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Practical Application and Implications of Transformative Learning in an Engineering Classroom: Step-by-step Guide to the Ten Phases

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Abstract

Engineering is a discipline that involves the development, acquisition, and application of technical, scientific, and mathematical knowledge to understand design, development, innovation, and the utilisation of materials, machinery, structures, systems, and processes for specific purposes. The South African higher education is currently faced with forever changing landscapes particularly through the current era of Fourth Industrial Revolution (4IR); hence, engineering education is set to also adapt to these changes. These adjustments facilitate the evolution of teaching and learning processes, providing students with novel learning possibilities in a world marked by continuous trends. Therefore, this paper argues that there is a need for the combination of cognitive and experiential learning theories which aim to foster the complexities of internal human mental processes while developing the societal technical abilities of students and transform them into competent young professionals. This paper presents a practical application of the transformative learning theory (TLT) in an engineering classroom, its implications and impact on the students through a comprehensive reflective mechanism. The overall findings suggest that TLT in engineering education encourages students to think independently rather than relying solely on statements or arguments presented by educators. Implementing the theory promotes deeper learning because different viewpoints broaden frames of reference.

Keywords
Engineering Education, Community of Practice, Transformative Learning Theory, Student-centred and Teaching and Learning Design.

1. Introduction
With the ever-increasing global challenges, which compelled the United Nations (UN) to meet in order to formulate and introduce the Sustainable Development Goals (SDGs) as well as the Fourth Industrial Revolution (4IR), it is inevitable that engineers would be required to play a vital role (Tien et al., 2019). Therefore, the training programmes for engineers need to ensure that graduates possess the necessary requisite capabilities to avert or solve some of these challenges. These training programmes must be well structured, adequately designed, student-centred and ensure they fit well within our current South African education system.

The education and engineering worlds are not isolated from each other. Engineering systems need to operate efficiently such that they are less expensive, more durable, and faster; in contrast, education systems seek to produce highly skilled, knowledgeable, and expert persons who ideologically transform by participating in a community of practice. The fundamentals of engineering inform how an engineering design may be formulated, and learning theories are expected to inform the teaching and learning design (Newstetter and Svinicki, 2014). With this comparative notion, I submit that designing a learning architecture without a grounded learning theory is comparable to designing an airplane without applying any aerodynamic principles and laws. In both cases, the results are unfortunately dire. Theory is essential to teaching because it offers frameworks for creating educational experiences and systematic perspectives on the learning process (Briese et al., 2020).

1.1 Objectives

This paper gives a comprehensive discussion and reflection of transformative learning theory (TL) in a first-year engineering classroom. The paper discusses the framework of the transformative learning theory (TLT) which includes its origin, design principles of TLT, practical application and implications of TLT and the value it brings within the classroom context, and unforeseen limitations of TLT and ways to overcome them.

2. Transformative Learning Framework

Learning is about transformation, change, and a new way of viewing yourself differently in relation to the outside world. This is the potential of transformative learning — the way learning may occasionally change people's perspectives, empowering them to act and perceive the world in new ways (Apte, 2009, Mabuza, 2024). Through this backdrop, transformative learning theory (TLT) was first introduced to the adult education field in 1978 by an American Sociologist, Jack Mezirow, which he initially defined it as "the process by which we transform our taken-for-granted frames of reference (meaning perspectives, habits of mind, mindsets) to make them more inclusive, discriminating, open, emotionally capable of change, and reflective so that they may generate beliefs and opinions that will prove more true or justified to guide action" (Mezirow, 1978).

Since its inception, transformative learning has gained an explosive global interest and has been applied in different fields of education, including engineering education. The "transformative learning" approach has not received much attention in engineering education (Woschank and Pacher, 2020); however, it is strongly gaining grounds with several recent studies (Daramola, 2018, Joslyn and Hynes, 2022, Leung et al., 2012, Siddiqui and Adams, 2013, Tien et al., 2021) recognizing the impactful application of TLT in engineering education context.

To ensure transformative learning, cognitive and experiential learning theories are combined in engineering education at colleges and universities. The application of experiential learning theory seeks to develop the students' social skills in technical observation and social responsibility for transforming them into competent engineers, while the cognitive learning theory focuses on understanding students with regard to the complexity of human knowledge retention (Daramola, 2018). Hence, the cognitive and experiential learning theories are the two main strong pillars of effective transformative learning in the engineering education context, with the teaching philosophy being the foundation, as demonstrated in Figure 1.

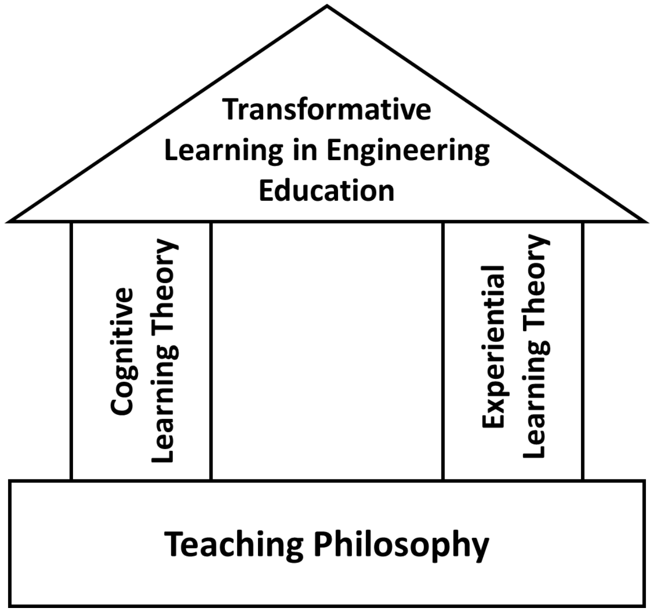

Figure 1. Fundamental pillars of transformative learning theory in engineering.

With this framework, students are expected to transform their mindset, and this transformation should be consciously remarked by the students and society since transformative learning is projected to shape individuals and reorient their thinking (Daramola, 2018). Building on the idea, Woschank and Pacher (2020) highlight that this enables students to develop creative and critical thinking through their cognitive intuition, be in contact with the actual engineering environment through "learning by doing" and society, critique some theoretical assumptions, draw a logical conclusion with respect to the analysis through sound judgement, and later self-reflect on the entire experience.

The transformative learning theory is based on two primary assumptions: (i) learners are adults, and (ii) these learners are radical and rational thought and discourse. It is easy to meet the first assumptions since the majority of university or college students are adult-aged (Mezirow, 1997). The second assumption is independent of age and may only be met conditionally, depending on the characteristics of an individual student. However, students are expected to gradually achieve the second assumption as they progress within the higher education system, provided the TLT is adequately and consistently applied (Merriam, 2004).

3. Design Principles for Transformative Learning

According to Mezirow (2008), two major principles govern transformative learning, including:

1. Instrumental: Critical reflection/self-reflection on assumptions. This includes critically assessing the nature, sources, and effects of our prior learning and habits of mind.
2. Communicative: Taking a full and open part in the dialectic conversation to support the finest reflective judgment. This is a person's approach to keeping track of the epistemic nature of issues and the veracity of potential and alternative solutions.

For these two principles to be effectively achieved, students need to go through a 10-stage-based meaningful cyclic process (Mezirow, 1978), which Collins et al. (2022) support and recommend that it should be addressed in sequential order starting from Disorienting Dilemma to Reintegration as presented in Figure 2 although some of the phases may take parallel effects. A brief discussion of how the sequence of these events unfold is given in the subsequent section.

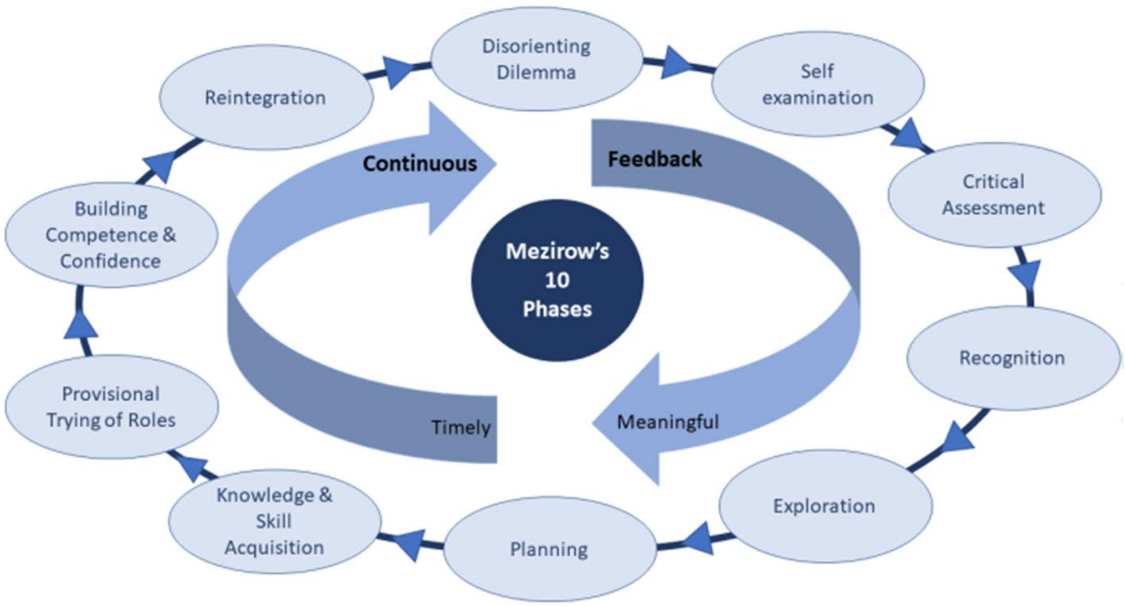

Figure 2. The ten phases of Mezirow's transformative learning (Kitchenham, 2008).

3.1 Ten Phases of Transformative Learning

As outlined by Kitchenham (2008) and Christie et al. (2015), the initial phase of the TLT is "a disorienting dilemma," in which the students encounter a problem that needs to be solved. Learning may not go as planned during this experience, which triggers the second phase, "a self-examination" with outlooks of guilt or shame. Students may encounter phase three, "a critical assessment" of epistemological, sociocultural, and psychic expectations, during the scenario or debriefing, during which they may start to doubt and alter their worldviews. Students go into phase four during debriefing conversations with their peers, where the "recognition" that one's dissatisfaction and the transformation process are shared and others have negotiated a similar change. In phase five, students develop strategies for raising their performance through "exploration" of potential new roles, connections, and actions.

"*Planning*" a course of action for the next experience during phase six, prepares the student for phase seven, which is the "*acquisition of knowledge and skills*" for executing the plans. The eighth happens when students run into a similar issue and engage in "*provisional trying of new roles*," which enables them to see the situation, themselves, and their peers from a different perspective. In phase nine, the students begin "*building of competence and self-confidence*," which allows them to improve their fluency and confidence in their transformation by implementing the new perspective. The final phase of the TLT assumes that this experience transforms students' mental habits and worldviews, and there is a "*reintegration*" into one's life based on circumstances determined by one's perspective.

4. Application and Implications of Transformative Learning in my Classroom

To demonstrate how I apply the tenets of TLT and how they may further assist me in redesigning some aspects of my teaching and learning context, I will use an applicable example of how I conduct activities in my classroom. One of the modules that I teach in our Chemical Engineering Programme at the University of Johannesburg is a first-year module called Chemical Engineering Fundamentals 1B (CEFCHB1). In general, the module aims to develop problem-solving strategies and skills using mass and energy conversation laws. In this context, my example will be confined to energy balance and how it may be used to solve related problems.

When introducing the concept of energy balance to the students, I explain to them that even though the entire equation is quite complex when written in its entirety without understanding, it can be broken down into only two parts: Part 1 is the energy that resides within the system boundaries, and Part 2 is the energy that crosses the system boundaries to and from the surrounding – see Figure 3. The equation can be divided into even more manageable components, each of which is introduced in an organized manner to assist the students in systematically building up their knowledge.

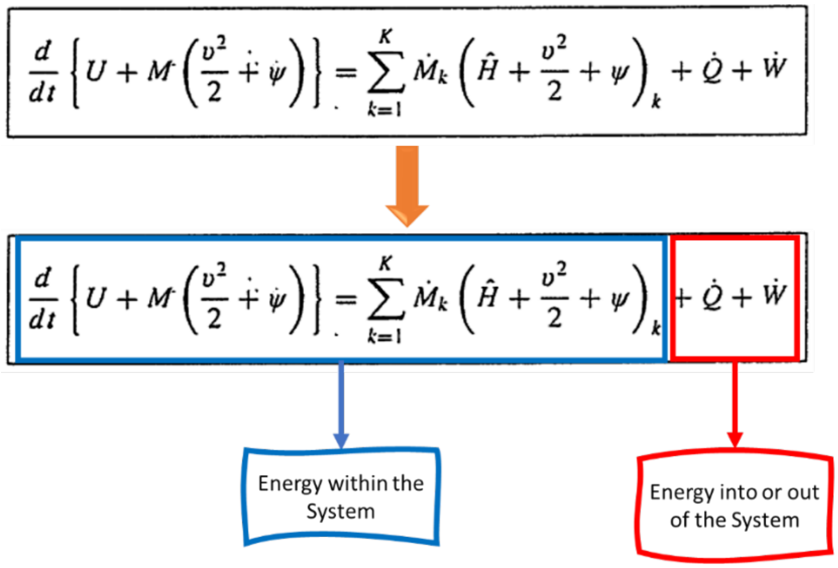

Figure 3. Explanation of the Energy Balance Equation.

I often choose to use an example that is familiar to all the students (e.g., the pouring and drinking of a hot cup of tea) to explain the small different components of the energy balance equation, which activates their personal experiences and prior knowledge. By so doing, Thomas (2009) agrees that the misconception models are corrected while the students can build-on the existing models generated through previous experiences. This facilitates the students' understanding of the structural foundations of various forms of energy and how they relate to one another.

During tutorial lessons, I allow the students to attempt problems by themselves and use the Mentimeter audience response tool to get feedback/solutions; this becomes an opportunity to deeply engage the students in processing the material. Once the entire class has agreed on the correct solution, I let them compare their solutions to one another and allow them to write a reflection note on their answer, correct or incorrect, by giving a summary of their engineering model (assumptions, strategy, and analysis); through this, I can evaluate some of the enduring misconceptions.

At the end of the energy balance lesson, the majority of the class is devoted to having students work on more complex problems that embed their learning in real-world scenarios where this specific problem might arise. This includes students formulating their unique approach and perspective in solving different versions of the problems, which may require unconventional solution strategies. Table 1 describes the TLT phases in relation to the classroom events and how students transitioned from phases 1 to 10.

Table 1. Description of each TLT phase in relation to the classroom events.

Phases	Description	Events
1	A disorienting dilemma	Introduction of the concept of energy balance
2, 3, 4	Self-examination Critical assessment Recognition	Complex energy balance equation
5	Exploration	Example of the pouring and drinking of a hot cup of tea
6, 7, 8	Planning Acquisition of knowledge and skills Provisional trying of new roles	Solving problems in class Writing reflection notes
9	Building of competence and self-confidence	Keenly solving more complex problems based on real-world scenarios
10	Reintegration	Using unique approaches and perspectives in solving different versions of related problems

4.1 The Value of Transformative Learning Theory in my Teaching and Learning Context

The theory of transformative learning in engineering education encourages students to think independently rather than relying solely on statements or arguments presented by educators. Implementing the theory promotes deeper learning because different viewpoints broaden frames of reference. Additionally, it puts forth several viewpoints for students to consider and reflect upon. The theory acknowledges the advantages of providing differentiation and diversity in the classroom. The diversity of viewpoints promotes students' understanding of the topic and cultivates tolerance and acceptance of opposing viewpoints. When students can think critically, it helps them learn the material being taught and makes them more open to new concepts and theories. Experienced educators can create such nourishing environments for students.

Figure 4 shows the impact of the application of TLT through the statistical analytical evaluation of the students' results of Test 3 for 2024 and 2025 academic years. Annually, Test 3 only addresses the application of energy balance and problem-solving within the Chemical Engineering Fundamentals 1B (CEFCHB1) module. In the 2024 academic year, there was no application of the TLT, and during the 2025 academic year TLT was introduced for the first time. The data show that there were significant improvements in terms of students' grades and performance with majority of the students passing the assessment in 2025 compared to 2024, with overall average of 56%. No student acquired full marks in 2024 with the highest mark achieved being 80%; while in 2025 five students were able to get more than 90% of the total marks. The 2025 probability mass function resembles the Cauchy Distribution with a heavy tail leaning to the left, which implies positive students' outcomes with high average.

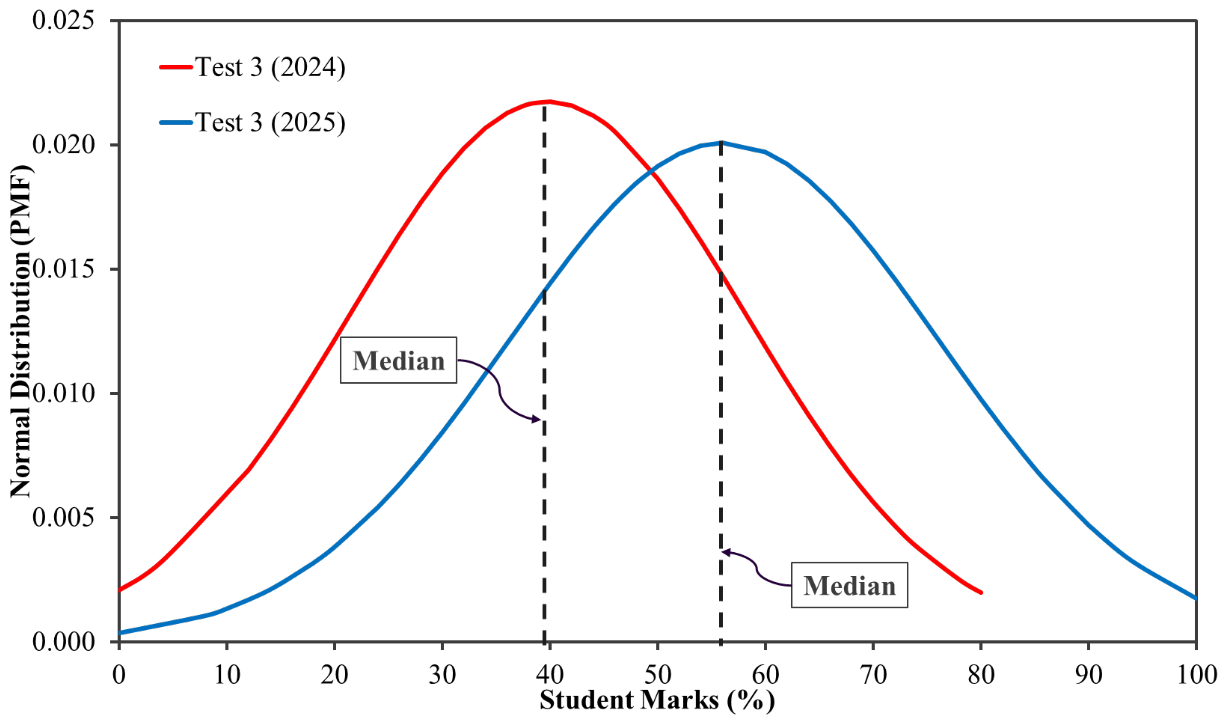

Figure 4. Performance Trends and Impact of TLT.

5. Unforeseen Limitations of the Transformative Learning Theory

Several philosophers (Kitchenham, 2008, Merriam, 2004, Nairn et al., 2012, Nohl, 2015) who have been engaged in studies of the transformative learning theory have discovered some flaws and limitations in the theory. Kitchenham (2008) has argued that during the self-reflection process of TLT, the role of emotions is not fully considered. The human species is not always rational; hence, emotions always emerge during learning and decision-making developments. As a result, educators need to expect some negative emotional responses from students during learning, which may potentially deter their performance. Another criticism pointed out by Nairn et al. (2012) is that TLT neglects to take social constructs into account when analysing learners' actions and capacity for critical reflection on their encounters; this is crucial because humans determine their place in society through reflexivity. These criticisms and limitations lead me to believe that when using TLT as a framework for teaching and learning, there may be other aspects of adult learning that require careful consideration.

6. Conclusion

This paper has looked at a practical example of the application of transformative learning theory (TLT) in a typical engineering classroom. It was demonstrated through this reflective discussion that the application of TLT in engineering education promotes independent thinking among students, rather than dependence on assertions or arguments put out by instructors. Implementing the theory promotes deeper learning because different viewpoints broaden frames of reference. Furthermore, educators can gain a better understanding of the process by which students encounter a disorienting dilemma, reflect on the situation through the perspective of their personal viewpoint, act to overcome the dilemma, share their values and emotions about the experience with other individuals, and plan for future experiences.

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Biography

Major Mabuza is a Senior Lecturer and the Head of the Department of Chemical Engineering Technology within the Faculty of Engineering and the Built Environment at the University of Johannesburg. He holds a Doctor of Engineering (DEng) in Chemical Engineering from the Tshwane University of Technology and a Postgraduate Diploma in Higher Education from the University of Johannesburg. He is currently registered as a professional engineering technologist (Pr Tech Eng) with the Engineering Council of South Africa (ECSA). Dr Mabuza has comprehensive experience in teaching and learning, research and innovation, leadership, as well as industrial operations. His research interests fall within the fields of engineering education, chemical and metallurgical engineering. In 2012, he was awarded the prestigious Mandela Rhodes Scholarship (master's degree) whose pillars are focused on education, leadership, entrepreneurship, and reconciliation. Most recently, in 2023, he was awarded the prestigious Future Professors Programme – Phase 1 Cohort 3 based on his excellence in teaching and supervision, impactful research, academic leadership, including socially responsible activities with societal impact. He has over ten years of teaching and learning experience with various higher education institutions in South Africa and started working for the University of Johannesburg as a Senior Lecturer in August 2022. Dr Mabuza has several papers published in peer-reviewed journals and others presented at international conferences.