Evaluating The Role of Transdisciplinary Course Design and Its Efficacy In Teaching A Personal Communication Course For Engineering Students

Brainerd Prince
Centre for Thinking, Language and Communication
Plaksha University
Mohali, India
brainerd.prince@plaksha.edu.in

Rukmani Keshav
Centre for Thinking, Language and Communication
Plaksha University
Mohali, India
rukmani.keshav@plaksha.edu.in

Anenya Kez
Centre for Thinking, Language and Communication
Plaksha University
Mohali, India
anenya.kez@plaksha.edu.in

***Abstract*—This innovative practice full paper seeks to gauge the significance of using a transdisciplinary approach in designing a personal communication course for engineering students. The design of a humanities or a communication course is critically important when delivered to engineering students as these courses contain non-technical subject knowledge which is not a part of the regular engineering curriculum. Therefore, while conventional course design structures, typically composed of lectures, quizzes, lab work and examinations, have shown to be efficient methods for teaching core engineering courses, these same conventional course designs become ineffective for teaching communication courses in an engineering context. This research, based upon a course design innovation shows that the context provided by the core engineering course offered a meaningful and valuable environment for the practical application of personal communication course outputs. This research was conducted on a personal communication course taught to first-year engineering students. This course was redesigned through an interdisciplinary collaboration with the Programming Data Structures (PDS) course. The critical skills associated with personal communication were instructed and practised in the context of the PDS course project, as the PDS course, by design, is centred around a team-based project. However, traditionally the PDS course does not provide training on how to effectively build and communicate within a team to realize the objectives of its student projects which are always done by a team of students. Thus, the personal communication and PDS courses were able to complement one another with each one providing context for learning in the other respectively. This study uses a repeated measures research design and gathers data from 104 students using their class performance to gauge their learning efficacy and a survey that used both a subjective and objective questionnaire in which the students' perceptions of the value of transdisciplinary course design was gauged after undertaking the course. The course was taught in two parts, each culminating in a project. The first part (control group) project was done without any transdisciplinary collaboration. The second project (experiment group) had a transdisciplinary collaboration with the PDS project. The data shows that for the students, the context provided by the PDS course project offered a meaningful and valuable environment for the practical application of personal communication course outputs. Additionally, student performance data reveals that the experiment group, with collaborative design, performed better than the control group. This shows that when communication courses take on a transdisciplinary design by collaborating with another core engineering course in this case with PDS, it increases the efficacy of learning communication courses for engineering students.**

Keywords—transdisciplinary, curriculum, interpersonal skills, engineering, teaching efficacy

I. INTRODUCTION

Human beings and the societies in which we live are dynamic and constantly evolving. The complexity of issues facing our society today demands an approach to knowledge creation that equips graduates with the skills to collaborate effectively with others and synthesise knowledge across disciplines [1].

Traditional academic structures often focus on siloed disciplines and hinder the creation of integrated knowledge systems that are crucial for tackling complex planetary challenges. Engineering solutions for problems like climate change require expertise not only in traditional engineering disciplines but also in social sciences (understanding human behaviour and societal impacts) and natural sciences (comprehending the environmental systems involved). The limitations of discipline-bound knowledge become particularly problematic in these scenarios. Specialization, while valuable for an in-depth understanding, can lead to reductionism in engineering [2]. Engineers trained solely in their disciplines may struggle to see the bigger picture and how their work interacts with social and environmental factors. This can result in solutions that are technically sound but impractical, unsustainable, or ethically problematic [3].

To solve real-world problems with ethical considerations and often competing stakeholder needs, engineering graduates will need to work with a wide range of people with different backgrounds, experiences, and expertise [4], hence, the requirement of communication courses for engineers. While the engineering discipline has always demanded a strong command over technical knowledge, in our digital era engineers need to possess good communication skills to convey their ideas efficiently and persuasively to a variety of audiences, including technical experts, non-technical stakeholders, and the public [5].

As highlighted by the International Commission on Sustainable Development in 2008, the complex challenges we face, from poverty to climate change, can only be addressed by leveraging knowledge and skills from a broad range of disciplines [6]. In other words, cross-functional communication and teamwork are the way forward. Even Requests for Proposals (RFPs) from funding agencies such as National Institutes of Health (NIH) and National Science Foundation (NSF) regularly include language that emphasizes teamwork in tackling complex societal issues through interdisciplinary approaches.

However, even in these initiatives, teams from diverse backgrounds often fall into familiar patterns, with social scientists focusing on social aspects and natural scientists on the physical ones [1]. Similar dynamics often play out in engineering student group projects. Students with specific skills, like coding or project management, tend to focus solely on their designated area. This compartmentalization hinders their ability to see the “bigger picture” and effectively collaborate as a team. The project becomes a collection of individual tasks rather than a unified effort.

Hence, the role of a broader communication education that emphasizes interpersonal communication, effective teamwork, and diversity, equity, inclusion, and justice (DEIJ) principles cannot be overlooked in engineering. What is needed, then, is to bring new pedagogical innovation in the engineering curriculum to improve and develop the ability and skills of the engineering students’ communication competencies [7].

The way we pursue and apply knowledge is constantly evolving, becoming more untraditional, dynamic, global, and adaptable. This shift is reflected in the increasing use of terms like “multidisciplinary,” “interdisciplinary,” and “transdisciplinary” to describe the future of scholarship [8]. Multidisciplinarity can be characterized as a combination of disciplinary components, whereas interdisciplinarity requires methodological or conceptual synthesis with the aim of deepening knowledge and skills between two disciplines [9]. Transdisciplinarity takes this synthesis a step further by starting from two or more disciplines and applying their knowledge and skills to real-world problems or projects in collaboration with stakeholders thus seeking to equip students with enhanced learning engagement [10]. While both multidisciplinary and interdisciplinary approaches can share common goals, the key difference lies in their level of integration. To situate the integration of communication instruction in core engineering courses, we borrow Rosenfield’s framing of transdisciplinarity [11]. This transdisciplinary model stands out by creating a shared framework for achieving those common goals. Rosenfield's definition of an effective and transdisciplinary team exemplifies this concept: “The team moved as one, almost from the beginning, and showed openness and readiness to consider and combine diverse concepts” [11]. This collaborative spirit marks the initiation of the transdisciplinary process.

To bring about this collaborative spirit and address the communication needs of the engineering students in our technological university, we experimented with merging Personal Communication, a one-credit mandatory course for first-year students with their core engineering course, Programming Data Structures (PDS). This was done keeping in mind two goals. First, it broke down the artificial separation students saw between communication courses and core engineering courses such as PDS. We aimed to show how communication skills not only enhance teamwork but even improve overall course outcomes in core engineering courses. Second, it created an incentive for students to take the Personal Communication course seriously which they conventionally resist learning. The challenges remain, however, including developing an appropriate incentive and reward structure for transdisciplinary scholarship when academia remains largely structured along disciplinary lines [12].

II. BACKGROUND

Students learn best when the teaching style aligns with their preferred way of taking in and processing information. Richard M. Felder's influential model identifies four key aspects of learning styles that are particularly important in engineering education [13]. Studies suggest that many engineering students are visual, sensing, active, and sequential learners. This means they tend to learn best by: Seeing information presented visually (visual); Focusing on practical applications (sensing); Working on problems (active); Understanding details in a logical order (sequential) [14].

Conventional teaching methods can align well with the dominant learning styles in engineering education. Some educators lecture, others demonstrate and discuss; some focus on principles and others on applications; some emphasise memory and others understanding. Lectures with visuals (diagrams, graphs) cater to visual learners. Assessments that require applying knowledge to solve problems (quizzes) resonate with active learners. The focus on core principles and problem-solving steps aligns with the sensing preference for concrete information [15].

However, conventional methods have limitations. They might not cater to all learning styles and may not adequately develop the broader skill set required by modern engineering graduates. A crucial skillset often underemphasised in conventional engineering teaching is the intercultural and interpersonal communication competencies of engineers [16]. Engineering students are generally expected to passively acquire interpersonal proficiency from classroom activities, group assignments, and lab work.

However, with the advent of the digital age and Industry 4.0, society exerts greater demands on engineering students [17]. The emphasis on purely technical skills is no longer enough. Engineering graduates now need a complementary set of skills, often referred to as “soft skills,” to tackle the complex, interdisciplinary, and multicultural challenges facing our planet and society [18].

Communication, encompassing its theoretical and practical aspects, is a vital component of this skillset [5]. The practice of engineering itself has undergone a similar shift, moving beyond tasks confined to a desk. Today's engineers dedicate a significant portion of their time to non-technical activities compared to their early 20th-century counterparts. Communication sits high on this list, encompassing written design reports, client presentations, proposals for government agencies, and even global team coordination via email. A recent Industry-University-Government Roundtable for Enhancing Engineering Education surveyed 420 engineers and engineering managers in the aerospace and defence industries. When asked to rank the skills crucial for entry-level engineers, communication landed within the top 11, surpassing even the ability to design a product or work effectively in a team setting [4].

Universities and higher education have never made communication skills an utmost priority for the students [19] and so, the education system has particularly failed to train and prepare the students for the current job market which demands a good command over interpersonal skills [20]. If taught, communication is frequently essentialized to technical writing and visually appealing presentations. As a result, the empirical richness of the communication field is rarely recognized or incorporated into engineering communication training programs [4]. This narrow approach has resulted in a persistent gap between the communication skills taught in universities and the needs of the engineering workforce. The traditional way of teaching communication thus lacks preparing engineers for the job market. There is a noticeable skills gap [21]. Employers demand that engineers be able to clearly express ideas and issues within teams to avoid misunderstandings and errors to efficiently complete complex technical projects [21]. They also need the hired employees to be able to translate the technical aspects of their projects to various stakeholders in an audience-appropriate jargon. A closer engagement between academia and industry is necessary to prepare the students for career readiness [22].

Implementing a communication-intensive engineering curriculum faces several hurdles. Firstly, the pool of faculty skilled in both communication and engineering might be limited. Secondly, communication courses, perceived as subjective compared to the objective nature of core engineering subjects, can struggle to motivate students [23]. Group projects with presentations offer a potential solution for developing communication and teamwork. However, students may not prioritize these projects unless they significantly contribute to their overall grade or core subject learning.

Research shows that integrating interpersonal communication into technical engineering courses offers a roadmap for effective professional communication instruction [15]. Curriculum designers should develop curricula to obtain communication capability, i.e., the “ability to function effectively in real-life contexts” [24]. The pedagogical approaches and learning activities for the function of communication in an overall engineering curriculum can be looked at as ‘learning-to-communicate’ and ‘communicating-to-learn [25]. A broader vision for such pedagogy could be the term ‘communicating-to-engineer’. Educators should prioritize interpersonal skills as all the communication elements in engineering education contribute to factors like learning experience, maturity, motivation, and to a larger extent how communication can be proficiently and meaningfully taught and learnt [25].

To merge communication courses into the engineering curriculum, we have borrowed Rosenfield’s framing of transdisciplinarity which is distinct from a multi-disciplinary approach. According to Rosenfield [11], transdisciplinarity allows for the elimination of borders between disciplines and instead gives more permeability and flexibility across disciplines. Since most problems and situations are within the scope of multiple fields and necessitate complex evaluation, a transdisciplinary approach aligns perfectly with the need for engineers to work with diverse stakeholders.

The focus of a transdisciplinary curriculum is on inquiry-based learning, mirroring the problem-solving nature of engineering itself. Students are encouraged to ask critical questions such as “What is the problem?”, “How do we best learn and work as a team” and “How can we communicate the solution effectively?” They then actively participate in the learning process by collecting data, organizing information, and presenting their findings [26]. This approach aligns with the concept of “communicating-to-engineer,” where communication becomes an intrinsic part of the engineering learning process [25]. A **transdisciplinary approach** can offer a powerful method for developing well-rounded engineers [27].

To exemplify Rosenfield's model where "representatives of different disciplines are encouraged to transcend their separate conceptual, theoretical and methodological orientations to develop a shared approach to the research, building on a common conceptual framework" [11], we implemented a communication course in transdisciplinary collaboration with a core engineering course, "Programming Data Structures (PDS)." This approach allowed course instructors to transcend their individual disciplines to design a shared framework for achieving common goals. In this paper, we argue that engineering students learn communication skills better when the communication course is designed in partnership with a core engineering course. If engineering students are less receptive to non-engineering courses such as communication courses, especially when they are taught in isolation, then based on our research findings we put forward the argument that a transdisciplinary design that integrates a communication course with a core engineering course is not only perceived to be more useful by engineering students but also enhances their learning and performance in the course.

III. METHODS

A. Participants

The participants for this study were 104 undergraduate engineering students, in their first year enrolled in a personal communication course. The data was de-identified before the analysis.

B. Context

The course Personal Communication was designed to help students develop and improve their communication skills in various personal and social settings. The students learnt about different forms of communication, including verbal and nonverbal skills. They also explored how to effectively communicate with diverse individuals and in a variety of contexts such as relationships, teamwork, and public speaking.

C. Course Structure

The Personal Communication course consisted of two parts (5 weeks each):

Part One (Control Group): This part of the course focused on the theoretical foundations of communication through lectures, activities, and a project-based learning activity called Project 1. Project 1 did not involve any collaboration with other courses. Students were divided into teams of 6 and followed a five-step framework based on
Mitchel Resnick's "Four P's of Creative Learning".

1. *Empathetic Project-building:* Students explored the concept of communication as a tool for collaboration in "world-building projects". Here, the word 'project' is used in a broader and fundamental sense. It could include one's career, one's specific work assignment, one's family, one's social relationships, and one's entire life itself. Furthermore, a project must have a clear problem to resolve, and the resolution or solution of such problems must come through empathy. Students discussed the importance of empathy (active listening) by listening to each other's problems and then choosing a problem that was worthy of a project.

2. *Building passion with Intentionality (Passion):* Students practised passionate persuasive speech based on intentionality i.e., through deep noticing (observation) and curiosity showing ownership of the problem that was chosen to be addressed in their project. Here, each of the student demonstrated how the chosen problem resonated with themselves.

3. *Working with team members through relationality (Peers):* Students explored strategies for effective collaboration in teams, especially with team members having conflicting opinions. They focused on optimizing teamwork using the principles of relationality i.e., treating others as a "thou" rather than a "it", and assigning appropriate roles, functions, and responsibilities of the project to team members so that together they could resolve the problem and build the solution.

4. *Building Lasting Relationships through Effective Articulation (Play):* Play translates to building solutions together through effective articulation (i.e., conversations, dialogues) that results in both innovative solutions (to the problem) and long-lasting relationships.

5. *Presentation (Performance):* Presentation is the public showcasing of the student groups' project output in front of an audience.

Part Two (Experimental Group): This component mirrored the structure of the first part but solely focused on a project-based learning activity called Project 2. Project 2 involved collaboration with another engineering course, "Programming Data Structures" that the students were enrolled in during the semester. Students were again divided into teams and followed the same five-step process as Project 1, with the additional constraint that the chosen problem had to have a solution achievable through programming.

D. Data Collection

For both Project 1 and Project 2, students were required to journal their reflections on the asked prompts (mentioned in Table 1). These prompts aligned with the course framework (Resnick 4Ps) and the expected project outputs each week. These reflections contributed towards the students' grades. By journaling on these prompts throughout the course, students reflected on their communication skills development within the context of working as a team for the successful completion of the project. Additionally, at the project's conclusion, students presented their solutions to the class in their respective teams. These presentations were evaluated using a rubric that considered the significance of

TABLE I: COMBINED OUTPUTS OF PERSONAL COMMUNICATION AND PDS COURSE

Course Frame work (Resnick 4Ps)	*Personal Communication* Outputs Rubric	*Programming Data Structures* Outputs Rubric
Project	1. Autobiographical sharing (personal stories, narrative etc.) of problems 2. Empathy as Deep Listening 3. Consensus on a Problem for the Project	a. Think of a large problem that uses a programming solution from any domain. b. Significance of the problem to qualify to be taken up as a project. c. Sharing the problem with connection to data structures
Passion	1. Practice of curiosity by questioning 2. Personal reformulation/ statement of the Problem 3. Persuasive rationale for a possible Solution	a. Preparing the Detailed Software Requirement Specification (SRS) document b. Exploring the scope of various data structures that will be used. c. Team members buy-in
Peers	1. Team agreement on one Solution 2. Choose type of Final Output 3. Design a Plan of Action collaboratively to arrive at it. 4. Self-assigning Roles and Functions	a. Designing the overall solution architecture (the interface, implementation and application files layout), including the final output format b. Assigning responsibilities to different team members to author the different modules in the software
Play	1. Quality of Solution Build: Has it contributed to the solution. 2. Critical contribution of every team member 3. Amicable conflict resolution 4. Effective communication to build team and solution	a. Coding the logic behind the solution – writing the modules, including member functions b. Using test cases to check the robustness of the solution (both as individuals as well as a team) c. Debugging the software d. Interim reporting of the progress
Presentation	1. Stage Presence 2. Voice and Delivery 3. Content 4. Audio Visual Aid 5. Audience Engagement	a. Submitting the detailed documentation of the project b. Ensuring the code is well-commented. c. Refining the software d. Giving a demo of the software

the problem, the impact of the solution, the use of audio-visual materials, and presentation skills.

This research design allowed for a comparison between the control group (Part One with Project 1) and the experimental group (Part Two with Project 2) to gather insights on how integrating communication instruction with a core engineering course (for the experimental group) impacted their communication skills and project outcomes.

At the end of the course, a post-course feedback survey was conducted that focused on gauging students' perception of the effectiveness of the adopted transdisciplinary approach. The survey consisted of both quantitative and qualitative questions. Table 2 consists of the sample questions that we used for our study. A total of 7 questions were used to assess the success of the transdisciplinary course design approach. Moreover, a 10-point Likert scale was used for quantitative questions with 1 being 'strongly Disagree' and 10 being 'strongly Agree'.

TABLE II: COURSE-DESIGN EFFICACY SAMPLE QUESTIONS

How much resonance was there between 5Ps and different stages of the PDS project
What challenges did you identify in the trans-disciplinary approach?
How aligned were the session outcomes for both PDS and Personal communication course?
Did the interdisciplinarity approach of using PDS help…
Please elaborate why you liked/disliked interdisciplinary linking of the course.

E. Data Analysis

The study used a multi-method, repeated measures design to analyze the data. The quantitative data was analyzed using descriptive statistics followed by a t-test. The overall course efficacy score based on student perception rating in the survey was calculated by calculating the overall mean for all quantitative questions. Further, a paired t-test was used to compare the mean scores of students in Project 1 (control) and Project 2 (experiment group). The qualitative student reflections were analyzed using a thematic analysis approach.

IV. RESULTS

The paragraph below discusses the quantitative and qualitative results.

A. Quantitative Analysis

Descriptive statistics and t-tests were employed to analyse the data. Figure 2 depicts the mean of student perception rating of the course design's effectiveness, gathered through the survey. The Fig.2. reveals a mean rating of approximately 6.12 on a 0-10 scale. Further analysis using a t-test confirmed the statistical significance of this positive perception.

One Sample T-Test

	t	df	P
Students' perception rating of linking PDS with Personal Communication	6.192	103	< .001

Fig.1. Student Perception Rating t-test.

Descriptives

	N	Mean	SD	SE	Coefficient of variation
Student perception of linking PDS with Personal Communication	104	6.122	1.848	0.181	0.302

Fig.2. Descriptives for Student Perception of Course-Design Effectiveness

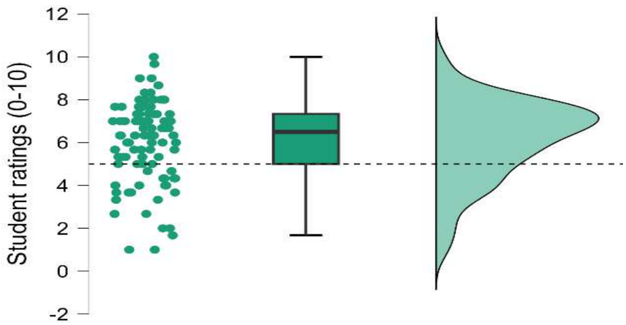

Fig.3. Student Perception of Course-Design Efficacy

Descriptives

	N	Mean	SD	SE	Coefficient of variation
Proj.1 score	104	25.006	2.152	0.211	0.086
Proj.2 score	104	27.093	1.791	0.176	0.066

Fig.4. Descriptives for Student Scores of Projects 1 and 2

Paired Samples T-Test

Measure 1	Measure 2	t	df	P
Project 1 score	Project 2 score	-7.858	103	< .001

Fig.5. Scores' for Project 1 and Project 2 paired samples t-test

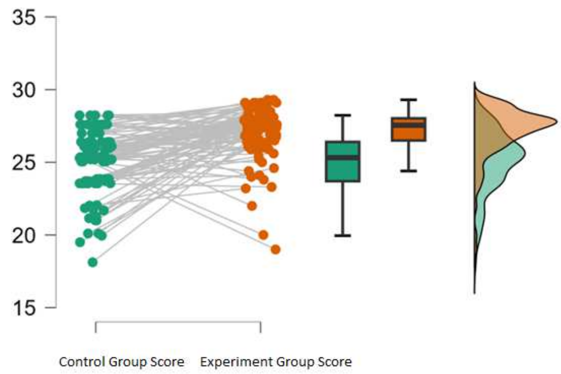

Fig.6. Student Scores for Project 1(Control) and Project 2 (Experiment)

The Figure 4 presents the average scores for Project 1 (Control Group) and Project 2 (Experimental Group). Notably, the average score for the Experimental Group on project evaluations was demonstrably higher than that of the Control Group. A paired-sample t-test corroborated this finding as statistically significant.

B. *Qualitative Analysis*

The reflection questions were qualitatively analyzed using thematic analysis. The themes that we generated from the post-course feedback survey are listed below:

C. *Feedback Survey Themes*

Theme 1: **Students appreciated the Practical application of communication skills:** Students found the transdisciplinary approach valuable because they could apply communication skills learned in the Comms course to a real-world engineering project (PDS). This helped them see the relevance of communication skills in their field. For example, S3 said, "The trans-disciplinary approach helped us apply the learning from communication courses in engineering courses." Along the same lines, S17 said, "It gave us instant applications for what we learnt in Comms, and it boosted the way we worked as a team".

Theme 2: **Enhanced teamwork and project focus:** The combined courses encouraged students to focus on both the technical aspects and their communication skills in a project setting. This fostered teamwork skills and holistic project experience. For example, S16 said, “The combining of the courses was a good idea as we get to work on our technical project with more depth... I liked it because it made us come out of our comfort zone and work on a project while working on our team dynamics.”

Theme 3: **Deeper understanding and real-world relevance**: Integrating communication training with the technical project made the PDS course more relevant to real-world problem-solving. As S5 highlights, “The communication project becomes an engineering project due to PDS, which is why it becomes more relevant... Combining a technical course with a communication course helped with expressing our technical solutions in a manner that's up to par with a communication course.” S33 mentions, “It helped me in learning new skills and coding for real-life problems.”

Theme 4: **Reduced Workload**: A few students appreciated that combining the courses reduced the overall workload compared to having two separate projects. “I liked that it was interdisciplinary and that it overlapped 2 subjects, and we had to do less work.” (This quote showcases a student who appreciated the potentially reduced workload).

Theme 5: **Transdisciplinary course Implementation Challenges:** This section encompasses the various difficulties students faced when the Communication (Comms) and PDS courses were integrated. A recurring challenge was finding a project theme suitable for both courses. As S14 said, “It was hard finding a topic that fit the criteria for both subjects and a little restrictive... The PDS part felt a little unnecessary, but it added some depth to the whole presentation.” Along the same lines, S88 says “There was not much of a crossover since if a problem was good for comms, then its application was not significant for PDS and we had to find a problem which worked for both but didn’t do justice to either, so it was not a good idea in my opinion.” Students also mentioned other issues such as unclear expectations and mismatched workloads.

Another challenge highlighted by students was that of faculty limitations. Students, like S101, highlighted limitations in faculty expertise when seeking guidance across both courses. S101 specifically mentioned that Comms TAs lacked the technical depth required to discuss the feasibility of implementing their ideas within the constraints of the PDS course (e.g., using C++). Another student points out “If only the professors of PDS could've been here to guide us more.” This lack of comprehensive faculty support across disciplines could leave students feeling unsure about the viability of their projects and hinder their ability to navigate the integration effectively.

V. DISCUSSION

The current study investigated the effectiveness of a transdisciplinary course design that combined a communication course with a core engineering course for undergraduate engineering students. This approach, informed by Rosenfield's model of transdisciplinary research, aimed to move beyond traditional disciplinary boundaries to enhance students’ communication competencies in the context of engineering education.

While acknowledging the importance of disciplinary expertise, Rosenfield emphasizes the potential for more profound and lasting impacts through transdisciplinarity compared to approaches that maintain rigid disciplinary boundaries. Through our work, faculties from different disciplines were encouraged to transcend their individual perspectives and methodologies and work together to develop a shared approach built upon a common conceptual framework to guide student projects.

The positive student perception interpreted from the survey’s qualitative and quantitative data suggests that the transdisciplinary approach has merit, particularly with respect to increasing engineering students’ affinity for communication courses when taught along with a core engineering course. Furthermore, the data (Fig.6) shows that the experiment group performed better compared to the control group indicating an increased learning efficacy. In other words, both communication competencies and technical outcomes improved when communication training is built into the technical courses.

However, a larger sample size and a more controlled study design that considers independent control and experiment groups would strengthen these findings. While some students appreciated the potentially reduced workload, others found it challenging to navigate two different courses for a common project. Therefore, finding a balance between workloads and ensuring meaningful projects that seamlessly integrate the learning outcomes of both communication and the engineering courses is crucial.

The faculty limitations highlight a need for improved communication and collaboration between faculty across different domains. This could involve workshops or training sessions to ensure that faculty from different disciplines can effectively work together to guide students on transdisciplinary projects. To refine project selection and expectations, it would be better to develop clearer guidelines and provide support to students with regard to project selection.

Addressing these identified challenges through improved faculty collaboration, clearer course expectations, and well-designed projects can further enhance the effectiveness of a transdisciplinary course design.

Finally, this research reveals the importance of nurturing a culture of openness between all stakeholders (students and faculty in this case) and the significance of effective collaboration, which is vital for attracting scholars and students accustomed to the security of orthodox disciplinary identities to transdisciplinary courses.

REFERENCES

[1] D. Baker *et al.*, "Moving toward a Trans-disciplinary Approach in the Land Grant-System: A Case Study," *NACTA J.*, vol. 53, no. 2, pp. 34–42, 2009.

[2] E. L. Boyer, "The Scholarship of Engagement," in *Building the Field of Higher Education Engagement*, Routledge, 2019.

[3] A. Bear and D. Skorton, "The World Needs Students with Interdisciplinary Education," *Issues Sci. Technol.*, vol. 35, no. 2, pp. 60–62, 2019.

[4] J. M. Williams, "Technical Communication, Engineering, and ABET's Engineering Criteria 2000: What Lies Ahead?," *Tech. Commun.*, vol. 49, no. 1, pp. 89–95, 2002.

[5] Y. Wu, L. Xu, and S. P. Philbin, "Evaluating the Role of the Communication Skills of Engineering Students on Employability According to the Outcome-Based Education (OBE) Theory," *Sustainability*, vol. 15, no. 12, Art. no. 12, Jan. 2023, doi: 10.3390/su15129711.

[6] R. Kahn, "Introduction," *Green Theory Prax. J. Ecopedagogy*, vol. 4, no. 1, pp. i–iv, Jun. 2008, doi: 10.3903/gtp.2008.1.1.

[7] C. Fischer, L. Wu, and G. Washington, "Evaluation of Online Learning in a First-year Engineering Design Course," Jun. 2018. doi: 10.18260/1-2--30453.

[8] C. Geisler, "The Relationship Between Language and Design in Mechanical Engineering: Some Preliminary Observations," *Tech. Commun.*, vol. 40, no. 1, pp. 173–176, 1993.

[9] A. Van den Beemt *et al.*, "Interdisciplinary engineering education: A review of vision, teaching, and support," *J. Eng. Educ.*, vol. 109, no. 3, pp. 508–555, 2020, doi: 10.1002/jee.20347.

[10] O. Renn, "Transdisciplinarity: Synthesis towards a modular approach," *Futures*, vol. 130, p. 102744, Jun. 2021, doi: 10.1016/j.futures.2021.102744.

[11] "Rosenfield, P.L. (1992) The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Social Science & Medicine, 35, 1343-1357. - References - Scientific Research Publishing." Accessed: May 13, 2024. [Online]. Available: https://www.scirp.org/reference/referencespapers?referenceid=1029151

[12] E. Nolan, F. D'Silva, P. Peters, A. Radjenovic, and J. Rose, "The Outside Within: Towards a Model of Transdisciplinary Integration of Communication into Engineering Design Courses," Apr. 2024.

[13] R. Felder, "Creativity in Engineering Education," *Chem. Eng. Educ.*, vol. 22, Jan. 1988.

[14] M. S. Zywno and J. K. Waalen, "The Effect of Individual Learning Styles on Student Outcomes in Technology-enabled Education".

[15] T. Rüütmann and J. Vanaveski, "Contemporary Teaching Methods Emphasizing Conceptual Understanding Adapted For Engineering Education At Estonian Centre For Engineering Pedagogy," vol. 11, 2009.

[16] D. Linvill, M. Tallapragada, and N. Kaye, "Engineering identity and communication outcomes: comparing integrated engineering and traditional public-speaking courses," *Commun. Educ.*, vol. 68, pp. 1–20, Apr. 2019, doi: 10.1080/03634523.2019.1608367.

[17] S. Çevik, A. Ustundag, C. Kadaifci, and B. Öztayşi, "The Changing Role of Engineering Education in Industry 4.0 Era," 2018, pp. 137–151. doi: 10.1007/978-3-319-57870-5_8.

[18] I. Kakepoto, A. Laghari, and T. Laghari, "Communication Skills across Engineering Curriculum: A Case Study," *Glob. Lang. Rev.*, vol. VII, no. I, pp. 23–32, Mar. 2022, doi: 10.31703/glr.2022(VII-I).03.

[19] R. Al-Mahrooqi, "English Communication Skills: How Are They Taught at Schools and Universities in Oman?," *Engl. Lang. Teach.*, vol. 5, Mar. 2012, doi: 10.5539/elt.v5n4p124.

[20] R. Belwal, P. Priyadarshi, and M. H. Al Fazari, "Graduate Attributes and Employability Skills: Graduates' Perspectives on Employers' Expectations in Oman," *Int. J. Educ. Manag.*, vol. 31, no. 6, pp. 814–827, 2017, doi: 10.1108/IJEM-05-2016-0122.

[21] J. Norback and T. Utschig, "Building a Stakeholder-Based Rubric to Enhance Student Communication Skills".

[22] S. Olson and K. Jarboe, Eds., *Engineering Societies' Activities in Helping to Align the Needs and Goals of Industry and Academia: Proceedings of a Workshopâ€"in Brief.* Washington, D.C.: National Academies Press, 2019. doi: 10.17226/25445.

[23] I. Kakepoto, A. Laghari, and T. Laghari, "Communication Barriers Among Undergraduate Engineering Students: Assignment Project," Apr. 2022, doi: 10.33195/jll.v6iI.355.

[24] H. Byrnes, "Grammar, Communicative Competence, Functions/Notions: Implications for and from a Proficiency Orientation," *Unterrichtspraxis Teach. Ger.*, vol. 17, no. 2, pp. 194–206, 1984, doi: 10.2307/3530222.

[25] C. Carlsson, K. Edström, and H. Malmström, "Engineering And Communication Integrated Learning - Collaboration Strategies For Skills And Subject Experts," Jan. 2010.

[26] B. Gürkan, "Transdisciplinary Integrated Curriculum: An Analysis of Teacher Experiences through a Design Model within the Framework of IB-PYP," *Particip. Educ. Res.*, vol. 8, no. 1, pp. 176–199, Jan. 2021, doi: 10.17275/per.21.10.8.1.

[27] J.-J. Lee and J. Chew, "Towards Design-Driven Transdisciplinary Education: Navigating the Challenges and Envisioning the Role of Design as a Facilitator," Aug. 2020. doi: 10.21606/drs.2020.344.