Breaking Boundaries: Exploring Engineering Faculty Perceptions of Transdisciplinary STEM Education

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The European Conference on Education 2024
Official Conference Proceedings

Abstract
This research paper explores the perceptions of engineering faculty about transdisciplinary STEM education. The importance of transdisciplinary STEM education, where disciplinary boundaries dissolve, comes from the authenticity of learning when STEM is taught with real-world, ill-defined, wicked problems. Where students find relevant and authentic solutions when learning by navigating between STEM disciplines as well as other disciplines. The researcher interviewed four engineering faculty from three different engineering departments in this paper. The data shows that the faculty's understandings of transdisciplinary STEM education are related to the specific fields of engineering. Civil engineering and architecture faculty use an integrative STEM approach in several levels of integration in their teaching and research. While faculty from the electrical engineering department, use less integrative approaches in teaching and research, boundaries are more solid and present. The justification behind the different levels of integrations, according to the data, is the nature of the courses taught, and the nature of the field of engineering. This research will contribute to growing research related to the transdisciplinarity of STEM education and its importance in delivering authentic, relevant, and sustainable learning experiences to students at all levels of education.

Keywords: Integrative STEM Education, Transdisciplinary Education, Engineering Education, Authentic Learning, STEM Education

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Introduction

The Transdisciplinarity of STEM education is increasingly recognized for its potential to address complex real-world problems. The term transdisciplinarity in academia, according to Bernstein (2001), is a way of thinking about education and research that challenges the opposing idea of dividing disciplines and fields of knowledge (Bernstein, 2001).

In this paper, we refer to the transdisciplinarity of STEM education to point out the full integration of science, technology, engineering, and mathematics with other disciplines, where boundaries between disciplines dissolve and fade (Bybee, 2018). This approach breaks down traditional disciplinary boundaries, encouraging authentic learning experiences and fostering innovative problem-solving skills among students (Bybee, 2018; Bernstein, 2001; Shanahan, 2016, Pratim et al. 2020). For instance, addressing wicked problems—complex, ill-defined issues with no clear solution—requires input from various disciplines to find sustainable and effective solutions. This type of education mirrors real-world scenarios where engineers must collaborate with experts from other fields to develop comprehensive solutions (Knowl, 2016, Holly, 2017, Stanly 2020).

The significance of transdisciplinary education is rooted in its ability to provide students with a more holistic, authentic, and sustainable understanding of the challenges they will face in their careers (Herrinton, 2014). Traditional education models, which often compartmentalize knowledge into discrete subjects, may not adequately prepare students for the complexities of the modern world (Baybee, 2018, Pratim et al. 2019, Honey et al. 2014).

By contrast, a transdisciplinary approach encourages students to think critically and creatively, integrating knowledge from various fields to address multifaceted problems (Bybee 2018; Harrington, 2014; Margot & Kettler 2019). This educational paradigm aligns with the needs of the 21st-century workforce, where professionals must navigate a rapidly changing landscape and collaborate across disciplines (Harrington, 2014). Also, it is one of the goals defined by the United Nations Educational, Scientific and Cultural Organization (UNESCO) Vision 2030, including globalization citizenship, and sustainable education. Moreover, this is one of the Saudi Arabian Vision 2030 goals to educate its students by providing quality education that graduates globally competitive citizens.

This research explores the perceptions of engineering faculty at Prince Mohammed Bin Fahd University (PMU) regarding transdisciplinary STEM education. Through phenomenological methodology, this study aims to understand how faculty members from various engineering departments perceive and implement transdisciplinary approaches in their teaching and research. The study's findings will contribute to the ongoing discourse on the importance of transdisciplinary education and provide insights into the challenges and benefits of implementing such an approach in higher education.

Methodology

This study employs a phenomenological methodology to capture the lived experiences and perceptions of engineering faculty regarding transdisciplinary STEM education (Creswell, 2013). Phenomenology is chosen for its effectiveness in exploring participants' subjective experiences and uncovering the essence of their perceptions (Creswell, 2013; Husserl, 1970). It will allow for a deep understanding of how faculty members conceptualize and practice STEM transdisciplinarity in teaching and research within the context of their specific disciplines. According to Creswell (2013) and Husserl (1970), phenomenology seeks to understand how individuals perceive and make sense of their experiences, making it an ideal methodology for this study.

Phenomenology also involves several key steps: bracketing, where the researcher sets aside their preconceptions; collecting data through in-depth interviews; and analyzing the data to identify common themes and patterns. This process ensures that the study captures the true essence of the participants' experiences without being influenced by the researcher's biases (Creswell, 2018; Husserl, 1970).

Methods

Participants

The study involved four faculty members from different engineering departments at PMU, including civil engineering, electrical engineering, and energy engineering. The participants were selected to provide diverse perspectives on transdisciplinary STEM education across various engineering fields. The selection criteria included faculty members with varying levels of experience in teaching and research, ensuring a comprehensive understanding of how transdisciplinary approaches are perceived and implemented at PMU.

Data Collection

Data were collected through semi-structured interviews, each lasting approximately thirty minutes. The interviews were conducted face-to-face and were audio-recorded with the participants' consent. The interview questions focused on the participants' educational backgrounds, definitions of transdisciplinary education, integration of other disciplines in their research and teaching, and perceived barriers and benefits of such integration. The semi-structured format allowed for flexibility, enabling participants to share their experiences and insights in depth while ensuring that the core topics were covered.

Data Analysis

The recorded interviews were transcribed verbatim. The transcriptions were then analyzed thematically to identify recurring themes and patterns. This process involved coding the data and categorizing the codes into broader themes. According to Braun and Clarke (2006), thematic analysis is a method for identifying, analyzing, and reporting patterns within data. It involves familiarizing oneself with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report. The analysis aimed to uncover the core themes that reflect the faculty's perceptions and practices regarding transdisciplinary STEM education.

Analysis and Findings

The thematic analysis of the interviews revealed several key themes related to the faculty's perceptions of transdisciplinary STEM education. The following table summarizes the main insights from the interviews:

Interview	Theme
Interview #1 (Male, Electrical Engineering)	Recognizes the value of interdisciplinary integration within engineering, but finds it challenging to extend to the broader fields without specific collaboration.
Interview #2 (Female, Civil Engineering)	Emphasizes the incorporation of economic and environmental aspects in engineering research, and highlights projects like carbon emission studies and the feasibility of wind farms.
Interview #3 (Female, Energy Engineering)	It focuses on sustainability and renewable energy, integrating economics into teaching.
Interview #4 (Female, Civil Engineering)	Discusses the application of sustainable materials in civil engineering and cultural considerations in design, acknowledging barriers related to curriculum and student diversity.

Table 1: Main Insights and Themes Found in the Interviews

Main Themes

Understand the Importance of Transdisciplinary STEM Education

Faculty recognize the importance of integrating multiple disciplines to address complex real-world problems. This includes the integration of STEM with broader fields such as economics, social sciences, and sustainability. For example, Dr. E emphasized the significance of sustainability and the integration of materials research in civil engineering (Interview #4). According to Holley (2017), interdisciplinary curriculum development in higher education is essential for addressing the multifaceted nature of modern challenges.

Application of Transdisciplinary in Teaching and Research

There is a variation in how transdisciplinary approaches are applied in research and teaching. Faculty from civil engineering and architecture departments employ integrative approaches more frequently compared to those in electrical engineering. For instance, Dr. C integrates economic feasibility studies in engineering projects, while Dr. B focuses primarily on technical aspects within engineering disciplines without extending to broader contexts such as culture or social sciences (Interviews #2 and #1). This variation aligns with findings by Honey et al. (2014), who noted that the degree of STEM integration can vary significantly across different educational contexts.

Barriers of Implementation

Several barriers hinder the full integration of transdisciplinary approaches in both teaching and research. These include curriculum constraints, time limitations, and the varying levels of students' preparedness. Dr. D pointed out that while she incorporates sustainability into her courses, some engineering subjects naturally limit the integration of broader disciplines due to their technical nature (Interview #3). Bybee (2018) discusses similar challenges, highlighting the need for systemic support to overcome these barriers.

Benefits of Transdisciplinary STEM Education

Faculty noted several benefits of adopting transdisciplinary methods, such as increased student motivation, better problem-solving skills, and a deeper understanding of real-world applications. Dr. C highlighted how real-life examples and projects enhance students' learning experiences and prepare them for practical challenges (Interview #2). Margot and Kettler (2019) found that transdisciplinary approaches can significantly enhance students' engagement and learning outcomes.

Discussion

The findings of this study align with recent scholarly work on transdisciplinary STEM education. Researchers such as Harrington (2020) and Honey et al. (2014) have emphasized the importance of integrating multiple disciplines to foster authentic learning experiences and prepare students for complex, real-world challenges. Engineering Faculty members at PMU recognize these benefits but also face significant barriers, similar to those reported in the literature. For instance, Klein (2017) and Bybee (2018) discuss the challenges of curriculum constraints and time limitations in implementing transdisciplinary approaches effectively.

Comparing the findings with the current literature, it is evident that while there is a strong acknowledgment of the importance of transdisciplinary STEM education, practical implementation remains a challenge. Faculty members at PMU, like their counterparts elsewhere, are navigating these challenges by focusing on integrative projects and highlighting real-world applications in their teaching. However, there is still a need for more systemic support and resources to overcome the barriers identified in this study.

The variation in the application of transdisciplinary approaches across different engineering fields at PMU reflects a broader trend in higher education (Harrington, 2020; Honey et al., 2014). While some fields, such as civil engineering, are more conducive to integrating broader disciplines due to the nature of their projects, others, like electrical engineering, face more significant challenges in doing so. This disparity underscores the need for tailored strategies to support transdisciplinary education across various contexts.

Conclusion

This study provides valuable insights into the perceptions and practices of engineering faculty at Prince Mohammed Bin Fahd University regarding transdisciplinary STEM education. The findings highlight the recognized importance of integrating multiple disciplines to address complex problems and enhance student learning. However, significant barriers such as curriculum constraints and varying student preparedness levels hinder full implementation. Future research should explore strategies to overcome these barriers and support faculty in adopting more integrative approaches. For instance, developing flexible curricula that allow for interdisciplinary projects and providing professional development opportunities for faculty could help address some of these challenges.

The implications of this study extend beyond PMU, offering insights for other institutions seeking to implement transdisciplinary STEM education. By understanding the perceptions and experiences of faculty, educational leaders can better support the adoption of transdisciplinary approaches and ultimately enhance the quality of STEM education.

Acknowledgment

This research was made possible through the generous support and funding provided by Prince Mohammad Bin Fahd University (PMU). We extend our sincere gratitude to PMU for their unwavering commitment to advancing rigid research and for their financial support, which has been instrumental in the successful completion and publication of this paper. The resources and encouragement provided by the PMU administration have greatly enriched our research capabilities and outcomes.

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