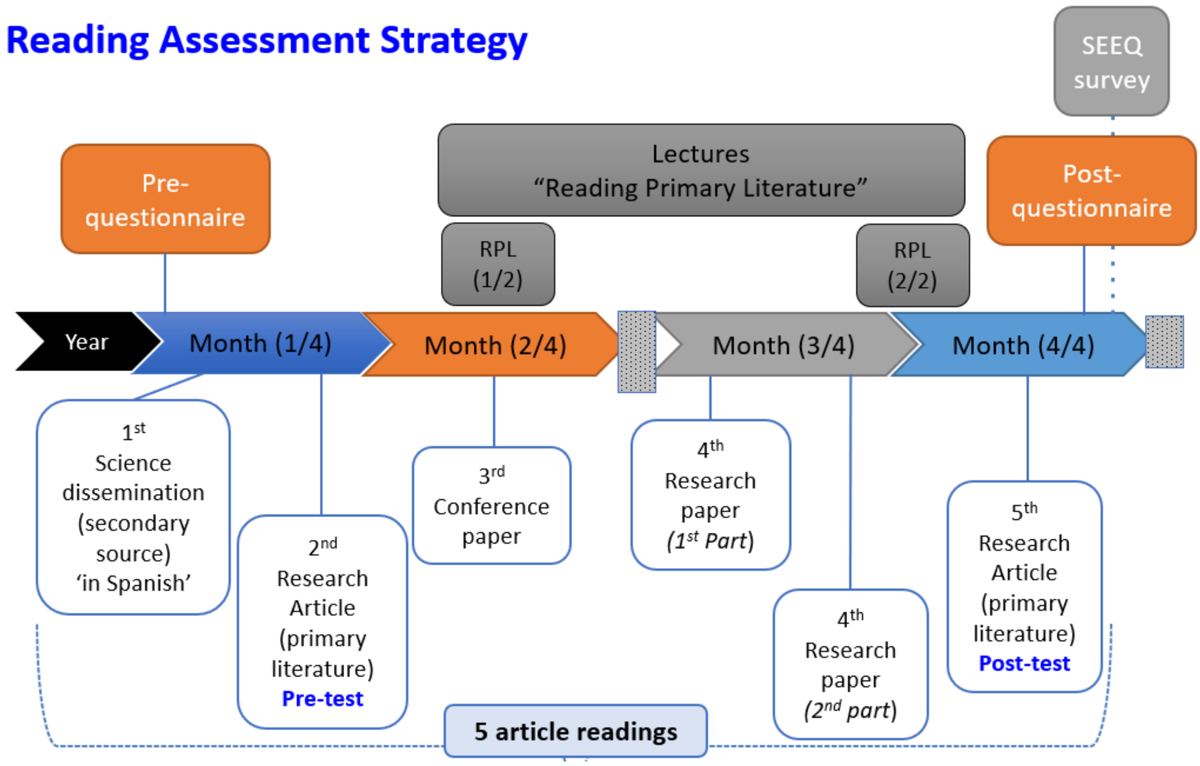

Fig. 1. The lectures on reading primary literature and reading assignments as post/out-class activities: the warm-up readings (1st, 3rd and 4th, part one and part two) and the test readings (pre-test 2nd and post-test 5th)

The intervention design presented is readily adaptable to other cases (f.i., subjects, classrooms, universities, etc.) to allow for rapid implementation in the learning environment. A more detailed explanation and context can be found in Gamez-Montero and Rodero-de-Lamo (Gamez-Montero and Rodero-de-Lamo 2023).

3 RESULTS

The data represent the 2023 fall semester student cohort, consisting of 72 students taking the pre- and post-tests (90% of the enrolment figure of 80 students).

3.1 Performance in the pre- and post- tests

The main objective of this intervention was to assess the ability of students to read research articles and their progression through a scheduled design, as shown in Figure 1. The test consisted of ten questions: five open-ended questions manually graded by the instructor’s using a rubric and grouped as “Research Argumentation”

(RA), as well as five computer-based multiple-choice questions grouped as "Contents and Results" (C&R). The students' grades in the pre-test were subtracted from the post-test grades, and the resulting distributions of the differences can be observed in Figure 2.

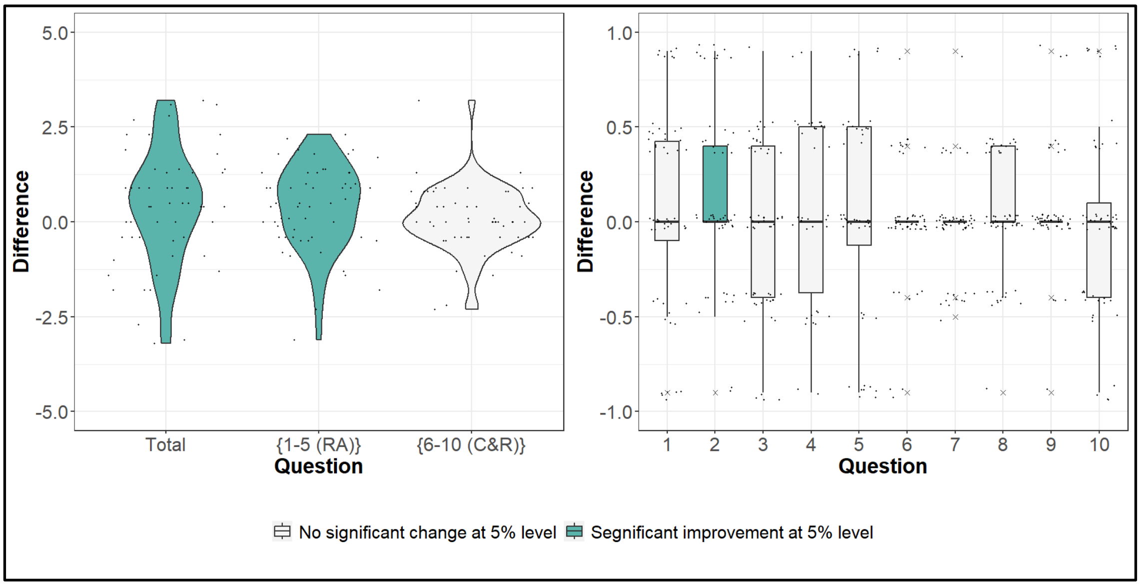

Fig. 2. Difference between the student post- and pre-test performance

The right section of the Figure 2 shows the distribution for individual questions, with adjusted box-plots. The left section of the figure shows the questions grouped by RA, C&R and Total, with violin-plots portraying the estimated density function of the data. The findings in this section imply that the students' ability to read primary literature did improve slightly during the intervention; however, it was only in the open-ended questions (RA), and these changes are mainly caused by the shift in question two. C&R questions are less related to reading skills than engineering concepts.

3.2 Students' responses in the pre- and post-questionnaires

The secondary aim of the intervention was the assessment of students' perceptions of their "Capability (A)", "Ability (B)", "Skills (C)", and "Background (D)" in reading the research articles by means of two scheduled questionnaires, before and after the intervention (see Figure 1). Figure 3 shows how the average score given by students' responses to each question changed over time.

It can be observed that overall, the students' self-judgment has improved. Most questions experienced a significant increase in response scores, but questions 2(A), 3(A), 7(A), 11(B), 12(B), 13(B), 16(C) and 17(C) did show a slight shift or were almost flat. These questions are related to the research question, materials, methods, and results of the article, along with the need to use a dictionary to translate English and a textbook to understand concepts. Hence, this slight significant change observed in these questions could be attributed to the fact that the articles were not given to the students in their native language, and the course did not last enough to get fully acquainted with the English terminology in fluid mechanics. The textbook question result is aligned with the C&R results. A paired test was performed to determine the significance of the results.

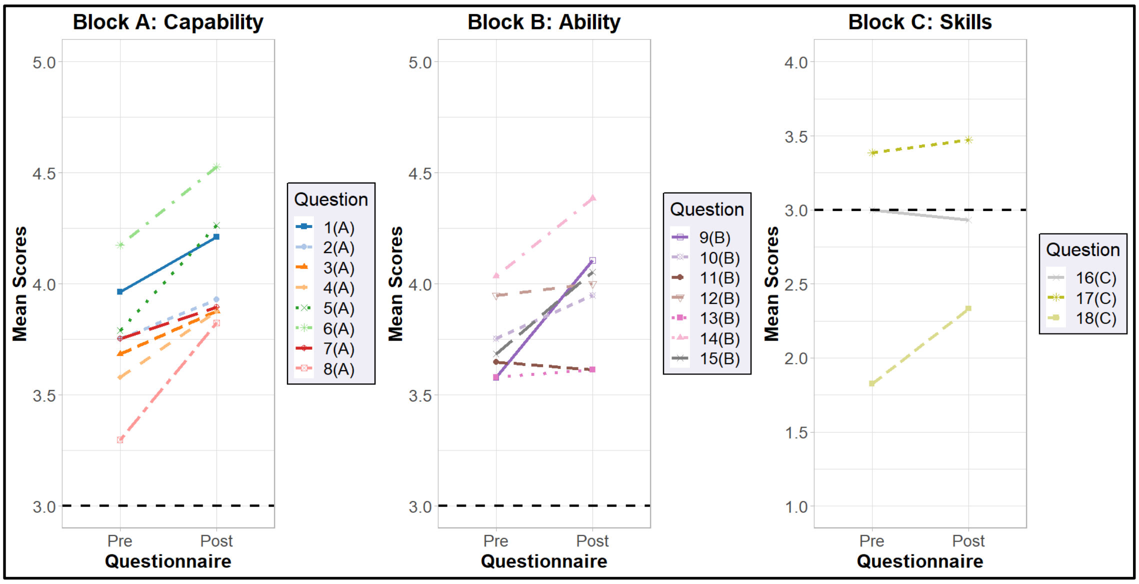

Fig. 3. Shift in students' average responses from pre- to post-questionnaire

Aside from the aforementioned cases, the improvements were shown to be significant at a 5% level using a Wilcoxon-signed test.

3.3 Conclusions

Through the four-month program, the students were given a set of tasks and lectures to enhance their engineering skills in reading research articles. The results of the tests, along with the questionnaires, showed that the strategy is satisfactory. This is both reflected by the students' perception of self-improvement as well as through the positive shift in grades, although it is worth noting to mention that the latter one was only observed in open-ended questions. This methodological approach still has room to grow, and as a future work based on the lessons learned, it will include citations as a factor in the selection of readings as a worthy bibliometric index to value the quality of the paper. In addition, a positive benefit will arise by providing a glossary with the main important words and descriptions in the articles to supplement them with additional information to aid readers in comprehending complex scientific concepts, since the vocabulary in research articles can differ drastically from the usual day-to-day English (Kararo and McCartney 2019).

4 SUMMARY AND ACKNOWLEDGEMENTS

The innovative educational research presented in this work has potential for educating responsible engineers; reading research articles makes it easier to embrace the challenging concepts of "roles of engineers" and "value of learning" that come with flourishing as engineer, and thinking and understanding as one. Students begin to take responsibility for their education, evolving into "self-directed learners" and aligning their strengths. Additionally, the findings may serve as a guide for engineering educators to improve the preparation of undergraduate students.

The authors gratefully acknowledge the Universitat Politècnica de Catalunya and its Galàxia Aprenentatge 2023 project for their invaluable support and funding. The authors also acknowledge the great aptitude of the students interested in improving the quality of engineering learning and teaching.

REFERENCES

Bartels, N. "How teachers and researchers read academic articles." *Teaching and Teacher Education* 19, 7 (2003): 737–753. https://doi.org/10.1016/j.tate.2003.06.001.

Benson, L. C., Becker, K., Cooper, M. M., Hayden Griffin, O., and Smith, K. A. "Engineering education: Departments, degrees and directions." *International Journal of Engineering Education* 26, 5 (2010): 1042–1048.

Brew, Angela. "Teaching and Research: New relationships and their implications for inquiry-based teaching and learning in higher education." *Higher Education Research & Development* 22, 1 (2003): 3–18. https://doi.org/10.1080/0729436032000056571.

Bubou, G. M., Offor, I. T., and Bappa, A. S. "Why research-informed teaching in engineering education? A review of the evidence." *European Journal of Engineering Education* 42, 3 (2017): 323–335. https://doi.org/10.1080/03043797.2016.1158793.

Fernandez Carro, R. "What is a scientific article? A principal-agent explanation." *Social Studies of Science* 51, 2 (2021): 298–309. https://doi.org/10.1177/0306312720951860.

Finelli, C. J. and Froyd, J. E. "Improving Student Learning in Undergraduate Engineering Education by Improving Teaching and Assessment." *Advances in Engineering Education* (2019): 1–30.

Fry, J. and Talja, S. "The intellectual and social organization of academic fields and the shaping of digital resources." *Journal of Information Science* 33, 2 (2007): 115–133. https://doi.org/10.1177/0165551506068153.

Gamez-Montero, P. J. and Rodero-de-Lamo, L. "Effectively integrating research argumentation in syllabus learning: A case study of reading journal articles in four fourth-year engineering fluid mechanics courses." *International Journal of Mechanical Engineering Education* (2023): 1–36. https://doi.org/10.1177/03064190231194343.

Greenhalgh, T. *How to read a paper: the basics of evidence-based medicine*. London: John Wiley & Sons, 2014.

Griffiths R. "Knowledge production and the research–teaching nexus: the case of the built environment disciplines." *Stud Higher Educ* 29 (2004): 709–726.

Healey, M. "Linking research and teaching exploring disciplinary spaces and the role of inquiry-based learning." In R. Barnett (Ed.), Reshaping the university: New relationships between research, scholarship and teaching. Maidenhead, England: Open University Press/McGraw-Hill Education (2005): 67–78. http://www.delta.wisc.edu/events/bbbbalance healey.pdf.

Hermida, D. "The importance of teaching academic reading skills in first-year university courses. " *The International Journal of Research and Review* 3 (2009): 20–30.

Kararo, M. J. and McCartney, M. "Annotated Primary Scientific Literature: a pedagogical tool for undergraduate courses." *PLOS Biology* 17, 1 (2019). https://doi.org/10.1371/journal.pbio.3000103

Kozeracki, C. A., Carey, M. F., Colicelli, J., and Levis-Fitzgerald, M. “An intensive primary-literature–based teaching program directly benefits undergraduate science majors and facilitates their transition to doctoral programs.” *CBE—Life Sciences Education* 5, 4 (2006): 340–347. https://doi.org/10.1187/cbe.06-02-0144.

Lohmann, J. R. “Global engineering excellence: the role of educational research and development.” *Revista de Ensino de Engenharia* 27, 3 (2009): 33−44. http://revista.educacao.ws/revista/index.php/abenge/article/view/64

Parkinson, J. and Adendorff, R. “The use of popular science articles in teaching scientific literacy.“ *English for Specific Purposes* 23, 4 (2004): 379–396. https://doi.org/10.1016/j.esp.2003.11.005.

Sanchez-Carracedo, F., Trepat de Ancos, E., and Barba Vargas, A. “Successful engineering lecturing based on neuroscience.” *International Journal of Engineering Education* 37, 1 (2021): 115–132.

Singer, S. and Smith, K. A. “Discipline-based education research: Understanding and improving learning in undergraduate science and engineering.” *Journal of Engineering Education* 102, 4 (2013): 468–471. https://doi.org/10.1002/jee.20030.

Yeong, F. M. *How to read and critique a scientific research article: Notes to guide students reading primary literature*. London: World Scientific Publishing Company, 2014.