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Novel Courses for the Professional Development of Graduate Students: Results and Reflection

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Novel Courses for the Professional Development of Graduate Students: Results and Reflection

Abstract

The Paul-Elder model of critical thinking has been adopted as the pedagogical framework for two, one-credit graduate courses for engineering (STEM) graduate students at the University of South Carolina. The courses aimed at explicit instruction in development of critical reading and writing skills. Course 1 is for new graduate students who need to develop an understanding of the literature for their research projects. This course focuses on finding, assessing, and critically reading the research literature relevant to their new project. Course 2 is for graduate students who are preparing to write or present their work in a professional venue. The second course focuses on writing, in the standards of the discipline, but with an explicit view of meeting critical thinking standards. These courses were developed to address common faculty concerns about their graduate students, e.g. poor writing skills; inability to comprehend and act on the literature; inability to develop independence of thought; etc.

This paper summarizes course syllabi and typical assignments and approaches to assessing student work. Work has begun on the efficacy of these courses, addressing several key questions concerning skill development. Preliminary assessment addresses the extent to which the two-course sequence promotes (a) level of mastery of information literacy skills and written communication skills; (b) the ability to produce high-quality research communications; (c) the development of scholarly independence; (d) the student's self-perception of their research capabilities and (e) ability to apply critical thinking skills. This particular implementation of the Paul-Elder framework could be adapted to different graduate program environments.

Introduction

Engineering masters and doctoral students must develop strong writing skills. Students typically prepare the first draft of research manuscripts and technical reports for sponsors, and of course they are the sole authors of their theses and dissertations. Another key writing task is preparing research proposals for a project sponsor, for a fellowship, or for a post-doctoral position. Strong writing skills are a key factor in post-graduate school success, but new graduate students matriculate with a range of writing ability. A student's progress as writer and communicator is usually assumed to develop with extensive practice via the student/advisor apprentice relation, but national studies call for new approaches to holistic and programmatic development of graduate students [1-4]. We have developed an explicit approach [5] to teach writing skills, and we deliver this with two one-credit courses that are taught in the first two years of a student's graduate program. Our approach is based on adapting the critical thinking model developed by Richard Paul and Linda Elder [6]. We have previously described these courses for engineering

(STEM) graduate students at the University of South Carolina [7]. It should be noted, however, that the tools and framework we use could be implemented in settings other than a formal course.

In this paper we review work in progress, namely the course design and the critical thinking framework [6] underpinning them. We also present results from preliminary assessment. A key premise of our approach to this course sequence is that graduate students first need explicit instruction to develop information literacy skills before they attempt major writing projects. We address this need for information literacy in our Course 1.We define information literacy as the ability to find and critically evaluate relevant research literature, and to synthesize from this the knowledge structure upon which their individual projects build. New graduate students need to develop an understanding of the knowledge structure for their research because ultimately the decision to publish or cite their primary research papers depends on demonstrating that the research has made a significant contribution to existing knowledge. Course 1 is for first-year graduate students who have chosen a research area and an advisor. Course 1 focuses on finding, skillfully reading, and critically assessing the research literature relevant to the student's new project. The Paul-Elder model is used to construct tools that assist students in identifying and assessing relevant primary research literature and in writing a critical review of that literature.

Having developed skills in information literacy, graduate students in their second or third year of work take Course 2, which is for graduate students who are preparing to write or present their work in a professional venue. Course 2 focuses on understanding the audiences for their scholarly work and writing in the standards of the discipline, with instruction built upon the same critical thinking framework. The Paul-Elder model is used to construct tools that assist graduate in understanding the standards by which journal papers and proposals are reviewed, and that assist graduate students in developing the drafts of their research papers.

A brief summary of the Paul and Elder model of critical thinking (CT) as follows. Theirs is a philosophical model of critical thinking [8] with an operational definition: "a process of purposeful, self-regulatory judgment that drives problem-solving and decision-making. This process gives reasoned consideration to evidence, context, conceptualizations, methods, and criteria." [9] Compared to behaviorist or educational models of critical thinking [8] the Paul-Elder model is chosen because it focuses on inculcating individual habits and attributes, and because the process-oriented definition can be taught to engineering students as just that: a process. According to Paul and Elder, CT comprises eight Elements of Thought, and the quality of thought is to be evaluated through nine core Intellectual Standards. Table 1 lists these elements and standards and illustrates succinctly the explicit linkage between the Paul/Elder model and reading or reviewing a paper. The Elements of Thought comprise the content of a typical primary journal paper. Likewise, the Intellectual Standards correspond to the core review standards of journals and proposals. In Course 1, we have developed exercises and templates using this CT model so that students learn to identify and critically assess journal articles and other literature that is relevant to their research projects. The term project for Course 1 is a critical review of several papers. Likewise in Course 2, we have developed exercises and templates that encourage students to organize their thinking and insure that their papers address all elements of thought as well as journal review standards. The term project for Course 2 is a

draft of a significant writing product (journal article, thesis chapter, or proposal) based on their research. The Paul/Elder model of CT provides a consistent framework and vocabulary for teaching aspiring writers how experienced authors and reviewers think.

Table 1. Summary of the Paul/Elder Model of Critical Thinking			
Eight Elements of Thought	Nine Intellectual Standards		
Purpose; Questions; Assumptions; Point of View; Data/Information; Key Concepts; Conclusions; Implications	Clarity; Precision; Accuracy; Relevance; Significance; Breadth; Depth; Logic; Fairness		
Linkage with typical sections in a refereed paper			
Introduction (purpose, or specific questions); Background (previous work, concepts, prior knowledge base); Theory (concepts and assumptions); Results and Discussion (new data/information; answers to questions); Conclusions	Standards that experienced researchers expect when reviewing a journal article; standards that journal editors promote to their authorship and reviewers.		

Course 1 Design and the Critical Thinking Framework of Paul and Elder

Course 1 (information literacy) is a one-credit, P/F course meeting one hour per week. Pass/Fail grading allows the instructor to serve as a mentor/coach to the students. Course 1 is typically taught in the spring or summer after the student matriculates. This scheduling allows adequate time for a student to match with a research project and advisor and to begin some research activities. The student will have some idea of the broad purpose, importance, or applicability of the research, as well as some specific direction in the form of an initial goal or question to investigate. However, new students typically do not have a firm grasp on specifics and have difficulty identifying relevant literature and drawing useful meaning from it.

Key elements of the syllabus from the most recent offering of Course 1 are given below.

<u>Course 1 description</u>: This course is intended for M.S. and PhD students who are just beginning their research project. Graduate students should take this course in the first calendar year after admission. Students at this point typically have just been assigned to a research advisor and project, and are attempting to collect, analyze, and understand the literature on their project. This can be a daunting task for the new graduate student who has neither specific exposure to both research and critical analysis in their field, nor formal training in engineering information literacy. The purpose of Course 1 is to provide such training, using the student's own project as the focus. Everything done in this course should enhance the student's research efforts and accelerate progress to being independent and productive.

The final term project will be to write and present a literature review on some aspect of the new thesis or dissertation topic. Almost all of the intermediate assignments are

cumulative, focused on helping students write this literature review for the final term project. The course will thus accelerate the learning curve of the students and make them more productive in the early stages of their project. The final project will be a report that can be used in subsequent papers, proposals, theses, and dissertations. All work submitted will be graded using an appropriate rubric.

Learning outcomes: 1. Students will demonstrate the ability to use electronic search resources to find archival literature relevant to their research projects; 2. Students will demonstrate the ability to use citation management software to maintain literature databases, and to prepare the citations and bibliography in their writing; 3. Students will demonstrate the ability to critically analyze research literature, and to prepare a written literature review in draft form; 4. Students will demonstrate the ability to use a formal model of critical thinking to guide the identification of research literature that is relevant to their research project. 5. Students will demonstrate the ability to apply a formal model of critical thinking in the reading and analysis of research literature. 6. Students will be able to identify and define professional and ethical norms that pertain to the writing of a literature review.

The CT template below is used in Course 1 to guide students in critical reading of a single paper. It is used as a basis for several intermediate writing assignments that guide students as they find and evaluate literature [6]. An initial assignment is to fill out Part I of the template; that is students must first state the broad scientific, technological, or societal drivers and significance of their work. Next they articulate the specific goals, objectives, or research question to be addressed in their work. Typically two or three rewrites of Part I are necessary in order for students to achieve the necessary level of specificity and to sharpen the vocabulary with which they explain their project. A doctoral project in particular may ultimately have considerable breadth and depth, so for first-year students some time is spent in narrowing the scope of their literature review; that is, identifying one or two specific, short-term goals of their research and thus focusing on how to identify literature.

Part II of the template uses the eight Paul/Elder Elements of Thought to guide student reading. Course 2 students are taught how to use the library and its electronic resources for identifying possibly relevant literature. Subsequent assignments require preparing a preliminary bibliography and using the template to take notes and summarize the essential content of a given paper. The Intellectual Standards are listed on the template to remind students to evaluate papers according to the standards. "Relevance" is particularly important in the early stage of finding literature; students should focus on finding and analyzing papers that are most relevant to the specific purpose and goals of their project. After reviewing 10 or 15 papers using the template, it is easy for students to prepare an annotated bibliography. The final term paper for Course 1 requires the students to compare the papers and to write a critical review; that is a review summarizing the state of knowledge on the particular topic of student interest. It is beyond the scope of the course for this review to be completely comprehensive; the premise is that by learning to critically review 10 or 15 relevant works the student, with time, could prepare a more comprehensive review.

Template to promote critical reading and assessment of literature in Course 1.
I. Student's Project: The broad purpose of my research is
The specific goals/aims/objectives/questions of my project are
My literature review for Course 1 will focus on (specify kinds of information, concepts, content etc in
the papers to be reviewed.)
II. Critical analysis of [Paper ID]. Summarize or paraphrase the elements of the paper.
Purpose:
Questions:
Information:
Concepts:
Assumptions:
Conclusions:
Point of View:
Implications:
Intellectual Standards: Relevance, Clarity; Precision; Accuracy; Significance; Breadth; Depth;
Logic; Fairness

Students submit assignments into individual Discussion Boards in the university's learning content management system, BlackBoard. Assignments are viewable by all students. Assessment and feedback are done in a variety of ways: by peer assessment and group discussion in class, by instructor oral comments in class or in office visits, by the instructor's written comments, or by the instructor's recorded verbal comments (which can be recorded and uploaded into BlackBoard). During the course, students are strongly encourage to discuss assignments with their research advisors and to seek direction on goals and objectives for the literature review.

Course 2 Design

Course 2 is also a one-credit, P/F course meeting one hour per week. Course 2 is typically taught in the spring and students take this in the second year or third year of their graduate studies. By this time masters students are heavily occupied with writing their thesis, while doctoral students ideally are preparing a first-author manuscript or a proposal. Students thus have a good deal of data addressing one or more key research questions, and they have identified a journal in which to publish. The term project for Course 2 is a complete draft of a journal paper or, for master's students, a draft of one or two thesis chapters. Intermediate assignments in Course 2 require using a template similar to the one above to begin outlining their paper. Several drafts are submitted in BlackBoard and feedback is given using generally the same methods as in Course 1. Additional lectures and assignments are aimed at understanding the process of how papers are submitted, reviewed, and selected for journal publication. One key assignment requires students to download their journal's "Instructions to Authors" and to discuss these with their classmates. Students are particularly asked to look at the intellectual standards by which journal reviewers evaluate manuscripts, and to compare these to the nine Paul/Elder Universal Intellectual Standards. To help students with matters of style and for further understanding of how to communicate effectively with journal audiences, Course 2 uses the textbook by Joshua Schimel: "Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded."

Key elements of the syllabus for Course 2 are given below.

<u>Course 2 Description</u>: This is the second of the graduate seminar courses. The first course focused on searching and analyzing the research literature. This second course is aimed at 2nd (or 3rd) year students who are now preparing their research results for publication and presentation. Students who are preparing for their comprehensive exam proposal will also find value in this course. This second course focuses on helping students to be better and more independent writers. Students will also learn more about professional norms, procedures and ethical issues in the research and publication process.

There is a required term project, which will be a significant written product (draft of a paper, chapter, or proposal), which the student defines based on their research needs. I will give students substantive feedback on several drafts, based on an accepted model of critical thinking. This will help students understand what reviewers and editors are looking for in a high-quality publication.

The expected outcomes are that students will develop the ability to use a formal model of critical thinking to guide their writing. Students will develop ability to prepare effective written manuscripts describing original research to an audience. Students will develop the ability to analyze different audiences and to tailor their communication to a given audience. Students will be able write according to professional and ethical norms. Students will be able to define and give examples of the three federally-recognized forms of research misconduct.

General instruction on CT, the	Typical assignments leading to the final
publication process and ethics.	term project
The process of critical thinking, reading,	-Identify and analyze different audiences.
and writing, and its relationship to writing	-Write and present a 1-page description of
and publishing. The processes of	a recent or current research assignments
submitting and reviewing papers.	-Oral presentation on a result from your
Publication and research ethics. Critical	research
reading and discussion of selected papers.	-Additional 2-4 short writing assignment
Characteristics of good and bad papers.	-Final Term Project: Draft a paper,
Understanding your audiences. Writing	chapter or proposal, based on original
conventions, preparing graphs and tables.	research (1 assignment; work on all
Common writing mistakes and problems.	semester)

Instruction and activities in Course 2 follow parallel tracks, as illustrated below.

Assessment of Course 1 and Course 2

One of the course objectives is to improve the critical thinking skills of participants. We have gathered preliminary results based on a pre-post self-assessment of the information literacy course (Course 1) and the writing course (Course 2). Students provided self-assessment of CT skills at the beginning of the course (pre-course assessment), and at the end of the course (post-

course assessment). Students also provided a retrospective pre-test score, where they were asked to self-assess CT skills by reflecting back on their level of skill prior to taking the course. Students in Course 2 provided self-assessment of CT skills at the end of the course through a retrospective pre-test and a post-test. Matched sample T-tests were conducted to determine whether there was a difference in students' post-test skill levels as compared to pre-test levels.

For course 1, the students were asked to rate on a 1 to 5 scale the following questions: (1) I am able to critically analyze research literature and to prepare a written literature review. (2) I am able to use a formal model of critical thinking to guide the identification of research literature that is relevant to my project. (3) I am able to use a formal model of critical thinking to critically read and analyze research literature. Considering Course 1, there was a statistically significant difference between post-test scores and pre-test scores averaged across these 3 questions, regardless of whether the retrospective or "true" pre-test scores were used.

For course 2 the questions were: (1) I am able to use a formal model of critical thinking to guide my writing. (2) I am able to prepare effective written manuscripts describing original research to an audience. (3) I am able to analyze different audiences and tailor my communication to different audiences. While a "true" pre-test was not administered in Course 2, there was a statistically significant difference noted between post-test scores and students' retrospective pretest score. (Note: retrospective and "true" pre-test scores were available for Course 2. No statistically significant difference was noted between scores, providing support that students accurately reported CT skill levels prior to receiving instruction.) While these are pilot results with relatively few students providing data (n = 21 students in Reading; n = 26 students in Writing courses), the data are compelling to support the capability of CT training to positively impact engineering graduate students' education.

Table 2. Pilot Results of Pre-Post Self-Assessment of Critical Thinking Skills in Course 1					
READING (COURSE 1) Average Scores – Paired T Test	Mean Difference	Std. Deviation	t	df	p-value
Avg Post (3.52) – Avg "True" Pre (2.44)	1.08	0.423	10.57	16	<0 .0001
Avg Post (3.52) – Avg Retro-Pre (2.55)	0.97	0.411	10.86	20	< 0.0001
Avg "True" Pre (2.44) – Avg Retro-Pre	-0.13	0.331	-1.57	16	0.136

Note: Mean values are provided in parentheses.

WRITING (COURSE 2)	Mean	Std.	t	df	p-value
Avg Post (3.42) – Avg Retro-Pre (2.56)	0.867	0.405	10.94	25	<0 .0001

Note: Mean values are provided in parentheses.

The other global learning objectives are of course to improve the critical reading and writing skills of the students. We do not at this time have a formal, independent assessment of pre- and post-course writing skills. It is our goal to continue this work as a fully-developed research project that will produce such assessment. Until then, we are developing rubrics and are accumulating samples of student writing that would support such formal assessment. Note that

we have defined three skill levels in writing: a Very Good draft, an Acceptable draft, and an Inadequate draft. These categories correspond roughly to our experience in how an advisor works with their students in developing manuscripts. The description of these follows:

Very Good Draft: Advisor and senior co-authors can easily edit paper for submission to intended audience. Draft shows strong organization of research thought, and good understanding of audience. The main task for advisor and senior co-authors is to evaluate science and research in depth and do some editing for the specific journal or conference venue. References are essentially complete. Very few spelling/grammar issues; draft was proofread thoroughly.

Acceptable Draft: Advisor and senior co-authors must do some structure and content editing but not a major/complete rewrite. Draft requires some work on organization of research thought, and some refinement for the specific audience, as well as in-depth check and evaluation of the science and research. Some work required on references. Some spelling/grammar issues to address, and another careful proofread is needed.

Inadequate Draft: Manuscript would require major rewrite. Thoughts, information, organization, logic, and basic elements of writing are very substandard. Manuscript does not address intended audience. References incomplete, not relevant, not properly cited. Spelling and grammar issues contribute significantly to confusion and lack of clarity.

Below we present representative parts of a rubric based on the Paul/Elder CT structure that we use for assessment of writing. We use the full rubric for both instructor feedback as well as peer feedback.

PURPOSE- Overall Field of Research, Science, Technical, Societal Drivers				
Very Good Draft	Acceptable Draft	Inadequate Draft		
Understandable to a general,	Mostly clear, some confusing	Reader cannot paraphrase/		
educated audience. Hourglass	aspects; relating drivers to	explain the research drivers		
structure of thought is	research is not always clear.	in own words. Relation of		
evident. Connection between	Level of detail/information not	drivers to student research		
drivers and research efforts	consistent. Hourglass structure	unclear. Hourglass structure		
are clear. Helpful (but	mostly evident. Helpful (but	not evident. Gaps/jumps in		
optional) graphics included.	optional) graphics included.	concepts. No graphics, or		
		graphics unclear.		

SPECIFIC OBJECTIVES, FOCUS- Research goals, questions, or hypothesis				
Very Good Draft	Acceptable Draft	Inadequate Draft		
Specific focus clearly	Focus of review mostly clear;	Focus is unclear, too broad,		
identified, and relevant to	some lack of specificity	too specific, not linked to		
Purpose. Appropriate breadth	compared to Purpose. Order	overall purpose, etc.		
of focus. Good linkage of	of thoughts and paragraphs			
ideas and paragraphs.	linkage needs work. Graphics			
Graphics (optional) are	(optional) are helpful.			
helpful.				

INFORMATION- Data in the form of tables, graphs, images, or other format			
Very Good Draft	Acceptable Draft	Inadequate Draft	
Scientific information in the	Scientific information in the	Information not. Sections not	
paper relevant to the subject	paper (numbers, tables,	clearly organized. Tables,	
and clearly presented. Depth	graphics,) mostly relevant to	graphs, etc. are ineffective for	
and breadth is appropriate.	the review and reasonably	comparing information.	
Tables, graphics etc. well laid	clear, some reworking	Breadth and depth need	
out, with numbers and title,	required. Fairly easy to	major re-work. Tables,	
and there is thorough	comprehend information.	graphics etc. missing, or not	
discussion of every table,	May need more	well laid out. Lacking in table	
graphic in the body of the	breadth/depth, or may need	number and title. Text does	
text.	more focus to eliminate	not discuss every table,	
	extraneous information.	graphic, or lacks adequate	
	Tables, graphics etc. mostly	discussion.	
	well laid out and discussion of		
	these is mostly adequate.		

INFERENCES, CONCLUSIONS				
Very Good Draft	Acceptable Draft	Inadequate Draft		
Discussion, comparison,	Discussion, comparison,	Discussion, comparison,		
interpretation of information	interpretation of information	interpretation of information		
has depth, breadth and logic.	is helpful but lacking some	lacks depth, breadth, logic.		
Conclusions are clear,	depth, breadth, or logic.	Lack of critical analysis.		
specific, and relevant to the	Conclusions are given,	Conclusions are not clear,		
subject.	mostly relevant to the subject.	specific, and relevant to the		
		subject.		

<u>Reflection on Critical Thinking for Graduate Students and the Adaptability of This</u> <u>Implementation in Other Settings</u>

Critical thinking is a skill highly valued in both undergraduate and graduate education. The national studies cited at the beginning of this paper indicate that imparting these skills is not consistent nationwide, and furthermore that critical thinking skills are assumed to develop organically in graduate education. A search of ASEE conference papers since 1997 showed 98 contributions with "critical thinking" as a theme, surely an indication of the importance of the subject. Fewer than 10 of these dealt with graduate education, however. As far as the Paul and Elder model of critical thinking specifically, the University of Louisville adopted it specifically as the core of their Quality Enhancement Plan for undergraduate education, e.g. [10] As far as we have determined, the present work is the first to apply the Paul & Elder approach to the teaching of critical reading and writing to engineering graduate students.

The Course 1/Course 2 sequence was originally implemented in the University of South Carolina College of Engineering and Computing (CEC) as part of the graduate curriculum in Biomedical Engineering, which was established in 2008. Since that time, the courses have evolved into their current form and have been taken by students in all CEC PhD-granting programs. The CT model is, of course, independent of any technical field. We further contend that the skill development we seek in our courses are universal for any graduate student conducting and publishing research. To date, only one instructor has offered these courses in CEC and it is admittedly a challenge for a single instructor to grasp the depth of a research project outside of his or her particular area of expertise. In the future, departments could identify and assign their own instructors and offer the courses; having an instructor within each graduate program would certainly make it easier to understand the details of a student's research project. However, an experienced faculty member (i.e. one who has successfully mentored students, published, obtained grant funding, and served on proposal review panels) can grasp the broad purpose and goals of almost any engineering graduate research project. Furthermore, such an experienced faculty member can recognize good thinking and writing at some level, sufficient to help a novice graduate student to improve. With training and background on the CT model, the rubrics, and on how to provide efficient, effective assessment we believe that faculty in other institutions could use and adapt the approach outlined here.

Here are some suggestions on adapting this critical thinking, reading and writing approach elsewhere. First as noted above, it would be easier on the instructor if the course were taught within a given department or program (although our students seem to enjoy and value the interdisciplinary experience they currently get.) Second, we offer our courses by the usual semester (spring, summer, for all) over a 14-week period. Programs on a trimester system might have to adapt accordingly. Third, for large research groups, it should be possible for the principal investigator(s) to present our approach via research group meetings. Students could then be provided with the appropriate templates and coached to use the CT framework in both presentations as well as in the drafting of papers. We believe research advisors and their students would benefit from having a consistent intellectual framework as well as a consistent vocabulary to use in developing critical reading and writing skills. Finally, other universities might wish to offer these graduate courses on a graded (A, B, C ...) basis. A possible advantage of graded coursework is that it can be computed in the student's GPA and counted toward the formal credit hour requirements of a student's program. A disadvantage of graded coursework is that it changes the role of instructor from being a mentor/coach to being an assessor/evaluator; this could negatively affect the instructor/student dynamic.

It might also be possible to deliver the basic CT framework and certain of the templates in a short course format. Students could then be encouraged in some way to retain and use these tools as they develop research and writing skills. However, a short course approach does not allow time for students to actually find, read and analyze papers. It does not allow time for students to submit successive paper drafts, reflect on feedback and revise their writing. We have upon occasion offered these courses in a ½ semester (6 week) format but it is our opinion that lack of

time for students to think, write, and reflect on feedback noticeably degrades from course effectiveness.

References

- [1] M. A. Maher, D. F. Feldon, B. E. Timmerman, and J. Chao, "Faculty perceptions of common challenges encountered by novice doctoral writers," *Higher Education Research & Development*, vol. 33, no. 4, pp. 699-711, 2014.
- [2] CGS-ETS, "The Path Forward: The Future of Graduate Education in the United States. Report from the Commission on the Future of Graduate Education in the United States." Princeton, NJ2010.
- [3] G. E. Walker, C. M. Golde, L. Jones, A. C. Bueschel, and P. Hutchings, *The Formation of Scholars. Rethinking Doctoral Education for the Twenty-First Century*. San Francisco: Jossey-Bass, 2008.
- [4] A. I. Leshner, L. Scherer, National Academies of Sciences Engineering and Medicine (U.S.). Committee on Revitalizing Graduate STEM Education for the 21st Century., Board on Higher Education and Workforce*Graduate STEM Education for the 21st Century* (A consensus study report). Washington, DC: The National Academies Press, 2018, pp. xx, 181 pages.
- [5] R. Parker, "Skill development in graduate education," *Mol Cell*, vol. 46, no. 4, pp. 377-81, May 25 2012.
- [6] R. Paul and L. Elder, *Critical thinking : Tools for taking charge of your learning and your life*, 3rd ed. Boston: Pearson, 2012, p. 493.
- [7] M. A. Matthews, G. Kunz, D. Freeburg, and K. Brock, "A novel course sequence on critical thinking for the professional development of graduate students," presented at the American Society of Engineering Education Annual Conference and Exhibition, Tampa FL, 2019.
- [8] E. R. Lai, *Critical thinking: A literature review*. Pearson, 2011, p. 49.
- [9] P. A. Facione, "Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction. Executive Summary.," Millbrae, CA1990.
- [10] A. Thompson, P. A. Ralston, and J. L. Hieb, "Engaging Freshman Engineers Using the Paul-Elder Model of Critical Thinking," presented at the American Society of Engineering Education Annual Conference and Exposition, San Antonio, 2012. Available: <u>https://peer.asee.org/21287</u>