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Understanding Research on Engineering Students' Experiences and Outcomes from Student Development Perspectives

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Abstract

In this paper, we have examined a major focus area of engineering education research—engineering students' experiences and outcomes, or ESEO—through a targeted literature review of 121 selected articles published by the Journal of Engineering Education from 2011 to 2021. We drew upon a methodological taxonomy (Malmi, et al., 2018), literature on student development theories, and particularly an integrative ecological systems theory (Bronfenbrenner, 1979, 1993), to guide our analysis. We have presented the findings with respect to engineering students' outcomes, and the contextual and individual factors in their learning experiences as exhibited in the selected articles, as well as the frameworks, methodologies and paradigms used by these studies. Based on these findings, we attempt to characterize ESEO studies in terms of topics, frameworks, methodologies and research paradigms. Our analyses have attested that student development perspectives in the field of higher education offer scholarly and useful insights to engineering education researchers and practitioners.

Keywords: engineering students' experiences and outcomes, student development theories, engineering competencies, methodological taxonomy, conceptual or theoretical frameworks

Introduction

Engineering students' experiences and outcomes constitute a major focus area of engineering education research (EER) although studies with such a focus may not be labelled using the same terms. For example, Borrego and Bernhard (2011) recognized student learning and its assessment as well as retention and diversity of engineering students as two of the three major areas of EER, along with instructional or curriculum development. As another example, a special report "The Research Agenda for the New Discipline of Engineering Education," published by the *Journal of Engineering Education* in 2006, identified engineering learning mechanisms (i.e., how learners develop knowledge and competencies) as one of the five broad research areas of EER. Our earlier review paper focusing on articles published in 2018 by four major engineering education journals showed that more than two-fifths of the articles addressed issues focusing on engineering students' learning; diversity and retention; or academic and career pathways (Liu, 2019); all these represent aspects of engineering students' experiences and outcomes.

In this paper, we use "engineering students' experiences and outcomes," or ESEO, to refer to the EER studies that examine various aspects of learning experiences on and off campus while engineering students pursue an engineering degree, and the concomitant outcomes they have achieved as a result of those learning experiences. We deliberately label this research area as such because ESEO is a central concern of the academic field of higher education (or, postsecondary education) (e.g., Bowman & Trolian, 2017; Jeff & Rinn, 2020) and there is an inherent connectivity between EER and higher education research. For us—an interdisciplinary team for this paper, EER is a discipline-based area of higher education research and an interdisciplinary academic discipline that requires knowledge of both engineering and education practices.

We choose to focus on this research area because it has rarely been approached systematically and theoretically although engineering students' experiences and outcomes are of great interest to educators in engineering schools and engineering education researchers. In this paper, we aim to address the following questions to explore the landscape of ESEO studies:

- What student outcomes have been studied in research on ESEO?
- What can be learned about engineering students' experiences associated with these outcomes?
- What conceptual or theoretical frameworks, methodologies and research paradigms have been used to study ESEO?

Our ultimate goal is to examine what characteristics can distinguish ESEO studies as an area of focus in EER; and uncover how student development literature in the field of higher education can contribute to this.

To address the research questions above, we examined 121 ESEO-focused articles from a selection of articles published during the period of 2011 to 2021 by the flagship journal in EER—*Journal of Engineering Education*. We used three frameworks to guide our exploration: (1) employing a methodological taxonomy (Malmi, et al., 2018) to code the research components in ESEO-focused studies; (2) relying on areas of inquiry and paradigms embedded within student development theories in higher education to help understand the theoretical groundings of some of these studies; and (3) utilizing an integrative student development theory—Bronfenbrenner's (1979, 1993) ecological systems theory—to map out the contextual and individual factors in student experiences.

In the sections to follow, we will first provide an overview of two bodies of literature that informed the conceptualization of this paper: student development theories in higher education; and literature on engineering competencies. Then, we will outline the methodology we used in our review and analysis, including selection criteria and the coding schemes. We will present the findings from our review in light of student development perspectives in higher education literature and discuss the scholarly and practical implications of our findings to engineering education and research. Our paper will contribute to enhancing the capacities for research on student-focused issues in engineering education.

Starting Point: Student Development Theories and Engineering Competencies

Our exploration began with attempts to connect student development theories—a long-standing area of focus in higher education—and engineering competencies—an area of increasing interest to engineering educators. The discussions on these two areas are closely linked to each other but start at different places. While student development theories focus on the process or the means, the discussions of engineering competencies begin with the outcomes or the end.

Student Development Theories

Student development involves professional practice, and it is also a research area that has been well established in higher education. As a practice, student development is a term extensively used by student life professionals and serves as a philosophy that has guided student life practice and program design (Rodgers, 1990). As a research area, it is grounded in certain ontologies, epistemologies and methodologies (Evans et al., 2010). A widely quoted definition of *student development* is as follows: “the application of human development concepts in postsecondary settings so that everyone involved can master increasingly complex developmental tasks, achieve self-direction, and become interdependent” (Miller and Prince, 1976, p. 3). There are at least two assumptions behind the discussions about student development. One is that student development is a positive growth process, which is conceptually different from change or growth (Sanford, 1967). The other is that student development is conceptualized and evaluated on the basis of the changing societal conditions (McEwen, 2003) so the context for discussing student development matters.

Student development theories in the field of higher education have grown since the 1950s, in the context of increasing diversity among student populations and with contributions from scholarly work in psychology, sociology and education (Patton, Renn, Guido, & Quaye, 2016). These theories were developed to address these questions:
(a) What interpersonal and intrapersonal changes occur while the student is attending postsecondary education?
(b) What factors lead to this development?
(c) What aspects of the postsecondary environment encourage or retard growth?
(d) What developmental outcomes are postsecondary students expected to achieve? (adjusted from Knefelkamp, Widick, & Parker, 1978).

Scholars on student development theories have categorized these theories in different ways. For example, Evans and her colleagues (2010) organized them into foundational theories, integrative theories, and social identity development theories. Schuh and Jones’s (2017) categorization is along the line of cognitive and intellectual development, psychosocial and identity development, student engagement and success, critical theoretical perspectives, and organizational perspectives. Similarly, Wilson (2011) identified the following “theory families”: developmental theories, cognitive development theories, psychosocial development theories, social identity theories, theories emphasizing holistic development, theories of organizational and campus environments, student success theories, typology models, and emerging theoretical perspectives. These categories reveal the major domains of student development in postsecondary education as well as the areas of inquiry in student development research.

Three waves have been identified in the evolution of student development theories (Jones & Stewart, 2016). The first wave focused on cognitive, psychosocial and moral domains of students, with the assumption of a linear, generally sequential process that applies to all individuals; the second wave centred on social identities and experiences of students from minority groups; and the third wave has shifted attention to broader structures of inequality to promote social change (Jones, 2019). Along this evolution is a shift of research paradigms—from the post-positivist to the constructivist / interpretivist and then to the critical / cultural paradigm (Patton et al., 2016; Schuh & Jones, 2017).

Engineering Competencies

Being like-minded to educators and professionals in higher education in general, communities of engineering education are also highly interested in student development. This interest is partially exhibited through their concern about engineering students' competency development (Davis, Beyerlein, & Davis, 2006; Dunwoody, et al., 2018; Kamp, 2016). These competencies are formalized and reinforced by engineering accreditation standards (e.g., the Accreditation Board for Engineering and Technology, or ABET, outcomes in the United States (U.S.), and the Canadian Engineering Accreditation Board, or CEAB, graduate attributes in Canada), and constitute an integral part of the outcomes-based engineering education (Froyd, Wankat, & Smith, 2012; Woolston, 2008). For example, the updated ABET outcomes used since 2019[1] include the following seven competencies: problem solving, engineering design, communication, teamwork, ethical and professional responsibilities, experimentation and investigation, and life-long learning.

The interest in engineering competencies may be ultimately driven by the need to produce qualified engineers. In 2005, the report "Educating the Engineer of 2020" published by the U.S. National Academy of Engineering presented a report for the role of engineering education in the development of engineering competencies in the 21st century. This report made a set of recommendations to different stakeholders on how to strengthen the system of engineering education to train qualified engineers for the future. Similarly, an advocacy report entitled "Assurance Competence in the Canadian Engineering Profession," released by the Canadian Academy of Engineering in 2003, recommended what different stakeholders can do to assure the public that professional engineers in Canada continue to acquire, retain and enhance the competencies that are required in fulfilling their evolving roles in society. As such, stakeholders from within and outside engineering educator communities demonstrate keen interest in engineering students' personal and professional development.

The interest in engineering students' competency development on the practical level is parallel to scholarship on engineering competencies and related developmental issues. One line of research attempts to define what engineering competencies are (e.g., Davis et al., 2006; Male, 2010; Passow & Passow, 2017) and identify what the gaps are between engineering students' competency levels and workplace expectations (e.g., Male, Bush, & Chapman, 2010; Passow, 2012). Related to this, literature shows various ways of categorizing engineering competencies. Dunwoody et al. (2018) discusses engineering competencies in a framework of three perspectives: people, communication and project. McMasters (2006) highlights four clusters of skills as being important to qualified engineers: foundational technical skills, professional, engineering, and business skills. Broadly speaking, there are technical and professional skills; and to combat the dualism embedded within these two domains, socio-technical skills are used to represent the nature of engineering competencies (Faulkner, 2007). Another line of research

[1] https://www.abet.org/wp-content/uploads/2018/03/C3_C5_mapping_SEC_1-13-2018.pdf

focuses on how to facilitate the competency development of engineering students; and summaries of some findings from this line of research can be found in two review papers (Ebrahiminejad, 2017; Shuman, Besterfield-Sacre, & McGourty, 2005).

In summary, our overviews above suggest that while both student development and engineering competencies represent aspects of engineering education practice, the scholarship on student development has offered much more profound theoretical groundings than that on engineering competencies. Thus, student development theories may help enrich the understandings of engineering competencies. In addition, while engineering students' competency development has become an integral part of engineering education, it is important to recognize that competency development is only one dimension of student development. We hereby deliberately use the term "outcomes" to add breadth and texture to the existing discussion of engineering competencies and make the discussion inclusive of all types of student development in the context of engineering education.

Methodology: A Targeted Literature Review

The data that informed the discussion in this paper were 121 carefully selected articles published by the *Journal of Engineering Education* (JEE) from 2011 to 2021. We chose to focus on JEE as it is a flagship journal on EER with a high impact in the field. We included the volumes published in the past 11 years to capture the most recent research. We acknowledge that our targeted review of papers in one journal will not allow us to make our claims conclusive. However, the high quality JEE articles do offer us an opportunity to make analytical claims that could, to some extent, reflect the state-of-art of research on ESEO by showcasing some excellent examples that employed rigorous research design. The relatively large sample size (i.e., 121 articles) also helps us ground our claims in rich empirical evidence. Table 1 shows a breakdown of the selected articles by publication year.

Table 1. Number of selected JEE articles

Year	**n**
2011	11
2012	15
2013	6
2014	7
2015	10
2016	10
2017	6
2018	14
2019	9
2020	20
2021	13
Total	**121**

In the article selection process, we included those articles with explicit research objectives of better understanding *undergraduate* engineering students' curricular, co-curricular or extra-curricular experiences that shed light on student development. We excluded those studies that collected empirical data from engineering students but aimed to better understand the effectiveness of a teaching or assessment method or an educational intervention as we view these studies as primarily pedagogy-focused research. We also excluded those studies that focus on the experiences of graduate engineering students or K-12 students. The selected 121 articles serve as a purposeful sample that represent the recent development in research on ESEO. Two of these articles are literature review (Ong, Jaumot-Pascual, & Ko, 2020; Smith & Aken, 2020); and all the others were empirical studies. Almost all of the empirical studies involved observational design (Creswell & Guetterman, 2019), by which researchers collected student data in natural, rather than experimental, learning settings.

In our analysis, we executed a hybrid approach of deductive and inductive coding (Fereday & Muir-Cochrane, 2006) on three types of information. We first used a methodological taxonomy (Malmi, et al., 2018) to qualify the dimensions of selected studies in terms of nature, explanatory framework (i.e., conceptual or theoretical frameworks that were used to interpret the findings), data sources, scope of data collection, and data analysis methods (see Table 2 for the coding scheme).

Table 2. A coding scheme based on the methodological taxonomy (Malmi, et al., 2018)

Dimensions	**Categories or Description**
Nature	Empirical papers, case reports, theoretical papers, position papers, literature review*
Explanatory framework	Whether or not a conceptual or theoretical framework was explicitly included
Data sources	questionnaires, interviews, focus groups, course grades, student assignments, and other data
Scope of data collection	Data were collected from one institution or multiple institutions
Data analysis methods	*Quantitative-Simple*: using statistical methods typically taught in an introductory statistics course at the postsecondary level, e.g., t-test and ANOVA *Quantitative-Complex*: using statistical methods typically taught in an intermediate or advanced statistics course at the postsecondary level, e.g., regression analysis and factor analysis *Qualitative-Simple*: typically applying a thematic analysis to qualitative data, without referring to any particular analysis methodology *Qualitative-Complex*: indicating a clearly specified analysis process, including specifying a particular methodology, e.g., grounded theory **Mixed methods*: using both qualitative and quantitative methods

* Literature review and mixed methods were not in the original taxonomy but were added during our article review.

We also coded each article into domains of student development according to the student outcomes of interest to the studies. We began with six domains of student development, which were used to organize the presentation of student development theories (Patton et al., 2016; Schuh & Jones, 2017), and added "diverse student groups" as a separate domain to capture studies with a focus on equity, diversity and inclusion. We piloted these categories on 30 articles. As a result, we did not make any changes to the naming of the seven categories but added more examples to each category to ensure the consistency of the coding conducted by team members. Table 3 shows the coding scheme we used, including the seven categories and specific examples.

The research team for this paper was interdisciplinary and consisted of one member with social science background, and two undergraduate engineering students. Each article was reviewed and categorized by two of the team members. The research team reviewed the coding results on a weekly basis to resolve discrepancies.

Table 3. A coding scheme for domains of student development

Domains of Student development	**Examples of Student Outcomes**
Cognitive and intellectual development	Academic performance, conceptual understandings, problem-solving skills, design thinking, research skills, and other cognitive skills
Psychosocial and identity development	Gender and racial identity, professional identity, self-efficacy
Affective changes	Empathy, ethical reasoning, awareness of human-oriented dimension of engineering (such as social responsibility and social justice), academic emotional engagement, environmental awareness, and changes in other attitudes
Behavioral changes	Co-curricular participation, classroom engagement
Educational attainment and persistence	Degree completion / graduation, course completion persistence / retention, dropping out / attrition, transfer from a two-year to a four-year institution
Career development	Career paths, career choice, intent of pursuing graduate study
Diverse student groups	Experiences of nondominant student groups

Note: The categorization of these areas is based on the outcome of interest, not the influencing factors, in the paper reviewed. Studies focusing on diverse student groups were further coded as per the first six domains.

Further, we coded the key findings of each of the 121 articles to identify the main factors in learning experience that were associated with student outcomes. We conducted this round of coding in light of Bronfenbrenner's (1979, 1993) ecological systems theory. Bronfenbrenner's theory is appropriate for our purpose as it is an integrative theory that captures multiple dimensions of student experience (Evans et al., 2010), and particularly the relationships between individual students and the learning environment.

Bronfenbrenner's theory posits that individuals' development takes place as a result of the interaction between the person and the environment. Bronfenbrenner's model consists of four main components—process, person, context, and time—and the interactions among them. *Process* means "proximal processes," which represent "particular forms of interaction between organism and environment that operate over time and are posited as the primary mechanisms producing human development (Bronfenbrenner & Morris, 2006, p. 795). For the purpose of our analysis, "person" refers to the engineering student; and we chose to focus on the period of undergraduate studies as the "time" in the model. We coded the factors associated with the domain of student development according to the four developmentally instigative characteristics (representing the "person") and the four levels of systems (representing the "context") in Bronfenbrenner's model. During our coding process, we added Student Background as a separate category as some articles included this as a factor that was associated with student outcomes. We will include the definitions of related terminologies in the second sub-section of the Findings section.

Findings

To address the three research questions, in this section the findings are presented in four areas: (a) student outcomes; (b) student experiences; (c) frameworks used; and (d) methodologies and paradigms used.

Student Outcomes

Table 4 shows the frequency distribution of the domains of student development that the 121 selected JEE articles entailed. The most often studied area of student development was cognitive and intellectual development, which was studied by 47 articles, whereas behavioral changes were least often studied (only 8 articles). Roughly the same numbers of articles were devoted to the other four domains of student development: psychosocial and identity development, educational attainment and persistence, affective changes, and career development. These variations suggest that cognitive and intellectual development remains to be a primary concern for engineering education researchers focusing on ESEO (many are engineering educators). This is no surprise as one of the foundational theories in student development focused on intellectual development (e.g., Perry's cognitive structural theory, 1968).

Table 4. Domains of student development studied by selected JEE articles

Domains of Student Development	n
Cognitive and intellectual development	47
Psychosocial and identity development	19
Educational attainment and persistence	16
Affective changes	19
Career development	14
Behavioural changes	8

Note: The counts in this table include seven articles that focused on experiences of diverse student groups; and articles that entailed more than one domain of student development were counted more than once.

It is noteworthy that five of the 12 articles on diverse student groups did not include explicit domains of student development as the outcomes; rather, they focused on challenging, marginalized experiences of minoritized students and revealed inequity issues in those experiences:

- Hispanic women with parents having limited educational attainment experienced challenges in accessing and activating social capital in engineering education (Martin, Simmons, & Yu, 2013);
- LGBTQ students experienced devaluation, and health and wellness issues. (Cech & Rothwell, 2018);
- Minoritized students' experiences were unduly impacted by ruling relations in universities and engineering schools (Pawley, 2019);
- Black women experienced an acute sense of isolation, grappling with hypervisibility, difficulties forming study groups, and regular exposure to microaggressions (Blosser, 2020);

- Women racialized students' interest, motivation, self-efficacy and support entities; and how they used navigational strategies to address social pain and inequality (Ong et al., 2020).

These examples demonstrate that some ESEO studies focus entirely on student experiences, particularly when they are examined through a critical equity lens.

Table 5 shows the identified student outcomes for each development domain. Some of these student outcomes represent the engineering competencies in engineering education literature; these include development of technical and professional skills, and specifically engineering design capabilities and problem solving. However, findings in the table also suggest that student outcomes that have been studied in ESEO encompass a much broader range of student development than engineering competencies.

Table 5: Identified student outcomes for domains of development from selected JEE articles

Domains of Student Development	Student Outcomes	References
Cognitive and Intellectual Development	Academic performance	Allendoerfer et al, 2012; Chen et al., 2019; Hsiung, 2012; Kim, 2020; Leppävirta, 2011; Marbouti et al., 2018; Nguyen et al., 2020; Snyder et al., 2018; Stump et al., 2011; Taylor et al., 2020
	Development of engineering competence in general	Walther et al., 2011
	Development of technical skills	Genco et al., 2011; Magana et al., 2019
	Development of professional skills	Conrad, 2017; Gilbuena et al., 2015; Knight & Novoselich, 2017; Lattuca et al., 2017; Litchfield et al., 2016
	Engineering design capabilities	Coleman et al., 2020; Daly et al., 2012; Goncher & Johri, 2015; Hotaling et al., 2012; Juhl & Lindegaard, 2013; Mohedas et al., 2020; Moore, et al., 2013; Ro & Knight, 2016 ; Zoltowski et al, 2012
	Engineering problem solving	Dringenberg, 2018; Faber & Benson, 2017; Johnson-Glauch et al., 2019; Kirn & Benson, 2018; Lee et al., 2013; McNeill et al., 2016; Wang et al., 2018
	Conceptual understandings	Atadero et al., 2015; Brown et al., 2018; Brown et al., 2019; Jablokow et al., 2015; Johnson-Glauch et al., 2020; Koretsky et al., 2016; Nelson et al., 2017
	Math learning	Duffy et al., 2020; Engelbrecht et al, 2012; Faulkner et al., 2020; Gainsburg, 2015
	Growth of information literacy	Taraban, 2011; Wertz et al, 2013
Psychosocial and Identity Development	Self-efficacy	Frantz et al., 2011; Purzer, 2011; Schaffer et al., 2012
	Professional identity	Bairaktarova & Pilotte, 2020; Danielak et al., 2014; Eliot & Turns, 2011; Huff et al., 2021; Mazzurco & Daniel, 2020; Secules et al., 2018a; Secules et al., 2021
	Engineering leadership identity	Wolfinbarger et al, 2021
	Multiple identities	Koul, 2018; McCall et al., 2021; Secules et al., 2018b ; Trytten et al., 2012
	Researcher identity	Faber et al., 2020

Affective Changes	Ethical development*	Corple et al., 2020; Finelli et al., 2012; Leydens et al., 2021; Litchfield & Javernick-Will, 2015; Schif et al., 2021; Weber et al., 2013
	Academic emotional engagement	Villanueva, 2018; Wilson et al., 2014
	Empathy development	Walther et al., 2020
	Entrepreneurial intent	Gilmartin et al., 2019
	Affective factors	Scheidt et al., 2021
	Mental health	Jensen & Cross, 2021
	Social community outcomes^	Washington & Mondisa, 2021
Behavioral Change	Co-curricular participation	Millunchick et al., 2021; Simmons et al., 2018; Tomko et al., 2021
	Use of active learning strategies	Goller et al., 2020; Stump et al., 2011
	Civil or political engagement	Morgan et al., 2020; Niles et al., 2020
	Teamwork development	Baughman et al., 2019
	Classroom engagement	Ing & Victorino, 2016
Educational Attainment and Persistence	Persistence	Hall et al., 2015; Ikuma et al, 2019; Kamphorst et al., 2015; Ohland et al., 2011; Raelin et al., 2014; Samuelson & Litzer, 2016; Smith & Aken, 2020
	Graduation	Atwood & Pretz, 2016; Lord et al., 2019; Wilkins et al., 2021
	Attrition	Litzler & Young, 2012; Marra et al., 2012; Meyer & Marx, 2014; Min et al., 2011; Tyson, 2011
Career Development	Engineering career choice	Brawner et al., 2012; Cruz & Kellam, 2018; Godwin & Kirn, 2020; Godwin et al., 2016; Inkelas et al, 2021; Klotz et al., 2014; Peña-Calvo et al., 2016
	Pursuing a research career or graduate study	Borrego et al., 2018; Branch et al., 2015; Ro et al., 2017; Woodcock et al., 2012
	Workplace navigation after graduation	Huff et al., 2016

*Articles that addressed social responsibilities of the engineering profession are also included as the broader social responsibilities are macroethical issues (Herkert, 2001).
^ Social community outcomes refer to connectedness, resilience, communities of practice, social capital and satisfaction in the article reviewed (Washington & Mondisa, 2021).

Student Experiences

We mapped the key findings of the selected JEE articles onto the four types of developmentally instigative characteristics of the "person" and the four levels of system of the "context" in Bronfenbrenner's model (1979, 1993). Each of the four types of *developmentally instigative characteristics* entails a different type of interaction with the environment, or a proximal process (related verbs are italicized below for emphasis).

- Personal stimulus: personal qualities to *invite or inhibit* responses from the environment that is fostering or disrupting their growth;
- Selective responsivity: personal qualities of *reacting to, or being attracted by* particular aspects of the environment;
- Structuring proclivities: personal tendency to *engage and persist* in progressively more complex activities, and to restructure or create new features in the environment;

- Directive beliefs: directive belief systems about the relation of individuals to the environment. They serve as dynamic developmental forces interacting with particular aspects of the environment to *produce* successive levels of developmental advance (i.e., exercising agency in relation to the environment).

The four levels of systems for our analysis are the following:

- A microsystem: a pattern of activities, role, and interpersonal relations experienced by engineering students in their immediate environment.
- A mesosystem: consisting of linkages and process taking place between two or more settings that contain engineering students.
- An exosystem: consisting of settings that do not contain engineering students but exert influence on them through interacting with the microsystem. The selected articles would barely make this system explicit in the studies.
- A macrosystem: a broad context consisting of the overarching pattern of a given culture or social structure in engineering education settings.

Figure 1 presents examples of contextual and individual factors we identified from our review that were associated with the domain of cognitive and intellectual development. This figure attempts to integrate the findings from *across* studies (instead of within a study). While these factors are unlikely to simultaneously apply to each individual student, they can be true of how engineering students experience in an engineering program over a period of time.

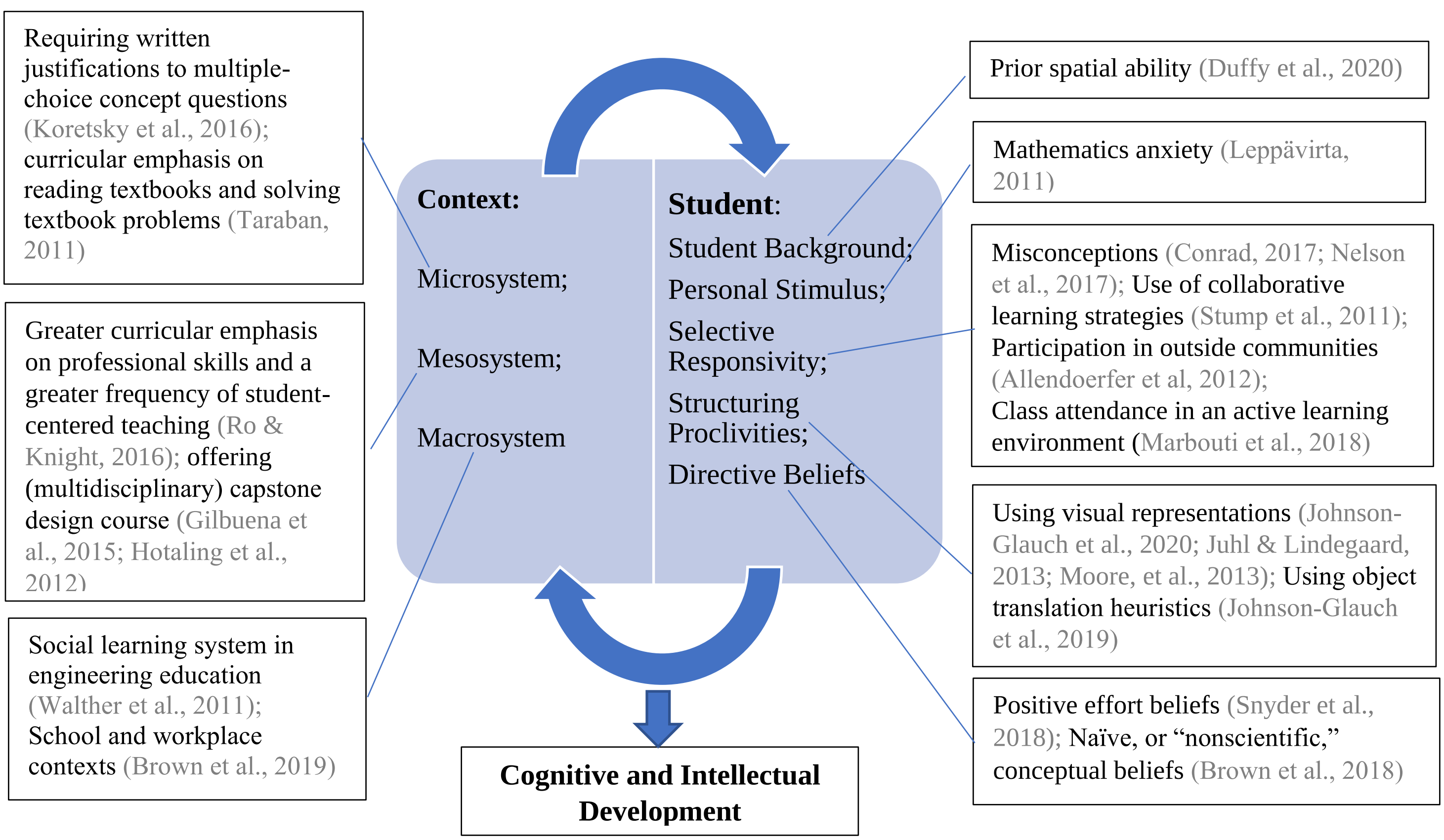

Figure 1. Examples of student experiences associated with cognitive and intellectual development based on findings of selected JEE articles

Frameworks Used

A total of 71, or 59%, of all selected JEE articles, explicitly included conceptual or theoretical frameworks (see the Appendix for these frameworks). Among these articles, 35 used theories from student development literature, constituting 49%. This means that student development literature has considerably informed the ESEO research published by JEE. These 30 frameworks can fall under the following family theories on student development.

- Student success / "college impact": *Terenzini and Reason's (2005)*[2] *college impact framework* (cited in Finelli et al., 2012; Knight & Novoselich, 2017; Lattuca et al., 2017; Ro & Knight, 2016); *Weidman's (1989) model of undergraduate socialization* (cited in Millunchick et al., 2021); *Tinto's (1993) model of student departure* (cited in Tyson, 2011); *outcome-based path models* (used by Kamphorst et al., 2015; Wilson et al., 2014); *social community framework* (Mondisa & McComb, 2015, cited in Washington & Mondisa, 2021).
- Social cognitive theories: *self-efficacy* (Bandura, 1977, cited in Fantz et al., 2011; Inkelas et al., 2021; Purzer et al., 2011; Schaffer et al., 2012); *self-concept* (used by Koul, 2018); *motivation* (Dweck & Legget, 1988, cited in Synder et al., 2018; Schunk, Pintrich, & Meece, 2008, cited in Nelson et al., 2015); *future time perspective* (Husman & Lens, 1999, cited in Godwin & Kirn, 2020); *Social Cognitive Career Theory* (Lent et al., 1994, 2002, cited in Atadero et al., 2015; Borrego et al., 2018; Litchfield & Javernick-Will, 2015; Peña-Calvo et al., 2016; Raelin et al., 2014).
- Intellectual development: *Perry's (1968) work on epistemic beliefs* (cited in Faber & Benson, 2017); *Perry's (1988) scheme of intellectual development* (cited in Gainsburg, 2015).
- Identity development: *critical race theory* (used by Ong et al., 2020 and Trytten et al., 2012; the white space, cited in Blosser, 2020); *social identity frameworks* (used by McCall et al., 2021; Jensen & Cross, 2021); *models of leadership identity development* (used by Wolfinbarger et al., 2021); *model of political identity development* (Morgan, 2016, cited in Morgan et al., 2020); *critical engineering agency* (Johnson et al., 2011, cited in Godwin et al., 2016).
- Moral development: *Kohlberg's (1981) Theory of Moral Development* (cited in Harding et al., 2012).
- Integrative approaches (i.e., exploring how factors from multiple dimensions of student development are interwoven through life, Evans, et al., 2010): *Relational Developmental Systems Theory* (Lerner et al., 2013, cited in Gilmartin et al., 2019).
- Typology theories: *Person-environment fit - personality and career interests* (Holland; 1997, cited in Branch et al., 2015).

As shown in the list, some of the studies were informed by well-recognized student development theories in higher education (e.g., work by Bandura, Holland, Kohlberg, Perry, Terenzini, Tinto, and Weidman). On the other hand, several studies (i.e., Gilmartin et al., 2019; Godwin et al., 2016; Jensen & Cross, 2021; Nelson et al., 2015; Washington & Mondisa, 2021)

[2] Please note that we did not include the original citations for these frameworks. Interested readers can consult with the relevant JEE articles for their references. All the JEE articles we selected for analysis in this paper are included in Appendix B.

used frameworks that emerged within the past 15 years, thus contributing to the dissemination and application of these relatively new frameworks.

While 35 articles used frameworks from student development literature, the other 36 articles were mainly informed by[3]:

- Learning theories: e.g., *experiential learning theory* (Kolb, 1984, cited in Litchfield et al., 2016); *situative learning theory* (Sawyer and Greeno, 2009, cited in Gilbuena et al., 2015).
- Psychology: e.g., *Maslow's (1968) hierarchy of need* (cited in Allendoerfer et al., 2012); *person-thing orientation* (Graziano et al., 2011, 2012, cited in Bairaktarova & Pilotte, 2020).
- Sociology: *community cultural wealth* (Yosso, 2005, cited in Samuelson & Litzer, 2016); *social capital framework* (used by Brawner et al., 2012); *framework of ruling relations* (Smith, 1990, 1999, cited in Pawley, 2019).
- Education: *an integrative pedagogy model* (Tynjala, 2008, cited in Täks et al, 2014); *theory as liberatory practice* (bell hooks, 1992, 1994, cited in Secules et al., 2018b).
- Notably, engineering education (indicated by having been first published by journals with a focus on engineering education): *design thinking* (Dym et al., 2005, cited by Coleman et al., 2020); *framework of professional shame* (Huff et al., 2016, 2018, 2020, cited by Huff et al., 2021; Secules et al., 2021); *model of empathy in engineering* (Walther et al., 2017, cited in Walther et al., 2020); *Professional Social Responsibility Development Model* (Canney & Bielefeldt, 2015, cited in Schiff et al., 2021); *Engineering for Social Justice model* (Leydens & Lucena, 2018, cited in Leydens et al., 2021); *a framework of reflexive principlism* (Beever & Brightman, 2016, cited in Corple et al., 2020).

Methodologies and Paradigms Used

Of the 121 articles, nearly half of them used quantitative methods, nearly 40% used qualitative methods, and about one-tenth used mixed methods, as shown in Table 6. Within both quantitative and qualitative studies, most used research methods that involved a high level of complexity, i.e., advanced statistical methods or sophisticated qualitative methods, for analysis.

Table 6. Methodologies used in selected articles

Methodologies		n	%
Quantitative			
	Simple	11	9%
	Complex	50	41%
Qualitative			
	Simple	17	14%
	Complex	30	25%
Mixed methods		13	11%
Total		121	100%

[3] This list only shows the source subject areas or disciplines that informed more than two frameworks. The subject area or discipline under which a framework falls was determined based on our knowledge and/or the focused discipline of the journal that had first published the framework.

Only a small proportion of studies, mainly qualitative ones, indicated the paradigms their studies were using. Presumably, quantitative studies are mostly in positive or post-positive paradigm; and the paradigmatic differences lie in qualitative studies (Guba & Lincoln, 1994, 2005). Within the 30 qualitative studies that used sophisticated methods (i.e., those in the category of Qualitative – Complex), seven used grounded theory, six used narrative analysis or narrative inquiry, four used phenomenology and phenomenography respectively, four used ethnography, and three used case study methodology (Table 7). These findings reveal a stronger orientation toward using constructivist or interpretative paradigms in qualitative studies than toward the critical theory paradigm. This pattern aligns with the postpositivism-constructivism/interpretivism-critical theory paradigm shifts in the development of student development theories (Patton et al., 2016; Schuh & Jones, 2017).

Table 7. Methodologies and paradigms used by "Qualitative-Complex" studies

Methodologies	Paradigms	Studies
Grounded theory	Constructivism	Blosser, 2020; Dunsmore et al., 2011; Johnson-Glauch et al., 2019; McCall et al., 2021; NcNeill et al., 2016; Tomko et al., 2021 (also used phenomenology); Walther et al., 2011;
Narrative analysis / inquiry	Interpretivism, critical theory or feminism	Cruz & Kellam, 2018; Mayer & Marx, 2014; Pawley, 2019 (feminism); Secules et al., 2018b (critical theory); Wolfinbarger et al., 2021
Phenomenology	Interpretivism	Kirn & Benson, 2018; Huff et al., 2021; Lee et al., 2013; Walther et al., 2020
Phenomenography	Interpretivism	Dringenberg, 2018; Magana et al., 2019; Taks et al., 2014; Zoltowski et al., 2012
Ethnography	Interpretivism or critical theory	Danielak et al., 2014; Gilbuena et al., 2015; Secules et al., 2018a (critical theory); Secules et al., 2021
Case study methodology	Constructivism or interpretivism	Goncher & Johri, 2015; Leydens et al., 2021; Martin et al., 2013

Concluding Thoughts

In this paper, we have examined a major focus area of engineering education research—studies on engineering students' experiences and outcomes, or ESEO—through a targeted literature review of 121 selected JEE articles published from 2011 to 2021. We examined these articles from the perspectives of student development primarily in three ways: (a) categorizing them into literature-based domains of student development; (b) mapping the contextual and individual factors associated with student outcomes of interest in these articles onto an integrative student development theory—Bronfenbrenner's (1979, 1993) ecological systems theory; and (c) identifying how student development theories were used in these studies.

The findings from these efforts have directed us to the following characteristics that could distinguish research on engineering students' experiences and outcomes (ESEO).

- Topics: ESEO studies examine both learning experiences and associated outcomes of engineering students but can focus on experiences alone, most often through an equity lens. These studies inform a variety of individual and contextual factors that could interact with each other in students' learning experiences to foster their development in various domains. The student outcomes encompass, but goes beyond, engineering competencies. These outcomes can be grouped into domains of student development, which include cognitive and intellectual development, psychosocial and identity development, affective changes, behavioral changes, educational attainment and persistence, and career development.

- Frameworks: While some ESEO studies are grounded in student development literature, others draw upon theories from learning theories, psychology, sociology, education, and notably engineering education literature.
- Methodologies: Quantitative, qualitative and mixed methods can be used in ESEO studies. The complexity involved in these methodologies can vary.
- Research paradigms: ESEO studies can be conducted under various paradigms such as constructivism, interpretivism, and critical theory, in addition to positivism or post-positivism.

Furthermore, it is important to note our two tentative claims regarding the frameworks for ESEO research as conceptual or theoretical frameworks serve as the lens through which to frame a research study (Imenda, 2014). The first one is related to the general proposition in many student development theories (e.g., Tinto's theory of student departure, 1993; Weidman's socialization theory, 1989; Holland's typology of vocational choices, 1997) that student development is a function of the interaction between the person and the environment. These interactions are represented as four types of developmentally instigative characteristics in Bronfenbrenner's (1979, 1993) model. While our attempt to use the model to map the contextual and individual factors that emerged in the key findings of the selected JEE article was exploratory, our mapping may provide tentative evidence for a common presumption that exist in ESEO studies: engineering students' development is a function of their interactions with the learning environment. A closer examination of the contextual and individual factors revealed in each ESEO study can help provide better support for this presumption.

Our second tentative claim is related to the multiple disciplines that have informed the framing of ESEO studies. As shown earlier, nearly half of the ESEO studies we reviewed that explicitly included conceptual or theoretical frameworks have used, or expanded upon, concepts and models that fall under existing "theory families" in student development literature. The other half of ESEO studies drew upon concepts and frameworks from subject areas other than student development but look to learning theories, and disciplinary knowledge of psychology, sociology and education. The fact of the matter is that many student development theories are well grounded in the disciplinary knowledge of psychology, sociology and education (as explained in Patton et al., 2016; and also see a discipline-based analysis in Perna & Thomas, 2008). All this means that the frameworks that inform student development, either in the foundational theories or in the emerging ones, have been foregrounded in particular domains of disciplinary knowledge. A particularly interesting finding from our review is that some ESEO studies employed frameworks that were developed in prior engineering education research. These theoretical directions in framing ESEO studies demonstrate inward looking to parent disciplines for conceptual guidance and outward looking to problems in the practice of engineering education—two tendencies in engineering education research as identified by Klassen and Case (2021). They can also suggest that ESEO research is an area that requires knowledge that transcends disciplines. We wonder how a transdisciplinary approach could help advance ESEO research. Potentially, a transdisciplinary approach can bring together knowledge from multiple disciplines into a united framework (Pohl & Hadom, 2007) to better understand engineering students' development. Moreover, while we began our review with an attempt to explore what student development theories in higher education can contribute to ESEO research, our findings suggest that studies on student experiences and outcomes in the context of engineering education, in other words ESEO studies, can contribute to the further development of student development theories in the field of higher education as well. Future work is needed to further explore this potential.

Our findings also have implications to engineering education practice. When engineering competencies are all expressed in terms of skills (Passow and Passow, 2017), ESEO studies reveal that engineering students grow in their conceptual understandings, professional and personal identity, ethics and empathy, self-efficacy and motivation, civic engagement, and career choice, all of which are in the scope of student development. As such, engineering students' development during their undergraduate studies involves far more than competency development; hence, engineering educators and engineering accreditation agencies should grant greater attention to engineering students' well-rounded development. Another practical insight can stem from an integrative approach to viewing student experiences; that is, student experiences and outcomes are the result of how individual students engaged with their learning environment. This knowledge can help engineering educators more intentionally design the components that constitute students' immediate environment (or the microsystem) while becoming more aware of the enablers and constraints that could be afforded by the broader environments (or the meso- or macro-systems) and the determinants of student engagement with the environments (i.e., student agency).

Finally, the targeted literature review in this paper has allowed us to embark on a journey of exploring research on engineering students' experiences and outcomes. Despite the limitations in our review, this paper has attested that student development perspectives in the field of higher education offer scholarly and useful insights to engineering education researchers and practitioners. Extending the review to a broader scope of literature than one academic journal will help build a stronger case and strengthen the claims we have made in this paper.

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Appendix A: Conceptual or Theoretical Frameworks Used in Selected JEE Articles (2011-2021)

Domains of Student development	**Frameworks Used**	**Cited in …**
Cognitive and intellectual development (21 frameworks)	Representation fluency, and Lesh Transaction Model (rooted in Bruner's learning theory in 1966)	Moore et al., 2013
	Kuhlthau's (2004) information search process	Wertz et al., 2013
	*Perry's (1988) scheme of intellectual development	Gainsburg, 2015
	Nested structuration (Perlow et al., 2004)	Goncher & Johri, 2015
	Kirton's (1976, 1999) adaptation-innovation theory for cognitive style assessment	Jablokow et al., 2015
	Kolb's (1984) experiential learning theory	Litchfield et al., 2016
	Transfer and conceptual understandings	Koretsky et al., 2016
	*Terenzini and Reason's college impact framework	Lattuca et al., 2017
	Misconception and knowledge use frameworks	Nelson et al., 2017
	*Engineering epistemic beliefs (originally based on Perry's (1968) work on epistemic beliefs)	Faber & Benson, 2017
	*Social-cognitive approach to achievement motivation (Dweck & Leggett, 1988)	Snyder et al., 2018
	Vosniadou's (2001) framework on conceptual change	Brown et al., 2018
	Cognitive load theory in problem solving (Sweller, 1988)	Wang et al., 2018
	Hegarty's (2014) domain knowledge, external displays and mental conceptual model	Johnson-Glauch et al., 2019
	Adaptive and routine expertise (Hatano & Inagaki, 1986)	Magana et al., 2019
	^Design thinking (Dym et al., 2005)	Coleman et al., 2020
	Calculus content framework (Sofronas et al., 2011)	Faulkner et al., 2020
	Mayer's (1992) framework for math problem-solving	Duffy et al., 2020
	Hegarty's (2014) framework about comprehension	Johnson-Glauch et al., 2020
	*Terenzini and Reason's (2005) college impact framework	Ro & Knight, 2016; Knight & Novoselich, 2017
	Integrative pedagogy model of an entrepreneurship course (Adapted from Tynjala, 2008)	Täks et al, 2014
	Situative learning theory (Sawyer & Greeno, 2009), and communities of practice (Lave and Wenger, 1991)	Gilbuena et al., 2015
Psychosocial and identity development (14 frameworks)	*Self-efficacy in Bandura's social cognitive theory (1977)	Fantz et al., 2011; Purzer et al., 2011; Schaffer et al., 2012 ;
	*Critical race theory	Trytten et al., 2012
	Maslow's (1968) hierarchy of need	Allendoerfer et al., 2012
	Cultural construction (McDermott & Varenne, 2006)	Secules et al., 2018a
	*Self-concept; and ^model of work and family identities and engineering identity (adapted from Cech et al., 2011 and Cinamon, 2006)	Koul, 2018
	Person-thing orientation (Graziano et al., 2011, 2012).	Bairaktarova & Pilotte, 2020
	*Social identity frameworks	McCall et al., 2021
	^Framework of professional shame (Huff et al., 2016, 2018, 2020)	Huff et al., 2021; Secules et al., 2021

	*Models of leadership identity development (Komives et al., 2005, 2006)	Wolfinbarger et al., 2021
	bell hooks' theorizing (1992, 1994)	Secules et al., 2018b
	*Social cognitive career theory (Lent et al., 2002)	Raelin et al., 2014; Litchfield & Javernick-Will, 2015
	*Motivational and self-regulated learning profile (Schunk,Pintrich, & Meece, 2008)	Nelson et al., 2015
	*Model of College Student Political Identity Development (Author constructed: Morgan, 2016)	Morgan et al., 2020
	Intersections of epistemic cognition and researcher identity within a community of practice (Author constructed)	Faber et al., 2020
Affective changes (10 frameworks)	*Astin's Inputs-Environments-Outputs (I-E-O) model and Terenzini and Reason's (2005) college impact model	Finelli et al., 2012
	^ Three-Layer Model of Environmental Awareness (Authors constructed)	Weber et al., 2013
	*A path model connecting co-curricular activities, academic emotional engagement, self-efficacy and academic outcomes (Author constructed)	Wilson et al., 2014
	*Relational Developmental Systems Theory (Lerner et al., 2013; Overton, 2010, 2013),	Gilmartin et al., 2019
	^A theoretical model of empathy in engineering (Author constructed: Walther et al., 2017)	Walther et al., 2020
	^Professional Social Responsibility Development Model (Canney & Bielefeldt, 2015)	Schiff et al., 2021
	*Social identity theory (Hogg, 2016; Tajfel, 1974)	Jensen & Cross, 2021
	^Engineering for Social Justice model (Author constructed: Leydens & Lucena, 2018)	Leydens et al., 2021
	*Social community framework (Author constructed: Mondisa & McComb, 2015)	Washington & Mondisa, 2021
	^A framework of reflexive principlism (Beever & Brightman, 2016)	Corple et al., 2020
Behavioural changes (4 frameworks)	*Kohlberg's (1981) Theory of Moral Development, Modified version of Ajzen's (1991) theory of planned behaviour	Harding et al., 2012
	Job demands-control-support (JDCS) model (Johnson and Hall, 1988)	Goller et al., 2020
	*Weidman's (1989) model of undergraduate socialization	Millunchick et al., 2021
	Community of practice, and legitimate peripheral participation (Lave and Wenger, 1991)	Tomko et al., 2021
Educational attainment and persistence (5 frameworks)	*An extension of Tinto's (1993) model of student departure	Tyson, 2011
	*A path model connecting engagement, intent to persist, and retention (Tinto's 1993 work cited)	Kamphorst et al., 2015
	a five-factor personality model (Costa & McCrae, 1992)	Hall et al., 2015
	Community cultural wealth (Yosso, 2005)	Samuelson & Litzer, 2016
	*Social cognitive career theory performance model (Lent et al., 1994)	Atadero et al., 2015
	Social capital framework	Brawner et al., 2012

Career development (6 frameworks)	*Person-environment fit - personality and career interests (Astin, 1993; Holland; 1997)	Branch et al., 2015
	*Critical engineering agency (Johnson et al., 2011)	Godwin et al., 2016
	*Social Cognitive Career Theory (Lent, Brown, & Hackett, 1994, 2000).	Borrego et al., 2018; Peña-Calvo et al., 2016
	*Identity and motivation, engineering role identity, future time perspective (Husman & Lens, 1999)	Godwin & Kirn, 2020
	Undermatching, and *psychosocial factors related to math self-efficacy (Bandura, 1977, 1994)	Inkelas et al., 2021
Diverse student groups (3 frameworks)	Smith's theoretical framework of ruling relations	Pawley, 2019
	*Critical race theory, and the white space (Anderson, 2015)	Blosser, 2020
	*Intersectionality, critical race theory, and community cultural wealth	Ong et al., 2020

Notes: * indicating a framework in student development literature; ^ indicating a framework that was developed specifically in the context of engineering education.
The original sources for the frameworks are not included in this paper. To retrieve the original sources, readers can consult with the references (see Appendix B) under the column of "Cited In …".

Appendix B: References of the 121 selected JEE articles

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Bairaktarova, D.N., & Pilotte, M.K. (2020). Person or thing oriented: differences of first-year engineering students and practitioners. *Journal of Engineering Education, 109*(2), 230-242.

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