# BOOSTING CAREER MATURITY: THE IMPACT OF INTERDISCIPLINARY HANDS-ON STEM TRAINING ON FIRST-GENERATION COLLEGE STUDENTS

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The article examines how first-generation college students engage with interdisciplinary, hands-on science, technology, engineering, and mathematics (STEM) training and how these experiences shape career maturity through a narrative literature review. Drawing on scholarly research and program evaluation, the article highlights students' agency, challenges, and meaning making in interdisciplinary hands-on learning, demonstrating implications for curriculum design, mentoring, structured career support, professional skill development, and fostering equity and inclusion in emerging STEM fields.

**Keywords:** career maturity, interdisciplinary hands-on training, STEM, first-generation college students

Rapidly developing industry has brought an unprecedented demand for skilled research professionals. A 2024 report estimates that by 2030, the U.S. lithium-ion battery supply chain will need up to 310,000 workers, many of which require at least a bachelor's degree (Horrigan, 2024). This requirement highlights the need for colleges and universities to implement reforms and initiatives to train students to prepare for emerging science, technology, engineering, and mathematics (STEM) careers. To strengthen the STEM workforce, the federal government continues to invest billions of dollars in STEM education and promotion projects, recognizing the key role of schools and universities in building career paths. Recent federal reports show that multiple institutions manage large-scale STEM projects and funded projects, reflecting continuous national investment (National Science Foundation, 2025; U.S. Government Accountability Office, 2025). However, emerging budget proposals and funding adjustments show that these investments are still uneven and vulnerable to policy changes, bringing uncertainty to the long-term development of the STEM path (Afterschool Alliance, 2025). Research shows that interdisciplinary STEM courses and hands-on research experience can enhance students' participation, thinking ability, and problem-solving ability, especially for underrepresented groups (Joseph & Uzondu, 2024; Miller et al., 2021).

With the growth of STEM enrollment, demographic factors increasingly affect students' career paths (Engberg & Wolniak, 2013; Li et al., 2024). First-generation college students (FGCS) now account for more than half of the undergraduates in the United States (Center for First-Generation Student Success, 2024). However, compared with peers, FGCS often faces limited resources and career support (Tate et al., 2015; Toyokawa & Dewald, 2020). Most existing studies regard FGCS as a demographic variable, focusing on quantitative trends such as continuity and degree acquisition. This method ignores their personal experience and autonomy and has limited understanding of how FGCS participate in interdisciplinary, hands-on training and experience that are crucial to career development. To solve this gap, research needs to take a deeper look at the perspective and meaning construction process of FGCS in interdisciplinary and hands-on training. This discussion combines interdisciplinary hands-on training, STEM education, and career maturity to discuss their impact on STEM education and institutional practice with equity as the core.

## Aims and Objectives

This article deeply explores how FGCS in the field of STEM can improve career maturity by participating in interdisciplinary and hands-on training. Specifically, it explores how these experiences shape FGCS' understanding of their career path and affect their career maturity. By revealing these processes, this article aims to provide guidance for strengthening the FGCS' career path, promoting growth, and promoting equitable institutional practice and project design in higher education.

## Theoretical Framework

This article draws on Kolb's (1984) experiential learning theory (ELT) and Super's (1984) life-career rainbow (LCR) to provide a multilevel framework for understanding FGCS' career development. ELT explains the microlevel process of learning through hands-on training, progressing from concrete experience to reflection, conceptualization, and experimentation. In contrast, the LCR situates this process within a broader developmental context, emphasizing that FGCS, in the exploratory stage of life, face key tasks such as forming self-concept and clarifying career preferences. Failure to complete the developmental tasks of this stage indicates low career maturity that can delay career development at this phase. Integrating these frameworks allows the article to examine both how experiential learning unfolds during interdisciplinary hands-on training and why these experiences are particularly consequential for FGCS' career maturity.

### ELT

Kolb's (1984) ELT establishes a framework for evaluating an expanded range of classroom activities rather than relying on conventional methods. Kolb proposed that learning unfolds through a four-stage cycle. It begins with direct engagement in a concrete experience (i.e., laboratories, observations, simulations, fieldwork) followed by reflection from multiple perspectives to interpret its meaning. From this reflection (i.e., discussion, brainstorming), learners develop abstract concepts (i.e., model building, projects), often integrating their own insights with existing theories. These conceptualizations then inform active experimentation (i.e., simulations, case study, laboratory, field work, projects) that, in turn, generate new experiences and continue the cycle (Svinicki & Dixon, 1987).

The effective instructional methods such as ELT are essential when determining practices for the preparation of career service professionals (Hayden & Osborn, 2020). Hands-on interdisciplinary training aligns closely with experiential learning in which students gain knowledge and skills through active engagement, reflection, conceptualization, and experimentation. As such, ELT provides a framework to interpret how training experiences can foster career maturity.

### LCR: Life Roles in Schematic Life Space

From a horizontal perspective, ELT (Kolb, 1984) provides a framework for understanding how first-generation STEM undergraduates engage with short-term hands-on training, progressing through experience, reflection, and application that can inform their development of career maturity.

Vertically, there is continuity throughout life with individuals facing new achievements and responsibilities at each stage of development. The major life stages include growth or childhood; exploration or adolescence; establishment or young adulthood; maintenance or middle adulthood; and decline or old age (Super, 1984). The theory of LCR provides theoretical support for selecting the research population. Individuals between the ages of 15 and 24 are in the exploratory period, conducting self-cognition, role, and career exploration in school learning and internship experience. People in the exploratory phase have three developmental tasks: to form an accurate self-understanding, to develop their own career preferences, and to create more opportunities. Undergraduate students are in the trial and initial commitment period in which the group has preliminarily determined the career choice and probed its possibility of becoming a long-term career. However, FGCS may face different challenges in this stage due to a lack of familial context for the college experience and professional networks (Tate et al., 2015). Thus, it is of practical significance to study the specific pathways of how hands-on training helps FGCS successfully go through the exploration stage.

ELT and the LCR define the research scope of this article: FGCS in the age of exploration (15–24 years old). The interdisciplinary hands-on STEM training in this article is multidimensional experiential learning. It includes various iterative procedures such as concrete experience, reflective observation, abstract conceptualization, active experimentation, etc. The procedures include different education settings, discussion and cooperation with others, deep understanding within STEM, etc.

## Method

This article employed a narrative literature review to provide a comprehensive overview of the current research on interventions aimed at enhancing career maturity among FGCS through interdisciplinary, hands-on STEM training. The literature search was conducted in Fall 2025 using databases including Google Scholar, EBSCOhost, and ERIC. Keywords related to the target population and topic such as FGCS, career development, career maturity, and STEM education were paired with terms reflecting intervention and assessment, including hands-on learning, experiential learning, interdisciplinary training, and learning outcomes assessment.

## Literature Review

### FGCS and Career Development

FGCS usually refer to students whose parents have not completed a bachelor’s degree (Pascarella et al., 2004) and are a unique and historically underrepresented group in higher education (Kena et al., 2014). For most of the 20th century, college attendance was highly related to family education background that brought systemic obstacles to students from nonuniversity families. These obstacles are often manifested in limited access to information, insufficient academic preparation, and fewer financial resources than the continuing generation of their peers. Despite these challenges, the demographic structure of higher education has changed in recent decades. FGCS have now become a significant and growing presence in higher education (Center for First-Generation Student Success, 2024). This growing representation highlights the need for institutions to better understand how FGCS adapt to college life under the guidance of fewer families and how these conditions affect not only persistence and academic success but also career development.

Career maturity has undergone a historical development. With the acceleration of social development and change, researchers proposed *career* maturity (Crites, 1973) to broaden the earlier concept of *vocational* maturity (Super, 1953). Vocation is usually related to profession, reflecting the classification and relatively static characteristics of jobs, whereas career emphasizes more dynamic and developmental processes. This transformation emphasizes the role of comprehensive cognitive development in career maturity, indicating that when individuals have sufficient professional awareness and self-awareness to make career decisions consistent with their personal development, career maturity will be higher (Westbrook, 1983).

Career maturity is an important indicator for assessing the level of personal career development. For college students, career maturity is shaped by internal psychological factors, social environment, and personal characteristics. Internal psychological factors such as personality traits, professional self-efficacy, control points, self-concept, and identity all play an important role. Students with proactive personalities tend to actively explore themselves and the external environment and often seek clearer career goals (Hu et al., 2023). The difference in locus of control is also related to the difference in career maturity, value orientation, and career decision-making confidence. Locus of control refers to an individual's belief in the extent to which the results are shaped by their own behavior versus by external forces such as accidental or systemic factors (Rotter, 1966). Students with a stronger internal locus of control usually show higher career maturity while students who tend toward an external locus of control usually report lower career maturity (Sholikah & Muhyadi, 2021). In addition, self-concept is defined as an individual's understanding and evaluation of self, which is related to career maturity. The more positive and stable students' self-awareness and self-evaluation are, the more likely they are to develop higher career maturity (Azhenov et al., 2023; Patton & McMahon, 2018).

From the broad perspective of career maturity, FGCS face barriers to career development. These barriers are not isolated; on the contrary, they are deeply interrelated and reinforce each other. First and foremost, financial pressure is one of the most urgent and lasting challenges. Due to the limited financial support of many FGCS from their families, they tend to take on work and family responsibilities that distract them from their studies and career exploration (Engle & Tinto, 2008). These pressures may prompt students to do multiple jobs at the same time or prioritize short-term income over long-term career goals, limiting opportunities for internships, networking, and professional skills (Perna & Odle, 2021; Rehr et al., 2022). Social isolation may also make them lack role models for understanding effective job search strategies such as resume writing, interviewing, and networking (DeOrtentiis et al., 2021). In this sense, financial barriers are not only financial constraints; they also affect students' opportunities to acquire career-related experience, interpersonal relationships, and professional knowledge.

Secondly, structural and cultural barriers, including limited social and cultural capital, shape how FGCS respond to institutional norms and career expectations (Ricks & Warren, 2021; Stephens et al., 2015). Limited exposure to middle-class cultural capital and the mismatch between students' self-culture and university norms may lead to a persistent social class gap between FGCS and the continuing generation of peers. The theory of cultural mismatch explains that U.S. higher education institutions often emphasize independence as a core cultural ideal that can conflict with the interdependent norms many FGCS value (Stephens et al., 2012). Although independence-oriented norms may motivate some students, they may also weaken the sense of belonging and academic performance of others thereby making institutional expectations unfamiliar and difficult to achieve (Kim, 2009; Phillips et al., 2020; Stephens et al., 2012). This cultural mismatch also extends to career development. Students with limited social and cultural capital are unlikely to participate in informal networking or career-building activities such as internships and mentoring programs that are crucial to career development (Leigh, 2021; Levine & Aley, 2021; O'Shea, 2016). Research shows that FGCS often regard these areas as exclusive or intimidating, further widening the career preparation gap compared with peers (Ma & Shea, 2019).

Third, psychological barriers often limit FGCS' ability to seek and use career-related support. Many students hesitate to share their struggles because they can experience the difficulties faced by their parents, which may lead to depression and increased stress (Wheeler, 2016). This tendency to protect family members from additional worries also reduces the possibility of them making full use of existing social support networks (Jenkins et al., 2013). In addition to emotional isolation, structural and situational barriers such as financial pressure and lack of guidance shape students' expectations for achievable goals thus weakening career self-efficacy (Garriott et al., 2017; Ma & Shea, 2019). Weak self-efficacy is associated with a decrease in confidence in making career decisions and a decrease in the participation of proactive behaviors such as networking, internship and career exploration that are crucial to career development (Lent et al., 2002).

Overall, these structural, cultural, and psychological barriers limit FGCS' access to career-related experience and resources. Financial pressure, cultural mismatch, limited social capital, and reduced sense of professional self-efficacy have formed a cumulative path that systematically limits opportunities for skill development, network building, and career exploration. The situation shows that it is necessary to go beyond the mere record barrier and explore the structured learning environment, especially interdisciplinary hands-on STEM training as a mechanism to expand FGCS' access to career-related opportunities and support their career achievements.

## Interdisciplinary Hands-On STEM Training on Career Development

Based on the limitations found in FGCS career development, interdisciplinary hands-on STEM training may become a key mechanism to expand students' acquisition of career-related skills, experience, and professional networks. To promote students' career maturity in the field of STEM, a variety of interdisciplinary hands-on STEM projects have been developed. Since the concepts of interdisciplinary and hands-on STEM projects in the literature sometimes overlap, the impact of interdisciplinary STEM training may also be embedded in practical learning such as integrating knowledge across fields, applying concepts to real problems, and cultivating broader problem-solving skills (Chen & Liu, 2025; Gao et al., 2020; Mayes & Rittschof, 2021). In view of these overlaps, this article first discusses how hands-on STEM projects can promote students' career development and career maturity. After laying the foundation, the next section will focus on the unique characteristics of interdisciplinary STEM education and clarify how interdisciplinary integration can bring additional value beyond simple hands-on learning.

Hands-on STEM projects are the core of STEM education because they provide a platform for collaboration, communication, and practical design (Lavi et al., 2024) so that students can apply theoretical knowledge in practice and participate in the experimental foundation of the subject (Connor et al., 2013; Kilty et al., 2022). Depending on the project design, their contributions to career development vary. First, hands-on STEM training is widely considered to be crucial to promote in-depth conceptual understanding and practical ability. Research shows that experiential learning methods can improve cognitive performance, problem-solving ability, and knowledge retention compared with traditional teaching (Christensen et al., 2015). These experiences are usually organized in the form of small classroom experiments, ubiquitous experimental classes, and mobile studios, enabling learning to go beyond formal laboratory space (Connor et al., 2013). This flexibility reflects the principles of constructivism, emphasizing active participation and situational learning (Kolb, 1984). Importantly, these forms of participation not only strengthen academic learning but also provide application experience closely related to career preparation.

Secondly, initiatives such as peer tutoring, summer bridge projects, and direct interaction with local industries play a key role in strengthening students' professional networks and career preparation in the field of STEM. Peer tutoring improves academic performance while promoting collaborative relationships beyond the classroom and establishing a supportive community among students who pursue similar career goals (Davari et al., 2016; Lin et al., 2025). These programs encourage reciprocal learning, improve communication skills, and build self-confidence, which are the key attributes of networking and career success (Mama et al., 2024). In this sense, hands-on STEM projects not only support knowledge acquisition but also serve as an environment for students to acquire social and professional capital.

Third, hands-on STEM training helps to cultivate engineering self-efficacy and professional identity. Through the experimental process and project ownership, students increase their confidence in their abilities, especially among those vulnerable groups who pursue STEM careers (Okundaye et al., 2022). These experiences further shape the STEM professional identity (Lambert et al., 2024; Rodriguez et al., 2019). By applying classroom knowledge to real-life situations, students enhance their sense of ability and learning control that are crucial for continuous participation in career development.

In addition to these contributions, for students with non-STEM backgrounds, hands-on training with an interdisciplinary perspective can cultivate basic STEM literacy and multidisciplinary skills such as data analysis, statistical evaluation, and predictive modeling. These abilities better train students to become professionals with STEM literacy and make up for the diversity and equity gap in STEM participation (Petrus et al., 2025). The development of STEM literacy, combined with practical application and institutional participation, can improve students' interdisciplinary confidence and career preparation (Joyner-Matos & Islam-Zwart, 2021). These approaches not only strengthen conceptual understanding but also cultivate system-level design skills, which are increasingly important for STEM professions in the 21st century (Hu, 2023; Li & Schoenfeld, 2019). In addition, the design orientation and exploration-driven strategies integrated into these projects cultivate high-level thinking, creativity, and innovation ability and prepare students for solving complex problems in the professional environment (Saseendran & Thomas, 2025).

Overall, whether through classroom laboratories, mobile platforms, or industry-related experiences, hands-on STEM training is not just a teaching method; as a mechanism, it expands students' opportunities for applied learning opportunities, professional networks, and career-related abilities. Combined with the barriers faced by FGCS, these programs can be understood to expand skills, social capital, and career confidence thus combining STEM training with career development and achievement more directly.

**Interdisciplinary STEM Training and Career Development of FGCS**

Based on the structural, cultural, and psychological constraints that shape FGCS' career development, interdisciplinary hands-on STEM training may play a particularly important role in addressing barriers that limit their access to career-related opportunities. Specifically, FGCS usually need more comprehensive support than continuing generations, so interdisciplinary hands-on programs are particularly valuable. FGCS face structural disadvantages such as lack of access to professional networks and career guidance that may hinder their transition from college to the workplace (Grineski et al., 2017).

First, the traditional one-on-one guidance has limited effect on FGCS because it fails to fully make up for the gap between social capital and experiential learning opportunities (Grineski et al., 2017). In contrast, high-impact practices such as internship, cooperative education, and undergraduate research provide real interdisciplinary experience, strengthen technical skills, and expand access to professional networks (Shortlidge et al., 2025). These programs enable FGCS to work together to solve problems across STEM fields and improve academic ability and career readiness. In this sense, these experiences are not only opportunities for learning but also mechanisms for expanding career-related resource access.

Second, hands-on experiences create opportunities for FGCS to cultivate social capital, which is a key resource for navigating the STEM path. Short-term immersive programs, including research internships and industry-related internships, connect FGCS with tutors, peers, and professionals from different backgrounds and expand the channels for obtaining instrumental and information support (Gonzalez Perezchica, 2025; Hanna et al., 2021). The network construction is closely related to persistence and identity development in the field of STEM (Martin et al., 2020; Saw, 2020). By integrating students into a collaborative environment, these programs reduce the social barriers that FGCS often face and provide a structured entry point for entering professional communities.

Third, FGCS often experience low academic self-concept and limited social capital. Hands-on STEM projects provide structured opportunities for peer cooperation and mentors, reducing the isolation and enhancing the sense of belonging (Beier et al., 2019; Chen & Liu, 2025). The mentoring system in the field of STEM not only supports the development of technical skills but also enhances psychosocial outcomes, including the formation of self-confidence and identity (Joyner-Matos & Islam-Zwart, 2021). These interactions enhance social and emotional support networks, reduce stress, and promote resilience, which are crucial for FGCS in the navigation STEM path.

In addition to these social and structural benefits, interdisciplinary STEM training also leads FGCS to real-life challenges that require knowledge integration across multiple fields. These experiences are particularly important because they enable students to apply classroom concepts to real situations and cultivate self-confidence and engineering self-efficacy, which are the key predictors of STEM majors (Jones et al., 2023). Unlike traditional courses, interdisciplinary programs emphasize collaborative problem solving and design thinking so that FGCS can see the relevance of their learning and cultivate a sense of belonging (Joyner-Matos & Islam-Zwart, 2021). This sense of dynamism is closely related to the formation of strengthened self-efficacy and professional identity, which are crucial to overcoming structural obstacles in the STEM pathways (Harlow & Bowman, 2016).

In addition, interdisciplinary programs usually involve cross-field teamwork so that FGCS are exposed to diverse perspectives and professional practices. This not only enhances technical ability but also accumulates social capital through the interaction between peers and mentors, which is also a well-founded factor in improving the retention rate and equity of FGCS (Martin et al., 2020; Syed et al., 2011). By combining the cultivation of technical skills with the experience of building self-confidence and networking, these programs create an inclusive environment that supports both persistence and career preparation.

Overall, interdisciplinary hands-on STEM training does not merely provide skill development; on the contrary, as a mechanism, it expands the acquisition of technical ability, social capital, and career-related confidence. Through these projects, the structural, cultural, and psychological barriers previously identified have been directly resolved to reshape FGCS' opportunities for career opportunities and support an equitable career path.

## Conclusion and Research Gap

Taken together, the literature shows that the career development of FGCS is limited by structural, cultural, and psychological barriers and interdisciplinary hands-on STEM training may become a key mechanism for expanding skills, connections, and career-related experience acquisition. These elements no longer operate as independent fields but form an interrelated process through which access to resources and opportunities is limited or expanded.

However, existing literature mainly regards FGCS, STEM training, and career development as independent fields, and the integration of these fields is limited. In addition, literature relies on quantitative methods to regard FGCS as one of many population groups rather than focusing on their lived experiences and meaning construction processes.

This gap highlights the need to study how FGCS view and participate in interdisciplinary hands-on STEM training and how these experiences shape their professional identity, sense of self-efficacy, and long-term career trajectory. By highlighting the views of FGCS, such research can more carefully understand how the structured learning environment is a mechanism that affects the career path.

## Implications of the Argument

The review of existing research shows that supporting FGCS needs to adopt a comprehensive approach in STEM education and career development to address interrelated financial, cultural, and psychological barriers. Interdisciplinary hands-on STEM training is particularly effective because it enhances technical ability and key psychosocial achievements, including self-confidence, self-efficacy, and sense of belonging. Combined with mentor guidance and peer collaboration, these experiential learning opportunities reduce the sense of isolation, expand social capital, and promote resilience thus supporting the formation of professional identity, adherence to the STEM path, and labor readiness. These findings together emphasize the value of inclusive and high-impact practices that combine experiential learning with structured mentorship to promote equity in the STEM field.

Based on this synthesis, the article outlines the practical and evidence-supported impact on STEM departments. For the STEM department, the literature emphasizes the role of intentionally designed interdisciplinary and hands-on learning experiences in curriculum and extracurricular programs in promoting FGCS' career maturity. These approaches not only improve technical ability but also cultivate psychological resources that are crucial to persistence and career development. Integrating problem-solving, collaborative design, and structured peer interaction in

STEM training can support the formation of professional identity and meet academic and psychosocial needs at the same time.

For career services, the findings emphasize the importance of combining career development support with experiential STEM learning. By cooperating with academic units to integrate mentor guidance, peer cooperation, and professional network opportunities into practical training projects, career services can help FGCS expand social capital, reduce the sense of isolation, and cultivate skills related to the labor force thus strengthening the transition from STEM education to career path.

At the institutional level, the literature emphasizes the need for a coordinated support structure rather than decentralized intervention. Institutional leaders can promote equity by prioritizing funding, policy alignment, and cross-departmental collaboration; promoting inclusive and high-impact practices; and combining experiential learning with structured mentors. Comprehensively addressing financial, cultural, and psychological barriers may enable institutions to promote the equitable career development of FGCS in the STEM field more effectively.

## Importance to Higher Education

This article promotes academic development within higher education by deepening the conceptual understanding of the career development of FGCS in the field of STEM. By highlighting the voice and experience recorded in the previous research of FGCS, this article goes beyond the main quantitative methods in the literature and provides a more detailed understanding of how career-related abilities develop in the higher education environment.

This article also contributes by integrating three academic directions: interdisciplinary education, hands-on learning, and FGCS's career development in the field of STEM, which are usually examined separately. Considering these elements as interrelated reflects the trend of contemporary higher education and labor preparation and provides a more comprehensive perspective on equity-oriented STEM education.

Finally, this article contributes to the theory of career development by proposing a framework to link interdisciplinary and hands-on learning with the career maturity of FGCS. By incorporating the unique characteristics of social capital and FGCS, the framework expands the existing theoretical models that are often insufficiently theorized for the role of experiential learning and sociocultural factors. This contribution lays the foundation for future research and further explores how educational practice can shape an equitable STEM career trajectory.

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