Reflection and Goal Setting: Methods for Improved Performance and Engagement in Engineering Courses

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Abstract

Students who consistently set goals and reflect on the outcome of their efforts get the most out of their engineering education. Instead of solely focusing on the technical content of their courses, the most successful engineering students form habits that include evaluating their aspirations, performance, time management, commitment level, etc. Additionally, faculty who encourage these practices in their courses may see better student engagement and knowledge retention. Unfortunately, these skills rarely come naturally to students, and many do not get the chance to develop them before pursuing their undergraduate degree. Engineering courses should not only help students learn technical content but should also help them develop the skills of goal setting, expectation development, reflection, and self-assessment. This paper aims to address the following two research questions: 1) What are the effects of self-efficacy, goal setting, and reflection on undergraduate engineering students? 2) What would a practical model for implementing these strategies look like for students and faculty?

To do so, this paper reviews the available literature on self-efficacy, implicit beliefs (growth mindset), and resilience, describing their importance for engineering students. The authors also present a literature review of specific techniques that are useful in developing self-efficacy—goal setting and reflection. The paper then outlines a process students can use to enhance their personal goal setting and reflection techniques that could help improve comprehension of the technical content of their engineering courses. The authors offer suggestions for faculty, from a student perspective, on techniques and mindsets related to self-efficacy, goal setting, and reflection that they can incorporate into their classrooms to help with student engagement and knowledge retention.

Introduction

Research shows that student success in science, technology, engineering, and mathematics (STEM) fields can be correlated not only to their innate ability and intelligence but also to their self-efficacy and implicit beliefs (growth mindset) [1, 2]. Many students enter their courses at the university level with the belief that their peers are only doing well because they are more intelligent or more naturally gifted. While there may always a few students with greater natural ability, the reason for most engineering students' success appears to be their ability to learn, grow, and adjust based on feedback and criticism instead of crumbling under pressure.

Providing students with the opportunity to develop self-efficacy, implicit beliefs about themselves, and resilience will help them in engineering [1, 2] However, the practical aspect of implementation is often lacking. In other words, while the importance of these skills is recognized in literature, many articles do not offer practical steps that students or faculty can take to learn and use in a typical classroom. Additionally, it is not feasible for most students to seek out this sort of training nor for faculty to teach these skills in their classrooms as their expertise is in their engineering field.

This paper seeks to briefly review the literature on self-efficacy, growth mindset, and resilience in engineering students, specifically. It also seeks to review the literature on two important practical applications central to helping students develop self-efficacy, a growth mindset, and resilience—these being goal setting and reflection. The authors feel that these two aspects, more than any others, are important for engineering students' development of self-efficacy because they contributed most to their own success as engineering students. Importantly, developing these skills does not require additional workshops, coursework, or reading. However, students need to be given specific techniques and methods to easily incorporate these into their learning processes. This paper aims to address the following two research questions: 1) What are the effects of self-efficacy, goal setting, and reflection on undergraduate engineering students? 2) What would a practical model for implementing these strategies look like for students and faculty?

In order to be useful, these constructs need to go beyond a mere mindset to offer real, tangible methods for helping students develop self-efficacy and resilience. Therefore, the final aspect of this paper displays a practical framework to help with implementation. Using the established literature and their own experiences, the authors have developed a framework that students can use to help integrate goal setting and reflection into their lives to help improve their self-efficacy and academic success. Faculty or students can implement these pragmatic techniques, either during or outside of class. The authors hope that they will be able to validate this model with future research studies in first-year engineering courses.

Self-Efficacy, Growth Mindset, and Resilience in Engineering Students

Several research studies in STEM fields have shown that simply having a "growth mindset" can positively affect a student's performance and negate the effect of other traditionally negative external factors on their ability to graduate with a STEM degree (socioeconomic status, health, etc.) [3-5]. Other studies have shown that resilience training can also help improve academic performance [6]. These skills and lessons apply to all types of problems, both in education and life in general. However, while engineering is a part of the STEM fields, this section of the literature review focuses very specifically on engineering students. Broadly focused research on self-efficacy, growth mindset, and resilience is widespread, but there are a limited number of research studies focused on engineering students. Additionally, there appears to be limited agreement among authors on a clear definition of the term "resilience" as it applies to students, and there is little consistency in both the definition and evaluation of resilience in much of the literature on education. Each of these terms was combined and used in searches through both Google Scholar and the university's library database for relevant articles (i.e., "self-efficacy in engineering students"). These search terms yielded overlapping results, with some previous researchers using the words interchangeably or collectively. Therefore, they were combined in this literature review section.

Self-efficacy was first proposed by Albert Bandura in 1997. He defines self-efficacy as a person's self-belief in their capacity to accomplish a specific task [7]. Self-efficacy is not a fixed capacity—it can be altered and improved over the course of an individual's life. Bandura suggests that there are three ways self-efficacy can be improved, namely belief in success, mastery experiences, and vicarious experiences or models (i.e., seeing someone you know complete it) [7].

The term "growth mindset," originally known as implicit theory, was developed by Carol Dweck in the late 1990s. In this paper, these terms will be used interchangeably. The idea has since grown in popularity and reputation. It is now widely used in both academic research and pop culture. Implicit theory and growth mindset refer to a person having the belief that they can change their abilities and that their effort has an impact on their outcomes, as opposed to their capabilities being fixed or completely innate. According to Martin and colleagues, "Implicit theories of intelligence (sometimes also referred to as implicit beliefs about intelligence) refer to the beliefs individuals hold about the malleability of intelligence." They continue, explaining that "individuals can either see intelligence as something that is a fixed and immutable entity (entity theory; or entity belief) or as a dimension that can be changed or improved upon with effort (incremental theory; or incremental belief)" [8].

Resilience is the ability of a person to cope with and adapt to changing circumstances successfully. For many engineering students, the adjustment to college from high school includes stressors both related and unrelated to academics. New living conditions, routines, and challenging classes all contribute to the stress of undergraduate students in engineering [6]. Students that have higher resilience have been shown to have better mental health and well-being, better educational outcomes, and better employability [4, 8, 12].

Exploration of these theories specifically in engineering contexts is limited. Tek and colleagues explored the effect of self-efficacy in an introductory programming course with first-year engineering students. They concluded that students with high self-efficacy performed better in the course with the exception of students who were repeating the course [13]. They stated that "students who believe in improvable programming aptitude and have higher programming efficacy study more and get higher grades" and that a "belief in a fixed programming aptitude and having a low programming efficacy significantly increases the likelihood of course failure [sic] and thus repeats." This is similar to the findings from other, non-engineering research on self-efficacy. Additionally, Tek and colleagues noted the importance of teaching students about developing a growth mindset stating that, "an intervention must target increasing programming efficacy and the false theory of "fixed programming aptitude," and show the student that programming skill is improvable by practice."

Interestingly, some studies have shown disparities between the level of self-efficacy in engineering students when categorized by gender [9-11]. This further shows the need to provide techniques and methods for improving self-efficacy among students who may be at a disadvantage or of a minority status [11]. These findings may inspire future research.

Van Wyk and colleagues explored resilience in first-year engineering students in South Africa. The authors used three separate assessments (Stress Mastery, Positive Affect, and Early-Life Stability) to evaluate student resilience [6]. The stress mastery assessment measures students' ability to handle stress and how past stressful events affect them. The Positive Affect assessment measures students' positive emotions and personality characteristics such as optimism, gratefulness, and forgiveness. The Early Life Stability assessment measures the extent to which the student felt safe and protected while growing up. The study found positive correlations between the Stress Mastery component of resilience and academic performance as well as a positive correlation between the Positive Affect aspect of resilience and academic performance. The authors conclude that "regardless of cognitive factors, resilience can [sic] help first-year students navigate the demanding transition from school to university" [6].

Another ongoing study ranked students based on how they were doing in a first-year engineering course. The students filled out a psychometric online survey that ranked them in five subcategories of resilience (adaptability, self-sufficiency, self-control, optimism, and persistence) based on their responses. The students who were more successful in the course ranked higher in all the sub-categories except self-sufficiency [14]. This means that, similar to what has been shown by others, students who were more resilient experienced improved academic performance. However, according to the authors, an explanation for this outcome could also be that students who have a better understanding of themselves and their strengths have already developed strategies that work for them.

The authors believe that goal setting and reflection are specific ways in which students might improve their self-efficacy through mastery experiences. Goal setting will allow students to determine what success means to them and begin to set up small steps to achieve their goals. In doing this, they are having mastery experiences. Having success in these small steps also improves the belief in themselves—both of which are key, according to Bandura, to improving self-efficacy.

Similarly, reflection is a way of assessing how the student performed toward their goals. Having these small checks along the way allows the student to adapt, self-regulate, and persist—all hallmarks of resilience. The combination of goal setting and reflection together produces a self-assessment for the student to examine their own behavior and outcomes. Regardless of whether the student exceeded or fell short of their goals, this feedback loop, and how the student reacts to it, is crucial. If the student believes they can change their performance toward the goal, then they can also develop a growth mindset. Goal setting and reflection are actionable pieces and methods that may help students improve their self-efficacy, growth mindset, and resilience. Chung and colleagues have discussed the importance of goal setting and self-assessment for writing courses in higher education [15], however, no research was found specifically on this topic in engineering.

Goal Setting in Engineering Students

The literature on goal setting specific to engineering and engineering education is limited, though some general information about goal setting and goal-setting theory applies to engineering as well as any other subject. The terms “goal setting AND engineering students” and “goal setting in engineering education” were used in searches through both Google Scholar and the university’s library database for relevant articles. This, however, yielded few results, so the search expanded to “goal setting theories,” which was used for the introduction of this section of the literature review, and the highest impact theories were presented along with the other engineering-specific articles.

Goal Setting Theory, originally developed by Latham and Locke [16], states that the best motivational goals are those that a person views as actionable—that is, that they are both specific and, surprisingly, difficult. The authors state that “people normally adjust their level of effort to the difficulty of the task undertaken and thus try harder for difficult than for easy goals.” They also suggest that the difficulty of the goal is relative to that individual. For example, one student may find a specific homework assignment difficult while another does not. However, this relationship also relies heavily on the individual’s ability to accurately categorize their goal as easy, moderate, or difficult, which relies on accurate self-assessment of one’s abilities.

SMART goals have also been widely used as a framework for goal setting since the early 1980s. THE SMART goal framework, published by George Doren, states that goals should be Specific, Measurable, Attainable, Realistic, and Timely [17]. This overlaps with Latham and Locke’s goal-setting theory but is much more detailed and seems to diverge from their suggestion that goals be difficult, rather than stating that goals should be both attainable and realistic instead of lofty or difficult. If we are to follow Bandura’s self-efficacy model, students need “mastery experiences,” which should be somewhat challenging but attainable. The ideal degree of difficulty is likely individualistic, but the experience itself can be small or large.

Several papers have noted the effect of goal setting on students and engineers [16-22]. However, only two papers specifically address this effect on students in engineering education [21,22]. Wan and colleagues showed evidence that, with students utilizing e-learning systems, simply exposing them to goal setting strategies helped the students perform better [18]. Meyer and colleagues showed similar results in software developers with whom they noted their goal setting strategies [19]. The authors noted that most of the software developers were also constantly updating their priorities and reflecting on the progress they had made. Interestingly, the authors noted that reflecting on goals was a common behavior of more productive employees, and four key items for goal setting were identified: 1) Self Reflection 2) Support for Goal Identification 3) Monitoring Goal Achievement, and 4) Supporting Goal Maintenance [19]. This emphasizes how important it is for people to have a strategy, and even support, in setting their goals, but also to continually revisit them and their progress. Reflection will be discussed independently below, but it was also addressed extensively by these authors as a helpful tool for staying on track with goals [19].

Another study focusing on students in language classes showed that students who used tools that helped them track self-assessment, goal setting, and achievement, revealed a statistically significant relationship between the goal-setting process and their mastery of the topic [20]. This study was done with high school students; however, the results are still relevant and further illustrate the relationship between goal setting and achievement.

Specifically in engineering education, a group of researchers focused on the tools needed for teaching engineering digitally to students in higher education. They found goal setting to be one of the five major components that helped keep students on track and making progress [21]. Additionally, Bowman and colleagues discussed strategies to help engineering students recover after they had struggled in their engineering classes to the point that they were on academic probation. As universities continue to focus on the retention of students, this is likely to be a key issue for engineering students. Their study explored the effectiveness of a "goal-setting academic advising intervention on the improvement of grades of engineering students who were on academic probation" [22]. Interestingly, the intervention increased the grades of the students who were past their first year but did not have a statistically significant effect on first-year students on academic probation [22]. Overall, however, goal setting as a strategy in engineering seems to be effective for improving performance.

Reflection in Engineering Students

The literature on reflection in engineering education is also quite limited with only a few relevant articles appearing when "reflection in engineering education" and "reflection AND engineering students" search terms were used. These searches were executed in both Google Scholar and the university's library database. However, search terms like "reflection AND education" returned many more results.

Students are suffering from a phenomenon exemplified by T. S. Elliot's quote, "We had the experience but missed the meaning" [23]. For students, the university experience today is a constant cycle of attempting to absorb new information, learning just enough to complete assignments, turning in those assignments, and moving on to the next. Educators typically provide ample opportunity to practice skills, but little opportunity to reflect upon them. Academia does not always approach reflection with the most favorable perspective. It is often seen as a nonsensical outpour of emotions or a simple summary of events, neither of which are compatible with the rigorous and "objective" world of higher education. Because it is typically not explicitly required of them, students rarely dedicate time to reviewing how individual assignments and activities contribute to the "big picture." However, reflection has been shown to improve both cognitive and metacognitive knowledge [24]. Students who reflect have a better grasp of the conceptual content of their courses and a better understanding of their own learning process.

Rogers states that reflection helps to "integrate the understanding gained into one's experience," the purpose of which is to "enable better choices or actions in the future as well as enhance one's overall effectiveness" [25]. Schön describes reflection as the "continual interweaving of thinking and doing" [26]. It allows us to repeatedly evaluate what we are doing based on where we want to be, and the process of learning is incomplete without it. Without this necessary step, even students with an abundance of pragmatic experience have "little capacity to turn learning into improved action." Critical reflection involves generating, deepening, and documenting learning [27].

A study conducted by Bo Chang at Ball State University demonstrated that the completion of guided reflections at key points during the semester led to improved cohesiveness and overall quality of work [24]. Upon completion of assignments and projects, Chang requested that his students "reflect on the highlights, or the uniqueness, or the most significant parts of their assignment, the process of how they completed their assignments, the lessons/tips they gained in this process, and on other information they wanted to share." At the end of the semester, Chang evaluated the performance of the students and recorded their opinions about the practice. Through the reflection process, students identified the areas that were not clear, examined strategies for completing their tasks, and identified the areas that required more effort. This awareness allowed them to make the necessary adjustments to improve their performance. It also forced them to revisit the course content instead of quickly moving past it. Chang noted that "when students conduct the reflections, they repeatedly retrieve the information from memory, and the retention of experience is thereby increased."

Research by Eyler and Giles on service learning, the experiential education method that utilizes a cycle of action and reflection focused on the application of learning to community problems, shows that more rigorous reflection leads to better learning outcomes [28]. Students who engaged in deeper reflection had a deeper understanding of the subject matter, found it easier to apply their knowledge, and were more able to tackle related problems. They were also more open to new ideas and showed superior problem-solving and critical thinking skills.

However, Welsh pointed out that "instructors…merely telling students 'it is now time to reflect' is a clumsy approach for them and students alike" [29]. In other words, simply instructing students to reflect is not enough—most require more direction to make cognitive connections between experiences and course content. Without direction and structure, they are also unlikely to challenge their own perspectives, beliefs, and attitudes, which is necessary for deeper learning. As students grow, mature, and have more experience in reflection, however, less direction and structure will be needed.

Conclusions Drawn from Research

While there was limited research on each of the topics specific to engineering students, there were three major conclusions that were drawn from the research.

1. Belief and ability (self-efficacy) come from modeled or mastery experiences, and these experiences do not have to be vast or prolonged. These experiences help reinforce students' growth mindsets and resilience in the face of failure.

The cumulation of small wins (successfully achieving small goals) helps students become more self-efficacious; it helps them truly believe in their abilities. This leads to the belief that students' abilities are not simply inherent and that their abilities can grow, change, and improve with practice. In engineering courses, where most students are challenged with at least part of the curriculum, providing mastery experiences or modeling them for students, especially at the beginning of their college careers, could help with student retention. Several studies have shown that self-efficacy is lower in students who have one or more minority classifications. Therefore, it is especially important to help those students attain these mastery experiences and improve their self-efficacy. Students can be successful in engineering regardless of their background, but not if they give up the first time they fail. To attain mastery experiences in engineering, students also need to be resilient.

Resilience as an engineering student is therefore a critical educational component that should be built and nurtured. Since there are more challenges present, there are also more opportunities for failure. In the face of failure, it is crucial to consider how to change, adapt, or re-strategize to succeed the next time. Students are more successful when they adopt a growth mindset and treat failures as an opportunity for learning. This should be modeled for the students by the faculty because it is difficult to do so without guidance or confirmation that immediate success is uncommon.

2. It is often difficult for students to break down a large goal or a long-term goal (such as succeeding at a mastery experience) into smaller steps or short-term goals. This is especially true in first-year courses or courses with large projects, and faculty should help students with this task.

Goals are necessary for attaining the experiences that students need to build on to master a topic and build self-efficacy. However, being able to set solid attainable goals is a rare skill, especially for first-year college students. Students may need help from faculty to set goals, and reminders about how their assignments may have a greater purpose for their long-term goals—as it is easy to lose track of this over the course of a semester.

The goals presented to students are often unattainably large or vague (i.e., get an A this semester). Being able to break these up into smaller goals so that there is a faster cadence to the cycle of setting the goal, doing the work, and reflecting on how it went, is critical. Having this established for them in a class might be helpful, especially to first-year engineering students who can then apply this themselves during later semesters.

3. Reflection after any attempt at a goal (short-term, long-term, success, or failure) is exceptionally important in order to adapt, address what went wrong or right, and then start again (either with the same goal or the next one).

Students need guidance to reflect properly—in a way that helps them retain the information and correlate their behaviors with their successes. Regardless of success or failure, periodic reflection is not a common practice of students, and having a structure for how and when to do this will help with deeper learning.

Reflection activities need to be encouraged and assigned by faculty until students can develop these habits and specific cadences on their own. For example, if there is a large project due at the end of a course, building small pieces of it throughout the semester by cycling through setting a goal, working toward that goal, and reflecting on the progress toward that goal could help students make more continuous progress and retain more information. Having continuous progress, small wins, and more frequent reflections leads to greater engagement in the course as opposed to rushing at the end of the semester without allowing students to reset, adapt, or change strategies if they make a small mistake.

Proposed Engineering Learning Model

Through the literature review conducted in this paper and personal experience as engineering students, the authors propose a cyclic system that engineering students might employ as part of their learning process. This model could also be used by faculty to help develop various assessments and assignments in class that maximize engagement with the material by continually providing feedback. Anecdotally, they have found this process helpful during their own education. This is a multi-layered process that includes the following steps: goal setting, application, and reflection (GAR), at varying frequencies (see Figure 1).

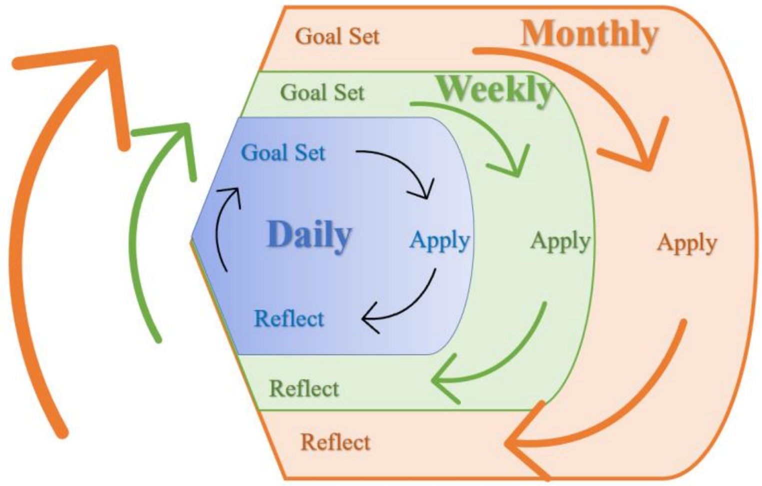

Figure 1: Illustrating the Steps of GAR as a repetitive cycle. There are several daily/weekly/monthly cycles all happening simultaneously.

As undergraduate engineering college students, many factors need to be balanced, both internal and external to academics. By continually setting and evaluating goals using the GAR model, students may find that they have better focus and performance. The frequencies may vary depending on the individual's needs and timelines. The key characteristic of the model, though, is that multiple frequencies are happening simultaneously. For example, the levels could be daily, monthly, and semesterly for some individuals or weekly, monthly, and yearly for others.

The core of the model is that while goals will be both small and large, the larger goals should be broken down into smaller mini-goals. This allows for continuous mastery experiences and more frequent success. By reflecting at a shorter and more regular frequency, a near-continuous self-assessment is taking place so that the student can track if they are getting off track over the long term or if they simply had a bad day. They can also then course-correct more quickly so that a small issue does not grow into a larger problem.

However, this can be a daunting process for students to complete on their own if they have never done it independently before. As the goal for students is to grow and mature in their ability to learn, helping students implement a learning cycle that includes goal setting and reflection is an important part of the educational process. Therefore, the authors hope that faculty may be able to incorporate aspects of the model, or the spirit of the model, into their assignments and assessments.

Applications of the GAR Model in Engineering Courses

In engineering courses, students may initially have a hard time implementing the GAR model, especially with breaking down larger goals into smaller ones and reflecting effectively. Faculty can help students do this by breaking down large assignments, or even large exam questions, into smaller, more condensed portions. Additionally, adding reflection tasks both before and after large assignments (like exams and projects) can further encourage students to first set their goal(s) and then reflect on them. For busy students, setting aside time to reflect does not seem prudent, but it is a necessary activity to learn. Having faculty model this process, especially in first-year courses, can help them build this habit on their own.

Something the authors especially recommend in project-based courses is to have students try to break down the steps of the entire project before the faculty discuss the various assignments. This exercise, even without all the information, can help students create mini-goals for themselves. Then, they can compare their thoughts to the assigned steps. Another quick and easy step to help students work on their goal setting and reflection is to give them a small amount of time to do this each week as part of the course. Whether in class or as an assignment, have the student set their own goal for the week and then reflect on their past week's goal as part of the course assignments. Even if this is worth few points, it forces the student to take the time to do this and helps them develop good habits, skills, and methods to do this on their own.

If a faculty member is looking for something more specific to implement, they might consider The Articulated Learning process put forth by Ash and Clayton [27]. This involves answering four guiding questions: 1) What did I learn? 2) How, specifically, did I learn it? 3) Why does this learning matter, or why is it significant? and 4) In what ways will I use this learning; or what goals shall I set in accordance with what I have learned in order to improve myself, the quality of my learning, or the quality of my future experiences or service?

Worded in this way, however, the Articulated Learning Process sounds very theoretical. It can be implemented much more simply and specifically in a class by reworking the questions. For example, one direct way would be to have students do test corrections and write down a short reflection about where they went wrong on the initial exam, what they have learned since, and how they plan to prepare next time compared to this time.

It can also help to have a final course review and self-assessment that shows the student how much they have learned and covered during the semester with the hope of providing many small mastery experiences that culminate in one large one. Oftentimes, students get bogged down in the details of each week and forget to think about the experience of a course as a whole. Discussing the topics and varying steps covered throughout the course can help the students visualize their progress. Even though the student did not set these steps up themselves, it helps them to see it in retrospect and can encourage this as a valuable practice to continue, even if future courses do not require it.

Conclusion

This paper examined the available literature on self-efficacy, implicit beliefs (growth mindset), resilience, goal setting, and reflection. Engineering students are especially prone to concluding that their peers are successful due to unchangeable innate abilities. However, research shows that students who believe in their ability to grow and embrace changing circumstances are more successful. Additionally, students who set goals for themselves and reflect on the outcome of their efforts typically perform better in their courses. Since these skills rarely come naturally to students, engineering courses should not only help students learn technical content but should also help them develop the skills of goal setting, expectation development, reflection, and self-assessment.

Based on this information, the authors suggest techniques and mindsets related to self-efficacy, goal setting, and reflection that faculty can incorporate into their classrooms to help with student engagement and knowledge retention. If courses do not encourage these practices, students may implement them themselves to increase the likelihood of their success. These practices include breaking down large problems or projects into smaller steps, creating mini goals from those steps, using the GAR cyclic assessment to continually set goals, apply knowledge, and reflect on the outcome, and incorporating reflections into coursework at varying frequencies.

In the future, the authors hope to validate this model with a research study in first-year engineering courses. Other research topics inspired by this review include reflection in engineering students, goal setting in engineering students, how minority status affects engineering students' implicit beliefs, the evaluation process of self-efficacy and resilience in students, and how/why certain students may develop a GAR-type learning method on their own before college.

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