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A Narrative Literature Review: The Interplay of Motivational Theory and Cognition in STEM Education

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Reviewing the Interplay of Motivational Theory and Cognition in STEM Education – A Narrative Literature Review

Abstract

In this research paper, we conducted a literature review to see how STEM education researchers have used motivational theory and correlated constructs from these theories to students' cognition. Using motivational theories helps researchers conceptualize a complex psychological construct and categorize students' motivational orientations. Determining the usefulness of each orientation is often established through measures of cognition, with correlations that can be made between the two. While these types of studies are common in fields such as education and psychology, their use in undergraduate STEM education is lagging. Understanding the current state of motivational theory research within STEM education would help researchers know the major conclusions made and what future contributions should focus on. This review was narrative and seeks to synthesize findings from articles to create important and useful discussion points. For this review, we highlighted three motivational theories: self-determination theory, expectancy-value theory, and achievement goal theory. These three were the focus of this review as they are the more widely used and well-established motivational theories. From our review, we found that research using self-determination theory focused on autonomy and how to improve feelings of autonomous motivation in students to increase cognition. Researchers using expectancy-value theory were more balanced in their investigations, focusing on how both student expectations and values play a part in student cognition. For researchers using achievement goal theory, the focus was on the benefits of both mastery- and performance-based orientations and the use of multiple goal perspectives. Related to measuring cognition, we note that different measurements of achievement can make comparisons across projects difficult; as such, researchers should consider the best measurement for their specific goals and questions. From an engineering-specific context, we suggest that researchers attempt to develop and implement motivation-focused interventions to see the effects on students' motivational mindsets and cognitive abilities, as well as investigate how departmental or students' familial cultures affect their motivational orientations.

Introduction

Motivation is one of the key elements to academic success, tied to several aspects of student achievement [1], [2]. A student motivated through their academic coursework is more likely to continue their studies and obtain their degree [3]–[5]. Another important factor for student success is the development of thinking patterns that allow students to memorize, transform, and store the information they are learning in class, often called cognition [6]. A student's cognitive abilities in a particular course could affect their motivational orientation and their uptake of self-regulated learning behaviors [7]. In an educational setting, these two concepts are linked. Svinicki [8] points to this linkage, stating, "[l]earners have to be motivated to develop the mental model [of learning] in the first place and to perform the behavior once they have their models in place" [p. 64].

Within STEM education, both constructs have been a focus for researchers. Many investigators have studied engineering students' motivation, but there has been a lack of using motivation theories established within educational psychology [9]. The use of these theories has been increasing within the STEM education space, as researchers have found that incorporating these theories helps them to better understand and interpret the constructs and factors affecting motivation. Of note, the three motivational theories most extensively used are self-determination theory, expectancy-value theory, and achievement goal theory. See the Key Terms and Definitions section for more information about these theories.

Regarding STEM education and cognition, a review in 2020 looked at the cognitive assessment tools used in interdisciplinary STEM education. The authors found that while these interdisciplinary assessments were not designed to measure interdisciplinary learning and practices, they focused more on monodisciplinary learning and transdisciplinary attitudes [10]. For a full and multifaceted review of STEM cognition, the authors suggest reading Dori, Mevareh, and Baker's 2021 publication on the subject [11].

While motivation and cognition are both important concepts for student success, there has not been any major review of literature relating the two concepts within STEM education. A relevant article was written in 2015 that tied students' cognition and motivation to institutional culture to understand their effects on achievement and retention [12]. While the paper discusses several aspects of motivational concepts, such as the relevance of the topic and positive beliefs of self, the use of a single motivational theory was not present. The reason for this lack of a grounding theory might be that different motivational theories use separate constructs or variables (see the Motivational Theories Explored section below). This issue has been highlighted as a major reason why it can be difficult for academic policymakers to make informed decisions about best practices for classrooms and universities [13]–[15]. Understanding the findings from motivational literature, including multiple theories, and tying them together to have a full scope of the literature could be useful to university administrators who wish to enact new policies to help increase student achievement, satisfaction, and retention.

In this paper, we begin this process of literature scoping through a narrative literature review of motivational theory and cognition in undergraduate STEM education. We focused on three of the most popular motivational theories based on previous literature [9], [16]; self-determination theory, expectancy-value theory, and achievement goal theory. The major findings from this work are synthesized and discussed, with a major focus being on any correlations made between concepts from each of the theories and cognitive measures. We also discussed the importance of this work and what steps engineering education researchers can take moving forward.

Research Questions

While conducting this review, the following research questions were used as guides for interpreting findings and determining relevant articles:

- How have motivational theories been used in the undergraduate STEM education literature to determine links between motivation and cognition in students?
- What are the major variables or concepts that are tied to cognition in each of the theories explored in this paper that are tied to increased student cognition?

Key Terms and Definitions

Self-Determination Theory

Self-determination theory (SDT) is based on the understanding that external incentives to motivate individuals can be counterproductive and decrease motivation [17]. Instead, the developers of SDT saw that internal (or intrinsic) motivations were superior to extrinsic ones. Indeed, one aspect of SDT is moving on a continuum from amotivational to extrinsic to intrinsic [18]. Along with this continuum of amotivation, extrinsic motivation, and intrinsic motivation, self-determination theory is built upon psychological necessities [18]. SDT states that a student has a psychological need for autonomy, relatedness, and competence. Autonomy can be defined as the self-regulation of behaviors [19]. From an educational perspective, an autonomous student willingly devotes time and energy to their studies, and an autonomous classroom would be one in which teachers support acknowledgment of feelings, student choices, and opportunities for self-direction [18].

Competence, as described within STD, refers to the need of a student to feel that they are effective and mastering material [20]. For educational practices, instructors can increase competence through material that is challenging to the student, but within their ability to solve. Making material too challenging will frustrate students and lower their motivation, while content that is too easy will bore them and have a similar effect [8], [21]. In addition, actions such as personal criticisms and social comparisons can undermine feelings of competence [20]. The last concept of SDT, relatedness, does not necessarily have to do with the content. Instead, relatedness involves a sense of belonging within the social group. Some have suggested that relatedness and autonomy are antagonistic towards one another, as they involve collective and independent identities, respectively [18]. However, the two can be rectified easily within the classroom. A teacher can allow students to make individual choices while ensuring that the student feels liked, respected, and valued [22]. In doing so, the student can feel both autonomous and related to the classroom.

Expectancy-Value Theory

Expectancy-value theory (EVT) has a history dating back to roughly the 1960s [23]. Briefly, Atkinson posited that individuals were motivated based on their expectations of success and the perceived value of succeeding. Expectations were originally defined as the individual's anticipations for either a successful or unsuccessful outcome, while value is the relative attractiveness of either success or failure [24]. Over time, there have been several updates and modifications to the original theory, including Feather [25], Wigfield and Eccles [1], and Eccles et al. [26]. Of these more modern expectancy-value theories, this paper focuses on the Eccles et al. theory of EVT, as this was the one used in the article as the basis for the discussion of motivation in STEM education [9].

In this theory of EVT, expectancies are defined similarly to that of Atkinson, but the addition to the theory comes from the further distinction of values into four distinct categories; attainment value, intrinsic value, utility value, and cost [26]. Briefly, attainment value is related to the importance of doing well on a task and is often related to self-identity. Intrinsic value is related to the enjoyment of doing the task and is related to self-interest. The utility value of a task is related to how well it aligns with the current or future goals of the individual. Lastly, the cost of

a task measures the time, effort, and possible losses that will occur when trying to complete the task [9], [17], [24].

Student expectancies can also be influenced by a myriad of factors. To reiterate, expectancies are the beliefs of whether a student can succeed in their task. Some common variables that can influence expectancies include past experiences (both positive and negative), the student's internal belief about the task's difficulty, their self-confidence, and what others tell them [8]. Again, with the example of the engineering student, their expectancy of the difficulty of obtaining the degree would be influenced by their previous grades in math and science, their own beliefs about how difficult engineering is, and whatever stories their family has told them regarding their own experiences in engineering education.

Achievement Goal Theory

Achievement goal theory (AGT) was posited as a model of motivation after educational psychologists made clear distinctions between students' academic goals. To use AGT, one must first determine what goals the students possess. The researchers started by differentiating between two main categories of goals; those aimed at developing one's competence and the other at outperforming others [27], [28]. These two orientations were labeled as mastery and performance goals, respectively. Originally, AGT valued mastery over performance goals, but over time, a shift occurred, and AGT was revised to emphasize that there was positive potential for either goal [29].

A second aspect of motivational orientation was also developed, adding more depth to AGT's intrinsic motivational aspect [30]. While a dichotomy exists between performance and mastery, a second dichotomy was added to account for approach and avoidance orientations [31]. In approach-based orientations, the student's goal is to achieve success. On the other hand, students with avoidance-based orientations seek to avoid failure. At first, the approach/avoidance dichotomy was only placed on performance goals, so students were placed within one of three categories: mastery, performance-approach, or performance-avoidance. However, another adaptation occurred, and a separate model was developed to account for the mastery-approach and mastery-avoidance orientations [32]. This four-orientation model will be used for the remainder of the discussion.

For a mastery-approach student, the overall goal is to reach a level of competence or skill for their personal growth. The student would believe that they can do well in a course through hard work and effort, and tend to enjoy challenges [30]. The same is not true for mastery-avoidance students, whose motivations stem from not wanting to miss an opportunity for skill or competence development. A student who holds this orientation would strive to avoid forgetting course content and worry that they might have misunderstood the material [33].

A student with a performance-approach orientation is more concerned with achieving a goal with an external measurement of success, usually a grade or class ranking. These students can also be excited by a challenge, hoping to prove themselves and display their competence to others [31]. However, it should be noted that this can leave students open to negative emotional outcomes, such as jealousy and hostility toward peers that perform better than them [34]. Students who take a performance-avoidance orientation are not excited by a challenge and see it as a possibility to be identified as incompetent or lesser than their peers. Of the four orientations, this alignment is

considered the least productive for students, as those who are in this mindset will often suffer from anxiety and self-handicapping behavior in the face of academic challenges [32], [35], [36].

Cognition

For this paper, a definition of cognition that would be appropriate, especially in a STEM context, comes from Purzer, Moore, and Dringenberg [37]. Briefly, cognition can be seen as the merging of knowledge acquisition and knowledge application that allows students to arrive at viable solutions to difficult problems. Within the reviewed literature, cognition was often measured through a metric of academic achievement, be it exam scores, final grades, or GPAs. We have included each of these metrics in our review and refer to this as academic performance or achievement throughout our discussion. We also discuss the differences in cognitive measures and what that might mean for making useful interpretations of the findings.

Method

This paper follows a narrative review structure. Unlike systematic reviews, narrative reviews do not follow a specific protocol that allows others to replicate the process [38], [39]. Although narrative reviews suffer from this inability to reproduce the methodology, they are still useful when making a first appraisal of the field of knowledge. The review was conducted first by looking into several articles that were listed in the Brown et al. review of motivational theory usage in engineering education [9]. Snowballing was then used to see who recently cited these articles and what work was done by similar research teams since the time of the review paper. Databases such as Google Scholar and Education Full Text were also used, focusing on the three motivational theories described above, cognition/academic achievement, and STEM education. For example, a search string in Google Scholar would be “achievement goal theory AND cognition AND STEM education.”

To further narrow the scope of the review, we limited our findings in the following ways: First, we narrowed the results to those studies focused on undergraduate STEM education. Second, we emphasized peer-reviewed journal articles. And third, when reviewing the journals, we ensured that the research integrated the motivational theory within the study.

A total of twenty-three articles were reviewed for this work. A breakdown of these papers based on the theories they utilized is shown below in Figure 1. Briefly, self-determination theory (SDT) was used in six (about 26%) of the studies. Expectancy-value theory (EVT) was used in eight, or approximately 35% of the studies. In nine studies, the achievement goal theory (AGT) was used, making up the remaining 39% of the work reviewed. When seeking answers to our research questions, we used qualitative content analysis [40] to see how researchers have reported possible links between motivational constructs and cognition.

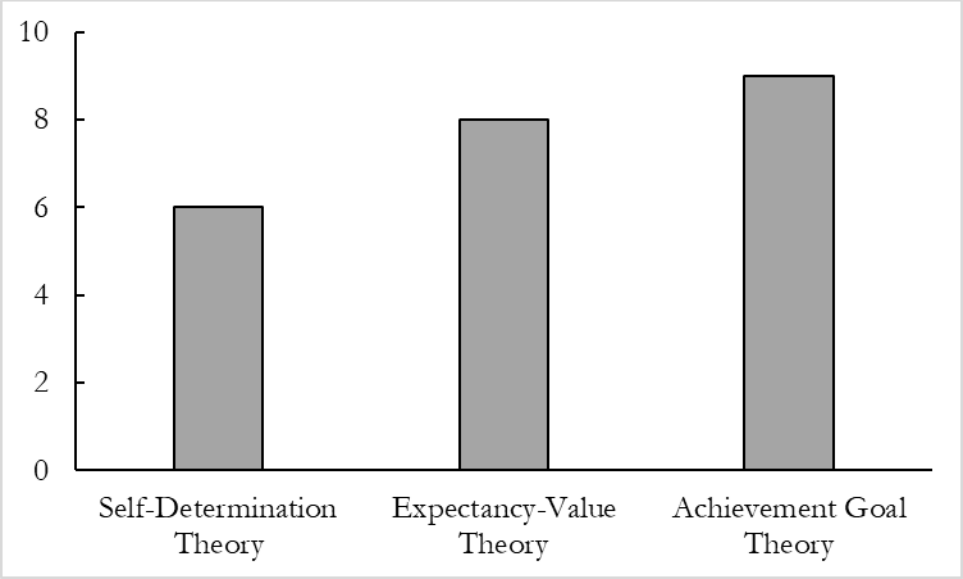

Figure 1. The number of articles reviewed grouped by the motivation theory used.

Review of the Literature

Major Findings from the Theories – Tying Motivational Constructs to Cognition

No matter what theory was used, researchers were able to find a correlation between one of their constructs and academic achievement. In SDT, many studies focused on student autonomy. Black and Deci [41] specifically investigated an autonomy intervention, while Botnaru et al. [42] focused on student autonomous motivation. The use of these autonomous support methods (measured as leader autonomous support or LAS) was positively correlated with both exam scores and final grades but was dependent on students' initial levels of autonomy. A student that started the course high in self-autonomy would see little change in their performance when an instructor used these methods, but a student with low self-autonomy saw much higher benefits to their performance [42].

Certainly, many investigated multiple components of STD [43]–[46], but none would give recommendations based on improving all three of the psychological needs. This pattern could be due to correlational work that showed only one of the needs was statistically correlated with an outcome. The researchers focused their recommendations on methods to fulfill or improve that need. This was seen in a study from 2018, in which perceived competence was found to be the strongest predictor of dropout intentions and academic achievement [45]. A student with high competence is less likely to drop out and is more likely to have a higher grade. Liu et al. [46] and Koh et al. [43] found autonomy to be the only psychological need that had statistically significant correlations with academic outcomes in their studies.

EVT research was more balanced between expectancies and values. Results from various researchers often showed that a mix between expectancy perceptions and task values influences student performance [47]–[50]. The major findings from these studies suggest that a balance between promoting positive expectancies and ensuring high task values (specifically in the case of attainment, intrinsic, and utility value) can help motivate students toward academic success.

This is not to say that there were no papers in EVT that did not focus on a single concept within EVT. Two papers, which were linked to the same research group, investigated the utility-value concept of EVT and how to increase it among students in biology courses [51], [52]. The utility-value intervention, or UVI, was successful in increasing students' course grades and motivating them to continue studying biology.

Another subtheme from the EVT review was a focus on differences in expectancy-value beliefs in students based on biological sex. An excellent example of this focus within engineering education comes from a study by Jones et al. [47]. The researchers were interested in first-year engineering differences in self-efficacy expectations, engineering success expectations, engineering identity, engineering values, achievement, and career plans between male and female students. An interesting finding was that males had higher expectancy beliefs, including those related to self-efficacy than females, but both populations saw losses in their expectancy and value beliefs over the first year. Another important finding was that expectancy beliefs were positive predictors of academic achievement in the form of higher GPAs, while value beliefs were predictors of more concrete career plans. Another study that found differences based on sex was looking into intelligence beliefs and social comparisons [50]. The results of this paper showed that strong self-efficacy, which relates to expectancy measures, was more beneficial to females than males regarding final course grades. Another interesting, and concerning, finding was that intelligence growth mindsets had no correlational effect on self-efficacy for women and that students concerned with social comparisons were just as detrimental to self-efficacy for both males and females. Social comparisons were also found to be more deleterious to exam scores for females than for males. Findings suggest that classroom environments should be modified to de-emphasize social comparisons to allow for better self-efficacy, and, therefore, higher expectancy beliefs and course performance.

In the AGT research, the mastery approach was often found to be tied to better academic performance [53]–[58]. Correlational studies found significant increases in effective teamwork behaviors correlated to higher exam grades and greater acceptance of mastery orientations [55]. This study implies that positive teamwork experiences can help both cognition and positive motivational orientations. Another study examined how motivational orientations correlated with reflection behaviors and academic performance. The results indicated a mastery approach significantly affected exam scores and the total number of reflections, while a performance-approach only affected exam scores [56]. The findings suggest that mastery-approach students would adopt self-reflection strategies at higher rates than performance-approach students. A similar pattern was found in a study of motivational orientations in pharmacy students and their exam scores on multiple-choice and short-essay exams [57]. Findings indicated that the mastery-approach orientation correlates with higher scores on essay exams, while performance-avoidance orientations correlate with lower scores on either exam type. These results align well with the literature, as avoidance orientations tend to perform worse in academic settings [30], and essay-type questions better assess the depth of knowledge, reasoning, and problem-solving skills [59], which better correlate with mastery orientations [60].

While mastery orientations were found to be correlated with higher achievement, there was also research that showed performance approach orientations were correlated with academic achievement [53], [54], [56], [61]. As previously mentioned, performance orientations were

correlated with high exam scores, but not with reflection behaviors [56]. Performance orientations were also found to be linked to self-efficacy beliefs within an engineering context [54]. These findings are not surprising, as the assumption about performance orientations being detrimental to academic success has been challenged for some time [29], [30], [32], [34], [35].

Another finding that is important to discuss is the use of multiple achievement goals among students. One of the papers in this review found evidence to suggest that students will use a multiple-goal perspective in their learning [62]. The team hypothesized that Filipino students in a math course would use a combination of mastery and performance goal orientations in class, as Asian cultures often interpret the goal orientation used in AGT differently due to cultural pressures such as systemic normative-assessment exams. The researchers collected data on students' achievement goals, intrinsic motivation, effort, persistence, and exam scores. The study found that students who used multiple orientations had higher exam scores than those that only used one motivational orientation. This study would imply that performance orientations might be linked to cognitive growth when balanced with aspects of mastery orientations. An interesting finding that was not discussed in much detail in another study found that mastery orientations were also correlated with performance orientations, indicating a possible link between the two [54]. This research is important to highlight, as this is a current discussion within the greater AGT literature [30], [61], [63]–[65].

Motivational Theories and Their Relations to Self-Efficacy

One aspect that all the theories had in common was that they were tied in some measure to self-efficacy. It seems that motivational researchers, no matter the theory they use, are interested in self-efficacy and relating it to their framework. This finding is not surprising, considering that other educational researchers outside of STEM have also been interested in self-efficacy [66].

Within the review, Koh et al. [43] found correlations between self-efficacy and high competence measures in their students. This finding indicates that perceived self-confidence is crucial for a student if they are to believe that they can accomplish a task. In the EVT literature, researchers would often use self-efficacy measures to determine students' expectancy inclinations [47], [50]. Here, comparisons were not between motivational concepts of the theory and self-efficacy but were fully integrated to measure expectancy. Within the AGT space, Mamaril et al. [54] looked at several different types of engineering self-efficacy (general, experimental, tinkering, and design) in a correlational analysis, and showed that mastery orientations were linked to all four, while performance approach orientations were correlated with all but tinkering. More work on the relationship between goal orientations and self-efficacy within the STEM space would be useful for the AGT field to see if there is a similar consensus.

Critique on Cognitive Measurements

One of the major critiques of this review was that it could be difficult to make comparisons between studies using different variables for cognition. Within each theory, research groups would measure academic achievement using different metrics, usually either exam scores, final grades, or GPA. In one instance, a combination of exam scores and final grades was used [41]. With all these different measurements used, one question comes to mind: Do these academic

performance measures equally measure cognition? It could be argued that these measurements are not the same because they account for different variables.

To elaborate, a student's exam scores are primarily measures of whatever content the instructor included in the test. Final course grades, by comparison, account for not only whatever subjects were on exams, but also homework assignments, quizzes, and projects. In addition, the student's participation in class might also be a factor. And GPA is even larger in scope, as it accounts for multiple class subjects and different tasks. As an example, consider a student with a standard GPA, but they are doing very well in an engineering class, except for one exam where they received a below-average grade. If that student were assessed using each of these three measures, and then each of these measures was compared to their motivational profile, the results could end up with vastly different interpretations. This comment is not to say that one measurement is better than any other, but only to suggest that cross-comparisons between these achievement measures have limitations, and care should be taken to consider what is the most appropriate measure for a study.

For other researchers in the field, it would be prudent to consider the specific measurement that they intend to use to ensure that it aligns with their research questions and goals. If one is investigating the effects of a singular intervention on a student's ability to understand one or two concepts, measuring cognition using exam scores might be best. If, however, the researcher is more interested in how motivation shifts and changes over a semester and how that might affect cognition, looking at multiple cognitive measurements for the semester and the final grade might be a more viable option. In any case, researchers should consider comparing their work with similar studies that use comparable measurements of cognition.

Engineering Education Context

While this review focused on STEM education, we would like to take a moment to shift the focus to engineering education specifically, as this would be of particular importance to conference attendees. There is still much work to be done in understanding student motivations within an engineering context, as others have described the lack of motivational theory that has historically been used in the field [9]. Of course, Brown's review is close to ten years old now, and a more updated review would provide insight into the current state of the field and what changes have occurred since then.

Nonetheless, one important takeaway from the engineering portion of the review is that more studies can be developed by the engineering education community around motivation-based interventions. Of the seven articles that focused on engineering education, only two of them used an intervention that focused on changing motivation and/or performance [43], [55]. More work should be conducted to determine intervention effects on motivation profiles. As an example, classroom interventions based on AGT (i.e., TARGET) have been used to move students towards mastery motivations in other contexts [67]–[69]. It would be interesting to see how instructors use similar interventions within engineering classrooms and how engineering students respond to these environments.

Another aspect that engineering educators could target is how classroom or departmental attitudes and cultures can affect motivational profiles. Other work in the medical sciences found

that students' perceptions of mastery-based curriculums and positive workplace affordances were correlated with students reporting a mastery goal orientation [58]. Cultural differences among students also seem to affect their orientations, such as the use of multiple-goal orientations of Filipino students, as described by Dela Rosa and Bernardo [62], [63]. As we continue to strive towards a more diverse engineering population, these cultural differences and how they may change the motivational setup of classrooms should be considered.

Discussion and Implications

There were several key takeaways from each of the theories of interest. For self-determination theory, autonomy was the psychological need most directly correlated with cognition. If this is the case, STEM researchers should continue to develop teaching approaches and assessments that allow students to have a level of autonomy with their learning in the classroom. An example would be allowing students to choose a topic of interest that relates to the learning objectives of the course or having them pick from a pool of project topics so that they are working on a task that resonates with them. While these tactics might work best in higher-level courses, educators can also develop this autonomy in lower-level courses that require more structure. For instance, going over classroom behaviors or the syllabus and asking for feedback from the students regarding the policies can give students the feeling of autonomy.

From the use of the expectancy-value theory, evidence suggests there are differences in expectancy and value beliefs based on biological sex. However, there is not enough evidence to confirm this finding. We strongly suggest that researchers explore this area more thoroughly, as having different expectancy and value beliefs can lead to certain interventions being ineffective for targeted groups. If, as one study suggests, social comparisons are much more likely to negatively affect female students [50], then focusing on reducing the social comparisons in class might be a viable tactic if the goal is to further motivate female students in classes that suffer from low female student motivation.

The work within achievement goal theory suggests that there is no clear orientation tied to cognition. Both mastery and performance profiles seem tied to cognition, but the implication is that mastery-aligned students have more internal motivation as opposed to their performance-aligned peers. The clear definition, however, comes from comparing approach and avoidance-based orientations. Approach-based students have more ties to cognition, as these students will be more involved with the course content than those who are avoidance-based. There is also the added layer of complexity, in that some students may be using multiple orientations within the same context. Research projects should be developed to understand how STEM students, and especially engineering students, motivate themselves through their studies, and how that corresponds to the orientations listed in AGT. More work should be done to understand how engineering students respond to AGT-based interventions that either change or reinforce students' motivational inclinations. Instructors should set up their classes to try and reinforce approach-focused motivations, and research should investigate how mastery and performance-based environments can affect students.

Tying all these motivational theories together, self-efficacy is an important construct to consider when developing interventions or exploring students' motivational profiles. Boosting self-efficacy is a net positive, no matter the motivational theory used as a framework for the study.

Researchers should take careful consideration, however, in which measurement they will use to perceive cognition or academic achievement. The appropriate measurement depends on what aspect of learning or cognition the researcher is trying to investigate. Exam scores may take a precise measurement for students, as exams are meant as assessments in class. At the same time, final grades or GPA may be effective to get a more encompassing understanding of a student's cognition in multiple different environments and situations.

While this paper is a good first step in understanding the current state of the motivation and cognition literature within STEM education, there are limitations to the work. The foremost of these limitations is that this work is a narrative review and is not replicable. We strongly encourage other researchers interested in the topic to conduct a systematic literature review to confirm or contrast with our review. Another limitation of the work is the use of multiple theories, making it difficult to gather a unified consensus that can lead to a specific recommendation. It can be difficult to tie mastery-based orientations seen in AGT with expectancy or value beliefs from EVT. For this reason, others have suggested looking into developing unifying theories [13]. While this might be the case, it does seem that self-efficacy can be a unifying concept that underlines each of the theories and can be used to tie them together.

Conclusion

A narrative literature review was conducted to investigate how STEM education researchers used motivational theories to analyze student motivational profiles and determine how those profiles relate to cognition. The review focused on three specific theories: self-determination theory, expectancy-value theory, and achievement goal theory. The findings varied depending on the theory used. For instance, self-determination theory emphasizes autonomy and how to enhance students' autonomous motivation to increase their cognition. The findings suggest that STEM education researchers should consider and explore interventions based on increasing autonomy. Expectancy-value theory results were more balanced between both expectancy and value focus, and results showed that both play a part in student cognition. Thus, researchers should consider how these multiple beliefs interact with one another, and interventions should consider targeting multiple concepts from EVT as opposed to just one of them. Achievement goal theory results were consistent with current discussions in the field, highlighting the benefits of performance-based orientations and the use of multiple goal perspectives. We recommend that researchers align the cognitive measurement with their research goals and questions, as these measurements may account for multiple factors. From an engineering educational perspective, we suggest developing interventions that target motivational concepts and observe their effects on engineering students' motivational profiles and cognition. Additionally, engineering educators should consider how students' cultural backgrounds and departmental culture might influence students' motivational orientations.

References

[1] A. Wigfield and J. S. Eccles, “Expectancy-value theory of achievement motivation,” *Contemp. Educ. Psychol.*, vol. 25, no. 1, pp. 68–81, 2000, doi: 10.1006/ceps.1999.1015.

[2] J. Guo, P. D. Parker, H. W. Marsh, and A. J. S. Morin, “Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective,” *Dev. Psychol.*, vol. 51, no. 8, pp. 1163–1176, 2015, doi: 10.1037/a0039440.

[3] J. Allen and S. Robbins, “Effects of Interest-Major Congruence, Motivation, and Academic Performance on Timely Degree Attainment,” *J. Couns. Psychol.*, vol. 57, no. 1, pp. 23–35, 2010, doi: 10.1037/a0017267.

[4] I. M. Hasbún, H. M. Matusovich, and S. G. Adams, “The Dissertation Institute: Motivating doctoral engineering students toward degree completion,” *Proc. - Front. Educ. Conf. FIE*, vol. 2016-Novem, pp. 0–4, 2016, doi: 10.1109/FIE.2016.7757508.

[5] M. Fokkens-Bruinsma and E. T. Canrinus, “Motivation and degree completion in a university-based teacher education programme,” *Teach. Educ.*, vol. 26, no. 4, pp. 439–452, 2015, doi: 10.1080/10476210.2015.1034682.

[6] M. Alias, T. A. Lashari, Z. A. Akasah, and M. J. Kesot, “Translating theory into practice: Integrating the affective and cognitive learning dimensions for effective instruction in engineering education,” *Eur. J. Eng. Educ.*, vol. 39, no. 2, pp. 212–232, 2014, doi: 10.1080/03043797.2013.838543.

[7] B. Finn, “Exploring Interactions Between Motivation and Cognition to Better Shape Self-Regulated Learning,” *J. Appl. Res. Mem. Cogn.*, vol. 9, no. 4, pp. 461–467, 2020, doi: 10.1016/j.jarmac.2020.08.008.

[8] M. D. Svinicki, *Learning and motivation in the postsecondary classroom*. Anker Publishing, 2004.

[9] P. R. Brown, R. E. McCord, H. M. Matusovich, and R. L. Kajfez, “The use of motivation theory in engineering education research: A systematic review of literature,” *Eur. J. Eng. Educ.*, vol. 40, no. 2, pp. 186–205, 2015, doi: 10.1080/03043797.2014.941339.

[10] X. Gao, P. Li, J. Shen, and H. Sun, “Reviewing assessment of student learning in interdisciplinary STEM education,” *Int. J. STEM Educ.*, vol. 7, no. 1, 2020, doi: 10.1186/s40594-020-00225-4.

[11] Y. J. Dori, Z. R. Mevarech, and D. R. Baker, *Cognition, Metacognition, STEM Education*, Electronic. Springer International Publishing, 2021.

[12] J. G. Cromley, T. Perez, and A. Kaplan, “Undergraduate STEM achievement and retention: Cognitive, motivational, and institutional factors and solutions,” *Policy Insights from Behav. Brain Sci.*, vol. 3, no. 1, pp. 4–11, 2015, doi: 10.1177/2372732215622648.

[13] C. S. Dweck, “From needs to goals and representations: Foundations for a unified theory of motivation, personality, and development,” *Psychol. Rev.*, vol. 124, no. 6, pp. 689–719, 2017, doi: 10.1037/rev0000082.

[14] E. M. Anderman, “Achievement motivation theory: Balancing precision and utility,” *Contemp. Educ. Psychol.*, vol. 61, no. April, p. 101864, 2020, doi:

10.1016/j.cedpsych.2020.101864.

[15] A. C. Koenka, “Academic motivation theories revisited: An interactive dialog between motivation scholars on recent contributions, underexplored issues, and future directions,” *Contemp. Educ. Psychol.*, vol. 61, no. March, p. 101831, 2020, doi: 10.1016/j.cedpsych.2019.101831.

[16] S. Beecham, N. Baddoo, T. Hall, H. Robinson, and H. Sharp, “Motivation in software engineering: A systematic literature review,” *Inf. Softw. Technol.*, vol. 50, no. 9–10, pp. 860–878, 2008, doi: 10.1016/j.infsof.2007.09.004.

[17] J. S. Eccles and A. Wigfield, “Motivational beliefs, values, and goals,” *Annu. Rev. Psychol.*, vol. 53, no. February, pp. 109–132, 2002, doi: 10.1146/annurev.psych.53.100901.135153.

[18] R. M. Ryan and E. L. Deci, “Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being,” *Am. Psychol.*, vol. 55, no. 1, pp. 68–78, 2000, doi: 10.1037/0003-066X.55.1.68.

[19] R. M. Ryan and E. L. Deci, “Self-regulation and the problem of human autonomy: Does psychology need choice, self-determination, and will?,” *J. Pers.*, vol. 74, no. 6, pp. 1557–1586, 2006, doi: 10.1111/j.1467-6494.2006.00420.x.

[20] R. M. Ryan and E. L. Deci, *Self-Determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford Publications, 2017.

[21] R. M. Felder and R. Brent, *Teaching and learning STEM: A practical guide*, First. 2016.

[22] C. P. Niemiec and R. M. Ryan, “Autonomy, competence, and relatedness in the classroom: Applying self-determination theory to educational practice,” *Theory Res. Educ.*, vol. 7, no. 2, pp. 133–144, 2009, doi: 10.1177/1477878509104318.

[23] J. W. Atkinson, *An introduction to motivation.* Oxford, England: Van Nostrand, 1964.

[24] A. Wigfield, “Expectancy-value theory of achievement motivation: A developmental perspective,” *Educ. Psychol. Rev.*, vol. 6, no. 1, pp. 49–78, 1994.

[25] N. T. Feather, “Values, valences, expectations, and actions,” *J. Soc. Issues*, vol. 48, no. 2, pp. 109–124, 1992.

[26] J. Eccles *et al.*, “Expectancies, values, and academic behaviors,” in *Achievement and achievement motives*, J. T. Spence, Ed. W. H. Freeman, 1983, pp. 75–146.

[27] J. G. Nicholls, “Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance,” *Psychol. Rev.*, vol. 91, no. 3, pp. 328–346, 1984, doi: 10.1037/0033-295X.91.3.328.

[28] C. Ames and J. Archer, “Achievement goals in the classroom: Students’ learning strategies and motivation processes,” *J. Educ. Psychol.*, vol. 80, no. 3, pp. 260–267, 1988, doi: 10.1037//0022-0663.80.3.260.

[29] J. M. Harackiewicz, K. E. Barron, and A. J. Elliot, “Rethinking achievement goals: When are they adaptive for college students and why?,” *Educ. Psychol.*, vol. 33, no. 1, pp. 1–21, 1998, doi: 10.1207/s15326985ep3301_1.

[30] C. Senko, C. S. Hulleman, and J. M. Harackiewicz, “Achievement goal theory at the crossroads: Old controversies, current challenges, and new directions,” *Educ. Psychol.*, vol. 46, no. 1, pp. 26–47, 2011, doi: 10.1080/00461520.2011.538646.

[31] A. J. Elliot and J. M. Harackiewicz, “Approach and avoidance achievement goals and intrinsic motivation: A mediational analysis,” *J. Pers. Soc. Psychol.*, vol. 70, no. 3, pp. 461–475, 1996, doi: 10.1037/0022-3514.70.3.461.

[32] A. J. Elliot, “Approach and avoidance motivation and achievement goals,” *Educ. Psychol.*, vol. 34, no. 3, pp. 169–189, 1999, doi: 10.1207/s15326985ep3403_3.

[33] M. Karakus, “Understanding the mastery-avoidance construct: An investigation among middle school students in two domains,” Temple University, 2016.

[34] A. J. Elliot and A. C. Moller, “Performance-approach goals: Good or bad forms of regulation?,” *Int. J. Educ. Res.*, vol. 39, no. 4, pp. 339–356, 2003, doi: 10.1016/j.ijer.2004.06.003.

[35] A. J. Elliot and M. A. Church, “A hierarchical model of approach and avoidance achievement motivation,” *J. Pers. Soc. Psychol.*, vol. 72, no. 1, pp. 218–232, 1997, doi: 10.1037/0022-3514.72.1.218.

[36] A. J. Elliot and H. A. McGregor, “Test anxiety and the hierarchical model of approach and avoidance achievement motivation.,” *J. Pers. Soc. Psychol.*, vol. 76, no. 4, pp. 628–644, 1999, doi: 10.1037//0022-3514.76.4.628.

[37] S. Purzer, T. J. Moore, and E. Dringenberg, “Engineering cognition: A process of knowledge acquisition and application,” in *Cognition, Metacognition, and Culture in STEM Education. Innovations in Science Education and Technology*, Y. J. Dori, Z. R. Mevarech, and D. R. Baker, Eds. Springer, 2018, pp. 167–190.

[38] R. Ferrari, “Writing narrative style literature reviews,” *Med. Writ.*, vol. 24, no. 4, pp. 230–235, 2015, doi: 10.1179/2047480615z.000000000329.

[39] J. A. Byrne, “Improving the peer review of narrative literature reviews,” *Res. Integr. Peer Rev.*, vol. 1, no. 1, pp. 10–13, 2016, doi: 10.1186/s41073-016-0019-2.

[40] K. Williamson, L. M. Given, and P. Scifleet, “Qualitative data analysis,” in *Research Methods: Information, Systems, and Contexts*, Second., K. Williamson and G. Johanson, Eds. Elsevier Ltd, 2018, pp. 453–476.

[41] A. E. Black and E. L. Deci, “The effects of instructors’ autonomy support and students’ autonomous motivation on learning organic chemistry: A self-determination theory perspective,” *Sci. Educ.*, vol. 84, no. 6, pp. 740–756, 2000, doi: 10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3.

[42] D. Botnaru, J. Orvis, J. Langdon, C. P. Niemiec, and S. M. Landge, “Predicting final grades in STEM courses: A path analysis of academic motivation and course-related behavior using self-determination theory,” *Learn. Motiv.*, vol. 74, no. April, p. 101723, 2021, doi: 10.1016/j.lmot.2021.101723.

[43] C. Koh *et al.*, “Investigating the effect of 3D simulation-based learning on the motivation and performance of engineering students,” *J. Eng. Educ.*, vol. 99, no. 3, pp. 237–251, 2010, doi: https://doi.org/10.1002/j.2168-9830.2010.tb01059.x.

[44] E. M. Dell, Y. Verhoeven, J. W. Christman, and R. D. Garrick, “Using Self-Determination Theory to build communities of support to aid in the retention of women in engineering,” *Eur. J. Eng. Educ.*, vol. 43, no. 3, pp. 344–359, 2018, doi: 10.1080/03043797.2017.1410522.

[45] L. M. Jeno, A. G. Danielsen, and A. Raaheim, “A prospective investigation of students’ academic achievement and dropout in higher education: A self-determination theory approach,” *Educ. Psychol.*, vol. 38, no. 9, pp. 1163–1184, 2018, doi: 10.1080/01443410.2018.1502412.

[46] W. C. Liu, C. K. J. Wang, Y. H. Kee, C. Koh, B. S. C. Lim, and L. Chua, “College students’ motivation and learning strategies profiles and academic achievement: A self-determination theory approach,” *Educ. Psychol.*, vol. 34, no. 3, pp. 338–353, 2014, doi: 10.1080/01443410.2013.785067.

[47] B. D. Jones, M. C. Paretti, S. F. Hein, and T. W. Knott, “An analysis of motivation constructs with first-year engineering students: Relationships among expectancies, values, achievement, and career plans,” *J. Eng. Educ.*, vol. 99, no. 4, pp. 319–336, 2010, doi: 10.1002/j.2168-9830.2010.tb01066.x.

[48] T. Perez *et al.*, “Interrelations among expectancies, task values, and perceived costs in undergraduate biology achievement,” *Learn. Individ. Differ.*, vol. 72, no. April, pp. 26–38, 2019, doi: 10.1016/j.lindif.2019.04.001.

[49] T. Perez, S. V. Wormington, M. M. Barger, R. D. Schwartz-Bloom, Y. K. Lee, and L. Linnenbrink-Garcia, “Science expectancy, value, and cost profiles and their proximal and distal relations to undergraduate science, technology, engineering, and math persistence,” *Sci. Educ.*, vol. 103, no. 2, pp. 264–286, 2019, doi: 10.1002/sce.21490.

[50] H. Lee, S. L. Yu, M. Kim, and A. C. Koenka, “Concern or comfort with social comparisons matter in undergraduate physics courses: Joint consideration of situated expectancy-value theory, mindsets, and gender,” *Contemp. Educ. Psychol.*, vol. 67, no. October, p. 102023, 2021, doi: 10.1016/j.cedpsych.2021.102023.

[51] J. M. Harackiewicz, E. A. Canning, Y. Tibbetts, S. J. Priniski, and J. S. Hyde, “Closing achievement gaps with a utility-value intervention: Disentangling race and social class,” *J. Pers. Soc. Psychol.*, vol. 111, no. 5, pp. 745–465, 2016, doi: 10.1037/pspp0000075.

[52] C. A. Hecht, J. M. Harackiewicz, S. J. Priniski, E. A. Canning, Y. Tibbetts, and J. S. Hyde, “Promoting persistence in the biological and medical sciences: An expectancy-value approach to intervention,” *J. Educ. Psychol.*, vol. 11, no. 8, pp. 1462–1477, 2019, doi: 10.1037/edu0000356.

[53] K. J. Crippen, K. D. Biesinger, K. R. Muis, and M. Orgill, “The role of goal orientation and self-efficacy in learning from web-based worked examples,” *J. Interact. Learn. Res.*, vol. 20, no. 4, pp. 385–403, 2009.

[54] N. A. Mamaril, E. L. Usher, C. R. Li, D. R. Economy, and M. S. Kennedy, “Measuring undergraduate students’ engineering self-efficacy: A validation study,” *J. Eng. Educ.*, vol. 105, no. 2, pp. 366–395, 2016, doi: 10.1002/jee.20121.

[55] S. Anwar and M. Menekse, “Unique contributions of individual reflections and teamwork on engineering students’ academic performance and achievement goals,” *Int. J. Eng. Educ.*, vol. 36, no. 3, pp. 1018–1033, 2020.

[56] D. Heo, S. Anwar, and M. Menekse, “The relationship between engineering students’ achievement goals, reflection behaviors, and learning outcomes,” *Int. J. Eng. Educ.*, vol. 34, no. 5, pp. 1634–1643, 2018.

[57] S. Alrakaf *et al.*, “An international comparison study of pharmacy students’ achievement goals and their relationship to assessment type and scores,” *Am. J. Pharm. Educ.*, vol. 79, no. 3, pp. 1–8, 2015, doi: 10.5688/ajpe79335.

[58] H. C. Chen *et al.*, “Students’ goal orientations, perceptions of early clinical experiences and learning outcomes,” *Med. Educ.*, vol. 50, no. 2, pp. 203–213, 2016, doi: 10.1111/medu.12885.

[59] D. Dathe, K. O’Brien, G. Loaker, and M. Matlock, “Learning from the assessment of problem solving,” in *The Challenge of Problem-based Learning*, D. B. Swanson, S. M. Case, and C. P. van der Vlueten, Eds. Kogan Page Limited, 1991, pp. 260–273.

[60] D. M. Belenky and T. J. Nokes-Malach, “Motivation and transfer: The role of mastery-approach goals in preparation for future learning,” *J. Learn. Sci.*, vol. 21, no. 3, pp. 399–432, 2012, doi: 10.1080/10508406.2011.651232.

[61] K. R. Muis, J. Ranellucci, G. M. Franco, and K. J. Crippen, “The interactive effects of personal achievement goals and performance feedback in an undergraduate science class,” *J. Exp. Educ.*, vol. 81, no. 4, pp. 556–578, 2013, doi: 10.1080/00220973.2012.738257.

[62] E. D. Dela Rosa and A. B. I. Bernardo, “Testing multiple goals theory in an Asian context: Filipino university students’ motivation and academic achievement,” *Int. J. Sch. Educ. Psychol.*, vol. 1, no. 1, pp. 47–57, 2013, doi: 10.1080/21683603.2013.782594.

[63] E. D. Dela Rosa and A. B. I. Bernardo, “Are two achievement goals better than one? Filipino students’ achievement goals, deep learning strategies and affect,” *Learn. Individ. Differ.*, vol. 27, pp. 97–101, 2013, doi: 10.1016/j.lindif.2013.07.005.

[64] E. A. Linnenbrink, “The dilemma of performance-approach goals: The use of multiple goal contexts to promote students’ motivation and learning,” *J. Educ. Psychol.*, vol. 97, no. 2, pp. 197–213, 2005, doi: 10.1037/0022-0663.97.2.197.

[65] K. E. Barron and J. M. Harackiewicz, “Achievement goals and optimal motivation: Testing multiple goal models,” *J. Pers. Soc. Psychol.*, vol. 80, no. 5, pp. 706–722, 2001, doi: 10.1037/0022-3514.80.5.706.

[66] D. H. Schunk and M. K. DiBenedetto, “Self-efficacy and human motivation,” in *Advances in Motivation Science*, 1st ed., A. J. Elliot, Ed. Elsevier Inc., 2021, pp. 153–179.

[67] M. Hinzman, “Educational applications of achievement goal theory,” University of Northern Iowa, 2011.

[68] S. Deemer and L. Hanich, “Using achievement goal theory to translate evidence-based principles into practice in educational psychology,” *Clear. House*, vol. 78, no. 5, pp. 197–201, 2005.

[69] L. Bardach, S. Oczlon, J. Pietschnig, and M. Lüftenegger, “Has achievement goal theory been right? A meta-analysis of the there relation between goal structures and personal achievement goals,” *J. Educ. Psychol.*, vol. 112, no. 6, pp. 1197–1220, 2020, doi: 10.1037/edu0000419.