

Characterizing Research Self-Efficacy among Undergraduate Engineering Students

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Abstract—This full research paper seeks to understand the self-efficacy of engineering students in a research communication course. Grounding our investigation into Bandura’s assertion that personal beliefs about one’s effectiveness are pivotal for motivating actions, we hypothesize that students’ self-efficacy and their positive perceptions of their abilities are crucial for enhancing their learning experiences. Self-efficacy in general is a well-researched area in undergraduate education but there are very few studies that focus on research self-efficacy of undergraduate engineering students. This study was conducted in an undergraduate-level engineering classroom at an Engineering University located in India. The goal of this research was to assess the research self-efficacy of students enrolled in a research communication course. A multi-methods approach was used to assess the self-efficacy development of 77 students. A pre-post 5-point Likert Scale survey was used to collect the quantitative data and the results of the analysis revealed that students showed a statistically significant gain in research self-efficacy from pre to post test, suggesting that the course effectively improved the research self-efficacy levels of the students. The qualitative data was collected using an open-response tool. The responses were analyzed using thematic analysis; the results highlighted that the students expressed the need for mentorship and guidance on research. The students also showed eagerness and a positive attitude to learning research techniques. Further, the post-survey questions were analyzed, and the analysis revealed that upon completion of the course, students felt competent in conducting literature reviews. They also felt more confident in framing the research problems, writing academic papers, and doing presentations. This improvement illustrates the impact of the course in improving research self-efficacy and also in equipping students with skills crucial for academic and professional success. However, some students also expressed challenges with designing their research methodology sections. This indicates the areas where further support and instructional focus could be beneficial. Overall, the findings of the study highlight the course’s success in enhancing students’ research self-efficacy and skills, while also pointing to the necessity of continuous support and targeted instruction to address identified challenges.

Keywords— *Self-efficacy, Learning, Research approaches*

I. BACKGROUND

Research is and remains to be a vital part of undergraduate engineering education. However, when it comes to undergraduate research writing, engineering students tend to

struggle as research writing is based around extensive literature survey and writing both of which have been indicated as not the strongest suits for engineering students. Through this study we aim to evaluate the efficacy of teaching academic research writing to engineering students through the use of: a) engineering taxonomy, b) a process driven research schema and c) problem solving components in order to change student perceptions of research. Since the goal of the course was to develop research writing ability amongst the engineering undergraduate students, we aimed to assess their research self-efficacy. Therefore, the primary goal is to characterize the research self-efficacy of undergraduate engineering students undertaking a research communication course, based on a socio-cognitive viewpoint on learning.

A. Self-Efficacy

Self-efficacy can be characterized as a construct which describes a person’s belief in their ability to succeed in a particular situation or achieve a particular goal [1]. According to Bandura, self-efficacy can be defined as “an individual’s belief in his or her own ability to organize and implement action to produce the desired achievements and results” [2]. When someone has high self-efficacy, they believe they can do a task effectively, however, when they have low self-efficacy, they believe they will fail at that endeavour [3]. It is important to note that self-efficacy is used only for specific goals/outcomes and is not used as a general and blanket term for the perception of one’s own capabilities. Self-efficacy of an individual, according to Bandura emerges from four different sources namely [3]:

1. **Mastery Experiences:** are associated with the memory of similar tasks previously performed by an individual successfully.
2. **Vicarious Experiences:** are associated with inspiration from others and are obtained by witnessing other people’s successes.
3. **Verbal Persuasion:** is associated with advice, opinion or even speech from other people.
4. **Physiological and affective states** refers to how an individual interprets information obtained via their own senses.

According to Bandura, understanding these many sources can aid in our comprehension of the formation of self-efficacy

beliefs and, more significantly, the modification of such beliefs [3]. Strong self-efficacy beliefs can support us in overcoming obstacles and being dedicated to our objectives, while low levels can have the opposite impact, leading to avoidance behaviour and unfavourable emotions that can be harmful to our well-being as well as our performance [1]. This is why understanding the self-efficacy of students becomes essential to gauge their learning more comprehensively.

B. Self-Efficacy and Learning

Self-Efficacy, according to previous studies, is a significant predictor of academic behaviour, including goal setting, self-evaluation, and learning [1][4][5]. Learning is often defined as the change in behaviour, knowledge, or brain function that results from practice, observation, or other experiences and the subsequent acquisition of new information, behaviours, or abilities [6]. According to previous literature, learning is also described as mentally arranging new information into a cohesive mental representation, integrating it with pertinent prior knowledge that has been triggered from long-term memory, and paying attention to pertinent features of the information as it comes in [7]. As indicated earlier, research indicates that self-efficacy is a crucial concept to describe how students acquire and use cognitive skills in a variety of situations to learn [8][9]. Therefore, student learning from a course can be represented by the rise of student self-efficacy for that particular course.

C. Developing Research Skills Among Engineering Students

Research is an important part of the modern engineering curricula. Experiences such as running a simulation study, assisting graduate students with their research, doing experiments, gathering and analysing data, etc. are helpful to not only students who want to pursue jobs in the academia but also teaches crucial skills that are important for industry jobs [10][11]. Research shows that undergraduate study participants show demonstrable improvements in a number of areas that are either directly or indirectly related to metacognitive development by engaging in research tasks [8]. Additionally, modern engineering curricula are primarily geared towards innovation and creating technical solutions as 21st century employers are looking at engineers not only to solve niche problems, rather they are looking at them for solutions towards bigger world problems like economic growth, environmental challenges, and public health etc. [12]. Therefore, innovation becomes one of the primary goals of engineering education and according to the framework provided by Dekoninck [12], research is one of the major skills needed for innovation, along with skills like tenacity, creativity, independence, decision-making (risk analysis, intuition) and leadership. Similarly, other scholars have also identified competencies like research and technological expertise as the primary requirements for innovation [10].

The importance of research for engineering students has been long established, however academic research writing,

which is an important part of research, remains inaccessible to undergraduate engineering students in India. This is primarily due to an ideological divide where engineering students prefer hands-on, problem-solving work, and academic research, with its emphasis on extensive literature reading and writing, which becomes difficult for students to grasp [11][13]. This is due to several factors including but not limited to factors such as: 1) Lack of a good foundation: Students receive inadequate academic writing instruction prior to enrolling in institutions. As a result, students lack the necessary skills to think critically and creatively, which are the skills required for academic research writing. 2) Lack of perceived need: Many engineering students believe that their engineering knowledge would be adequate for their jobs, and are unaware of what companies want from them, which is why they don't take academic research writing seriously enough [14].

As a result of both the aversion of engineering students toward academic research writing process as well as a lack of space for research writing within the curriculum design for engineering students, their writing self-efficacy also goes down [15][16].

D. Contextualized Approach To Teaching Academic Research Writing

Problems in academic research writing therefore persist amongst students not just at an undergraduate level but in graduate and PhD students as well [17][18]. Therefore, to solve this gap, this study suggests the following:

1. Contextualizing and renaming the basic principles of academic research writing in accordance with engineering taxonomy.
2. Organizing the various tasks research writing into a clear process which can be easily followed by the engineering fraternity.
3. Making problem solving central to all the aspects of academic research writing.

In fulfilling the aforementioned, studies suggest that academic research writing might become easier for engineering students, while simultaneously increasing their research self-efficacy [14]. Therefore, the research question addressed through this study is: To what extent does a structured research communication course increase the research self-efficacy of the undergraduate level engineering students?

II. METHODS

A. Participants

The participants for this study were 77 undergraduate engineering students, in their second-year enrolled in a research communication course. The data was de-identified prior to the analysis.

B. Context

The main objective of the Research communication course was to make students proficient in academic research writing. The Research Communication course had two major components: the 'Lecture/Discussion component' and the Lab/Tutorial component (see Fig. 1).

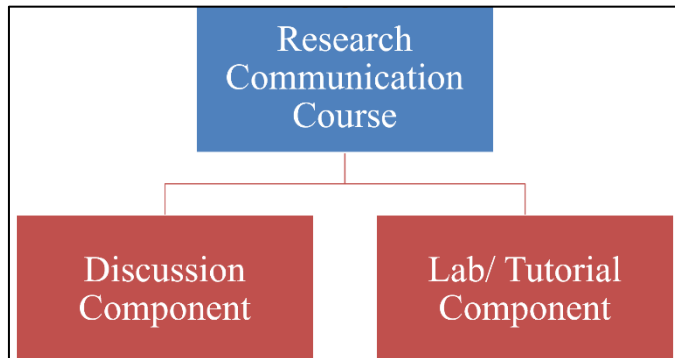


Fig. 1. Course Layout

The 'Lecture/Discussion component' had eight modules namely:

1. Decision-making: In this module, each student was introduced to critical thinking and communication skills as well as a practical skill-based experiential approach to research and decision-making.
2. Towards Self-Knowledge: This module was based on building a theoretical basis of why the rigorous research writing process is important, in the context of engineers.
3. Fields of Research: In this module, the students were allowed to identify their research interests, or decision-making arenas which align with their future goals. Here students were given autonomy so that the research process turns into a proposed solution to a real-world problem. They had to come up with a theme/field of research by the end of this session.
4. Raising a Critical Research Question: Once the field of research and the theme/problem for the paper had been identified, the important task becomes identifying a viable research question thus resulting in identifying problems and questions for research.
5. Surveying Past Solutions and Staking a Claim: The goal of this session was to identify two different contemporary solutions provided by previous research by conducting a literature review. The next step was to critique both solutions with a view to finding their limitations. Through this quest, they were able to find out the gap in the literature, which is the real problem – the problem behind the visible problem, which needs to be resolved.
6. Argumentation: In this session, the students were instructed to propose their solution to the identified gap or the hypothesis, whose validity had to be established through evidence and proper reasoning. The key was that the evidence has to be relevant and must speak directly to the question raised. Once there was an alignment between one's hypothesis and the evidence gathered through data analysis, then the students were able to form an argument with sound reasoning.

7. Self-Critique and Present Counterarguments: In this module, the students were taught to critique one's own argument and present counterarguments in order to develop the ability to view a problem from multiple perspectives.

8. Writing out your Research Paper: Finally, the students were trained to write out their research script consolidating all the aforementioned parts and giving it a coherent structure.

The first three modules of the course are not conventionally part of an academic research writing course, however, they were added to the research process so as to explain the relevance of research writing to undergraduate engineering students. Furthermore, all the sessions integratively built upon the process of research and their outputs contributed to the structure of a research script. Additionally, the entire research process was portrayed as finding a real-world problem in the field of student's choice and proposing a viable solution to that problem, thus making it more relevant to the engineering students.

The Lab/Tutorial component had two parts: writing component and a final exam.

Writing component: The major assignment and output was to write a research script of 1200 words. The Lab/Tutorial component was conducted in six weekly sessions of two hours each over a period of six weeks. Every part of the writing project was done during the tutorials itself so that the tutors can guide students on how to navigate each specific part of the research script. It was interesting to note that the final research scripts were on a variety of fields ranging from 'cryptocurrency', 'cyber-security' to social scientific fields like 'evolution of hip-hop collaborations' and 'ethics of dark tourism'.

Final exam: a quiz based upon the methods and skills taught to the students throughout the course.

C. Data Collection

The data was collected in the form of pre-post survey and reflection. All the students were required to take the survey at the start and end of the course. The survey consisted of questions that focussed on the research self-efficacy of the students. The scale used in this study was adapted from the scale created by Gary and Tom [19]. Table I consists of the sample questions that we used for our study. A total of 9 questions were used to assess the research self-efficacy of the students. Moreover, a 5-point Likert scale was deployed to assess the research self-efficacy of the students with 1 being "Strongly disagree" and 5 being "Strongly Agree". The same survey was conducted two times. The pre-survey was conducted at the start of the semester in Week 1, and the post-survey was conducted in the final week of the semester.

TABLE I. RESEARCH SELF-EFFICACY SAMPLE QUESTIONS [20]

How confident are you that you can. . . .
Do effective electronic database searching of the scholarly literature?
Use various technological advances effectively in carrying out research (e.g., the Internet)?
Formulate a clear research question or testable hypothesis?
Choose a research design that will answer a set of research questions and/or test a set of hypotheses about some aspect of practice?

Each time the survey was followed by reflection questions. The same reflection question was asked to students after every pre and post survey, the reflection question was, *“At this point, how do you perceive yourself regarding academic research? Please choose one of the choices from the options below and explain your preference in 150-200 words. (Options: 1) Novice learner: Negligible to no understanding of research, 2) Intermediate learner: good understanding of academic research but still needs some help from experts, 3) Expert learner: you have the ability to design small research studies on your own, collect data and write up results).”* Students were required to complete the reflection along with the survey.

D. Data Analysis

The study used a multi-method design to analyze the data [20]. The quantitative data was analyzed using descriptive statistics followed by a t-test. The overall research self-efficacy score was calculated by calculating the overall mean for all 9 questions. Furthermore, a t-test was used to compare the mean research self-efficacy scores for the pre and post-test. The qualitative student reflections were analyzed using a thematic analysis approach. The steps delineated by Braun and Clark [21] were followed to conduct the thematic analysis. To ensure the trustworthiness of the data, first, the 10% data was independently coded by two researchers; upon completion of the first round of coding, they met and created a code book. Based on the codebook, the 30% data was re-coded by the two researchers, and peer debriefing was conducted. This time, there was a good overlap between the coders. The remaining 70% of the data was divided among the two researchers and coded independently by two researchers. Upon completion of the final coding, inter-rater reliability was calculated, which accounted for 85% similarity in the coding process.

III. RESULTS

The paragraph below discusses the quantitative and qualitative results.

A. Quantitative Analysis

The data was analyzed using descriptive statistics and t-test. The Figure 2 shows the mean research self-efficacy scores for the pre-test and post-test. From the figure, we can observe that the students showed a gain of 0.57 points from the pre- to post-test. Furthermore, the analysis of the t-test revealed that gain

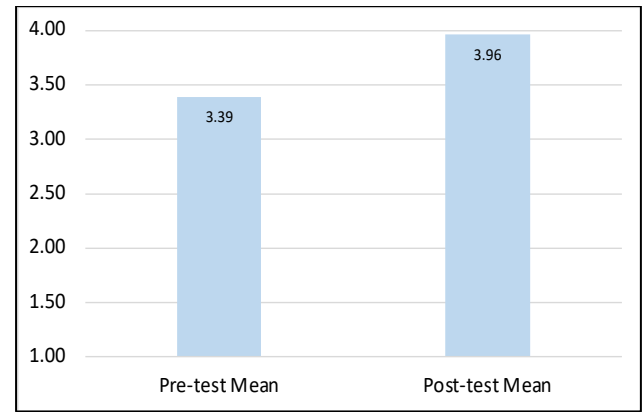


Fig. 2. Research Self-Efficacy Mean Scores

from pre-test ($M= 3.39$, $SD= 0.68$) to post-test ($M= 3.96$, $SD= 0.59$, $t= 5.61$, $p < 0.01$) was statistically significant.

B. Qualitative Analysis

The reflection questions were qualitatively analyzed using thematic analysis. The themes that were generated from the pre-survey were:

a) Pre Survey Themes

Theme 1: Students expressed the need for mentorship and guidance on research. Under this theme students expressed the need for mentorship and guidance for research as research and academic writing was very new to them. They requested assistance from the instruction team for the same. For example, S2 said *“I need substantial guidance and support from experts to navigate the world of academic research effectively”*. On the similar lines another student expressed the need for mentorship and guidance to conduct quality research, the S6 said, *“Being at this stage in my academic journey allows me to build upon my knowledge and develop my research skills further. Seeking guidance from experts can enhance the quality of my work and provide opportunities for collaboration and networking.”* On the other hand we also found a few students who felt competent in engaging with research projects, for example S11 said, *“While I can independently handle many research tasks, the insights, feedback, and guidance from experienced researchers are crucial to navigating complex issues”*. This quote highlights the finding that even when the students had prior research experience, they acknowledged having a knowledgeable mentor is always essential as it helps to navigate the complexities of the research journey.

The second theme that emerged from the data set was regarding student attitudes towards research. **Theme 2: The students also showed eagerness and a positive attitude to learning research techniques.** This theme showcases the eagerness or the urge of the students to engage in academic research. For example, S17 mentioned, *“I’m eager to learn and improve my research skills, but I have a long way to go.”* This quote reveals that students demonstrated a willingness to develop and improve their research skills as they wanted to

pursue research in the future. Similarly, student S32 said, *“My strength lies in my eagerness to learn and adapt. Each research project offers an opportunity to broaden my knowledge, refine my skills, and contribute meaningfully to the academic community.”* From this student quote, we again see that the student is motivated to pursue research and has a positive attitude toward their learning goals. In this quote, the student reflects on their experience of conducting research and how each research project has been beneficial to them to foster their research skills and contribute to the academic community. The third theme that evolved as a part of the analysis was that a majority of students expressed the challenge of analyzing the data using advanced research/statistical techniques. The theme that emerged was Theme 3: **Students lacked advanced statistical and data analysis knowledge.** For example, S15 said, *“I might face challenges in intricacies like advanced statistical analysis.”* Similarly, another student, S 48, said, *“The ability to independently design and execute research studies and effectively collect and analyze data remains a formidable hurdle.”* In both cases, we believe that students felt that they needed more support in statistical skills and wanted to develop data analysis skills.

b) Post Survey Themes

Students also completed the same survey at the end of the semester. The data was again analyzed using thematic analysis techniques. The first theme that emerged was Theme 1: **Developed Competence in Conducting Literature Reviews.** Upon completion of the course, students felt competent in conducting the literature review. For example, S 17 said, *“Initially, I grappled with structuring my thoughts coherently and engaging with academic sources critically. However, through persistent practice and guidance, I've learned to formulate clear thesis statements and support them with well-researched arguments.”* The quote reflects a student's academic growth, initially struggling with organizing thoughts and critically engaging with literary sources. Through continuous practice and expert guidance, they improved significantly. The student also mastered the art of crafting clear and logical statements and supporting them with well-researched arguments. This transformation showcases the role of expert guidance or mentorship in developing essential academic skills, demonstrating a successful transition from confusion to clarity and competence in academic writing.

The second theme that emerged from the post-reflection analysis was, Theme 2: **Students developed confidence in framing research problems and writing academic papers.** Under this theme, students described how the course helped to develop the ability to identify the research problem and develop academic writing skills. For example, a student S18 mentioned, *“After the amount of exposure this course has given me in terms of research, I am fairly confident that I have the ability to design small research studies independently and proficiently.”* This statement highlights the student's improved research skills, particularly in formulating and designing independent research projects. It reflects a deeper understanding and confidence in

navigating academic inquiries, indicating significant progress in critical thinking and analytical abilities essential for effective research. Moreover, students also mentioned that participating in the course helped them develop academic writing skills. For instance, S22 mentioned, *“This platform [Course] has provided me with valuable insights into the intricacies of writing academic papers and the various elements involved in the research process.”*

The post-survey also revealed additional themes, such as students developing critical thinking skills and feeling confident in exploring research problems. For example, S60 said, *“I think that I am now able to ask the right questions and dive deep into finding the answer to the question.”* This quote showcases the student's ability to think critically about the problem and ask the right questions. Further, the student elaborated that *“I am better informed about the ins and outs of academic research. I feel somewhat more confident about finding academic sources for my research and comparing, contrasting, and critiquing it.”* This quote shows the student's confidence in conducting research.

IV. DISCUSSION

The study focused on characterizing the research self-efficacy of undergraduate engineering students undertaking a research communication course. The study used a research self-efficacy questionnaire for students and adapted from the self-efficacy scale developed by Gary and Tom [19] to answer the primary research question: ‘To what extent does a structured research communication course increase the research self-efficacy of undergraduate level engineering students?’

Research self-efficacy for engineering students

In order to answer this research question, the survey data was collected for research self-efficacy and was analysed quantitatively using descriptive statistics and qualitatively using thematic analysis. The quantitative data analysis using a t-test showed that the research self-efficacy level of students increased significantly after they had completed the course. This result suggests that recontextualizing and streamlining academic research writing for undergraduate engineering students positively impacts their self-efficacy. This is in line with the previous literature which suggests that gaining mastery experiences impacts self-efficacy and simultaneously increases their further interest in the field [3].

Similar results were observed from the themes that emerged through the qualitative analysis. The pre-course themes revealed that students perceived themselves to be beginners in the field and they mentioned the need for mentorship and learning advanced statistics and data analysis for research. The results of the study are similar to previous literature, that undergraduate students have low research self-efficacy during the initial years of their undergraduate programme [14]. Additionally, student responses also revealed that students

showed a high affinity towards learning research techniques and academic research writing.

The aforementioned results when compared with post-test themes showed that students after taking the course developed competencies in conducting literature reviews, framing research questions and writing academic research papers, which shows the importance of expert mentorship and guidance in developing research skills, which was given to the students in the form of personalized tutorials in the course. This has also been depicted by previous research in which mentoring has been identified as one of the most important factors in fostering a research culture in university students [22].

Implications

Overall, this study has numerous implications for instructors who are looking to integrate academic research writing into their engineering courses. First, the act of deliberately reimagining and contextualizing the comprehensive process of academic research writing, and presenting it as a problem-solving endeavor specifically tailored for engineering students, significantly simplifies their comprehension and engagement with the research process. Hence, this unique approach transforms what was once perceived as *mundane* research writing tasks into an intriguing exercise which in turn has a positive impact on their research self-efficacy. Furthermore, the requirement for personalized mentorship and guidance from educators throughout this journey emerged as a critical theme. The mentorship is especially beneficial when teaching academic research writing to undergraduate engineering students. Given that the entire process is uncharted territory for them, the importance of having guidance at every pivotal step of the process cannot be overstated. This close support system not only helps them navigate through the research writing process but also builds their confidence and understanding, which are crucial for their academic growth.

V. CONCLUSION

The study's results provide ample evidence that intentionally structured research courses can help undergraduate students develop self-efficacy and curiosity in exploring research problems. The findings also suggest that such courses can help undergraduate engineering students identify their research interests, which could lead to creating a research pipeline for the future. Therefore, Higher Education Institutions are developing strategies to introduce undergraduate students to research early on in their educational journey. This strategic step of engaging undergraduate students in research will help students to get hands-on research experience and develop relevant skills to pursue higher degrees in their discipline of interest.

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