Self-Regulated Learning in First Year Engineering: Opportunities for Practical Implementation

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Introduction & Background

The first year of an engineering program plays a large role in shaping students' academic and professional trajectories, as it helps them shape and inform their academic plans and career interests by teaching them foundational skills needed to be successful in an engineering program. Over half of the engineering programs in the U.S. and abroad surveyed in a study (~70%) have implemented some sort of 'common' first-year engineering (FYE) course, program, seminar, etc. [1]. These foundational or fundamental engineering skills have traditionally consisted of basic programming, solid modeling, design, problem-solving, and teamworking skills [1], [2], [3]. While these skills have been foundational to most engineering programs, recently a new gap in incoming engineering students' knowledge and skills for success in college has emerged.

Navigating the first year as a college engineering student consists of much more than learning to code or design an object through computer-aided design. In this crucial period of students' lives, they are often transitioning to a new environment in which day-to-day living and learning are significantly different and require more independence than they have experienced before coming to college [4]. Many students are not yet equipped for the self-regulation necessary to handle such dramatic transitions [5]. The absence of incoming engineering students' knowledge, skills, and behaviors related to their own self-regulation of their behavior and learning is becoming increasingly apparent. The habits and behaviors associated with positive self-regulation and self-regulated learning (SRL) are important building blocks for future academic and career success [6]. The purpose of this paper is to highlight the importance of self-regulation and SRL habits, skills, and behaviors in supporting a successful transition and provide opportunities for first-year engineering programs to seamlessly integrate these habits, skills, and behaviors into topics, activities, and assessments common in first-year engineering courses and curriculum.

First-Year Engineering Program Context

The General Engineering program (GE) at Virginia Tech, hosting over 2,500 students in Fall 2023, consists of two sequential two-credit hour courses ENGE 1215 and ENGE 1216 spanning consecutive fall and spring semesters or—for students meeting certain criteria—a four-credit hour single semester version is available. In alignment with most FYE programs, these courses prioritize the development of professional skills and tools required across engineering disciplines. These include engineering discipline exploration, teamwork, communication, engineering ethics, problem-solving, engineering design, programming, and computer-aided design. Additionally, each student in the program is assigned a first-year Academic and Career advisor who facilitates the transition to college through one-on-one advising appointments, workshops, and electronic communications, including emails and newsletters. The instructors and advisors share information about students and resources for mutual support.

General Engineering Advising

The General Engineering advisors facilitate the development of academic success skills in FYE students using a framework that conceptualizes time management, metacognitive study skills, and resource utilization as an integrated system for academic success. In this systemic approach, the limited availability of academic support resources—like office hours or tutoring time—necessitates efficient time management. Efficient time management, in turn, enables the

implementation of in-depth metacognitive study activities, which helps students generate questions that target their respective academic trouble spots that can be addressed through feedback from the academic success resources. Generating questions can also encourage students to overcome avoidance of office hours, which often stems from a fear of asking the wrong questions or wasting the professor's time [7]. By integrating these three academic success concepts (See Figure 1) we expect students to enter a virtuous cycle of experimentation, reflection, and growth. Although the General Engineering advisors spend most of their time meeting with students, having nine advisors for over 2,500 students constrains the proportion of the student population who can be assisted through one-on-one advising appointments. However, there is a recent and ongoing effort to integrate the advising and instruction teams such that more students can benefit from advising practices transferred to the classroom [8].

Self-Regulated Learning Literature Exploration

A team of GE advisors and faculty determined that Self-Regulated Learning (SRL) habits and skills can provide an effective framework for guiding efforts to integrate academic success lessons and skill development into our FYE program. We explored publications that either described SRL theoretical frameworks or detailed how others successfully leveraged self-regulation and SRL in classrooms to improve students' learning and development. The primary themes that emerged in the literature regarding preparing students to navigate college and develop their SRL skills and behaviors included these themes: Goals / Goal Setting / Planning, Motivation / Drive / Passion, Growth / Improvement, and Reflection / Metacognition.

Through this focused literature exploration of classroom-based strategies for improving self-regulation, self-regulated learning, and college preparedness of first-year students, we encountered repeated references to the importance of students having clear goals to work towards. Whether those goals were learning goals set by the course and educators (e.g., [9], [10]) or the students themselves for short- or long-term success (e.g., [11], [12]), having a clear goal to work towards was an important first step. This crucial step should be followed by the development of plans for how to achieve these goals [13]. The importance of leveraging students' passions and motivation for working towards that goal is also highlighted. Whether it be a passion or drive to achieve long-term career goals and encourage students to persist through difficulties and provide a stronger sense of purpose, or the motivation to achieve a short-term goal such as studying for an upcoming exam, students' motivation is important in the development of skills and regulating themselves on a day-to-day basis [10], [14], [15] [16].

Also frequently mentioned was the need for students to reflect often and meaningfully on their progress toward goals so they can monitor their own learning and learning processes [10]. Reflecting on goals, plans to achieve goals, as well as their actions/behaviors and learning can help students develop self-regulatory and metacognitive habits [10], [13], [17], [18]. The practice of reflection had a complementary theme throughout literature exploration, namely the importance of growth, a growth mindset, and clear pathways for improvement. Strategies shown to improve aspects of students' cognitive learning and performance, motivation, or satisfaction with their learning experiences, include the following: 1) Interventions that teach growth mindset (e.g., [15], [19], [20], [21]); 2) assignments or activities designed such that students are rewarded for learning from their mistakes (e.g., [22]); and 3) detailed and targeted feedback for improvement paired with opportunities to demonstrate that improvement (e.g., [23], [24]). These two themes of reflection and growth are particularly complementary to one another because as

students reflect on challenges or shortcomings it is important for them to believe that they are capable of growth, change, and improvement.

After exploring the literature and becoming more familiar with strategies for helping college students learn and develop SRL-related skills, we found a distinct overlap in the Academic Success Skills Development Framework used by General Engineering advisors and the outcomes of this SRL literature exploration. This overlap is visually represented in Figure 1.

SRL Integration Opportunities

As engineering education researchers and practitioners, we underscore the essential role of SRL in fostering the academic and personal growth of FYE students. Integrating SRL seamlessly into the FYE curriculum is crucial, embedding it within existing educational structures to enhance its relevance and impact. Our strategic focus on four key SRL areas—Motivation, Goal Setting, Growth & Improvement, and Reflection & Metacognition—employs a tripartite approach of discussion, practical implementation, and role modeling. This methodology, inspired by Bandura's Social Learning Theory [25], helps students learn through observation and practice, fostering a culture of continuous development by emulating skilled instructors and peers.

Motivation / Drive / Passion: Fostering motivation, drive, and passion of first-year engineering students is essential for their academic and professional development. Intrinsic motivation, which correlates strongly with student success [26], energizes students' enthusiasm for engineering and sustains their perseverance through challenges, enhancing their sense of purpose. Educators can ignite this passion by showcasing the importance of enthusiasm in professional achievements, supplemented by empirical evidence. For example, a weekly feature discussing various

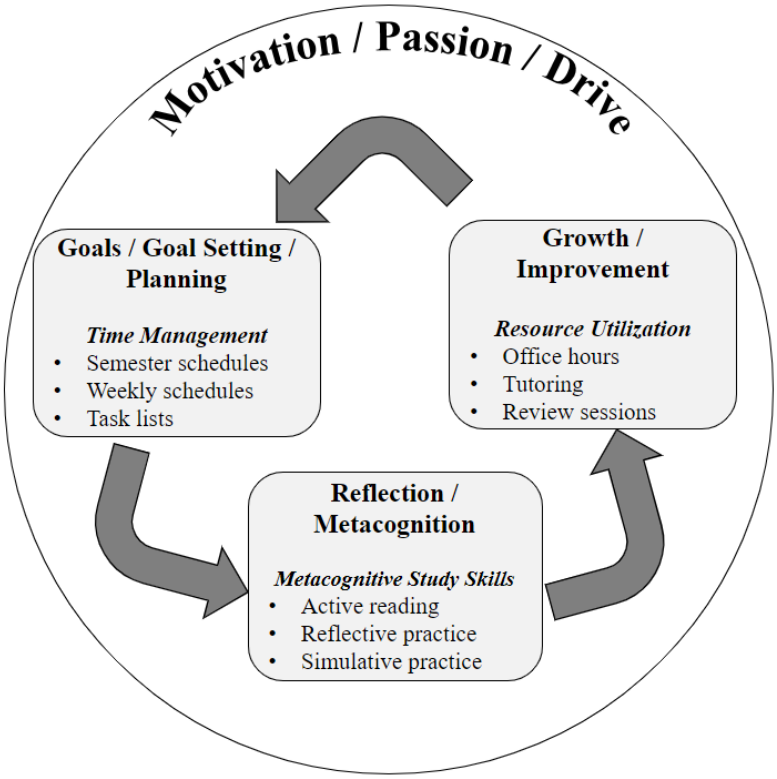

Figure 1. GE Advising framework overlapped with major themes from the literature (top headings)

engineering roles and inviting engineers to share their career stories can spark student interest. These stories not only emphasize the significance of passion but also personalize the engineering experience.

Peer educators also play a vital role in deepening student engagement. Through sharing their experiences, they illustrate how passion has influenced their educational and early career paths. This peer interaction complements instructional efforts, creating a dynamic learning environment that demonstrates the real-world impacts of passion in engineering. Additionally, instructors should encourage students to discuss their career goals and reasons for choosing engineering. FYE programs are pivotal, providing insights into various engineering fields and aiding students in making informed decisions [1]. Activities like peer discussions and reflective essays can help students articulate and explore their professional aspirations, fostering self-awareness and aligning their studies with their career objectives.

Finally, instructors are key in modeling the significance of motivation and passion by sharing their professional journeys and demonstrating their enthusiasm for teaching and engineering. Such leading by example, enhanced by engaging passionate teaching assistants, underscores the value of dedication in both educational and professional contexts. This comprehensive approach aims to instill in FYE students an appreciation of the critical roles that motivation, drive, and passion play in their educational and career paths. Recognizing that students' motivation stems from varying factors, this strategy seeks to harness these drives, guiding students through their engineering education and career choices effectively.

Goals / Goal Setting / Planning: The second focal area in fostering SRL among FYE students emphasizes the significance of setting and achieving realistic goals. FYE programs are instrumental in teaching students how to establish goals and develop actionable plans, which are crucial skills for academic and professional success. Instructors should highlight the pivotal role of goal setting by discussing its relevance in both academic and professional realms. They could integrate discussions on resource management and budgeting as essential components of effective planning, thereby broadening the students' understanding that goal setting encompasses both defining objectives and considering the timeline, resources, and limitations inherent in achieving these goals.

Peer educators could enhance this learning by sharing personal insights and experiences related to goal setting and planning. Their real-life examples from navigating FYE programs provide practical and relatable perspectives that enrich the learning environment. Practical application of these concepts can be facilitated through design projects included in FYE curricula [1]. Students could be tasked with planning and budgeting these projects over the semester, which would improve their project management skills and promote accountability and time management. Further, students might engage in self-evaluation against project criteria to enhance their critical assessment skills.

An effective method for students to visualize and manage project timelines is through the creation of Gantt charts, particularly for team projects. This tool helps them understand task dependencies and manage time more efficiently. Instructors can support this process by presenting a well-organized semester plan, possibly using a Gantt chart that outlines all class assignments and activities. They can also demonstrate the alignment of tasks with the class’s learning outcomes,

showing how each assignment contributes to broader educational goals.

By consistently discussing students' progress and upcoming tasks each class, instructors foster a habit of continuous self-assessment and forward planning. These strategies equip FYE students with vital skills in goal setting and planning, crucial for managing complex projects and navigating their academic and future professional paths effectively. These skills form a foundational component of their growth as future engineers.

Growth & Improvement: This approach to SRL among FYE students emphasizes fostering a mindset of continuous development and resilience. There are several strategies to effectively nurture this mindset. First, instructors could play a pivotal role by initiating discussions that normalize the concept of growth and learning from experiences. Emphasizing that failures are part of the learning curve and not a mark of shame sets a foundation for a supportive environment. This helps students feel comfortable taking risks and learning from setbacks. Further, instructors highlight the expectation of continuous growth, accommodating the diverse backgrounds and varying career interests of students, thereby fostering an inclusive and supportive learning atmosphere.

Peer educators could also be instrumental by sharing personal stories of overcoming challenges, thus providing tangible examples that demystify the journey of learning and development. These narratives help normalize the iterative process of learning, bolstering a culture of resilience and continuous improvement among students. Furthermore, encouraging students to incorporate iterations in their term projects—in alignment with the engineering design process—could allow them to progressively refine their work, learning from each iteration. This practice not only enhances the quality of their projects but also instills a habit of continuous refinement and responsiveness to feedback, mirroring real-world engineering processes.

Finally, instructors could model growth by designing courses that progressively build complexity, demonstrating to students how knowledge and skills develop incrementally. Flexibility in course management, such as adjusting deadlines when needed and soliciting course feedback, exemplifies adaptability and responsiveness, further reinforcing the importance of growth and adaptability. Through these integrated strategies, FYE students learn the importance of growth and continual improvement. They are encouraged to view challenges and setbacks as opportunities for learning and development, a mindset that is essential for success in both their academic and future professional lives.

Reflection & Metacognition: This perspective emphasizes enabling FYE students to internalize their learning experiences and cultivate a deep understanding of their cognitive processes. This focus is critical for their personal and academic development. Instructors could introduce the concepts of reflection—critically examining one’s experiences and actions—and metacognition—understanding one's thought processes. Integrating these practices into the curriculum transparently helps students see the value and application of reflection and metacognition in their studies. Through sharing personal experiences and demonstrating reflective practices, instructors help students comprehend and adopt these strategies for their own learning and development.

Peer educators could also play a crucial role by providing practical examples and sharing techniques that have been effective in their own academic experiences. They can guide students in exercises such as journaling and setting study goals, which illustrate the practical benefits of

reflective practices, making the abstract concepts of reflection and metacognition tangible and actionable. Activities designed to encourage reflective thinking and metacognitive practices could also be integrated into the curriculum. For instance, students might engage in a coding challenge to track and analyze aspects of their daily lives, linking personal behaviors with academic performance. This not only enhances technical skills but also encourages students to consider the impact of their habits on their academic success.

Finally, instructors could exemplify these actions by clearly connecting course skills or learning outcomes (LOs) with specific assignments, explaining how these align with students' goals and future plans. This could help students engage in metacognitive processes by understanding the purpose behind their assignments and how they relate to larger educational and career objectives. By incorporating Reflection and Metacognition alongside Growth and Improvement, the FYE curriculum fosters a comprehensive understanding among students of their learning processes. This foundational understanding is vital for deep engagement with academic material and successful navigation of future professional challenges.

Conclusions & Future Work

This paper underscores the critical role of self-regulated learning (SRL) in enhancing the academic success and personal development of first-year engineering (FYE) students. We delineated four pivotal domains crucial for nurturing and advancing SRL among FYE students: 'Motivation / Drive / Passion,' 'Goals / Goal Setting / Planning,' 'Growth & Improvement,' and 'Reflection & Metacognition.' The integration of SRL within the FYE curriculum, specifically through discussing, practicing, and modeling each of the four areas, represents a strategic tripartite approach to fostering these essential skills.

However, integrating SRL into the curriculum is not without its challenges. Monitoring the success and progress of these initiatives is critical, requiring regular check-ins and progress reports to track student development, as well as formative assessments to provide ongoing feedback and adjust teaching strategies accordingly. Additionally, supporting struggling or non-traditional students necessitates targeted interventions, such as peer tutoring and supplemental instruction sessions, along with workshops focusing on time management, study skills, and stress management. Tailoring recommendations to provide diverse learning experiences is also essential, incorporating various instructional methods and resources to ensure inclusivity.

Our recommendations are designed such that they can be integrated into existing coursework in a low-effort way, making SRL a natural and integral part of the learning process without adding a significant additional load to FYE faculty or students. Leveraging potentially existing resources like peer educators, semester-long projects, and contacts with alumni and practitioners can make this integration even more seamless and impactful.

Looking to the future, we are committed to transitioning from the theoretical and planning stages to the practical implementation of our recommendations. A pilot phase had been initiated, targeting a systematic evaluation of the impact of integrated SRL practices on students' perceived abilities in SRL. The data collected from this pilot phase would be instrumental in understanding the influence of our recommendations on students' SRL experiences. Such insights are expected to not only refine our program but also contribute to the larger conversation in engineering education.

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