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Connecting Theory to Practice: Using Self-Determination Theory To Better Understand Inclusion in STEM

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In the United States, persistence for women and ethnic minorities in science, technology, engineering, and math (STEM) careers is strongly impacted by affective factors such as science identity, agency, and sense of belonging. Policies aimed at increasing the diversity of the national STEM student population and workforce have recently focused on fostering inclusive learning environments that can positively impact the experiences of underrepresented minorities (URMs) in STEM, thus increasing their retention. While research on inclusion in STEM in higher education is relatively new, inclusion research has a rich history in several other disciplines. These fields have developed theoretical frameworks and validated instruments to conceptualize and assess inclusion. Self-determination theory (SDT) is a well-established theoretical framework in educational psychology that states that ones' internal motivation is strongly correlated with the satisfaction of three specific psychological needs: autonomy, competency, and relatedness. In this paper, we introduce SDT and discuss how it relates to inclusion and to ongoing efforts to increase retention of STEM URM students in higher education environments. We argue that grounding inclusion initiatives in the SDT framework increases our understanding of the mechanisms mediating their impact, thus facilitating their reproducibility and generalizability. Finally, we describe how this theoretical framework has been adapted by the field of Industrial and Organizational Psychology to define and assess inclusion in the workplace as an example of how STEM education researchers can use this framework to promote and assess inclusion in their fields.

INTRODUCTION

In the United States, women and ethnic minorities represent less than 29% and 13%, respectively, of the science, technology, engineering, and mathematics (STEM) workforce (1). This diversity deficit impacts the productivity of American companies and organizations (2). To promote a diverse workforce and future success in STEM fields, it is necessary to cultivate and retain a diverse pipeline of talent from K–12 to graduate levels. The underrepresentation of minorities in the STEM workforce is not due to a lack of interest in STEM by these populations, but is instead due to a higher rate of attrition after entering college (3, 4). Affective factors have been shown to be key mediators of this disproportionate attrition among underrepresented minorities (URMs) in STEM (5, 6). Different models of student retention have highlighted the role of specific social and psychological constructs, such as science identity, self-efficacy, growth mindset, resilience, and sense of belonging in mediating student retention (7, 8). Supporting the importance of these constructs, interventions focused on increasing science identity (9) and growth mindset (10) have been shown to increase retention of URM students. Furthermore, the success of early experiential learning opportunities and mentoring programs is likely mediated by their impact on some of these factors, in particular, science identity, self-efficacy, and sense of belonging (11, 12). Which of these social science constructs may be most influential and how these constructs relate to one another remain unclear.

In recent years, increasing inclusion in STEM, usually under the label of achieving "inclusive excellence," has become the focus of several governmental reports and funding agencies (13–15). Yet, while in the last 20 years the diversity of the freshman STEM population has increased,

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graduation-rate diversity still lags, presumably due to a lack of inclusion of URM students in STEM at their institutions (16). Achieving meaningful inclusion in STEM is difficult, as it requires changes at several levels (from individual to institutional) and must involve different stakeholders (from undergraduates to administrators). These efforts are further hampered by a lack (in the context of STEM higher education) of common definitions of "inclusion/inclusive excellence" and of validated assessments of inclusion. In addition, many of these efforts are being driven by faculty and administrators that lack training in the theoretical constructs and methods common to the social sciences. These tools are key to the development and assessment of effective and generalizable interventions focused on inclusion in STEM (17–19). Thus, current efforts at increasing inclusion in STEM could benefit greatly from the incorporation of relevant theoretical frameworks, research findings, methodology, and measurement instruments from the social sciences.

In this paper, we (i) describe self-determination theory (SDT), a well-established theoretical framework in educational psychology focused on understanding people's motivation, (ii) discuss how SDT relates to ongoing research aimed at increasing student retention in higher education, and (iii) discuss the relevance of this framework to inclusion and how it can be adapted to research inclusion in STEM.

SDT AND FOSTERING STUDENT SUCCESS

In the last 10 years, research has examined factors that are likely to play key roles in mediating inclusion. In particular, the following three affective factors are highlighted: (i) students' sense of agency or ownership of learning, (ii) the importance of mastering tasks, and (iii) students' perception of the extent to which they belong in STEM (6, 20–25). In the social sciences, these affective factors correspond to well-defined (conceptualized) theoretical constructs (i.e., abstract factors that have been carefully defined and validated within a particular research field). The social science constructs corresponding to the aforementioned affective factors are autonomy, competency, and relatedness, respectively. These three constructs, also called psychological needs, compose the macro theory of human motivation known as SDT (26). In the next few paragraphs we describe this theory and its constructs, providing examples of interventions that have implicitly or explicitly targeted one or more of these constructs with the goal of increasing retention of students in STEM.

SDT states that one's motivation in any situation exists on a continuum from amotivation to extrinsic motivation to intrinsic motivation (Table 1). The continuum represents the fluid nature of one's motivational state and how susceptible one's state is to internal and external influences. For example, one may feel internally motivated to work on a problem in class because they find the problem compelling, but if the instructor announces partway through the activity that the work will be taken up for a grade, the student may lose internal interest and focus solely on crafting the assignment to meet the perceived desires of the instructor, thus shifting the motivation to extrinsic. SDT states that the more a person's psychological needs are met, the more internally motivated they will be in that particular situation (27). Research on different aspects of biology education has shown that SDT can explain the positive effects of team-based learning (28), socioscientific issues-based laboratory curricula (29), mentoring interventions (30), and STEM retention resulting from scalable STEM academy programs (31, 32).

Autonomy is potentially the most challenging construct of SDT to promote in traditional higher education settings. A person's psychological need for autonomy in learning is conceptualized as the degree of control someone perceives they have over their learning environment (27). Autonomy can be a difficult need to meet, as it requires more work on the part of the instructor so as to provide students with multiple options for activities when they traditionally have provided only a single option. An example of an autonomous learning assessment is allowing students to select 6 questions from a set of 10 to answer, instead of requiring them to answer 6 instructor-selected questions. Autonomy perception is highly influenced by an individual's personal (likes, dislikes, and past experiences), environmental ("Does the classroom feel welcoming?"), and social ("What do my friends or peers think?") contexts, and therefore varies greatly from student to student (33, 34). Research suggests that providing students with more choices in their learning will lead to an increase in persistence and resilience (35) and that autonomy-disruptive teacher behaviors, such as suppressing independent opinions and disrespecting students (by making snide remarks to students or teasing them), negatively impact student motivation and engagement (36). Additionally, embedding skill development in courses has been shown to further increase students' sense of autonomy if the students perceive that these skills are transferable to future classes and careers (37). While supporting autonomy

TABLE 1.
The Three Phases of Motivation According to SDT (27).

Amotivation	Extrinsic Motivation	Intrinsic Motivation
Possessing no motivation to engage; possessing feelings of incompetence or a lack of understanding of the value of an activity	Being motivated by an external force such as grades or instructor praise	Being motivated by an internal force such as personal satisfaction or joy

is challenging, the two examples described above can serve as starting points for STEM instructors interested in making their classes more autonomous.

Perhaps the most widely studied component of SDT is competency (a.k.a. self-concept). A person's psychological need for competency in learning refers to their perception that they have mastered a task or topic (38). For example, if a student recalls answers to questions on a test regarding the flow of energy, the student perceives that they have mastered that concept. Competency has been positively correlated with interest in learning (39) and academic achievement (40). Thus, interventions targeted at students with low perceptions of competence have the potential to increase task engagement and performance in these students. Durik *et al.* (41) showed that low competency perceptions can be mitigated by informing students prior to beginning the task that they have an excellent chance of learning, what Dirk and colleagues refer to as an expectancy boost. In other words, telling your students that they have a very high likelihood of success can improve the performance of your unengaged, underperforming students. Competence perceptions have also been shown to be predictors of cognitive activation (deep thinking, metacognition) and achievement (42). It is likely that many curriculum reforms that lead to increased student engagement do so, in part, by increasing student's perceived competency. Jeno *et al*. in 2017 (43) used an SDT framework to evaluate the impact of implementing a team-based learning approach to a course and found that increases in perceived competence were one of the main mediators of the changes in student engagement. Competence perceptions have been shown to sometimes be lower in specific student populations (44, 45); thus, these groups may require more engagement opportunities to achieve higher levels of perceived competence. More research is needed on the relationship between competence perception and student performance in STEM, particularly in the context of underrepresented minorities. Perceived competency is often incorrectly used interchangeably with the social cognitive theory construct of self-efficacy (46). However, Rodgers and colleagues (38) argue that self-efficacy is only concerned with the perception of one's ability to succeed ("Can I do this math problem on my test?"), while competence pertains to one's perception of having achieved a state of mastery ("Have I been successful at doing similar math problems before?" [for a full review, see 47]).

The third component of SDT is relatedness. A person's sense of relatedness is defined as a feeling of connection to another individual or a group of individuals (27). For example, if a student perceives that their work in the lab is valued by others in that lab, they will feel a sense of connection to that lab, i.e., the student will feel that they belong in that lab. Research on relatedness has shown that perceived relatedness is predictive of one's level of engagement in an activity (48). Interventions that increase student perceptions of relatedness have been shown to improve health and academic outcomes for ethnic minorities (49) and first-generation math and science students (50). Additionally, relatedness has been shown to positively correlate with student perceptions of task value (51), autonomy, and mastery goal orientation (focusing on learning all there is to know about a topic or subject instead of focusing on getting good grades, which is known as performance goal orientation [52]). An example of research on relatedness in STEM are studies that explore science identity. While it is a different term, the essential elements of science identity are the same as those used to define relatedness (53, 54). The idea behind science identity is that the more one identifies as a scientist, the greater the sense of belonging to one's scientific discipline of choice. A comprehensive study on the impact of belonging in STEM was conducted by Findley-Van Nostrand and Pollenz (31) (their instrument is an adaptation of a previously validated survey of belonging in math [55]). While there have been many studies on student competency and autonomy, less work has been done on the impacts of relatedness interventions. Therefore, further research on the impact of relatedness on identity and inclusion is warranted.

While we have discussed each of the components of SDT in isolation, social scientists traditionally assess student perceptions of multiple SDT constructs, as they are known to be correlated (26). For example, an intervention that aims to increase student retention through mentored research experiences is likely to increase relatedness (student feels accepted by those in the lab), autonomy (student picks a project they are interested in), and competency (student gains knowledge of their subject area). This example further highlights the advantage of using theoretical frameworks when designing these types of interventions. A researcher unfamiliar with SDT may only measure one of these variables and thus miss important data that would allow the development of more robust models explaining the impact of their intervention.

APPLYING SDT TO INCLUSION: AN EXAMPLE FROM INDUSTRIAL-ORGANIZATIONAL PSYCHOLOGY

To better understand how STEM education researchers can adapt SDT to the study of inclusion in STEM, it is useful to see how other fields have successfully applied this framework to assess inclusion in their own contexts. Here, we present examples of how this theoretical framework has been adapted in the field of industrial-organizational (I/O) psychology to research inclusion. The measurement instruments and definitions presented here can serve as a foundation for STEM researchers designing programs and policies to promote inclusiveness in their fields and institutions.

Inclusion is a critical issue in the field of I/O psychology, as it has been shown to have a positive association with an employee's organizational citizenship behavior (56), decreased turnover intentions (57), decreased job stress (58), and increased job satisfaction (59). These positive outcomes, in turn, help to increase retention of top talent in organizations. When defining inclusion and developing appropriate measurement instruments of inclusion at work, I/O researchers combined two theoretical frameworks: SDT and optimal distinctiveness theory (ODT) (60). While SDT expresses that individuals have a need to relate to others (belonging), ODT stresses that individuals have a tension between needing to feel similar to others and having a need to be unique from others (uniqueness) (60). In this context, an example of belonging is being able to build interpersonal relationships in your workgroup or organization, whereas an example of uniqueness is feeling that you can be yourself without being judged by others in your workgroup or organization. Using these two theoretical frameworks as their backdrop, I/O researchers defined inclusion at work as meeting the needs of belonging while being able to display one's unique characteristics at work (61). STEM faculty and administrators may be able to apply this definition of inclusion to better understand the experiences of STEM URM students and develop policies focused on increasing inclusion.

To achieve comprehensive inclusion in STEM, changes need to take place at all institutional levels, from individuals to universities. I/O researchers face a similar challenge, as workplaces also have multiple levels (i.e., individual, group, and organizational levels (62). To address this issue, I/O professionals have developed several inclusion measures focused on each of these levels (63). Here, we highlight two relatively novel scales derived from the SDT framework that assess inclusion: the Work Group Inclusion Scale and the Perceived Group Inclusion Scale (64, 65). We chose to highlight these two scales as they have strong psychometric properties and can be adapted to assess inclusion in STEM for student groups and classrooms, the organizational levels that have been the primary focus of student retention interventions in STEM.

The Work Group Inclusion Scale is a 10-item measure that examines an individual's perceived degree of belonging and uniqueness in their workgroup, as outlined by the SDT and ODT frameworks (64). A sample item is, "I can share a perspective on work issues that is different from my group members" (64). While still new, this scale has been rigorously validated and its factor structure has been verified in the context of faculty and staff of an American university. Similarly, the Perceived Group Inclusion Scale is a 16-item measure that assesses the extent to which an individual perceives that they are included in their workgroup (65). Although this scale uses SDT as the theoretical framework, this measure is composed of two distinct subscales, affection (i.e., feeling of belonging) and authenticity (i.e., allowed to remain true to oneself). An example is, "This group encourages me to be who I am" (65). The Perceived Group Inclusion Scale is a valid and reliable instrument whose factor structure was examined and verified using first-year psychology students and organizational employees in various sectors (65). Both measures can be adapted to measure inclusion in the context of classrooms or laboratories, though further validation of the modified instruments would be needed (see 31 for examples).

CONCLUSIONS

Throughout this article we have strived to connect theoretical frameworks and constructs around inclusion to specific actions and metrics that readers can take to use in their own teaching or research. Through the assessment of the three constructs of SDT in their classrooms, faculty can revise their curricula and teaching to include strategies that can foster the desired characteristic. To promote autonomy and competence, faculty can look into making laboratories more inquiry-driven and to incorporate strategies such as problem-based learning or case studies to their lecture courses. Autonomy would be further promoted if instructors included students in the decision-making of class structure, either by working with them to develop class norms, asking feedback about the number of assignments, or even something as simple as allowing students to vote on the time allowed for online quizzes. Active learning strategies can foster competency and relatedness, by giving students more opportunities to explore their own understanding of a concept as well as opportunities to work with others as peers and members of the same community. The latter can be accomplished with think-pair-share activities or group work. Interviewing URM scientists after analyzing their work in class is another strategy that has the potential to improve self-efficacy and relatedness for URM students.

While there are many definitions for inclusion, the one presented here from the field of I/O psychology, "meeting the needs of belonging while being able to display one's unique characteristics" (61), can serve as a starting point for faculty and administrators for the development of strategies to foster inclusion. With this definition in mind, faculty could promote inclusion in STEM by designing instructional tasks that encourage students to (i) demystify scientists and the process of science to enhance the student ability to relate to scientists (54) and (ii) develop an understanding of what being a scientist means to them, through the lens of their own experiences and identities. Faculty and administrators can further foster inclusion by supporting initiatives that tell students that they do not need to lose who they are to become a scientist but should rather mold the definition of a scientist around their identity. In addition, the two inclusion measures here discussed, the Work Group Inclusion Scale and the Perceived Group Inclusion Scale can also serve as starting points to develop scales that STEM faculty and administrators can use to assess the perceived inclusiveness of their classes and adjust their curriculum and pedagogical strategies to increase their classrooms' inclusion. In particular, the two-factor structure of the Perceived Group Inclusion Scale provides faculty with the opportunity to identify specific areas that can be targeted for improvement. In addition, STEM education researchers could develop adapted scales and use them to assess the impact of interventions aimed at increasing inclusiveness. Exploring whether different items of the scales are more significant to specific student populations could also help develop more complete frameworks and models of inclusion.

In this paper we focused on SDT and how it can help us frame the challenges of inclusion in STEM; however, there are many frameworks developed in the social sciences that could be extremely beneficial to STEM education researchers tackling this issue. We strongly believe that inclusion practices and interventions led by groups of STEM faculty and experts in psychology and sociology are needed to improve the design and outcomes of these initiatives, as it is unrealistic to expect faculty to have the time and resources to master bodies of knowledge from these various disciplines. We recommend an approach consisting of cultivating networks of individuals with expertise in each of the relevant disciplines (STEM educators, social scientists, I/O psychologists, K–12 educators, statisticians, etc.) and then drawing from these networks to form interdisciplinary research groups with the skills needed to address the specific research questions of interest (18).

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