Comparing The Transformative Experiences of Two Cohorts of a First-Year Engineering Program

Sukeerti Shandliya
Department of Engineering and Computing Education
University of Cincinnati
Cincinnati, OH, USA
https://orcid.org/0000-0002-1346-0845

Cedrick A. K. Kwuimy
Department of Engineering and Computing Education
University of Cincinnati
Cincinnati, OH, USA
https://orcid.org/0000-0002-2949-3000

Abstract—**This research paper describes transformative learning experiences of first-year engineering students. Transformative learning methods aim to equip students with the necessary skills to address 21st century challenges by fundamentally altering their frame of reference. A student's frame of reference encompasses their habits of mind and personal point of view, which are influenced by past learning experiences and cultural norms. This paper examines a first-year engineering program at a midwestern (USA) institution to investigate the extent of transformative learning experiences and their impact on perceived changes in students' habits of mind. The study involves a sample of 90 students from the 2021-2022 academic year and 161 students from the 2023-2024 academic year. Participants completed a Qualtrics survey at the end of their second semester in engineering. The survey included items related to stages of transformative learning, habit of mind dimensions, factors influencing changes in habits of mind and demographic details. Based on the characteristics of the transformation journey, four clusters of students will be identified: 1. Students who experienced Profound Transformation through disorienting dilemmas, self-reflection, experimenting, and acting. 2. Students who experienced a disorienting dilemma without subsequent action. 3. Students who experienced Straightforward Transformation, characterized by experimenting and acting without a disorienting dilemma. 4. Students who experienced no transformation. It was found that the distribution of students was similar in both the years for all four clusters. The study found that for both cohorts, most students were in the profound transformation category, followed by no transformation, straightforward transformation and the least students were in the reflection without action categories.**

Keywords—transformative learning, first-year engineering experience

I. Introduction

Transformative learning can be understood as a process of perspective transformation that occurs when learners critically reflect on their assumptions and beliefs as a consequence of encountering a situation that does not fit well in their present meaning schemes [1]. Jack Mezirow, an American sociologist and proponent of transformative learning theory, believed that humans are meaning making beings. We make meaning of any experience on the basis of our prior experiences which makes for our "frame of references". The frame of reference consists of two dimensions- habits of mind (assumptions, predispositions, broad generalisations) and points of views (convictions, feelings, intuitions, attitudes). When we are not able to understand something with our existing frames of reference, we are compelled to reevaluate our previously held assumptions and beliefs. Mezirow called the process of re-evaluation of existing frames of references critical self-reflection. As a result, our frames of reference get transformed and become more inclusive and differentiating.

Daramola [2] highlighted that the combination of cognitive learning and experiential learning makes transformative learning particularly effective in engineering education. Engineering students exposed to transformative learning become aware of their perspectives' limitations and are better prepared to embrace and utilize various viewpoints. However, limited studies in engineering education have explored the significance and application of transformative learning [3]. Thus, the goal of this paper is to explore the transformative learning experiences of first-year engineering students using Mezirow's transformative learning theory..

A. *Needs and Challenges of First-year Engineering Students*

Engineering programs are often considered difficult, and successful engineering students are found to possess high levels of grit, self-discipline, commitment and perseverance towards various academic challenges [4-5]. The common challenges first-year engineering students face include dealing with new responsibilities, increased academic rigour, new social support networks, new study habits and routines and a myriad of other new experiences of adult life, for example, living alone for the first time [6-7]. This transition from high school to college leads to an increased sensitivity and vulnerability amongst first-year engineering students [6]. Consequently, the rate of attrition has consistently been higher for first-year engineering students [8-10] and it has been even higher for underrepresented minority students [11]. For instance, the number of undergraduate engineering degrees awarded to African American students have been stagnant, and a lower number of female students have been pursuing engineering majors as compared to male students [12].

In their study, Mena et al. [13] explored the experiences of first-year engineering students that eased the transition from high school to college and possibly motivated them to continue their engineering journey. They found that students associated their positive experiences with higher quality of classes, helpful and understanding instructors and greater diversity in class. Such experiences, whether positive or negative, depends on students' set of beliefs, value system and assumptions. The belief system and perspectives students have affects their self-efficacy, confidence, sense of belonging, satisfaction and other such constructs which are essential for their retention and success.

B. *Perceptions and Beliefs of First-year Engineering Students*

Engineering self-efficacy is defined as "one's perceived capabilities to learn or perform actions at designated levels." [14, p. 154]. Regarding first-year engineering student's self-efficacy beliefs, literature supports that first-year students rely less on mastery experiences (self-efficacy beliefs based on personal achievements) and more on vicarious experiences (self-efficacy beliefs based on observing and comparing others' performances) [15]. Hutchison-Green et al [15] found that when students find themselves in situations for which they perceive their performances to be inferior to those of their peers (for example, speed of learning), they become less confident in their ability to succeed in a course. A major source of first-year students self-efficacy and confidence is their satisfaction with their chosen major, which is found to be associated with their perceptions of a positive climate and their identification with their major [16-17].

In addition to self-efficacy beliefs, another important belief system that students have is their sense of belonging. Sense of belonging has been consistently found to be a crucial predictor of retention of students in engineering courses [18]. Sense of belonging is defined as the "degree to which an individual feels respected, valued, accepted, and needed by a defined group" [19, p. 87]. Students' sense of belonging could be affected by various psychological and personal factors such as their perceptions of their own performance and self-doubt regarding the course. Another factor that affects sense of belonging is related to the students' perception of academic and social identities [20].

Student beliefs are also dependant on their personal and demographic factors. For example, regarding gender, Besterfield-Sacre et al. [21] found that confidence in basic engineering knowledge, skills and abilities differ across genders, with male students reporting higher confidence than female students. Regarding race and ethnicity, Elizabeth et al. [17] found that African American and Hispanic male students reported higher average STEM confidence than White male students after controlling for other factors.

A major component for improving student retention in engineering is to understand the struggles faced by current engineering students [18]. Engineering education researchers have focused more towards interventions that help students with academic and transferable skills in engineering, but less initiatives have been taken to understand engineering students psychological needs [22-23]. Thus, there is a need to understand the experiences of engineering students holistically and explore the engineering course components that interact with those experiences. In its current scope, this paper leverages Mezirow's transformative learning theory and King's Learning Activities Survey to explore the extent of transformative learning experiences first-year engineering students experience in their course.

The research question developed for this study is as follows:

RQ: What type of transformative learning occurs in a first-year engineering program and what are the factors that affect the first-year engineering students' transformative learning experiences?

II. Theoretical Framework

The transformative learning theory proposed by Mezirow posits that experiential activities often lead to situations known as 'disorienting dilemmas' [1]. These disorienting dilemmas occur when learners current frame of references are rendered insufficient to make meaning of certain disorienting situations or problems. Learners then reflect on these insufficient frames of reference by critically reflecting on their preconceived notion and assumptions. The nature of reflection decides the nature of transformation.

Straightforward reflection results in either the expansion of current meaning schemes (learning within meaning schemes) or addition of new meaning schemes compatible with the existing meaning schemes (learning new meaning schemes). In contrast, transformative reflection leads to transformation of existing meaning perspectives (learning through meaning transformations)- development of new frames of reference by becoming aware of specific assumptions on which a distorted meaning scheme is based [24-25]. Only critical self-reflection involved in learning through meaning transformations leads to perspective transformation.

A learner's frame of reference comprises their habits of mind, shaped by life experiences, previous education, personal interests, and social influences [26]. Cranton [27] categorized the habits of mind into six dimensions: philosophical (dealing with transcendental worldviews), moral and ethics (related to conscience and morality), psychological (pertaining to self-concept and personality traits), sociological (involving social norms and cultural expectations), epistemic (related to knowledge acquisition), and aesthetic (concerning values, attitudes, and judgments).

Mezirow [28] conceptualised a ten-stage framework for describing transformative learning process.

Stage 1. A disorienting dilemma

Stage 2. Self-examination with feelings of guilt or shame,

Stage 3. A critical assessment of epistemic, sociocultural, or psychic assumptions,

Stage 4. Recognition that one's discontent and the process of transformation are shared and that others have negotiated a similar change,

Stage 5. Exploration of options for new roles, relationships, and actions,

Stage 6. Planning a course of action,

Stage 7. Acquisition of knowledge and skills for implementing one's plans,

Stage 8. Provisional trying of new roles,

Stage 9. Building of competence and self-confidence in new roles and relationships; and

Stage 10. A reintegration into one's life based on conditions dictated by one's new perspective.

This paper would utilize Mezirow's transformative learning theory to guide the conceptual framework and interpretation of results.

III. Conceptual Framework

We utilised King's learning activities survey (LAS) to measure the transformative learning outcomes of first-year engineering students. The instrument was first developed and validated by King [29]. The original instrument used a checklist of items that corresponded to the ten stages of transformative learning to measure how many stages are experienced by the learners.

We modified the original checklist response into Likert scale responses to capture the degree of agreement for each stage. The modification also helped us in exploring the factorial structure of the learning activities survey scale by performing exploratory and confirmatory factor analysis on the 11 LAS items (modified to Likert scale: 1 'strongly disagree' to 6 'strongly agree') (Shandliya et al., n.d.). Our analysis identified a two-factor structure: the first factor, with items 1 to 6 referring to experiencing disorienting dilemma and subsequent self-reflection and the second factor, with items 7 to 11 referring to experimenting with different perspectives and taking reflective actions. We established a cutoff value of 3.5 to categorize responses as high or low for each factor. This threshold helped us define four transformation categories based on the seminal work of Mezirow and Kitchenham. Table I describes the possible implications of the four transformation categories.

TABLE I. DESCRIPTIONS OF FOUR TRANSFORMATION CATEGORIES

Magnitude of the two Factors	Category	Description
High values for Factor 1, High values for Factor 2	Profound Transformation	Students who experienced Profound Transformation through disorienting dilemmas, self-reflection, experimenting, and acting.
High values for Factor 1, Low values for Factor 2	Reflection Without Action	Students who experienced a disorienting dilemma without subsequent action.
Low values for Factor 1, High values for Factor 2	Straightforward Transformation	Students who experienced Straightforward Transformation, characterized by experimenting and acting without a disorienting dilemma.
Low values for Factor 1, Low values for Factor 2	No Transformation	Students who experienced no transformation.

This paper used these four categories as conceptual frameworks to explore the nature of the transformative learning experiences of the first-year engineering students.

IV. METHOD

A. *Program Description*

The research study took place at a midwestern U.S. research R1 university in 2023. In 2018, the university's first-year engineering curriculum was revamped to be more design-centric to transform the undergraduate engineering education experience. The revamped first-year curriculum offers two three-credit courses in the first and second semesters: Foundations of Engineering Design Thinking I and Foundations of Engineering Design Thinking II. These design-centric courses use discussion, activities, long-term team projects, studio hours (hands-on activities to enhance understanding of course concepts), and other experiential opportunities that require students to develop creative approaches to engineering problems. Students are introduced to fundamental engineering concepts, societally relevant design challenges, computer tools (MATLAB, LabVIEW, Python, CAD, and Visual Basic), and extended exercises as part of the first-year curriculum. The objective of the first-year engineering curriculum is for students to develop project management, communication, critical thinking, and problem-solving skills.

Students enrolled in first-year engineering programs come from two pathways: students who were directly admitted to their chosen majors and students who were undecided on their engineering major and enrolled in First-year Engineering Programs. The first semester follows a standard curriculum across all engineering majors, including courses in English, Chemistry, Engineering Design, a general education elective, and a co-op elective.

B. *Participants*

The students enrolled in first-year engineering program participated in this study. The data for this study was collected as part of the Engineering Design course evaluation. Students participated voluntarily, without any financial incentive. At the end of their first academic year, the students were emailed to complete the Qualtrics survey. The data was collected for two academic years- spring 2022 (cohort enrolled in 2021) and spring 2024 (cohort enrolled in 2023). Table II below describes the sample sizes obtained for the two cohorts and Table III provides a demographic summary of the sample participants.

TABLE II. SAMPLE COLLECTION SUMMARY

Cohort Enrolment Year	Data Collection Session	Total Students Responded (N=301)	Total Responses kept (Final Sample Size, N = 251)
2021	End of Spring 2022	117	90
2023	End of Spring 2024	184	161

TABLE III. DEMOGRAPHIC SUMMARY

Demographic Category		Frequency	
	Choices	FYEE 2021-22 (N=90)	FYEE 2023-24 (N=161)
Gender	Females	19	40
	Males	70	118
	Gender-fluid/Gender non-confirming/Prefer not to say	1	3
Ethnicity	Hispanic	7	6
	Non-Hispanic	83	155
Race	American Indian/Alaska Native	0	0
	Asian	11	21
	Black or African American	10	14
	Native Hawaiian/Other Pacific Islander	0	0
	White	61	120
	Multiracial	2	2
	Other	6	4
International Status	International Students	7	20
	Domestic Students	83	140
Academic Pathways to College	Direct form high school without any delay	87	151
	Gap Year(s) without any work or education between high school or college	1	1
	Other (Working fulltime or halftime between school and	2	9

	college, military enlistment between school and college, etc.)		
First Generation Status	First-Generation	9	19
	Non First-Generation	81	142

Note: 1 student did not respond to the international status item in the survey

C. Instruments and Data Collection

Table IV provides information regarding the two transformative learning measures used in the survey. The survey included three sections. The first section utilized the Learning Activities Survey (LAS) which consisted of 11 Likert-style items aimed at measuring the stage-wise extent of transformative learning experienced by students in their first-year engineering courses. The second section collected data regarding the extent of changes the students experienced in the six dimensions of habits of mind (Philosophical, Moral & Ethics, Psychological, Sociological, Epistemic, and Aesthetic) and the factors that may have influenced those changes. Students were presented with a checklist of six factors including classmate support, instructor support, an encounter during the program, team project, college support and other. The third section collected demographic data regarding participants' gender, race, ethnicity, information about the international status of participants, the first-generation status of the participants, and their academic pathways to college.

TABLE IV. TRANSFORMATIVE LEARNING INSTRUMENT DESCRIPTION

Instruments	Description	Examples
Learning Activity Survey (King, 2009)	11 Likert-style items collecting responses on a 6-point Likert scale (1 = strongly disagree to 6 = strongly agree)	Please indicate the degree to which you agree or disagree with each statement below: Item#1: I had an experience that caused me to question the way I normally act. (associated with Stage 1- A disorienting dilemma) Item#7: I tried out new roles so that I would become more comfortable or confident in them. (associated with Stage 6- Planning a course of action)
Habit of Mind (Adapted from Cranton, 2006)	6 Likert-style items collecting responses on a 5-point Likert scale (1 = extremely influential to 5= not at all influential)	Please determine to what extent your FYEE experience was influential in the following dimensions of your habits of mind: Item#1: Philosophical: Personal philosophies, religious beliefs and transcendental worldviews Item#4: Sociological: Social norms, cultural interpretations of signs, symbols, and use of language

V. Results

A. Transformative Learning Outcomes

As shown in Table V, highest percentage of students in both cohorts experienced profound transformation, and the lowest percentage of students experienced reflection without subsequent action. From a cross tabulation analysis, we found that there were significantly greater number of students in the profound transformation category, significantly lower number of students who experienced reflection without action, and significantly lower students in the no transformation category in the year 2023-24 as compared to 2021-22 (X2(3, 251) = 10.447, p = 0.015). However, the percentage of students experiencing straightforward transformation remained almost the same.

TABLE V. FOUR CATEGORIES OF TRANSFORMATIVE LEARNING OUTCOMES

Categories	Percentage	
	FYEE 2022-23 (N=90)	FYEE 2023-24 (N=161)
Profound Transformation	46.7	60.2
Reflection without action	7.8	1.2
Straightforward Transformation	15.6	16.8
No Transformation	30.0	21.7

B. Habits of Mind Outcomes

For both cohorts, we found that most changes were noted in the epistemic dimension of habit of mind and the least changes were noted in the philosophical dimension of habit of mind. From an independent sample Mann Whittney U test, it was found that there was no significant difference noted for any habit of mind changes when comparing the 2023-24 cohort and 2021-22. Table VI shows the changes in habit of mind dimensions for both cohorts. Further, there were no significant differences observed in the number of students experiencing changes in the six habit of mind dimensions across the four categories of transformation.

TABLE VI. CHANGES IN HABITS OF MIND DIMENSIONS

Habits of Mind	Frequency	
	FYEE 2021-22 (N=90)	FYEE 2023-24 (N=161)
Philosophical	2.19	2.21
Moral & Ethics	2.57	2.69
Psychological	2.92	2.83
Sociological	2.78	2.81
Epistemic	3.20	3.08
Aesthetic	2.50	2.47

The Kruskal Wallis test results revealed that for both cohorts, students in the profound transformation category experienced significantly greater changes in all the dimensions of habit of mind when compared to students in the no transformation category. It indicates that students who experienced profound transformation were more likely to experience changes in philosophical, moral, psychological, sociological epistemic and aesthetic dimensions of habits of mind as compared to the students who did not have any transformative learning experience in their first-year engineering program.

C. Factors Affecting Habits of Mind

Across both years, classmate support and team project were the leading factors for affecting changes in students' habits of mind (see Table VII). The college support system was the lowest influential factor for both the cohorts. From the chi square results, we found that a significantly greater percentage of students attributed team project as an influential factor behind their habit of mind changes in the year 2023-24 as compared to 2021-22 (X2(1, 251) = 5.017, p = 0.022).

TABLE VII. COMPARISON OF INFLUENTIAL FACTORS ON HABITS OF MIND ACROSS COHORTS

Factors	FYEE 2021-22 (Percentage)	FYEE 2023-24 (Percentage)
Classmate Support	62.2	72
Instructor Support	36.7	46.6
An Encounter during Program	18.9	21.7
Team Project	60.0	73.9
College Support System	15.6	19.9

We conducted a chi square test to analyse differences across the four categories of transformation and transformative learning factors perceived by students (factors affecting habit of mind). We obtained significant differences for factors such as instructor support (p=0.003), college support (p=0.004) and any encounter during the first-year program (p=0.002). It was found that students in the profound transformation category were statistically more likely to perceive instructor support, college support and any encounter during the first-year program as factors that influenced their habit of mind. In contrast, students in the no transformation category were significantly less likely to perceive these factors as influential in changing their habits of mind. Students in the straightforward transformation category were statistically more likely to perceive instructor support as influential; but were less likely to perceive encounter with someone and college support to be influential in changing their habits of mind.

D. *Associations of Transformative Learning Categories with Student Demographics*

Although the overall Pearson chi-square values were not significant for any demographic groups, the significant residuals highlight specific transformation categories where the proportion of a certain demographic group of students deviates notably from expected frequencies. For example, across both years, female students were more likely to experience profound transformation and less likely to experience no transformation as compared to male students. Similarly, African American students were more likely to experience profound transformation and less likely to experience no transformation. Asian students were more likely to experience no transformation. White students were less likely to experience profound transformation but more likely to experience straightforward transformation. International students were more likely to experience profound transformation and less likely to experience straightforward transformation. First-generation students were more likely to experience profound transformation and less likely to experience straightforward or no transformation. We did not perform the cohort comparison for demographic variables because the sample size for cohort 2021-22 was not large enough to satisfy the expected cell frequency assumption.

VI. DISCUSSIONS

This study explored the types of transformative learning experiences (four categories of transformation) experienced by the first-year engineering students. For both cohorts, we found that most students were in the profound transformation category followed by no transformation category. Fewer students experienced straightforward transformative learning in both cohorts. This contrasts the results found in literature which state that most learning in engineering is informative rather than transformative [3]. While informative learning only aims to expand a person's knowledge, transformative learning also facilitates profound changes in the person's worldview, self-perception, and overall capacity [30]. There could be several explanations why we found more students in the profound transformation category.

First, students reported team projects as the most influential factor behind changes in their habits of minds. Literature has also noted that collaborative learning environments are enablers of transformative learning [31]. In our study, for 2023-24 cohort, which had more students who experienced profound transformation and less students who experienced no transformation, had a higher number of students who perceived team project to be impactful in changing in their deeply held beliefs and perspectives. Thus, students acknowledged team projects as a major source of transformative learning because these projects exposed engineering students to multiple perspectives from their peers, facilitating their perspective transformation. Further, our first-year engineering course had a design centric curriculum. Sperling et al. [12] provided evidence that a design-focused and project-based first-year engineering course positively impacts engineering students' self-efficacy beliefs and professional skills. Our results demonstrate the transformative potential of a design-centric project-based engineering course.

Second, the variations in student demographics that experienced profound transformation reflected the individualistic nature of transformative learning phenomena. Not all first-year students have the same motivations and expectations from their course, neither do they have the same set of beliefs and assumptions regarding themselves and others. In a study that investigated the self-efficacy beliefs of first-year students' mid-way through their first semester in engineering found that female students reported lower academic self-efficacy than their male counterparts and tended to reflect more on the negative experiences than the positive ones [15]. This could help in explaining the results of our study where female students had more transformative experiences as compared to male students, suggesting that a seemingly disadvantageous trait of having a greater susceptibility towards negative self-perception, could paradoxically act as a lever for deeper learning and critical self-reflection which is an essential driver for transformative learning.

Like female students, first-generation and international students were both found to have experienced more profound transformation as compared to their peers. First-generation students come from a wide range of prior experiences, family and cultural values, educational aspirations and motivation [32-33], which might be different from traditional engineering students in varied aspects. On the other hand, international students constantly cope with issues related to self-esteem and self-identity while adapting to the host country's cultures and educational system. This leads them to constantly reexamine their prior assumptions, values, and belief systems in order to successfully adjust with the novel cultures of a foreign country [34-36]. Thus, first-generation and international students would be more likely to experience disorienting dilemmas and take reflective action regarding their new perspectives. The same has been confirmed in our findings.

Our results also indicated that students who experienced either profound or straightforward transformation were more likely to perceive instructor support as influential, whereas students who did not experience any transformation were less likely to perceive instructor support and college support as influential. This sheds light on a pivotal entry point to provide equitable experiences to all first-year engineering students by leveraging increased faculty interactions and college support.

VII. Limitations

The data for both the cohorts were collected at the end of the first-year. The disorienting dilemmas engineering students face in their first semester (e.g. high school to college transition, sudden increase in academic load, etc.) is arguably higher than those faced by the students in their second semester. By the end of their first-year of engineering, students might have adjusted to the psychological challenges regarding their transition to college. Thus, it is important to collect transformative learning data from the first-year students for both the semesters to get a more comprehensive understanding of the factors that lead to transformative experiences.

The results and inferences are based on the quantitative data collected as part of the survey. Consequently, we were able to attain a snapshot of the extent of transformative learning experienced by the students on a broader level. The absence of qualitative methods in the study design led to a lack of individual level understanding of the nuances of transformative learning as experienced by students. Future studies will employ a mixed method design to understand the nature and extent of transformative learning experiences of first-year engineering students by leveraging both quantitative data (learning activities survey) and qualitative data (open ended questions, reflection assignments, etc.).

VIII. Conclusion

First-year engineering students face many common challenges such as the adjustment to college life and challenges of increased academic rigor in the engineering course. However, the experiences from these challenges are not the same for all students. Exploring first-year engineering student experiences through the lens of transformative learning theory provided a valuable tool for distinguishing between the experiences of students on the basis of their varied attributes and backgrounds. Through the process of transformative learning, students will be able to identify their limiting beliefs and uncritically assimilated assumptions that might be hindering their growth potential, both personal and academic. Consequently, transformative learning experiences would help engineering students become more reflective, creative and critical thinkers.

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