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Engineering Pathways from High School to Workplace: A Review of the Literature

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Engineering Pathways from High School to Workplace: A Review of the Literature

Abstract

Built upon the earlier literature review and research efforts on engineering pathways, we selected a total of 76 peer reviewed articles for a systematized literature review. Three inter-related developmental theories —the "life span, life space" theory, the Relational Developmental Systems Theory, and the Social Cognitive Career Theory—have informed our conceptual framework and guided our inquiry. We organize the selected articles by the life stages of high school, postsecondary education, and workplace experience. Through the review, we have identified pathway-related outcomes in each life stage, and various influencing factors in the categories of learning experiences and contextual factors, individual factors, and person inputs. We have discussed the implications of this review for engineering education research. Taking a student-centered approach, our review has suggested a number of practical implications for high school students and undergraduate students who desire to pursue engineering as a pathway.

Keywords: Engineering pathways, life stages, contextual factors, individual factors

Introduction

Engineering disciplines and careers have been continuously shifting over the past decades. With the recent emphasis on "STEM" (Science, Technology, Engineering and Math), a myriad of opportunities have emerged for students to navigate into engineering degrees and subsequently into engineering careers. Career development is an important domain of engineering students' professional growth [1], so engineering pathways have emerged as a topic of engineering education research [2].

Two major endeavors made over the past two decades have considerably shaped our understandings about engineering pathways. One was the U.S.-based Academic Pathways Study conducted in the 2000s by the Center for Advancement of Engineering Education of the University of Washington. The project investigated the experiences of engineering undergraduates and early-career engineers, with a focus on four aspects of becoming an engineer—skills, identity, education, and workplace [3]. The other was the report "Understanding Educational and Career Pathways of Engineers" produced by U.S. National Academy of Engineering in 2018 [4]. The report provides an informative review of relevant literature on internal / individual and external / contextual factors that influence the decision making and career choice of individuals who pursue engineering, and made intervention recommendations to providers of K-12 education and postsecondary education, and employers.

In addition, the past dedicated literature review efforts on engineering pathways have addressed diversity challenges in engineering by focusing on experiences and outcomes of minority groups in engineering—women [5][6], black women [7], African American students [8], and Latinx students [9]. Another review article focuses on two individual factors influencing STEM academic pathways: interest and motivation [10].

While all these efforts have considerably enriched the understandings of engineering pathways and related influencing factors, no literature review has been conducted using a life stage approach from individual students' perspectives. Our paper aims to fill this gap by conducting a systematized literature review [11], a type of review that does not involve a comprehensive search that a systematic literature review requires, but allows us to use a conceptual framework to guide our literature review while building upon the findings of the past similar research endeavors [3]–[10].

While our review does not aim to be comprehensive and exhaustive, our findings will inform youth in high school who consider pursuing an educational and career pathway toward engineering and engineering undergraduate students who ponder over how to optimize their postsecondary experiences for better academic and career development. These findings will also be informative and interesting to counsellors and advisors who support high school and engineering undergraduate students.

Conceptual Framework and Research Questions

In this paper, we use three inter-related developmental theories —the "life span, life space" theory [12], the Relational Developmental Systems Theory [13], and the Social Cognitive Career Theory [14]— to inform our conceptual framework and guide our inquiry. Both "life span, life space" theory and a Relational Developmental Systems Theory view individuals' changes as a result of individual-context relations. The "life span, life space" theory identifies five distinct life stages: growth, exploration, establishment, maintenance, and disengagement, with each stage being characterized by different developmental tasks pertaining to careers. In the stage of growth, an individual becomes aware of an impending career decision; in the stage of exploration, they evaluate alternative lines of action and consider various possible outcomes; in the stage of establishment, they pursue the preferred line of action but still with a tentative commitment; in the stage of maintenance, they hold onto the chosen line of action; and in the stage of decline, they turn away to a new line of action or taper off prior to retirement. In our study, we consider these as developmental stages. The Relational Developmental Systems Theory recognizes that variation in individuals' development "exists across time within contexts, and across contexts within time;" as a result, "differences in time and place constitute vital contributors to plasticity across the life span" [13]. Given the variations by time and place, we expect a diverse range of pathways of individuals who are on their way to the engineering profession.

The Social Cognitive Career Theory (SCCT) [14] posits that one's learning experiences can influence their self-efficacy and outcome expectations, which in turn influences their interests, goals and, ultimately, career choice actions; these learning experiences are affected by person inputs (such as predispositions, gender and race) and contextual affordances (such as family influence); and the contextual factors proximal to choice behavior have an impact on choice goals and actions. The theory informs us of specific individual and contextual factors that are important to individuals' career choices and the relationships among them. We used these factors to code the literature we selected.

Integrating these three theories, we make the following propositions about engineering pathways, with the individual factors (the first proposition) interwoven with the contextual factors (the second proposition):

1. Individuals' self-efficacy, outcome expectations, interests, and career goals and actions toward engineering evolve across the developmental stages of growth, exploration, establishment, maintenance, and disengagement.
2. Contextual differences in time and place at different life stages—high school, postsecondary education, and workplace—contribute to the diversity in individuals' pathways toward, or away from, engineering.

Figure 1 shows a visualization of the conceptual framework with the life stages and the developmental stages of growth, exploration, establishment, maintenance, and disengagement. These developmental stages can correspond to, but not perfectly align with, the life stages of high school, postsecondary education, and workplace experience. Within each of the life stages there are specific learning experiences which influence individuals' self-efficacy, outcome expectations and interests, which in turn influence their choice goals and actions; and choice actions made at the previous life stage lead to the learning experience in the subsequent life phase. Within each life stage there are also contextual factors that influence the learning experiences and choice goals and actions. Throughout the entire life span, individuals' person inputs and background factors influence the experiences in each of the life stages.

Based on this conceptual framework, we ask the following research questions:

- What does the literature tell us about individuals' engineering pathways from high school to workplace?
- What factors are important to shaping individuals' educational and career pathways toward, or away from, engineering, over the life stages from high school to workplace?

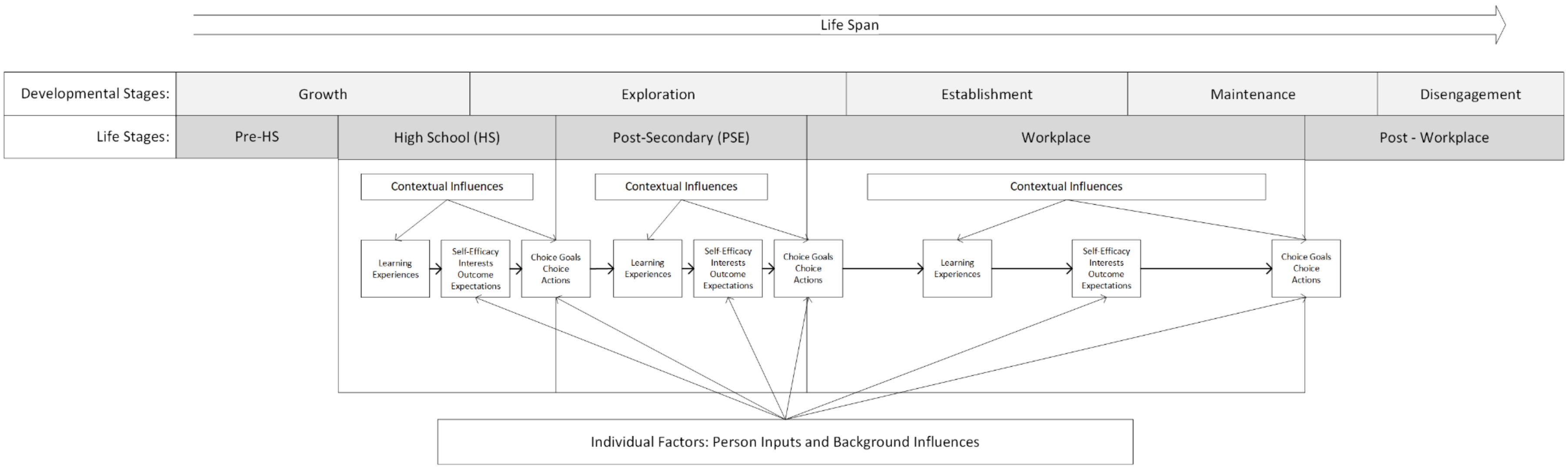

Figure 1: An illustration of the conceptual framework of this paper, combining concepts from "life span, life space" theory, the Relational Development Systems Theory and the Social Cognitive Career Theory

Methodology

Our systematized literature review followed a modified version of the PRISMA [15] approach and involved the following steps:

1. Literature searches of various scholarly databases
2. Screening of the literature search results based on specific inclusion criteria
3. Coding of the articles to identify themes
4. Review and analysis of the findings

We began with building upon our previous literature review [1] of the articles published by the Journal of Engineering Education (JEE) from 2011 to 2021 that focused on undergraduate engineering students' development. We used the database we had created but extracted articles on high school and undergraduate students' experiences in reference to the relevant research topics identified from our methodological review of articles published by four major engineering education journals [16]. We selected articles on the following topics to include in our current literature review on students' engineering pathways: "diversity and retention of engineering students," "academic / career pathways of engineering students," "admission of engineering students," and "engineering aspirations of secondary school students" [16].

We then searched scholarly databases of Compendex, Scopus, and Web of Science, using various keywords such as "engineering," "student pathway," and "career." Table 1 shows a summary of our literature search efforts. Table 2 shows the inclusion and exclusion criteria, which suggest the scope of our literature review.

Papers were coded based on the following coding options:

- Nature of the paper: empirical paper and literature review;
- The life stages: high school, postsecondary education, and workplace;
- Data analysis method [17];
- The components included in the SCCT: person inputs; learning experiences; self-efficacy, outcome expectations, and interests; and career goals and actions

After a process of identification and screening, as shown in the PRISMA flow chart in Figure 2, 76 articles were included in the review. Table 3 shows the breakdown of these articles by life stage.

Table 1: List of literature searches and keywords used

Databases used	**Searched in …**	**Keywords used**	**Numbers of results**	**Search dates**
Scopus	Title, abstract and key words (default option)	engineering AND career AND path*	1868	October 13, 2022
Scopus	Title, abstract and key words (default option)	engineer* AND career AND student AND (choice OR decision)	1947	October 22, 2022
Web of Science	All Fields	engineer* AND career AND student AND interest	1728	October 22, 2022
Compendex	All Fields	engineering AND entrepreneurship	7,814	November 1, 2022
Web of Science	Title, abstract and key words (default option)	engineering AND women AND career* OR path*	1000	November 1, 2022
Scopus	Title, abstract and key words (default option)	Engineering AND review AND path* OR pipeline AND career OR job OR employment OR occupation	261	January 5th, 2023
Web of Science	All fields	"career path" AND "high school"	62	January 6th, 2023
Scopus	All fields	"career path" AND "high school"	2,188	January 6th, 2023
Compendex	All fields	"career path" AND "high school"	87	January 6th, 2023
ASEE Peer	All fields	Career pathways	3390	January 29th 2023
ASEE Peer	Title	Career pathways	31	January 29th, 2023

Table 2. Inclusion and exclusion criteria for literature search

Inclusion Criteria	Exclusion Criteria
Papers from peer reviewed journals or conference proceedings	Non-peer reviewed articles or opinion pieces
Papers with focus on at least one of the three life phases of interest – high school, postsecondary education and workplace; Papers on undergraduate student experience	Life phases before high school, i.e., elementary school Life phases after the workplace, e.g., retirement Graduate-level student experiences excluded
Papers including a focus on a choice goal or choice action related to student pathways, as per our conceptual framework	Papers that focused on student experiences without relating to a choice goal

Table 3: Number of papers reviewed by life stage

Life Stages	**Count**
High school	14
Postsecondary education (PSE) experiences	50
Workplace experience	12
Total	**76**

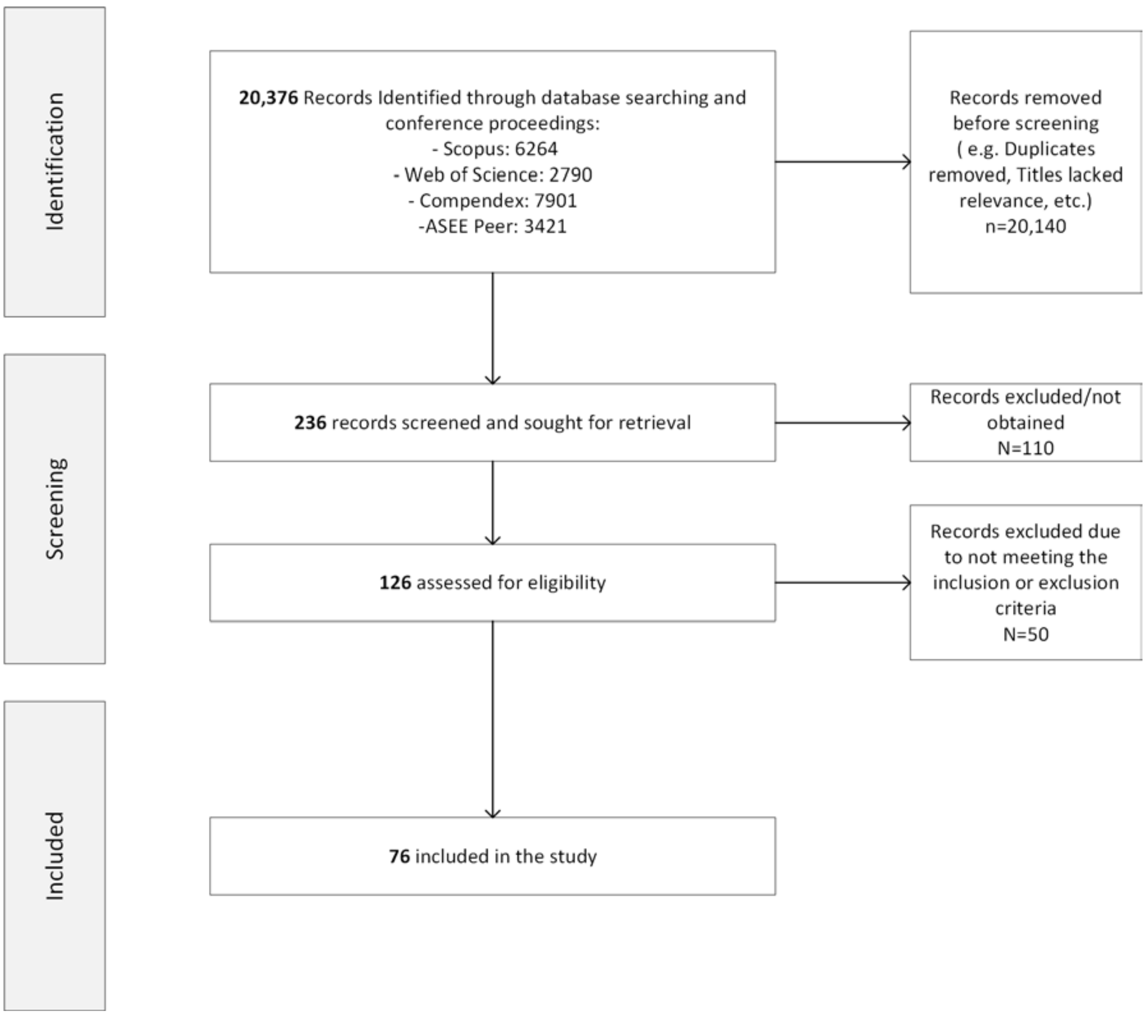

Figure 2. A PRISMA flow chart illustrating the literature search and selection process

Results

In this section, we report our literature synthesis for each of the 3 life stages: (a) High school (HS) and the transition to postsecondary education (PSE); (b) PSE experience and the transition to the workplace, and (c) workplace experience. For each life stage, we have organized the information under the following four categories based on the elements in the Social Cognitive Career Theory:

1. Choice goals, choice actions, and performance and attainments, which are pathways-related outcomes
2. Learning Experiences and Contextual Influences
3. Self-efficacy, outcome expectations, and interests, and other individual factors
4. Person Inputs and Background Contextual Affordances

High school and the Transition to Postsecondary Education

Pathway-Related Outcomes

Literature shows that high school students generally have STEM vs non-STEM pathways to choose between. This could be choosing STEM vs. Non-STEM subjects in senior high school [18] or choosing a STEM vs. Non-STEM major in postsecondary education [18]–[22]. Some literature references specific choice of engineering major, i.e., chemical vs. mechanical vs. civil etc. [23] and one paper focused on the choice of engineering vs. engineering technology [24].

Learning Experiences and Contextual Factors

During high school, various learning experiences, particularly math and science courses, are recognized in the literature that contribute to student pathways. High attainment in these courses correlates strongly to a choice in STEM pathways [25]. These science subjects can be physical science, computer science and health sciences, biology [18]; they can also be advanced courses such as advanced chemistry, or AP courses [19].

Extra-curricular STEM activities were also identified in much of the literature, including both in-school and out-of-school activities, outreach programs, school clubs, STEM hobbies and science centres. These extra-curricular activities increased students' interest in careers in STEM fields [22], [23], [26]. The structure and format of the learning experiences also played a role in developing interest in STEM and outcome expectations of STEM through hands-on activities and workshops, as well as content that was relatable to the students [20].

In addition, guidance from parents, teachers and guidance counselors/academic advisors played a role in the learning experiences, including influencing choice goals and actions directly and indirectly [23], [24].

Individual Factors

The importance of self-efficacy is the most often referenced in the literature in the high school life stage in terms of student pathway. Self-efficacy in math is identified as a significant influence [21], [27], followed by science self-efficacy particularly in physics and, in some instances, computer science [18]. Specific to engineering majors, self-efficacy in chemistry played a large role in students' choice to pursue chemical engineering [28], [29]. In addition, "tinkering self-efficacy" is a potential influencing factor for the engineering pathway although it is not related to a specific subject but more about the belief in hands-on capability [26].

High school students have particular outcome expectations about the engineering pathway. They expect engineering work to be hands-on and believe that those with an interest in hands-on activities are likely to choose engineering [24], [25], [28], [29]. They expect engineering work to be very challenging [23]. The expectation of chemical or nuclear engineers having to deal with hazardous chemicals was found to be a factor for students not choosing these fields as a major [28], [29]. In addition, personal inspiration is another factor for pursuing STEM fields [30], which can be a result of various individual and family factors.

Person Inputs

Gender and race/ethnicity were the most commonly identified factor associated with high school students' educational pathways [19], [27]. It was overwhelmingly reported in many of the papers that intentions to pursue STEM or self-efficacy / sense of belonging in STEM were much higher among male students than female students [18], [22]. Similarly, white/Caucasian students showed higher intentions or self-efficacy in STEM areas [18]. Similar gender-related patterns were shown in studies conducted in Europe, South America, Africa and Asia [20], [22], [25]. In addition, socio-economic status (SES) was also referenced as an influencing factor, with those of higher SES being more likely to pursue STEM pathways [21]. Further, parental / family influences were also a factor, with higher parental involvement leading to increased likelihood of interest in pursuing a STEM career [23]. These family influences can be stronger for some families than others; for example, family support was stronger for students in migrant returnee families than those who did not have migration experiences in Kosovo[31].

Post-Secondary Experiences and the Transition to the Workplace

Pathway-Related Outcomes

The 50 articles we have reviewed about engineering students' postsecondary education experience are mainly directed to two pathway-related outcomes. One is choice of engineering majors by direct-entry and transfer students (for example, [32]–[34]); the other is persistence in engineering (for example, [6], [35]–[37]).

Learning Experiences and Contextual Factors

School-related institutional factors are found to outweigh socio-demographics such as gender and race in affecting students' engineering pathway [37]. These factors are exhibited in curricular experiences, co-curricular experiences, institutional environment, and contextual supports and barriers, to be elaborated below.

Curricular experiences are found to impact students' intentions of studying engineering. Student perceptions of teaching barriers, satisfaction with course activities, and interactions with lecturers and classmates have an immense impact on students' intentions of pursuing engineering careers [38]–[40]. For example, engineering students, particularly male software and hardware students, perceived more teaching barriers than their peers in other engineering disciplines [39]. With respect to learning styles, for sense-making students who want to pursue a deeper understanding of concepts, heavy engineering workloads were a detractor in their learning experience [41]. Furthermore, specific courses that students take also affect their career pathways. For example, almost half of all the engineering graduates who took courses on entrepreneurship started a business [42].

In addition to classroom experiences, co-curricular activities also offer significant opportunities for growth. Participation in makerspaces, STEM outreach activities [43] or clubs and societies, such as National Society of Black Engineers, allows students to gain new experiences and find a community, thus leading to higher graduation rates [35]. Similarly, mentoring and advising programs help integrate transfer students into the community, thereby increasing persistence [44]. Disappointment in advising, on the other hand, contributes to non-persistence [45]. Internship experiences are found to increase work self-efficacy and student interests in engineering pathways [46]. Undergraduate research experiences also enable students to develop interpersonal skills, research skills, and professional competencies [47]. Working at partnering institutions helps broaden students' horizons [48]. Notably, encouragement from faculty is conducive to student participation in these programs [49]. Moreover, these co-curricular experiences are particularly valuable to women students as women benefit more from internships in terms of development of soft skills and technical self-efficacy [50]; and social and academic networks for women contribute to student success through providing sources of social capital [51], [52].

In addition, the broad institutional environment, such as university type (for example, historically black colleges and universities or HBCUs versus predominantly white universities in the U.S. context), institutional culture, and admission policy all affect student pathways in significant ways. Universities with stricter admission policies tend to "weed out" students, thus contributing to differences in persistence [37]. A gender bias can exist in the results of an admission process, which can be traced back to the admission policy[53]. Black students attending HBCUs fare better in terms of self-efficacy, outcome expectations, technical interests, social support, and educational goals than Black students at a predominantly White university [54], [55]. The institutional ruling relations determine who receives financial aid and the support available for transfer and Native students [56]. Transfer students also face challenges when navigating disorganized webpages regarding admission [34]. Women and other minority groups are affected more than their peers by certain aspects of institutional environment. In institutions that “craft ‘the ideal student’ as a young, single white male” [56], women are more likely to face an acute sense of isolation, grappling with hypervisibility and microaggressions due to contextual influences [57] and underrepresentation in student enrolment [52]. Similarly, LGBQT students face marginalization and devaluation in engineering programs, which creates increased health and wellness issues [58].

Further, student experiences are strengthened by contextual supports such as financial aid and encouragement from advisors, friends, family, and teachers [32], [49], [51], [54]. This was particularly true for women students [46], [59]. Conversely, economic need, discouragement, and pressure from parents to change career paths constitute contextual barriers [54], [59] [60]. Another contextual factor is work-life balance, which is equally important when considering different career paths [61]–[63]. An unreasonably heavy workload is a main reason for first-year students leaving engineering [60]. On the other hand, GPA and self-efficacy contribute to effective work-life balance, and students with such a balance exhibit stronger intentions to pursue engineering [62].

Individual Factors

Engineering students differ in self-efficacy beliefs, interest in engineering, and the anticipation of favorable outcomes [54], [55], [59], [64]. The variations in these individual factors can affect engineering students’ career choices, including non-engineering careers (e.g., product/project management, consulting, finance, venture capital) [38], [65].

With respect to self-efficacy, students who are intrinsically motivated are more likely to develop self-confidence in technical engineering work and in their ability to succeed in work, career, and academic pursuits [6], [38], [46], [61], [63]. Even with limited support from others, students with high coping efficacy overcome barriers independently [54], [55]. Further, students’ pride, self-actualization, and spirituality are connected with these self-efficacy beliefs [66] whereas low self-efficacy result from perfectionism and a fear of failure [6], [45]. Both academic and work self-efficacy are critical to student retention [46].

Students’ interest in engineering or non-engineering work motivates them to pursue a particular career path. This passion arises from the desire to challenge oneself or an enjoyment of working with technology, reading about engineering issues and research, interacting with businesses and stakeholders, contributing to social improvement, or solving complex problems [6], [32], [33], [54], [55], [67]. Students interested in environmental sustainability are more likely to pursue engineering than those interested in other issues such as poverty, disease, and opportunities for minorities [67]. Students’ vocational orientations and math/physics identities lead to their preferences for work involving science, technology, and math or identification with a specific profession [32], [33], [64], [65]. An emotional attachment to the concept of becoming an engineer was found to impact the experiences of undergraduates leaving engineering [45]. Students develop interest in engineering subject matters from interactions with peers and advisors [68]. Their interest in engineering and non-engineering graduate studies is related to the time that engineering students spend in different co-curricular activities [69].

Students also have expectations for positive outcomes from their engineering degree [54], [55]. As they invest considerable time and energy into postsecondary education, students anticipate the career utility of their degrees [61], [63]. Engineering students are externally motivated by financial incentives such as high salaries, income stability, and job security [6], [32], [54], [55], [65]. The level of prestige associated with different careers motivates students who are interested in improved career prospects and promotion into leadership positions [32], [65]. Together, these external and intrinsic motivations contribute to students' individual choice goals and actions.

Person Inputs

Students' person inputs and backgrounds contribute to their career pathways. White or female students tend to leave engineering earlier because they are more likely to have lower self-efficacy [6], [36], [60], [70]. Women are drawn more to certain disciplines such as industrial engineering due to their "warmth" and "more feminine" nature [71]. More broadly, gender differences stem from sociocultural influences relating to the status of women and the representation of female engineers in society [38]. The traditional demands of motherhood impose career constraints and work-family conflicts, and discourage engineering pursuits [50], [62]. However, women's participation in makerspaces is ascribed to early childhood experiences with making [72]. Unsurprisingly, societal pressures and work-family conflicts experienced by women students in face of choice goals exist across geographical boundaries (e.g., in Japan, [38]; in Thailand [62]; and in Canada [50]).

Similarly, different cultural backgrounds enable students to develop cultural resources within their communities and apply these resources to their university experience [73]. Familial capital supports marginalized students to pursue humanitarian engineering through encouraging stories and role models [74]. First-generation students also gain funds of knowledge from their families and communities regarding tinkering, perspective taking, and reading people [75], [76]. For international students, being away from home enables them to learn about new opportunities [48].

In addition, person inputs such as direct entry versus transfer status [77], high school performance [36], [78] and personality such as conscientiousness [78] play a role in student persistence. Studies have explored the differences between direct-entry versus transfer/returner students [61], [77]. For direct-entry students, high school experiences, academic performance (i.e., GPA and SAT scores), and "calculus readiness" contribute to their postsecondary achievement [36], [69], [78]. For transfer students, pre-transfer completion of engineering courses and academic performance in those courses contributes to persistence [44]; they have higher graduation rates than direct-entry students, or starters, in engineering [71]. However, transfer students can report less self-confidence and perceive higher financial, academic, and work-life balance costs [61]. In addition, poor performance and lack of preparation are significant factors leading to non-persistence [45].; the first-year grades and high school math scores are important influencing factors for choosing engineering and science majors [79]. Participation in certain types of high school programs can help as well. For example, women students who take engineering career and technical education (E-CTE) coursework in high school benefit more from E-CTE in connection to completion of an engineering degree than men

[80]. Factors in high school that contribute to science identity formation, particularly in physics, are significantly correlated to persistence in engineering pathways [81].

Furthermore, individual differences in aptitude and personality (e.g., openness, conscientiousness, extraversion, agreeableness, neuroticism, locus of control) [78] as well as thing and person orientations [28], [49] influence career and research intentions. Conscientious students are more likely to persist [78]. Person orientation impacts the perception of faculty encouragement to participate in research, indirectly affecting students' interests [49]. Thing orientation, i.e. the affinity for working with things in comparison to people, influence students' beliefs about research, which were more closely related to women's intentions of pursuing research than men [28].

Workplace Experiences

Pathway-Related Outcomes

The literature revealed two types of pathway-related outcomes for individuals' workplace experiences: (a) persistence in engineering or departure from engineering [83], [84], and similarly, consistency or change between original and future goals [85]; and (b) career paths of engineering graduates [86]–[90]. Specifically, engineering graduates' career paths have been defined

- by competencies and design responsibilities of specific roles/occupations: Engineering occupations (holding determinate responsibility for instantiating or governing design form, and sharing collaborative responsibility for targeted design function), Engineer-Conpar occupations (influencing and moderating design form, and sharing collaborative responsibility for targeted design function); and Other occupations (employing engineering related knowledge or skills but not in the role of collaborating on or influencing design form) [89]; Product Leadership, Operational Excellence; Customer Intimacy [90];
- by function and trajectory of roles (managerial, technical, and hybrid paths) [86], [88];
- by the combination and sequence of various roles during the career: company man, technical specialist, boundary spanner, entrepreneur, social impact change agent, and invisible engineer [87];

Person Inputs

A significant theme in literature on workplace experience in engineering is gendered engineering career pathways. Specifically, newly graduated women in engineering find a job faster than their men peers; and this is also true in engineering jobs with equivalent salaries [91]. Women and men tend to have a different career trajectory. Women graduates in engineering are more likely than men to changes their original career goals [85]. While women engineers are better represented in managerial and hybrid career paths, male engineers are better represented in the technical career path; and women on the managerial path report higher intent to leave engineering, lower identification with other engineers, lower perceived intragroup respect, and lower work satisfaction than men on the same path whereas women on the hybrid path report significantly higher levels of identification with engineering colleagues and meaningful careers than men on the technical path [86]. Certain career paths, such as those toward becoming a company man, an entrepreneur, and a social impact change agent, are more likely to be taken by men than women [87]. Encouragingly, women who continue in engineering tend to experience workplace supports and have higher levels of occupational commitment; however, women tend to leave engineering due to unmet needs in comfort and status [83], [84]. In addition to these workplace-related factors, the traditional demands of motherhood have imposed constraints on women's engineering pathways[92] . Notably, little is known about the career pathways taken by racialized engineering graduates or other minorities.

Work Experiences, Individual and Contextual Factors

Studies reveal that contextual factors outweigh individual factors in influencing engineering career pathways. While individual factors such as self-efficacy, outcome expectations, and interests matter, they do not appear to play a significant role in explaining gendered career paths. For example, no significant difference are found between women who left engineering and those who persisted in engineering with respect to vocational interests, self-efficacy, and outcome expectations in engineering task and managing organizational matters and multiple life-roles [83]. In contrast, negative work experience [85] such as unmet needs in the workplace in terms of job security, supportive supervisory relations, poor advancement opportunities [84], and engineering turnover interventions [83] play significant roles in women's career choice actions in engineering.

A significant undergraduate experience that contributes to engineering graduates' early career paths is co-op and internships. These co-curricular activities
play an important role in students' acquisition of technical knowledge and soft skills, clarification of educational and career pathways, and building of professional networks[50], [93], [94]. Similarly, participation in service learning activities during the undergraduate studies also contribute to engineering graduates' transitioning to the workplace, gaining workplace experiences and developing professional skills [95].

Discussion

Addressing the Research Questions

To address the first research question of this paper that explores individuals' engineering pathways from high school to workplace", our literature review shows the following patterns in pathways of students who consider pursuing, or have pursued, an undergraduate engineering degree. At the high school stage, the educational pathways are primarily categorized by 'STEM' vs 'non-STEM', either for choice of subjects studied in high school, or by the choice of postsecondary majors. However, at the postsecondary education stage, pathways are defined by choice of engineering disciplines and persistence in an engineering discipline till completion. At the workplace stage, pathways are defined by functions, roles or design responsibilities. This set of pathways can be exhibited in Figure 3. It appears that engineering pathway starts "wide" from a choice between STEM and non-STEM high school subjects, then narrow down to a specific engineering discipline during postsecondary education, and then become “wide” again in the workplace experience stage when engineering graduates could take on different functions and roles in the workplace. This life-stage-based career pathway pattern may provide an explanation for the fact that only about one-third, or less, of engineering bachelor’s degree holders are employed as engineers in both U.S. [4] and Canada [93], [96]. The diversity of career pathways is a distinctive and desirable feature of engineering education in comparison to other professional programs offered by universities.

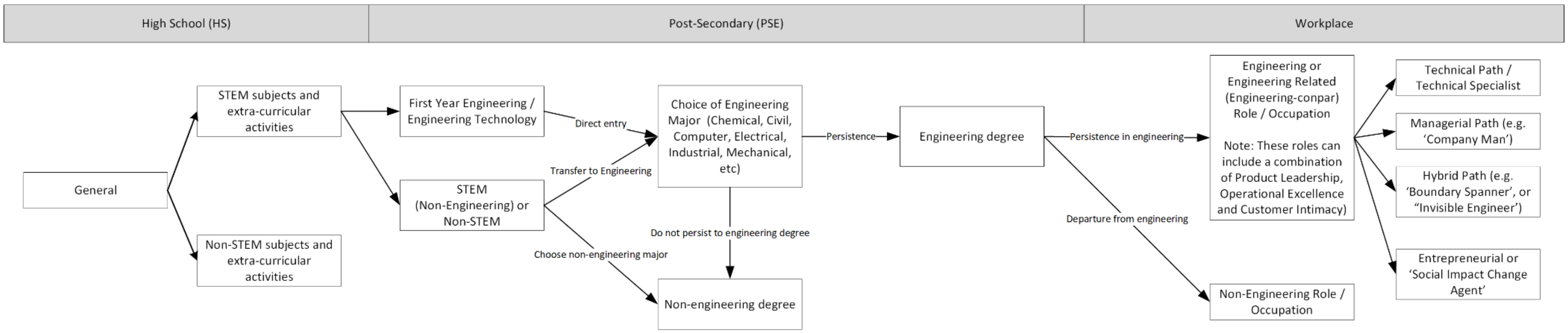

Figure 3: Summary of engineering pathway-related outcomes across the three life stages of high school, post-secondary education and workplace

To address the second research question that investigates important factors for shaping individuals' educational and career pathways, we have summarized the literature-based influencing factors for individuals' engineering pathways in Table 4. As shown in the table, in both high school and postsecondary stages, curricular and co- / extra-curricular experiences contribute to students' education and career choices. However, more influencing contextual factors are reported in the postsecondary stage. Across all three life stages, self-efficacy is an important influencing individual factor. However, individual factors seem to play a decreasing role in career choice, relative to contextual factors, from the high school stage to the workplace stage. In the high school stage, self-efficacy, especially self-efficacy in math and science, appears to be the most significant influencing factor, with some influence from interest and outcome expectations. At the postsecondary stage, self-efficacy, along with interest and outcome expectations, continues to be an influencing factor. Nevertheless, in the workplace stage, individual factors seem to play less of a role in career choices than workplace-related contextual factors. With respect to person inputs, gender matters to engineering pathways from high school, and all the way to the workplace stage. This means that gender inequality in engineering pathways is deeply rooted in every life stage of women who desire to pursue engineering as a career. Other person inputs, such as race and personal attributes, seem to have been studied much less.

Connecting with the Conceptual Framework

In light of the "life span, life space" Theory [12] and the Relational Developmental Systems Theory [13], the findings, as summarized above, corroborate that individuals' career choice and development is a result of individual-context relations. Individuals' pursuit of engineering as an education and career pathway appears to go through the developmental changes of growth, exploration, establishment, maintenance, and disengagement. High school students who are confident of their math and science abilities are more likely than their peers to explore the educational pathway toward STEM, particularly engineering. This exploration may continue on in their lower years of engineering studies in postsecondary education. With various curricular and co-curricular experiences, some of these undergraduate engineering students may be more determined to pursue engineering as a career pathway, and others may start to explore alternative career paths that could be somewhat distant from the engineering discipline *per se*. By the time of graduation from an engineering degree, some graduates maintain the pathway toward the engineering profession while many others become less engaged in the engineering path but turn to a variety of other career options that an engineering degree allows them to pursue. The cycle from growth toward engineering to disengagement from engineering varies from individual to individual. These individual variations exist across the three life stages, considerably depending on what the institutional contexts have afforded.

Revisiting the Social Cognitive Career Theory (SCCT), we find that the components of the theory provide a valid framework for capturing a range of factors that influence individuals' engineering pathways. In this paper, we have effectively used these components to map and organize the findings from our literature review. However, not all important factors that literature reveals in relation to engineering pathways are included in the theory. For example, science identity formation in high school[81], and engineering professional identity in postsecondary education [1], are important to individuals' engineering pathways; however, identity , is not an explicit component of SCCT. Therefore, how to add these factors into SCCT can be future work on engineering pathways.

Table 4. Summary of influencing factors for engineering pathways in three life stages

	High school	Postsecondary education (in an engineering school)	Workplace
Learning / work experiences and contextual influences	Experiences in math and science courses; Extra-curricular STEM activities; Guidance from teachers, counsellors and advisors	Curricular experiences; Co-curricular activities (e.g., makerspace participation, STEM outreach, club participation, undergraduate research, internships, and mentorship); Institutional environment, including university type, institutional culture, and admission policies; Contextual supports, including financial aid and encouragement from faculty and staff; Contextual barriers, including discouragement and lack of work-life balance	Negative work experiences; Unmet needs related to the workplace; Engineering turnover interventions Contributing learning experiences: co-op, internships, and service-learning activities
Individual factors	Self-efficacy in math and science subjects, and in tinkering	Self-efficacy; Interest in engineering or non-engineering work; Expectations about outcomes from an engineering degree, including financial incentives and prestige	Self-efficacy; Interest; Outcome expectations
Person inputs and background contextual affordances	Gender; Race; Socio-economic status; Parental / family involvement	Gender; Race; Cultural backgrounds; Direct-entry vs. transfer status; Personal aptitudes and orientations	Gender

Implications for Engineering Education Research

As discussed above, our literature review has generally informed us of the engineering pathways and the major influencing factors, thus serving as a starting point for our inquiries about engineering pathways. Our review demonstrates that research on engineering pathways closely intersects with research on Engineering Student Experiences and Outcomes (ESEO) [1], and the Diversity, Equity and Inclusion (EDI) research. Therefore, advancing research on engineering pathways will contribute to both ESEO and EDI research.

This work has also directed us to more questions that remain unanswered by the existing literature. These questions require further efforts to dive deeper into the area of engineering pathways in engineering education research.

- What can an engineering school do to attract high school graduates who are interested in engineering but do not have a strong self-efficacy in math and science?
- In addition to self-efficacy, interests and outcome expectations, how do other individual factors such as engineering professional identity affect undergraduate engineering students' career pathways?
- What factors affect undergraduate engineering students' choice of specific engineering disciplines?
- What factors detract enrolled undergraduate engineering students from completing the degree? What can an engineering school do to support the success of these students?
- What type of undergraduate students consider pursuing other career paths than the traditional engineering role? What experiences have shaped their considerations? What individual and contextual factors play a role in these career choices?
- What do racialized engineering students' career pathways look like? How do these pathways compare with their peers'? The same questions can apply to international engineering students, LGTBQ students, first-generation students, and students with disabilities.
- What strategies can engineering graduates, particularly women and other marginalized groups, use to navigate the complex workplace environment to optimize their potential? How can employers and workplaces maximize the productivity of engineering graduates?

In addition, how are the individual and contextual factors summarized in Table 2 actualized in the local settings of an engineering school? Engineering schools can take advantage of the variety of student data they collect every year about student experiences and outcomes to perform student data analytics work to answer questions about academic and career pathways of their own students. The results from this work will inform student advising, student programming, and curriculum renewal.

Implications for Students

A number of recommendations to high schools, postsecondary institutions and employers have been documented elsewhere [4]. Taking a student-focused approach, our literature review mainly targets at high school students and undergraduate engineering students while they navigate their educational and career pathways. Below are summaries of some practical implications for these students, based on the findings in this paper.

The literature we have reviewed suggests the following for high school students considering engineering pathways:

- Building confidence in math and science in high school contributes to their pursuit of an engineering degree.
- Having exposure to engineering work affects their decisions about pathways.
- High school students can build confidence and gain exposure through:
  - Engaging in extracurricular activities in STEM
  - Choosing STEM subjects in high school and obtaining high academic achievement
  - Seeking guidance and support from school counselors
  - Receiving encouragement from parents.
- When choosing a degree for postsecondary education, exposure to different STEM fields and subjects can help determine which engineering discipline students select.
- Selecting an institution that has a culture that aligns to their values and identity can lead to greater persistence in engineering (e.g., Black students attending HCBUs).
- Securing financial aid can also lead to greater persistence in engineering for high school students considering engineering degrees.
- Parental and family support is a factor contributing to their interest and confidence in pursuing a STEM pathway.

The literature we have reviewed suggest that undergraduate engineering students should consider the following:

- Both curricular and co-curricular experiences contribute to their career choice. Curricular experiences include engagement with course activities, course selection, and workload. Co-curricular experiences include club participation, networking, mentoring, internship, and research experience.
- During their studies, engineering students grow in self-efficacy and interest in engineering and non-engineering work, and develop understandings about the outcomes from an engineering degree.
- Building intrinsic motivation and coping efficacy can lead to persistence in engineering degrees. Students can build this intrinsic motivation through engaging in extra-curricular/co-curricular activities, and enhance self-efficacy by moving away from perfectionism and fear of failure.
- Every postsecondary institution has its own institutional culture. It is important for students to learn to navigate the institutional processes, utilize supports and overcome barriers. This is particularly critical for women and students in other minority groups. This can also be done by engaging with an academic advisor.
- An engineering degree allows graduates to pursue a range of career options, including technical roles, managerial role or a combination of both. In other words, the engineering degree does not limit graduates to engineering roles alone.

Students need to be aware that career pathways of engineering graduates can be gendered, which means that men and women tend to take on different types of career paths. Persistence in engineering roles is mainly related to contextual factors, such as job security, supportive supervisory relations, and advancement opportunities. Women students should start to learn how to navigate their factors during their undergraduate studies.

Conclusion

In conclusion, our systematized review was informed by human development perspectives of "life span, life space" theory, the Relational Developmental Systems Theory, and the Social Cognitive Career Theory. Although conducted in a limited scope, this review provides a foundation for categorizing and characterizing students' engineering pathways, as well as identifying influencing factors. This work not only sheds light on further research questions on engineering pathways but also provides guidance to high school students and undergraduate students who explore and navigate their educational and career pathways in engineering.

STEM skills are important to enhancing individuals' education and job opportunities as well as maintaining a country's levels of innovation, productivity, and economic growth [97]. Studying engineering pathways is significant to individuals' success and a country's economic prosperity. Our work in this paper has paved the way for a myriad of conceptual and empirical explorations ahead.

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