Student Awareness and Career Motivation in the STEM Fields[*]

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Bio-ITEST, a National Science Foundation-funded project of the Northwest Association for Biomedical Research, aims to raise awareness of STEM (science, technology, engineering, mathematics) and STEM-related careers among high school students. A recent review of literature concludes that "high school appears to be a key point at which young people's impressions of science influence their future career decisions."[1] This scan of literature[†] on high school student awareness and career motivation in the STEM fields summarizes relevant concepts and empirical research informing the theory of change and evaluation strategy that undergird NWABR's Bio-ITEST program to date. The literature scan focused particularly on student awareness, relevance, self-efficacy, and engagement as they relate to STEM subject matter and careers.

The Cognitive-Behavioral Building Blocks of Career Development

A large body of work addresses various cognitive-behavioral processes that lead to career choice (or discouragement), including the concepts of awareness, relevance, interest, self-efficacy (and closely related notions such as autonomy, confidence, proficiency, and competence), engagement (or involvement), motivation, and persistence. Though different conceptual frameworks use varying terminology, the approaches are largely complementary. These cognitive processes, occurring internally and mediated by both intrinsic and extrinsic motivators, result in external behaviors whose consequences in turn further reinforce or detract from emerging career choices.

Awareness. Of course, awareness of STEM careers is an essential precondition for interest, engagement, and self-efficacy to develop. A review of pertinent research has found that students typically have a limited understanding of available careers and requirements for success.[2] Career exploration activities can increase awareness and at the same time foster a sense of competence and ownership that becomes intrinsically motivating.[3] A longitudinal study has also demonstrated that early expectations of a career in science are a potent predictor, independent of academic preparation, of later STEM career choice.[4] These studies suggest that developing awareness through exposure to science and encouraging interest are effective and probably necessary strategies to boost STEM career participation.

Relevance. Perceived relevance of science and mathematics contributes to student engagement. Relevance is a critical component of the positive feelings associated with intrinsic motivation[5], and relevance can be reinforced through authentic inquiry that requires students to solve real-life problems. Conversely, a lack of meaning can lead to disengagement. Science relevance is typically measured in terms of student beliefs that science may be useful in everyday life and in the future.[6] Science can be

[*] This literature scan was conducted for the Northwest Association for Biomedical Research in support of its National Science Foundation-funded Bio-ITEST (Innovative Technology Experiences for Students and Teachers) project.

[†] The literature scan involved a review of resources available through the ITEST Learning Resource Center and a search of the ERIC database using appropriate search terms, such as "STEM," "science," "career choice/education/interest," and "efficacy." The bibliographies of articles were also scanned for additional sources. The principal target of this scan was research and theory focusing on high school students, with occasional findings drawn from studies of college and middle-school students.

relevant in everyday contexts when it is helpful in better understanding the world in ways that help students make better decisions about their health, the environment, or other issues of importance to them. Science relevance can also be future-oriented, for example in preparation for career success. Students' attitudes about the relevance of science can be altered over time through realistic, issue-oriented activities.[6]

Self-efficacy. Arguably the most widely influential concept informing this stream of theory and research is the notion of "self-efficacy".[7-12] Bandura defines perceived self-efficacy as "people's beliefs about their capabilities to produce effects," that is, achieve particular results.[13] Self-efficacy increases through four mechanisms: (1) mastery experiences (successes), (2) modeling the behavior of similar others who succeed, (3) persuasion, and (4) changes in mood or somatic experiences (e.g., reducing emotional or bodily stress reactions). Bandura further posits that as people prepare for careers, perceived self-efficacy is the foundation of cognitive, self-management, and interpersonal skills that inform career choice and success. A strong sense of self-efficacy allows students to handle obstacles and challenges[14] and contributes to persistence through expectations of success and subsequent increase in self-efficacy.[8,9,11]

A large body of work has found support for Bandura's theory as it relates to achievement in STEM fields.[15-18] Bandura's cognitive theory and related work of others[15] have been extended in several ways to improve our understanding of career development in general, and STEM career development in particular.

Engagement. Two extensions of Bandura help to explain how self-efficacy translates into engagement. Social Cognitive Career Theory[19,20] examines how outcome expectations (risks and rewards) and interests combine with self-efficacy to determine engagement and, ultimately, career goals and actions. Self-determination theory focuses on the external factors that affect intrinsic motivation. A longitudinal study of 526 youths found mastery of appropriately challenging tasks builds self-efficacy, which can then foster engagement, while a lack of challenge can lead directly to disengagement.[5] Thus it is important that learning challenges be neither too easy nor too difficult, because neither condition leads to self-efficacy, a situation that is frustrating and disengaging.

Although this review presents these conceptual elements in a particular causal order, it is clear that the various cognitive components of career development may operate in multi-directional, simultaneous, or mutually reinforcing ways. For example, engagement can lead to increases in self-efficacy, heightening both awareness and a sense of relevance, which is the reverse of the order above.

Experiences that Support STEM Career Choice

A number of experiences and external influences have been investigated that can positively affect STEM career awareness, relevance, self-efficacy, and engagement. These influences include, but are not limited to, support from significant others[10,21-26], instructional practices and academic experiences.[25,27]

Peers, mentors, and other important persons have been shown to shape student attitudes toward science and science abilities[28] and persistence in STEM fields.[24-26] Teachers are very frequently cited as supportive mentors and models.[29] One study of minority secondary students found that personally knowing a scientist was associated with higher scores on participation in science-related activities, academic self-image, science-related career interest, perceived relevance of math and science, and ability.[30] These findings have been qualitatively supported by NWABR's own focus groups on career engagement with high school students.[31]

Students report that individual and group work are more engaging than lecture.[5] In particular, there is considerable evidence from science enrichment activities that hands-on experiences offer the opportunity to develop self-efficacy.[32] Furthermore, conducting original research may be particularly effective in boosting confidence and engagement, at least for those who have experienced prior success, encouragement, and exposure to positive science role models.[28]

A recent survey[33] of secondary school students speaks to a variety of positive influences that support STEM career choice. The top activities that students reported might boost their interest in a career in a STEM-related field were experiential, all cited by a third to more than half of respondents. Ironically, as students enter high school, more advanced science courses have been found to allow less time for student investigation[34,35], and students notice a decrease in investigative activities from elementary to high school[36], with a corresponding drop in motivation. The top motivators particularly focused on work or volunteer experiences and interacting with professional role models in various ways: having a job or internship in a field of interest, having a program at school about future careers, learning about the job through volunteer opportunities, meeting successful role models, taking a field trip, letting career professionals teach lessons, and talking to career professionals about their jobs.

Connecting Theory and Practice in the Bio-ITEST Program

This initial investigation has identified the conceptual underpinnings of student engagement with STEM careers and research on specific types of experiences that increase student engagement. It is hoped that these findings, in conjunction with other evaluation components (e.g., ongoing investigation of the role of science teachers in STEM career guidance, results of the student surveys, etc.) can inform the development of the Bio-ITEST program's theory of change and suggest enhancements to the program's repertoire of strategies to foster student interest in bioinformatics and, more generally, STEM careers.

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