

# Student Reflections on a Graduate Course for Developing Research Thinking

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## ABSTRACT

Developing a researcher's mindset as the main learning outcome can ameliorate the absence of discipline specificity in a research methodology course. The purpose of this study was to assess the effectiveness of teaching such a course conceptualized with Self-Determination Theory. The effectiveness of the course was assessed by analysing student's course evaluations and one to two sentence reflective pitches of the course targeting entering graduate students that may want to assess the value of the course. The pitches from 98 students (six semesters) were coded and qualitatively analysed by two independent coders, and placed in one of three categories that, 1) directly captured the research thinking theme, 2) indirectly captured the research thinking theme, and 3) did not capture the research thinking theme. An inter-reliability of 82% was initially achieved and followed by coders resolving cases where they differed. Seventy-one percent (71%) of the pitches were in either the first or the second category, exceeding the 67% judged as the minimum threshold of success. The course successfully achieves its objective of developing, strengthening, or nurturing research thinking of graduate students. The findings from this study inform practitioners' efforts to structure courses with researcher mindset, research identity, or research thinking development outcomes. Also, this paper fulfils a need for conceptualizing and implementing instructional material for graduate students new to research in multidisciplinary settings.

## KEYWORDS

Research thinking,  
Self-determination theory,  
Broader impact, Creativity

## PUBLICATION

Submitted:  
20<sup>th</sup> June 2025

Accepted after revision:  
8<sup>th</sup> February 2026

## Introduction

Many engineering graduate programs require a research methodology course. Most of these courses are discipline specific and tend to focus on contemporary discipline tools. More than two decades ago, there was a need for a course that would jumpstart student research proposal development at the author's institution, soon after their arrival. The course evolved over the years. The main evolution

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embodied the transition from mainly focusing on proposal preparation to strengthening the development of a researcher's mindset or research thinking or researcher identity. Although students still write a proposal, it is more of a vehicle or instrument to achieve the research thinking outcome. It is well accepted that research thinking is critical for driving innovation and discovery, solving societal problems, and generally navigating the complexities of our world. Strengthening a research's mindset in graduate engineers early gives them a head start on the trajectory to innovation and discovery. The conceptualization of the course content and its delivery were driven by the Self-Determination Theory (SDT), first developed by Deci and Ryan (2000). Three basic human psychological needs of autonomy, competence, and relatedness define the SDT concept. The SDT has been applied before in the classroom with the goal of creating a need-fulfilling environment, e.g., Sanguinetti (2024) in a music education and Dutt et al. (2023) in ophthalmology education.

This article details efforts to meet each need through a combination of content, how it is delivered, and associated homework assignments. The effectiveness of the course toward achieving the learning outcome of developing, strengthening, or enhancing research thinking is assessed via analysis of reflective course pitches students make at the end of the semester. The pitches are a component of the overall course evaluation. The students are asked to pitch to an imaginary new graduate student who may be interested in learning more about the course before deciding to take it. The pitch is restricted to one or two sentence. It was hypothesized that two thirds of the pitches will carry direct or indirect "research thinking" themes. The two thirds target was informed by the human-centered design and in particular from International Standards Organization pass criteria for graphic symbols (Kisaalita and Sempira, 2020). In the graphic symbols' context, the interpretation of the meaning portrayed by a graphic by 100 participants is considered a success if 67 participants get it right. In a similar manner if the course is designed to convey meaning or understanding, if 67 of 100 students who have taken the course and get the course goal right, the course should be considered successful in achieving the intended aim. The literature on graduate course evaluation mainly focuses on grade distribution and feedback from students obtained with end-of class evaluation forms. Literature to corroborate the two-thirds "pass rate" as proposed in this study has not been found. However, setting a goal and assessing if the goal is achieved is consistent with current engineering program accreditation by the Accreditation Board for Engineering and Technology, Inc. (ABET) (<https://www.abet.org/>).

## Materials and Methods

### The course

The course content is presented in terms of modules shown in Table 1. The course is structured as a story, with a beginning, a middle, and an end. Given the main course objective, the beginning was conceptualized to get the students starting with a thinking or a mindset they are familiar with (design and entrepreneurship). The middle focusses on development of the intellectual merit and broader impacts. Intellectual merit and border impacts are defined by the National Science Foundation as "The potential for the proposed project to advance knowledge and understanding within its own field or across different field," and "The potential for the proposed project to benefit society and contribute to the achievement of specific, desired societal outcomes," respectively. The end or closure is focused on ethics and an integrating view of scholarship. Also, the final proposal presentation is included as end grand finale. A flipped format (Akçayır and Akçayır, 2018; Poudel and Sharma, 2022; Tomesko et al., 2022) is used for content delivery. For almost all the modules, a previously recorded lecture (15 to 20 min) and associated Power Point (PPT) deck are provided to the students in advance. Students come to class to discuss the material in the video, PPT deck and in some cases readings. The class time is divided into three segments. The first 10 minutes are devoted to housekeeping and/or what may be in

the news that is of relevance to the module in question. For example, in one of the offerings, the trial and conviction of Elizabeth Holmes (Former CEO of Theranos, convicted for lying to stockholders about blood drop analysis technology for many diseases) was ongoing at the same time the class was covering the ethics module. The next 20 minutes are devoted to questions or comments students might have about the material they viewed or read in advance. In the last 20 minutes, the instructor provides further content/context discussion. This format encourages a high level of student participation, learning, motivation, and anxiety as reported by Poudel and Sharma, (2022).

Deeper internalization of learning effect is achieved through seven assignments, in addition to the final proposal (Table 2). Each assignment is associated with a module. For example, the first assignment is a ‘get-to-know you’ type that is completed in the first two weeks of the course and is accompanied with a 3- to 5-minute presentation by each student. The second assignment is associated with Module #4 (Research papers selection and speed-reading). The third assignment is associated with Module #6 (The perspective). In Nature Methods Instructions to Authors, perspectives are described as, “a format for scholarly reviews and discussions of the primary research literature that do not meet the criteria for a review—narrow in scope, advocating a controversial position or a speculative hypothesis or discussion work from one group—usually commissioned.” The type of perspective of interest in the course is the controversial position or speculative hypothesis. This is the central module and assignment that put students on a creative journey to come up with their own research idea. The following three paragraphs highlight how the SDT concept basic human psychological needs of autonomy, competence, and relatedness are embedded in the course. A summary of the following three paragraphs is provided in Table 3 below.

Autonomy in SDT aligns with a sense of having choice and control over one’s learning (Deci and Ryan, 2000). To facilitate this sense, three instructional elements were built into the course. First, students are free to build their proposal on a topic of their choosing. Even when they are handed a project by their mentor, they are free to use their own idea in the course. Those who choose to pursue a project from their lab, they are encouraged to make it their own through assignments #3 (described above). The metaphor used to communicate this is for the students to think of a singer who records an existing song, but gives it his/her own character, thus making it his/her own. Second, the flipped class instructional approach was built in because flipped classroom models encourage student autonomy and reverse the order of traditional classroom content such as lectures and assignments (Tomesko et al., 2022).

The Flipped Learning Network (2014) defines flipped learning as “... a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter.” The “individual learning space” speak to autonomy in SDT. Third, the open-ended nature of the assignments is interpreted as allowing the formulation of any answer as opposed to the existence of the right answer that the student has to find. In the field of psychology, open ended questions have been shown to motivate autonomy and/or behavioral change (Van Quaquebeke and Felps, 2018).

Table 1. Foundations of engineering research course content

Content (Modules)	Comment
<b>BEGINNING: Thinking (or methodology)</b>	
Module 1: Research	Methodology history – from Socrates (469-399 BC) to Fleming (1881-1955).
Module 2: Design	Covered in two topics – 1) design problem identification case study, and 2) design methodology steps.
Module 3: Entrepreneurship	Emphasis is placed on the link between technology and society. Covered in two topics – 1) innovation, and 2) entrepreneurship methodology steps.
<b>MIDDLE I: Intellectual merit</b>	
Module 4: Anatomy of publications	Selection and speed-reading
Module 5: Literature	Sources (e.g., databases) and management (e.g., EndNote)
Module 6: Elements of a perspective	Covered in three topics with examples from different fields (e.g., bioengineering, environmental engineering, computer systems engineering, and public health)
Module 7: Elements of a hypothesis	Supported by previous work, precise with dependent and independent variables, and testable.
Module 8: Seven habits of highly effective presenters	The habits and anatomy of different presentation types
Module 9: Graphics, tables and references	The difference between low- and high-quality graphics/tables.
Module 10: Experimental approaches	Translating a hypothesis into specific objectives, toward testability.
Module 11: Seven habits of highly effective observers	The habits, illustrated with well-known discoveries.
Module 12: Budgeting	Modelled after NSF style budget to show what it takes to do the work.
Module 13: Institutional assets	Examples of assets include interdisciplinary programs, core facilities, etc.
Module 14: Creativity	What is it? Is it fixed or can it be enhanced? Also serves as a transition to broader impacts.
<b>MIDDLE II: Broader impacts</b>	
Module 15: Broader impacts	The six essential elements of a successful broader impacts plan.
Module 16: Mentoring	What is in it for the mentee, the mentor, and society?
Module 17: The civilized engineer	Covered in two case studies of exemplars. Also serves as a transition to ethics and scholarship.
<b>END: Ethics, scholarship, and student presentations</b>	
Module 18: Ethics	Covered in two topics: 1) responsible conduct of research, and 2) honour in science/engineering.
Module 19: Scholarship	An inclusive view of what it means to be a scholar.
Presentations (closure)	Conference style proposal presentation judged by independent faculty, contributing 20% of the final grade.

Competence in SDT aligns with the human desire for effectiveness in one's skill, social interactions (Deci and Ryan, 2000). A number of modules are designed to build researcher skills; for example, management of research literature (Module #5), effective presentation (Module #11), and mentoring (Module #16). Most importantly, the assignments are designed to be "building bricks," so in the end, assembling the full proposal is matter of "adding mortar" to build the proposal "wall." This metaphor

is communicated to the students early so there is an understanding that decisions made at the beginning influence consecutive decisions as it may be a challenge to change the main question of the proposal a few weeks before the end of the course. The final presentations are judged by independent professors and are organized like professional conferences presentations. The stakes are usually high, because the judges contribute 20% of the grade. There is a high level of competence expected and successful students are hypothesized to feel satisfied with their level of competence.

Table 2. Foundations of engineering research course assignments

Assignment number	Statement and maximum points that can be earned <sup>1</sup>
1.	In not more than 200 words, describe your area(s) of interest, career objectives, and any other interests and/or passions you might have. Note: this will be the content of your presentation on the due date. [5 points]
2.	Using any search technique, find three research articles (NOT REVIEW ARTICLES) published in reputable journals (NOT PREDATORY JOURNALS) related to your research area and/or area of interest. Critically review one from the three and provide a one- to 1.5-page (single space) write-up (following guidelines/discussion presented in Modules #4). Note: this will be the content of your presentation on the due date. [5 points]
3.	Conduct a literature search in your area of interest and prepare a Perspective (not a standard review) advocating a hypothesis. Your report should be modelled after the Cheng et al. perspective presented in class (not the Science journal perspective) as follows: a) A cover page with a title, your name, a one sentence summary “hypothesis” statement, and the number of main text words; b) Main text not more than 1000 words, excluding cover page, references, and figure caption; c) One figure/exhibit/table Note: this will be the content of your presentation on the due date. [10 points]
4.	Now that you have a well thought out hypothesis for your proposal, state your specific objectives and briefly describe the experimental design and/or methodologies (approach) with which you plan to test your hypothesis. Provide a report with the following characteristics: a) a cover page with a title, your name, your hypothesis statement, and number of words; b) main text (specific objectives, experimental design, and/or methodologies) up to 1000 words, excluding cover page, references, and figure caption—there is no need for a long problem statement already presented in assignment #3—a few sentences to provide the context of the hypothesis will be adequate; c) one-figure/-table/-exhibit illustration. Note: this will be the content of your presentation on the due date. [5 points]
5.	Create a budget to accomplish the work you proposed in Assignments #3 and #4. Follow the relevant activities (relevant major categories) discussed in Module #12. You do not have to use the NSF form; you can come up with your own way of presenting the relevant information. [5 points]
6.	Revisit the material in the video, ppt deck, and link provided in the material on BROADER IMPACTS – IMPROVING SOCIETY. Think about how your work (being proposed) can contribute to a broader impact or impacts and in approximately 300-500 words, share your thoughts. [5 points]
7.	In approximately 500-800 words, tell us about a living “civilized” engineer you would highly recommend to emulate and why. [5 points]
8. Term project (proposal)	Use the assignments in the course as building bricks and “construct” the final wall (the proposal). Follow the instructions provided. As indicated in the class schedule, you will do a 15-min presentation of your proposal in a conference style session that will be judged by independent faculty. [50 points – 30 from the instructor and 20 from the judges]

<sup>1</sup>Ten points are awarded for class participation.

Table 3. Summary of how SDT constructs are embedded in the course

<b>Self-Determination Theory basic human psychological constructs</b>	<b>Constructs are facilitated in the course through:</b>
Autonomy - a sense of having choice and control over one’s learning.	-students building their own proposals. -flipped class instruction format. -open-ended assignments.
Competence - human desire for effectiveness in one’s skill, social interactions.	-modules specifically designed to build research skills, e.g., effective presentation. -assignments that form “building bricks” for the final proposal. -final presentations judging by independent professors.
Relatedness - the human dependence on the creation and sustenance of close relationships with others,	-get-to-know-you assignment. -anonymous presentations peer review. -broader impacts module content. -relating design, entrepreneurial, and research skills.

The social interaction is an important component of the course and is addressed in the following “Relatedness” narrative (e.g., Ibarra-Saiz et al., 2020). Relatedness in STD aligns with the human dependence on the creation and sustenance of close relationships with others (Deci and Ryan, 2000). There are four dimensions in the course that align with relatedness. First, in the first assignment, which forms the topic of the first presentations, students are asked to describe their area(s) of research interest, career objectives, and any other interests and/or passions they may have. Students with related research and/or other interest connect. In one of the offerings, three students interested in music created a song they performed on the last day of classes, as an example. Second, three of the four presentations are anonymously peer reviewed. The assignment of the presentations to peer review is based on related research themes. For example, student working in the biomaterial/biomedical device are assigned presentations in the same space. Knowing others working in the same space that may not come from the same lab or have the same mentor may create a bond and trigger a new idea. There have been instances where student seek members of their dissertation advisory committee after learning of the mentor through the mentees work in this class. Third, the course extends relatedness beyond the class or university community to a broader community or society through broader impacts-related modules (#15 to #17) and assignments (#6 and #7). Before students come to this class, they are generally familiar with how a design solution targets a problem to which society or a given community need and how a successful entrepreneur creates value for society. Broader impacts in research follows the same logic. Although research may be far removed in time to when society will see its value, however, it is important to think about this value independent of how long it might take. Additionally, while on the journey to the value, design and entrepreneurial skills may be needed to get there. The hope we had was that this relationship should be central to research thinking.

Peschl et al. (2021) have advanced seven essential and teachable entrepreneurship thinking skills for future leaders: 1) problem solving, 2) tolerance of ambiguity, 3) failing forward (the ability of students to learn from their failures), 4) empathy, 5) creativity with limited resources, 6) responding to critical feedback, and 7) teamwork approach. Each of these thinking skills is germane to design and research thinking. However, the course includes two exceptions: 1) research thinking in the absence of teamwork, and 2) presentations on the concept of scholarship (Module #19). It should be pointed out

that ethics (module #18) cuts across the three “thinkings” of research, design, and entrepreneurship and meeting the three basic human psychological needs of autonomy, competence, and relatedness, should be done ethically

### **Participants, assessment and analysis**

The course assessment survey is presented in Table 4. As shown, students are asked to provide feedback under three questions. First, the students are asked to rate each of the assignments and the proposal with a Likert scale. The second question was designed to provide insights in what was working well and areas for improvement. The third question, the main reason of the assessment was the reflective course pitch. The assessment was conducted over six consecutive course offerings (2024 spring, 2023 fall, 2023 spring, 2022 fall, 2022 spring, and 2021 fall). Of the total of 109, 98 students (90%) returned the survey. The participants’ disciplines included electrical and computer systems, mechanical, civil and environmental, agricultural, and biomedical engineering. Unfortunately, data on prior research and progress through graduate school were not collected.

The results from the first questions were tabulated according to frequency of the Likert scale scores for each assignment and the proposal. The top three “works-wells” were: 1) sequence of the assignments that lead to easy building of the final proposal, 2) providing the class material in advance—flipped mode of teaching, and 3) in class interaction/discussions. The top three “works-least” were: 1) when a student does not have a research project in mind by the beginning of the class, 2) high frequency of assignments, making it difficult to manage with other courses, and 3) short time of presentations. The results from the second question were not relevant to the subject of this paper and are not presented herein.

The reflective pitches from the third question were qualitatively analysed by two independent coders, following an approach published by Litke (2002) and previously used in the freshman seminar study (Kisaalita, 2018). Briefly, two independent coders (trained on the methodology) reviewed the reflective pitches and identified a score each pitch belonged to. The initial inter-reliability was 82%. The coders met and reconciled differences. A score of 2 was given to a pitch that contained exact research thinking theme. A score of 1 was given to a pitch that indirectly pointed to research thinking theme, and a score of 0 was given for a pitch that was on any other theme that was unrelated to research thinking development. Our institutional review board (IRB) considered our study involving student homework assessment and pitches to be the “use of existing de-identified data, previously collected as coursework, for research purposes.” As such the board returned a “Not Human Research Determination” to our IRB approval application, indicating, “the proposed activity is not research involving human subjects as defined by DHHS and FDA regulations.”

Table 4. Assessment of assignments/term project conducted in ENGR 8910 (Foundations of Engineering Research)

The seven assignments conducted in 8910 and the term project/proposal are indicated in the table below. For each item, **bold or circle** the appropriate response to the statement:

This assignment was very effective, from a learning experience viewpoint.

- Where,  
 1 = absolutely not  
 2 = not  
 3 = not sure  
 4 = yes  
 5 = absolutely yes

When done, please send the e-copy of the form back to Dr. Kisaalita (wiliamk@uga.edu) or bring a copy to the class by the last day of the final presentations.

Project/assignment	Response	Add comments, if you have any, to back up your response
#1. Area of interest	1 2 3 4 5	
#2. Review of manuscripts	1 2 3 4 5	
#3. Perspective	1 2 3 4 5	
#4. Experimental/modelling approaches	1 2 3 4 5	
#5. Budgets	1 2 3 4 5	
#6. Broader impacts	1 2 3 4 5	
#7. Civilized engineer	1 2 3 4 5	
Term project/proposal	1 2 3 4 5	

In the space below provide two sentences on: 1) What worked best for you and, 2) What worked least for you in the course.

1) Worked best:

2) Worked least:

In addition, and in one or two sentence, how do you pitch this class to a newly arrived graduate student:

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## Results and Discussion

### Assignments and final proposal

The Likert scores per assignment are summarized in Table 5. Scores below three are negligibly small. In the ‘absolutely yes bucket’ (score of 5), the proposal scored highest as expected. However, broader impact and methodology (experimental/modelling approaches) scored as well as the proposal. These three items were in the high score category. In the middle score category was the perspective and

reading of manuscript. In the low score category was the civilized engineer, the budget, and the get-to-know-you (area of interest) assignments. The low score standing for the get-to-know-you opener assignment was initially surprising. The explanations associated with the low scoring were twofold. Some students viewed the assignment as an “opener” without any learning. As such, their responses were low. One student commented that, “More an intro assignment so not really all that useful for learning. Does give an idea of what the professor expects on assignments so there is some value there...” This assignment is uploaded the first day of class and the professor provides two contexts. First, sets up writing expectations where any “story” in this class is expected to have a beginning, a middle and an end. The way the assignment is presented gives opportunity for students to easily construct their narrative as such. Second, the importance of the research area of interest is emphasized. Students are asked to think of the class as an imaginary music class, where the most important learning outcome is development or strengthening “music thinking” or “musician identity”, and/or “musician attitude.” In this imaginary music course, students bring their own instrument and song that serve as the vehicle with which practice takes the student to the desired leaning outcome. Different individual instruments may belong to the same space (e.g., research interest may be under one biomaterial space but the projects—instrument/song—students will pursue will be different). Some students who scored this assignment high, found thinking about the project (instrument) carefully at this stage provided learning. One student commented that, “This was impactful as it brought more clarity for me about my research.” Another student commented that, “Great way to have students share their background and identify the research area they are in.” The lowest scoring assignment was the budget. The relevance of his assignment was not obvious to students since it is not required anywhere in their graduate program. A representative comment to this effect was, “since it was more of what happens in the background for budgeting on the project. More of an informational piece rather than an applicable thing a graduate student would do.” A few students however visualize the value beyond the graduate program: “This assignment helped me understand the costs that actually make up a project and made [me] more aware of how carefully I should use my resources throughout my research,” and “This assignment greatly increased my exposure to this topic and how [the University] operates.”

Table 5. Frequency of Likert scale scores for the assignments and the term project (proposal)

Score <sup>1</sup> / Assignment	1 absolutely not	2 not	3 not sure	4 yes	5 absolutely yes	Total responses
Assign #1: Area of interest	1	4	16	28	49	98
Assign #2: Review of manuscripts	0	4	9	32	53	98
Assign #3: Perspective	3	1	9	30	54	97
Assign #4: Experimental/modelling approaches	1	1	0	22	74	98
Assign #5: Budgets	3	9	8	30	48	98
Assign #6: Broader impacts	0	4	2	20	72	98
Assign #7: Civilized engineer	5	5	18	22	47	97
Proposal	0	2	2	19	74	97

<sup>1</sup>In response to the statement, “This assignment was very effective, from a learning experience viewpoint.”

Given the way the proposal is developed in this class, it was not surprising that it was one of the three items with the highest “absolutely yes” (5) score. The other two high scoring items (broad impact and methodology) were not obvious. Representative comments provide the explanation for the appeal for these two items. For the broader impact, one representative comment was, “I was able to put words to why I am doing my research. This strengthened my reason to why I want to do research and what I will get out of my research.” Another student commented, “I particularly loved this assignment, it made me more aware and intentional about why I was really doing this research.” Thinking and articulating the value of the students’ research to society seemed to strike a chord with the students, by providing a higher rationale for their projects. For the methodology, two representative comments were, “#4 [Assignment #4] was helpful in explaining and researching how the project would function. However, providing detailed methodology can be challenging if the project involves agile development and is in early stages. Nevertheless, this was necessary and extremely useful” and “Made me really sit down and evaluate/plan out the project and think through everything.” Although the students at this point have little experience with the methodology for executing their project, it seemed like thinking and putting the approach together brought the projects to life. As expected, some students had to go back and tweak their hypotheses for testability.

Despite the perspective being the most creative component of the course, its score was in the middle. A reason behind this score is that the concept was new to all the students and was most difficult to understand. Three examples from different disciplines are used to illustrate the concept. In one of these examples (Cheng et al., 2018) a single data point is extracted from 14 peer review papers and when these data points are assembled in a graphic, a new hypothesis emerges. The complexity nature of the perspectives is captured below with a couple of representative comments. One student commented, “I made the most mistakes here, but I learned a lot and I saw improvements on the next assignment.” Another student commented that, “I had never done a perspective before and didn’t really know what they were. Very helpful assignment for setting the pace for the rest of the semester.” A third student commented that, “The best assignment in my opinion—it really forces students to think about how they will be moving science in the selected area forward by offering a new hypothesis and narrowing in on the work of interest. This assignment also serves as a great outline for the preliminary studies section of a proposal/future work.”

### **Reflective pitches**

In Table 6, three representative pitch quotes under each of scoring categories are presented. As shown pitches under category “2” contain phrases that exactly captured the main intent of the course, with phrases like developing a research mindset, developing a research identity, preparing for a research career. The focus is way beyond the graduate school. On the other hand, pitches under score “1” category contain phrases that focused on the time scale of the graduate program, with phrases like proposal witting, graduate program research, etc. The pitches under score “0” category, predominantly focus on themes like quantity/quality of work expectations, non-specified value of taking the class, etc. Of the 96 pitches analysed, 25, 51, and 20 were scored under categories “2”, “1”, and “0” respectively. The combined total of categories “2” and “1” exceeded the two-thirds (67%) pass rate. The course is therefore considered effective in developing, building or enhancing the students’ research thinking.

The arguments for including score “1” counts in the total is based on Bielefeldt et al. (2010), who provided a conceptual schematic of student learning outcomes from project-based learning that traverses from knowledge and skills to attitude and identity. Therefore, the fact that this course is project-based, it is reasonable to assume that reflective pitches would capture any or a combination of

the four outcomes of knowledge, skill, attitude and identity. Bielefeldt et al. (2010) analysed project-based service-learning reflection essays and organized the student reflective themes in increasing levels of complexity in four concentric circles. The first most inner circle represented the knowledge dimension. The second circle represented skill dimension. The third circle represented the attitude dimension and the last outermost fourth circle represented the identity dimension. The suggestion with this increasing level of complexity was that knowledge and skill is a prerequisite to attitude and identity development or change. Given that a pitch can be thought of as a short reflection on the overall project-based course, student under the score of “1” may not have exhibited the exact identity (research thinking, researcher identity, or researcher attitude) at a higher level, but they are set on their way in the near future to be where the “2” scoring students are. In other words, unlike the “0” score students, who focused on a tree and could not visualize the forest, the forest vision in each “1” score student is present, albeit not as clear as that for “2” score students, and projected to get better in time.

The literature on research thinking in engineering graduate education is sparse. An example of the closest work is development of creative thinking in graduate students engaged in scientific research (Truran, 2027), in which the introduction of practical tools was expected to improve the productiveness of researchers, as well as reproducibility of research output. Another example of related work centered on developing transdisciplinary thinking (Miller and Cruz, 2025), in which the authors concluded that, “becoming a transdisciplinary researcher is not a matter of acquiring competencies, but a life-long process.” Taken together, the literature on related interventions is consistent with the notion that strengthening a research’s mindset in graduate engineers early gives them a head start on the trajectory to innovation and discovery.

The course successfully achieves its objective of developing, strengthening, or nurturing research thinking of graduate students. The findings from this study inform practitioners efforts to structure courses with researcher mindset, research identity, or research thinking development outcomes. Also, this paper fulfils a need for conceptualizing and implementing instructional material for graduate students new to research in multidisciplinary settings.

Several study limitations are worth mentioning. First, the study relied on self-reported data and there was no follow-up to monitor student overall performance in graduate school. Second, it was not possible to collect data from another institution. Since the course has not yet been adopted and/or taught long enough by other intuitions. However, these limitations do not severely compromise the conclusion from the cross-section nature of the study.

Table 6. Representative pitches under the three score categories

<b>Score “2” category for pitches directly capturing the research thinking theme<sup>1</sup></b>
1
“A class that make you <u>think and act like a researcher</u> ”
2
“ENGR 8910 teaches you how to think about research. While all the work is aimed at practicing for future publication/proposals, the soul of the class has more to do with <u>teaching a mindset</u> ”
3
“The class challenges students to become independent researchers and establishes <u>research thinking</u> . It also creates an entrepreneurial mindset and develops your soft skills.”
<b>Score “1” category for pitches indirectly capturing the research thinking theme</b>
4
“This course walks students through how to begin to write a thesis proposal from identifying your areas of interest, analysing scientific literature, applying perspectives to your research project, organizing a project timeline and budget, and considering how your research project could have broader impacts on society. This course set students up very well to begin writing a thesis by having a solid understanding of what the research project aims to accomplish and how <u>those objectives will be accomplished</u> .”
5
“ENGR8910 is a course that allows you to dive deeper into the philosophies behind research, as well as narrow in on <u>aspects of your own research</u> by encouraging you to explore preliminary studies, form a hypothesis, think about the impact it would have on society, and formulate specific objectives for an approach.”
6
“Foundations for Engineering Research is critical for any new graduate student as it offers a structured start to your research, enhancing your skills through practical assignments and leading to comprehensive <u>research project proposal</u> .”
<b>Score “0” category for pitches that do not fit in the above “2” and “1” score categories</b>
7
“I know the content looks bulky and unachievable but trust me, once you open yourself and you submit to the process, you [will] come out better than you came in.”
8
“The course is useful for both thesis and non-thesis students because it explains how research publications work. It also helps us improve our writing abilities.”
9
“It is an 8am [class] so you’re going to hate it when it’s happening but after it’s over you will be glad you did it.”

<sup>1</sup>Other phrases used in this article to describe research thinking are “researcher’s mindset” and “researcher identity.”

**Concluding Remarks**

Based on the results presented above, the course successfully achieves its objective of developing, strengthening, or nurturing research thinking among students. Students struggle the most when they come without thinking deeply about their research interest and/or project to serve as a vehicle for the learning. The students find writing the perspective the most difficult, although it is the most creative of the seven assignments. Overall, this course fulfils a need in graduate programs that particularly require research dissertations. Additionally, the findings from this study inform efforts to structure courses with guidance from Self-Determination Theory.

## Ethical Considerations

Our institutional review board (IRB) considered our study involving student homework assessment and pitches to be the “use of existing de-identified data, previously collected as coursework, for research purposes.” As such the board returned a “Not Human Research Determination” to our IRB approval application, indicating, “the proposed activity is not research involving human subjects as defined by DHHS and FDA regulations.”

We had applied for a Human Subjects approval. Our IRB gave us the go ahead to use the data without an approval number from the institution for the reason outlined above.

## Acknowledgements

The author is indebted to Prof. Brahm Verma, who conceptualized the early version of the course and taught it over 15 times. The author took over the teaching of the course, pivoted it to its current form, and has taught it over 23 times. This work was supported by funding from the author’s Georgia Athletic Association Professorship endowment.

## Declaration of Interest

The author has no conflict of interest with the content of this manuscript.

## Notes on Contributors

The author obtained his PhD in chemical engineering from the University of British Columbia. He is currently a Distinguished University Professor of Engineering at the University of Georgia. He is a Fellow in several professional societies, including AAAS. One of his areas of teaching/research interests is “development engineering.”

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