# Self-Regulated Learning Instructions in Engineering Education: A Systematic Scoping Review

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***Abstract*—While self-regulated learning has been studied in various academic domains in educational psychology research, the topic of self-regulated learning in engineering education has not been examined systematically and comprehensively. Therefore, we conducted a systematic scoping review to examine the existing literature on the intersection of self-regulated learning and engineering education. Specifically, through reviewing the literature, we examined how the theoretical perspectives of self-regulated learning have been adopted and adapted into engineering classrooms in post-secondary education. We also examined whether self-regulated learning has been contextualized into engineering entrepreneurship education, specifically. Reports of the current literature and implications for future research in engineering education are discussed.**

***Keywords—engineering education, self-regulated learning, metacognition, systematic scoping review, PRISMA, engineering entrepreneurship education***

## I. Introduction

This Research Full Paper presents a scoping review that examines the intersection of self-regulated learning (SRL) and engineering education. Although there is an abundant body of educational research on SRL, it remains unknown how engineering educators can adopt perspectives of SRL to facilitate their students' academic and professional successes. Several systematic reviews of SRL have suggested that SRL instructions, especially metacognitive strategy instructions are effective for students' strategy use and learning outcomes across a variety of academic domains and educational levels [1], [2]. However, these effective instructions have not been examined within an engineering education context adequately and specifically. Investigation on how to adapt SRL and metacognitive instructions into college engineering classrooms is critical and needed. We conducted a systematic scoping review to initiate our investigation on the intersection of SRL and engineering education and explore effective avenues for future SRL research in the engineering education context. In particular, a systematic scoping review identifies the literature gap and examines the nature of the existing empirical studies for a particular topic [3], [4]. Accordingly, in the present study, we aimed to identify and examine the literature on the intersection of SRL and engineering education given that the topic of SRL in engineering education has not been comprehensively examined. Therefore, conducting a systematic scoping review was appropriate and needed for addressing our research questions and advancing the literature. In particular, through this literature scoping review, our primary goal was to explore effective avenues to adopt and adapt SRL instructions for future research in engineering education.

In addition, within engineering education, the recent focus on entrepreneurship education for engineering students has been prevalent [5], [6]. Specifically, engineering educators and researchers have initiated research on entrepreneurship education and entrepreneurial mindset to prepare engineering students to become not only competent individuals in technical knowledge but also individuals who are able to seek opportunities and create value for society [7]. Research has shown that entrepreneurial-minded individuals share characteristics with self-regulated learners and SRL instructions can facilitate engineering students' learning in entrepreneurship-related concepts [8], [9]. Therefore, within this systematic scoping review, our secondary goal was to identify whether and how SRL has been adopted for engineering entrepreneurship education.

To sum up, our overall research questions were:

1) How is SRL applied and studied in engineering education?
2) Within engineering education, how is SRL applied and studied in engineering entrepreneurship education?

Recently, engineering education has focused on students' abilities to design products that are reflective of both their development of expertise in engineering knowledge and skills and values for society [10], [11]. This suggests that engineering students need to think and act like entrepreneurs. In order to become entrepreneurial-minded engineers, engineering students need to be able to foresee potential issues in their designs, learn and use appropriate strategies in problem-solving and evaluate their products. These self-regulatory characteristics of successful engineers correspond to the vast research on SRL in educational psychology. Specifically, SRL describes a set of cyclical learning phases that involves 1) appropriate goal setting and planning, 2) performance and strategy use, and 3) metacognitive evaluation and self-reflection [12]. Unfortunately, SRL has not been examined systematically and adequately in engineering education. Little is known about what effective means engineering educators can use to adapt and contextualize SRL instructions into their engineering classrooms in higher education. Therefore, this scoping review contributed to engineering education by providing summaries of relevant research and implications for implementing SRL in engineering classrooms.

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## II. Conceptual Background and Framework

### A. Self-Regulated Learning

Historically, SRL originated from social cognitive theory, which emphasizes learners' agentic roles in learning rather than as passive recipients of information [13], [14]. Specifically, the social cognitive theory describes the reciprocal interactions among an individual's personal factors, behaviors, and environmental factors [13]. For instance, in an engineering learning context, students who have high perceived self-efficacy beliefs for their learning (personal factors) may actively engage in performing tasks in an engineering-related class (behaviors). Reciprocally, while performing well on the tasks, students increase their self-efficacy beliefs for their learning in engineering. Further, the learning environment, such as instructors' teaching activities and feedback provided in an engineering course (environmental factors), interacts with students' self-efficacy beliefs and behaviors in performing. For example, teachers' feedback may foster students' self-efficacy beliefs in their learning of complex engineering-related concepts (personal factors) so that they highly engage in the learning activities behaviorally (behaviors) in the classroom. As such, social cognitive theory highlights the dynamic and reciprocal interactions among person (e.g., the student themself), behaviors (e.g., students' behavior), and environment (e.g., an introductory engineering classroom).

Self-regulation is a subprocess described in the social cognitive theory, which explains the individual-level self-regulatory processes, including self-observation, self-judgment, and self-reaction. Similar to the three broad factors (i.e., person, behavior, and environment) in social cognitive theory, these sub-self-regulatory processes interact with one another dynamically and reciprocally. Initially, these self-regulation processes were typically investigated in non-academic contexts [15]. Gradually, the self-regulation processes described by [13] started being adopted in educational and academic contexts to examine and facilitate students' learning. As such, the subprocesses of self-regulation in social cognitive theory influenced and informed the development of SRL models.

Several SRL models were established for the understanding and examination of SRL [12], [16]. Specifically, SRL refers to a set of cyclical processes that demonstrates learners' abilities to regulate their cognition, metacognition, motivation, affect, and behavior actively and intentionally within a specific learning context [17]. Self-regulated learners are sensitive to changes in the learning environment and are able to make adaptations to their learning processes and use deliberate strategies to overcome foreseeable and present obstacles.

In general, SRL includes three learning phases: 1) the forethought phase, 2) the performance phase, and 3) the self-reflection phase [12]. First, in the forethought phase, students set appropriate goals and plans that are in alignment with the task demands and expectations before the task. For example, when students were asked to complete an essay task, students will make specific writing goals and plans to complete the essay during the forethought phase. Second, in the performance phase, individuals monitor their progress and use effective strategies during task completion. For example, once students start working on the essay task, students may change strategies and monitor their progress in the process of task completion. Third, in the self-reflection phase, students complete the task and reflect upon their learning processes and outcomes to decide whether they need to make any adaptations for a future similar task. For example, once the students complete the essay task, they will self-evaluate their writing and decide whether they need to employ a new writing strategy for their next essay task. To note, these three phases do not operate linearly. Instead, they operate in a cyclical manner. The cyclical nature of SRL enables learners to exchange information dynamically in each SRL phase so that learners are informed of their learning simultaneously.

Educational researchers have examined SRL across a variety of academic domains. Several meta-analyses and systematic reviews have suggested that SRL can be taught in the classroom and SRL interventions and instructions can benefit students' learning processes and outcomes [18]–[20]. Existing SRL interventions across academic domains demonstrated moderate to medium effect on students' learning outcomes and SRL [19]. Thus, it is reasonable to hypothesize that SRL instructions can also benefit students' learning in engineering classrooms and support students to become future successful engineers.

Typically, and broadly, there are three types of SRL interventions depending on the delivery mode. The first type of SRL intervention is implemented by teachers or instructors in the classroom [21]. In particular, teachers or instructors would receive training to learn about SRL and how to integrate SRL instructions into their teaching. The second type of SRL intervention is implemented by SRL researchers. The SRL researchers would come to the classrooms and deliver SRL instructions to students directly [22]. The third type of SRL intervention is implemented either by the teacher or the researcher; however, students do not receive explicit SRL instructions from teachers or researchers directly in the classroom. Instead, they receive electronic or digital prompts through a learning application or a learning management system (e.g., Canvas) to cue their learning [23].

Prior literature has suggested that each type of intervention demonstrated effective outcomes; however, SRL instructions delivered by researchers or trained teachers tended to be more effective [1], [19]. These findings suggested that SRL is positively related to academic successes and suggested potential avenues for engineering educators to implement evidence based SRL interventions in their classrooms. This also suggests that systematic and well-designed professional development with a focus on SRL is needed for engineering faculty and instructors as they are the medium that is more likely to create a positive impact on students' learning. We hoped that this systematic scoping review can be the start of the systematic examination of SRL research in engineering education that can lead to an in-depth investigation of teaching and professional development for engineering faculty and instructors.

### B. Metacognition in Engineering Education

Metacognition is a critical component in SRL that is involved with every self-regulatory process [24]. Specifically, metacognition refers to one's thinking about thinking [25]. In other words, metacognition is learners' awareness of their learning that guides them to select and use effective strategies through metacognitive monitoring and reflection [26]. In

SRL, learners need to be metacognitive at every phase to succeed in their learning. For instance, in the first phase, the forethought phase, learners need to be metacognitive when setting goals and plans. In the second phase, the performance phase, students need to metacognitively monitor and judge whether they are using effective strategies. Further, in the third phase, the self-reflection phase, students need to metacognitively reflect upon their learning outcomes and improve their future learning. Therefore, it is important to examine metacognition in SRL research. Accordingly, in the present study, we also searched studies that focused on engineering students' metacognition.

## III. Method

The present systematic scoping review followed the updated guidelines suggested by [3], [4]. We also followed the PRISMA guidelines for searching and including relevant articles and demonstrating the literature review process with a flow chart [27]. Specifically, [4] suggested that a systematic scoping review should include 11 key components: An appropriate title and clear research questions, well-established inclusion criteria, defined participants (e.g., college students), main concept of the review, the context that the review focuses on, types of evidence sources, search strategy, screening and selection process, data extraction from the included studies, data analysis, presentation of results. Accordingly, we conducted and evaluated our scoping review based on these 11 key components.

### A. Inclusion Criteria

We established specific inclusion and exclusion criteria for the literature search. We searched the literature thoroughly through databases, including PsycINFO, ERIC, and Education ProQuest without any limitations on publication years. Table I displays the specific inclusion and exclusion criteria.

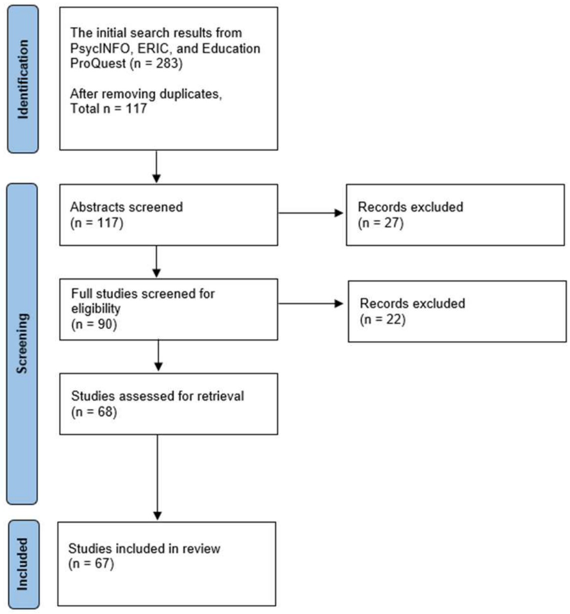
TABLE I. Scoping Review Components

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| Empirical studies including primary research studies, systematic reviews, and meta-analyses. | Book chapters. |
| Studies that focused on self-regulated learning and metacognition. | Studies that focused on other psychological constructs. |
| Studies that focused on undergraduate students or students in postsecondary education. | Studies that focused on younger students or graduate students. |
| Studies that focused on students within general education. | Studies that focused on students with learning disabilities or difficulties. |
| Studies that were reported in the English language. | Studies that were reported in other languages. |

### B. Search Strategy

In alignment with the main purposes of the present scoping review, we selected the keywords to represent three areas of research, including 1) SRL, 2) engineering education, and 3) research focused on college students, respectively. Metacognition is a critical component of SRL [26]. Metacognitive strategies also tend to be effective for students' learning according to prior systematic literature reviews [1], [2]. Therefore, the keywords we used to locate the relevant studies that focused on SRL included *self-regulated learning, self-regulation, self-regulatory, metacognition,* and *metacognitive*. In addition, the keywords we used to locate engineering education research included *engineering education* and *engineering*. Further, the keywords we used to locate studies that targeted college students included *postsecondary students* and *college students*. We used combinations of keywords from the three areas of research, such as a combination of "*self-regulated learning*," "*engineering education*," and "*college students*," to locate the relevant articles for the systematic scoping review. We also limited the search to peer-reviewed articles and articles reported in the English language. Please see Fig. 1 for the PRISMA flow chart.

Fig. 1. Screening and selection process illustrated by the PRISMA flow chart.




### C. Codebook

After the literature search, we started the literature screening and coding processes. In this systematic scoping review, instead of reviewing the details of each study, we focused on the broad themes of the included articles to identify a potential research gap in the intersection of SRL and engineering education. Therefore, we created and established the codebook accordingly. Specifically, the codebook included eight coding categories, including 1) region (i.e., where the study was conducted), 2) methodology, 3) sample size, 4) types of study, 5) theoretical support, and 6) specific engineering subject. In addition, we had another two coding categories were used to mark whether a study focused on 7) engineering entrepreneurship education; and 8) whether it was a review study. See Table II for the details of each coding category.

TABLE II. CODING CATEGORIES

| Coding Categories | Description | Sub-Codes |
|---|---|---|
| 1.Region | The location where the study was conducted. | - |
| 2.Methodology | The research method that the study followed. | Quantitative OR Qualitative OR Mixed methos |
| 3.Sample size | Number of participants included in the study. | - |
| 4.Types of study | The analytic approaches for quantitative studies. | Descriptive OR Correlational/ Regression OR Causal or (Quasi) Experimental or Intervention |
| 5.Theoretical support | Whether the study defined and introduced how the general principles of SRL or metacognition or was grounded in a SRL theory. | Yes or No |
| 6.Specific engineering subject | Which engineering subject the study was focused on. | e.g., mechanical engineering |
| 7.Engineering entrepreneurship education | Whether the study had a focus on engineering entrepreneurship education. | Yes or No |
| 8.Review study | Whether the study was a review study. | Yes or No |

Specifically, first, we coded the regions where the included studies were conducted to understand how SRL has been impactful on engineering education around the world. Second, we coded the methodology, sample size, and types of study to demonstrate an overview of the existing primary research studies at the intersection of SRL and engineering education. Further, the code methodology included three sub-codes: quantitative method, qualitative method, and mixed methods. Studies that used quantitative analytic approaches were coded as quantitative method, such as instrument validation studies. Studies that collected data through conducting interviews or observation or other qualitative data collection were coded as qualitative method. Studies that used both quantitative and qualitative methods were coded as mixed methods. Within the quantitative studies, we further coded studies based on the analytic approaches adopted. The specific sub-codes of types of studies were 1) descriptive study, 2) correlational/regression study, 3) causal or (quasi) experimental or intervention studies. We included these sub-codes to examine how systematically SRL has been investigated in engineering education and the extent to which SRL has been adapted into engineering classrooms through interventions.

Additionally, in terms of examining how the included studies were grounded in SRL theoretical frameworks through the coding category 5, we examined the literature review section of each article and evaluated whether the included studies provided explicit theoretical and empirical support to frame the studies with the general principles of SRL. For example, when a study described the theoretical background of SRL or metacognition, we would code this type of study as *Yes*. In comparison, when a study only mentioned SRL or used SRL as an outcome without providing any theoretical background, we would code this type of study as *No*.

## IV. FINDINGS

As a result, we searched for 283 relevant studies in total. After removing duplicates and screening the abstracts, we identified 117 articles based on our inclusion criteria. We further screened the abstracts of the 117 articles and identified 90 articles. After we reviewed the 90 full papers, we finally included 67 articles published between 2000 and 2021 for the present scoping review. We then coded the included 67 articles based on the established codebook. Appendix I displays the included studies and the coding results.

### *A. Research Question 1: How is SRL applied and studied in engineering education?*

Overall, the included 67 articles included three systematic or meta-analysis articles and 64 primary research studies. The 64 primary research studies were conducted in a total of 22 countries with most conducted (n = 27) in the United States. In addition, among the 64 primary research studies, most studies were conducted in a specific engineering subject or learning context in universities, such as civil engineering and mechanical engineering. Notably, 31 out of 64 studies were conducted in general introductory engineering courses, such as calculus courses for all engineering majors or with engineering students across various departments. These findings suggest that researchers need to further examine domain specific SRL instructions for undergraduate level engineering courses. In particular, in SRL and STEM education research, engineering as a critical academic domain has been understudied. In comparison to engineering education, SRL research has been often studied in other STEM domains, such as biology and physics [28], [29]. Future research is needed to investigate engineering specific SRL instructions that optimize engineering students' learning.

In terms of methodology, 42 out of the included studies followed quantitative methods, 14 studies followed qualitative methods, and eight studies followed mixed methods. Among the 64 primary research studies, the sample sizes ranged from 3 to 2374. Within the quantitative and mixed methods studies, 14 studies conducted descriptive analyses to describe a phenomenon, 28 studies conducted correlational or regression analyses to examine the statistical relations among SRL and other variables, and 13 studies conducted quasi-experimental or intervention studies to examine the effectiveness of educational interventions in engineering. This suggested that the majority of studies in engineering education with a SRL focus were of descriptive nature or non-(quasi) experimental. Most studies only examined the statistical relationships between SRL and other variables of interest through survey studies. However, in comparison, few intervention studies were conducted to examine the effectiveness of SRL on engineering students' learning and outcomes of interest. These findings suggest that although the intersection of SRL and engineering education has been examined previously, an in-depth and systematic examination of SRL in engineering learning contexts is needed.

Additionally, and notably, among the total of 64 primary research studies, 19 studies mentioned SRL or metacognition briefly without defining these terms or referring to the theoretical principles of SRL or metacognition. The lack of theoretical guidance and definitions of SRL and its related components in engineering SRL research is a critical challenge for assessing engineering students' SRL, implementing SRL instructions in engineering classrooms properly, and extending established SRL tools to engineering teaching pedagogies.

### *B. Research Question 2: Within engineering education, how is SRL applied and studied in engineering entrepreneurship education?*

In terms of Research Question 2, surprisingly, we only found one study that included entrepreneurship education and mentioned SRL among the included studies [30]. Specifically, this study was conducted in an undergraduate civil engineering course for first-year students. Students enrolled in this course learned about the basics of construction management and were asked to build their projects. The course included an entrepreneurship and innovation module where students could come up with new ideas and explore entrepreneurship. The design of the entrepreneurship and innovation module reflected some SRL principles (e.g., critical evaluation of one's learning), however, the connection between SRL and the design of the module was not described adequately in the study. Given that SRL has the potential to improve students' entrepreneurship and entrepreneurial mindset, this finding, however, suggests that within engineering education, SRL research has not been adequately examined and applied to entrepreneurship education. In other words, while there is a large body of research on entrepreneurship education within the engineering education context [7], there is a gap between engineering entrepreneurship education and SRL. It remains unknown how engineering instructors can adopt SRL to promote engineering students' learning in entrepreneurship and their entrepreneurial mindset.

## V. CONCLUSION

The systematic scoping review examined the research on the intersection of engineering education and SRL in the past 20 years and suggested future directions to bridge the research gap between SRL and engineering education. First, the lack of SRL intervention studies suggested that further intervention research on SRL in engineering education is needed. Given that many SRL interventions have been conducted in non-engineering subjects, future research should investigate possible avenues to adapt and create effective SRL instructors to promote engineering students' academic and professional successes specifically. Further, SRL research in engineering education needs to be explicitly grounded in the theoretical guidance of SRL to inform the intervention design and use of assessment tools. In addition, based on our review of literature, although SRL has been broadly studied in engineering education, there is a research gap between SRL and engineering entrepreneurship education.

## VI. LIMITATIONS AND FUTURE RESEARCH

We acknowledge that there were several limitations in the present systematic scoping review. First, although the present scoping review reported the current trend of SRL in engineering education, a detailed systematic review is needed to further examine what specific SRL instructions are more effective. Further, we did not include studies that focused on general undergraduate-level courses for all STEM students. Although these studies did not have a specific focus on engineering students, future review studies may include these studies as these are important gateway courses. In addition, future research should also examine how SRL has been assessed in engineering education and how SRL can be applied and examined in entrepreneurship education programs for engineering students specifically.

## REFERENCES


[1] Y. Wang and R. A. Sperling, "Characteristics of Effective Self-Regulated Learning Interventions in Mathematics Classrooms: A Systematic Review," *Front. Educ.*, vol. 5, 2020, Accessed: Apr. 22, 2022. [Online]. Available: https://www.frontiersin.org/article/10.3389/feduc.2020.00058

[2] J. Broadbent and W. L. Poon, "Self-regulated learning strategies & academic achievement in online higher education learning environments: A systematic review," *Internet High. Educ.*, vol. 27, pp. 1–13, Oct. 2015, doi: 10.1016/j.iheduc.2015.04.007.

[3] M. D. J. Peters, C. M. Godfrey, H. Khalil, P. McInerney, D. Parker, and C. B. Soares, "Guidance for conducting systematic scoping reviews," *JBI Evid. Implement.*, vol. 13, no. 3, pp. 141–146, Sep. 2015, doi: 10.1097/XEB.0000000000000050.

[4] M. D. Peters *et al.*, "Scoping reviews: reinforcing and advancing the methodology and application," *Syst. Rev.*, vol. 10, no. 1, pp. 1–6, 2021.

[5] A. Y. Huang-Saad, C. S. Morton, and J. C. Libarkin, "Entrepreneurship Assessment in Higher Education: A Research Review for Engineering Education Researchers," *J. Eng. Educ.*, vol. 107, no. 2, pp. 263–290, 2018, doi: 10.1002/jee.20197.

[6] N. A. of Engineering and N. A. of Engineering, *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press, 2004. doi: 10.17226/10999.

[7] S. E. Zappe, S. L. Cutler, and L. Gase, "A Systematic Review of the Impacts of Entrepreneurial Support Programs in Science, Technology, Engineering, and Math Fields," *Entrep. Educ. Pedagogy*, p. 25151274211040424, Sep. 2021, doi: 10.1177/25151274211040422.

[8] R. Harms, "Self-regulated learning, team learning and project performance in entrepreneurship education: Learning in a lean startup environment," *Technol. Forecast. Soc. Change*, vol. 100, pp. 21–28, Nov. 2015, doi: 10.1016/j.techfore.2015.02.007.

[9] C. M. Vogt, "Faculty as a Critical Juncture in Student Retention and Performance in Engineering Programs," *J. Eng. Educ.*, vol. 97, no. 1, pp. 27–36, 2008, doi: 10.1002/j.2168-9830.2008.tb00951.x.

[10] E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, and K. Edström, "Historical Accounts of Engineering Education," in *Rethinking Engineering Education: The CDIO Approach*, E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, and K. Edström, Eds. Cham: Springer International Publishing, 2014, pp. 231–255. doi: 10.1007/978-3-319-05561-9_10.

[11] T. Litzinger, L. R. Lattuca, R. Hadgraft, and W. Newstetter, "Engineering Education and the Development of Expertise," *J. Eng. Educ.*, vol. 100, no. 1, pp. 123–150, 2011, doi: 10.1002/j.2168-9830.2011.tb00006.x.

[12] B. J. Zimmerman and A. R. Moylan, "Where metacognition and motivation intersect (pp. 299-316)," *Handb. Metacognition N. Y. Routledge*, 2009.

[13] A. Bandura, "The Explanatory and Predictive Scope of Self-Efficacy Theory," *J. Soc. Clin. Psychol.*, vol. 4, no. 3, pp. 359–373, Sep. 1986, doi: 10.1521/jscp.1986.4.3.359.

[14] A. Bandura, "Social cognitive theory of self-regulation," *Organ. Behav. Hum. Decis. Process.*, vol. 50, no. 2, pp. 248–287, Dec. 1991, doi: 10.1016/0749-5978(91)90022-L.

[15] H. Leventhal, E. A. Leventhal, and R. J. Contrada, "Self-regulation, health, and behavior: A perceptual-cognitive approach," *Psychol. Health*, vol. 13, no. 4, pp. 717–733, Jul. 1998, doi: 10.1080/08870449808407425.

[16] A. Efklides, "Interactions of Metacognition With Motivation and Affect in Self-Regulated Learning: The MASRL Model," *Educ. Psychol.*, vol. 46, no. 1, pp. 6–25, Jan. 2011, doi: 10.1080/00461520.2011.538645.

[17] B. J. Zimmerman, “A social cognitive view of self-regulated academic learning,” *J. Educ. Psychol.*, vol. 81, no. 3, pp. 329–339, 1989, doi: 10.1037/0022-0663.81.3.329.

[18] H. de Boer, A. S. Donker, D. D. Kostons, and G. P. van der Werf, “Long-term effects of metacognitive strategy instruction on student academic performance: A meta-analysis,” *Educ. Res. Rev.*, vol. 24, pp. 98–115, 2018.

[19] C. Dignath and G. Büttner, “Components of fostering self-regulated learning among students. A meta-analysis on intervention studies at primary and secondary school level,” *Metacognition Learn.*, vol. 3, no. 3, pp. 231–264, Dec. 2008, doi: 10.1007/s11409-008-9029-x.

[20] A. S. Donker, H. de Boer, D. Kostons, C. C. Dignath van Ewijk, and M. P. C. van der Werf, “Effectiveness of learning strategy instruction on academic performance: A meta-analysis,” *Educ. Res. Rev.*, vol. 11, pp. 1–26, Jan. 2014, doi: 10.1016/j.edurev.2013.11.002.

[21] B. Kramarski and Z. R. Mevarech, “Enhancing Mathematical Reasoning in the Classroom: The Effects of Cooperative Learning and Metacognitive Training,” *Am. Educ. Res. J.*, vol. 40, no. 1, pp. 281–310, Jan. 2003, doi: 10.3102/00028312040001281.

[22] J. L. Nietfeld, L. Cao, and J. W. Osborne, “The effect of distributed monitoring exercises and feedback on performance, monitoring accuracy, and self-efficacy,” *Metacognition Learn.*, vol. 1, no. 2, p. 159, Aug. 2006, doi: 10.1007/s10409-006-9595-6.

[23] G. van den Boom, F. Paas, J. J. G. van Merriënboer, and T. van Gog, “Reflection prompts and tutor feedback in a web-based learning environment: effects on students’ self-regulated learning competence,” *Comput. Hum. Behav.*, vol. 20, no. 4, pp. 551–567, Jul. 2004, doi: 10.1016/j.chb.2003.10.001.

[24] P. R. Pintrich, “The Role of Goal Orientation in Self-Regulated Learning,” in *Handbook of Self-Regulation*, Elsevier, 2000, pp. 451–502. doi: 10.1016/B978-012109890-2/50043-3.

[25] J. H. Flavell, “Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry,” *Am. Psychol.*, vol. 34, no. 10, pp. 906–911, 1979, doi: 10.1037/0003-066X.34.10.906.

[26] P. H. Winne, “A metacognitive view of individual differences in self-regulated learning,” *Learn. Individ. Differ.*, vol. 8, no. 4, pp. 327–353, Jan. 1996, doi: 10.1016/S1041-6080(96)90022-9.

[27] M. J. Page *et al.*, “The PRISMA 2020 statement: An updated guideline for reporting systematic reviews,” *Int. J. Surg.*, vol. 88, p. 105906, Apr. 2021, doi: 10.1016/j.ijsu.2021.105906.

[28] M. L. Bernacki, L. Vosicka, and J. C. Utz, “Can a Brief, Digital Skill Training Intervention Help Undergraduates ‘Learn to Learn’ and Improve Their STEM Achievement?,” *J. Educ. Psychol.*, vol. 112, no. 4, pp. 765–781, May 2020.

[29] J. W. Morphew, “Changes in Metacognitive Monitoring Accuracy in an Introductory Physics Course,” *Metacognition Learn.*, vol. 16, no. 1, pp. 89–111, Apr. 2021.

[30] A. Salmisto and P. Nokelainen, “Knowledge Creation and Innovation in a Civil Engineering Course for the First-Year University Students,” *Eur. J. Eng. Educ.*, vol. 40, no. 5, pp. 506–521, Jan. 2015.


APPENDIX I. INCLUDED STUDIES AND CODING RESULTS

| **Publication year** | **Author** | **Region (Where was the study conducted?** | **Method** | **Sample size** | **Types of study (Quantitative)** | **Does the study describe any SRL theoretical guidance?** | **Specific engineering domain** | **Is it a review article?** | **Does the study have a focus on entrepreneurship education?** |
|---|---|---|---|---|---|---|---|---|---|
| 2021 | Cervin-Ellqvist Maria;Larsson, Daniel;Adawi, Tom;Stöhr, Christian;Negretti Raffaella | Sweden | Mixed methods | 416 | Descriptive research | Yes | Bioengineering, civil engineering | No | No |
| 2021 | Micari, Marina;Pazos, Pilar | U.S. | Quantitative | 1280 | Causal or(quasi) experimental or intervention research | Yes | STEM in general | No | No |
| 2021 | Morphew, Jason W. | U.S. | Quantitative | 284 | Causal or(quasi) experimental or intervention research | Yes | Physics | No | No |
| 2020 | Quinn, Diana; Aarão, Jorge | Australia | Mixed methods | Not reported | Descriptive research | No | Mathematics | No | No |
| 2020 | Selwyn, Rebecca; Renaud-Assemat, Irene | U.K. | Qualitative | 300 | | Yes | Mechanical engineering | No | No |
| 2020 | Kittur, Javeed | U.S. | Quantitative | 272 | Correlational/ regressional research | Yes | Electrical and electronics engineering | No | No |
| 2020 | van Gog, Tamara; Hoogerheide, Vincent; van Harsel, Milou | - | - | - | | No | | Yes | No |
| 2020 | Bosman, Lisa; Roy, Somesh; McDonald, Walter;Ababei, Cristinel | U.S. | Qualitative | 40 | | No | Civil, electrical, and mechanical engineering | No | No |
| 2020 | Saint, John; Whitelock-Wainwright, Alexander; Gasevic, Dragan; Pardo, Abelardo | Australia | Quantitative | 290 | Correlational/ regressional research | Yes | Computer engineering | No | No |
| 2019 | Pinxten, Maarten; Van Soom, Carolien; Peeters, Christine; De Laet, Tinne; Langie, Greet | Belgium | Quantitative | 1643 | Correlational/ regressional research | No | Engineering in general | No | No |
| 2019 | Magana, Alejandra J.; Fennell, Hayden W.; Vieira, Camilo; Falk, Michael L. | U.S. | Qualitative | 11 | | Yes | Computation and programming for materials science and engineering | No | No |
| 2019 | DeMara, Ronald F.; Tian, Tian; Howard, Wendy | U.S. | Quantitative | 109 | Descriptive research | No | Mechanical and aerospace engineering | No | No |
| 2019 | Concan0n, James P.; Serota, Susan B.; Fitzpatrick, Megan R.; Brown, Patrick L. | U.S. | Qualitative | 6 | | Yes | Pre-engineering program | No | No |
| 2019 | McCord, Rachel E.; Matusovich, Holly M. | U.S. | Qualitative | 270 | | Yes | Engineering in general | No | No |
| 2019 | Van Dyken, Jennifer; Benson, Lisa | U.S. | Qualitative | 7 | | Yes | Calculus | No | No |
| 2019 | Manganello, Flavio; Falsetti, Carla; Leo, Tommaso | Italy | Quantitative | 418 | Causal or(quasi) experimental or intervention research | Yes | Information engineering | No | No |
| 2019 | Lawanto, Oenardi; Febrian, Andreas; Butler, Deborah; Mina, Mani | U.S. | Quantitative | 248 | Correlational/ regressional research | Yes | Electrical engineering | No | No |

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| 2019 | Seiradakis, Emma0uela; Spantidakis, ?oannis | Greece | Qualitative | 3 | | Yes | Electrical and computer engineering | No | No |
| 2019 | Jdaitawi, Malek | Saudi Arabia | Quantitative | 160 | Causal or(quasi) experimental or intervention research | Yes | STEM in general | No | No |
| 2019 | McDowell, Linda D. | - | - | - | | No | | Yes | No |
| 2018 | Sedraz Silva, João Carlos; Zambom, Erik; Rodrigues, Rodrigo Lins; Cavalcanti Ramos, Jorge Luis; de Souza, Fernando da Fonseca | Brazil | Quantitative | 96 | Causal or(quasi) experimental or intervention research | Yes | Engineering in general | No | No |
| 2018 | Liu, Shiyu | U.S. | Quantitative | 39 | Correlational/ regressional research | Yes | STEM in general | No | No |
| 2018 | Morin, Sophie; Robert, Jean-Marc; Gabora, Liane | Canada | Mixed methods | 59 | Correlational/ regressional research | No | Engineering in general | No | No |
| 2018 | García-Ros, Rafael; Pérez-González, Francisco; Cavas-Martínez, Francisco; Tomás, José M. | Spain | Quantitative | 243 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2018 | Lawanto, Oenardi; Minichiello, Angela; Uziak, Jacek; Febrian, Andreas | U.S. | Qualitative | 112 | | Yes | Introductory thermodynamics | No | No |
| 2018 | Jaeger, Martin; Adair, Desmond | Kuwait | Quantitative | Not reported | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2017 | El-Maaddawy, Tamer | United Arab Emirates | Quantitative | 18 | Descriptive research | No | Civil engineering | No | No |
| 2017 | Martinez-Lopez, Ruth; Yot, Carmen; Tuovila, Iuliia; Perera-Rodríguez, Víctor-Hugo | Russia | Quantitative | 45 | Correlational/ regressional research | No | Engineering in general | No | No |
| 2017 | Lawanto, Oenardi; Santoso, Harry B.; Lawanto, Kevin N.; Goodridge, Wade | U.S. | Quantitative | 57 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2016 | Chen, Xin;Xiao, Gengsheng | China | Quantitative | 215 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2016 | Vogel, F. Ruric; Human-Vogel, Salomé | South Africa | Quantitative | 127 | Correlational/ regressional research | Yes | Material science | No | No |
| 2016 | Poh, Betsy Lee Guat; Muthoosamy, Kasturi; Lai, Chiang Choon; Gee, Ooi Chel | 0t reported | Quantitative | 98 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2016 | Salleh, Tuan Salwani; Zakaria, Effandi | Malaysia | Quantitative | 100 | Causal or(quasi) experimental or intervention research | No | Calculus | No | No |
| 2015 | Belland, Brian R.; Walker, Andrew E.; Olsen, Megan Whitney; Leary, Heather | - | - | - | | No | | Yes | No |
| 2015 | Meyer, Jan H. F.; Knight, David B.; Callaghan, David P.; Baldock, Tom E. | U.S. | Mixed methods | 540 | Correlational/ regressional research | Yes | Civil engineering | No | No |
| 2015 | Salmisto, Alpo; 0kelainen, Petri | Finland | Quantitative | 120 | Correlational/ regressional research | No | Civil engineering | No | Yes |
| 2015 | Nelson, Katherine G.; Shell, Duane F.; Husman, Jenefer; Fishman, Evan J.; Soh, Leen-Kiat | U.S. | Quantitative | 532 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2015 | Griese, Birgit; Lehmann, Malte; Roesken-Winter, Bettina | Germany | Quantitative | 2374 | Correlational/ regressional research | Yes | STEM in general | No | No |
| 2014 | Mullet, Hillary G.; Butler, Andrew C.; Verdin, Berenice; von Borries, Ricardo; Marsh, Elizabeth J. | U.S. | Quantitative | 76 | Causal or(quasi) experimental or intervention research | No | Engineering in general | No | No |
| 2014 | Ernst, Jeremy V;Clark, Aaron C | U.S. | Quantitative | 111 | Correlational/ regressional research | Yes | Engineering design | No | No |
| 2013 | Taasoobshirazi, Gita; Farley, John | U.S. | Quantitative | 125 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2013 | De Clercq, Mikael; Galand, Be0it; Frenay, Mariane | Belgium | Quantitative | 110 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2013 | González-Fernández, María Jesús; Sáiz-Manzanares, María Consuelo; Alaoui, Fatima E. M.; Aguilar, Fernando; Meneses, Jesús; Montero, Eduardo | Spain | Qualitative | Not reported | | No | Energy engineering | No | No |
| 2013 | Campos-Sánchez, Antonio; del Carmen Sánchez-Quevedo, María; Crespo-Ferrer, Pascual Vicente; García-López, José Manuel; Alami0s, Miguel | Spain | Quantitative | 56 | Causal or(quasi) experimental or intervention research | No | Tissue engineering | No | No |
| 2013 | Lawanto, Oenardi; Butler, Deborah; Cartier, Sylvie C.; Santoso, Harry B.; Goodridge, Wade; Lawanto, Kevin N.; Clark, David | U.S. | Quantitative | 70 | Descriptive research | Yes | Engineering in general | No | No |
| 2013 | Lawanto, Oenardi; Santoso, Harry | U.S. | Mixed methods | 115 | Descriptive research | Yes | Electrical engineering | No | No |
| 2012 | Mazumder, Quamrul H. | U.S. | Mixed methods | 55 | Causal or(quasi) experimental | Yes | Engineering in general | No | |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | or intervention research | | | | |
| 2012 | Nesbit, Susan E.; Sianchuk, Robert; Aleksejuniene, Jolanta; Kindiak, Rebecca | Canada | Mixed methods | Not reported | Descriptive research | No | Civil engineering | No | No |
| 2012 | Sun, Jerry Chih-Yuan; Rueda, Robert | U.S. | Quantitative | 203 | Correlational/ regressional research | Yes | Gerontology and engineering | No | No |
| 2012 | Dixon, Raymond A.; Johnson, Scott D. | 0t reported | Qualitative | 11 | | Yes | Chemical engineering | No | No |
| 2012 | Hsieh, Pei-Hsuan; Sullivan, Jeremy R.; Sass, Daniel A.; Guerra, 0rma S. | U.S. | Quantitative | 297 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2012 | Miyazoe, Terumi; Anderson, Terry | Not reported | Quantitative | 28 | Causal or(quasi) experimental or intervention research | No | Engineering in general | No | No |
| 2011 | DeLuca, V. William; Lari, Nasim | U.S. | Quantitative | 118 | Correlational/ regressional research | No | STEM in general | No | No |
| 2011 | Arco-Tirado, Jose L.; Fernandez-Martin, Francisco D.; Fernandez-Balboa, Juan-Miguel | Spain | Quantitative | 141 | Causal or(quasi) experimental or intervention research | No | Civil and chemical engineering | No | No |
| 2010 | Lawanto, Oenardi, PhD | Not reported | Quantitative | 168 | Descriptive research | Yes | Engineering design | No | No |
| 2010 | Sarvari, Csaba; Lavicza, Zsolt; Klincsik, Mihaly | U.K. | Quantitative | Not reported | Descriptive research | Yes | Engineering mathematics | No | No |
| 2010 | Chyung, Seung Youn; Moll, Amy J.; Berg, Shelley A. | U.S. | Quantitative | 59 | Correlational/ regressional research | Yes | Engineering in general | No | No |
| 2009 | Rahman, Md. Baharuddin Haji Abdul; Daud, Khairul Azhar Mat; Jusoff, Kamaruzaman; Ghani, Nik Azida Abd | Malaysia | Qualitative | Not reported | | No | Engineering in general | No | No |
| 2008 | Hanson, James H; Williams, Julia M | U.S. | Mixed methods | 176 | Causal or(quasi) experimental or intervention research | Yes | Engineering in general | No | No |
| 2008 | Gynnild, Vidar; Holstad, Anders; Myrhaug, Dag | Norway | Qualitative | Not reported | | Yes | Engineering in general | No | No |
| 2007 | Vogt, Christina M.; Hocevar, Dennis; Hagedorn, Linda Serra | U.S. | Quantitative | 713 | Correlational/ regressional research | Yes | Engineering in general | | No |
| 2007 | Kosnin, Azlina Mohd | Malaysia | Quantitative | 460 | Correlational/ regressional research | Yes | Electrical engineering | | No |
| 2006 | Case, Jennifer; Gunstone, Richard | South Africa | Qualitative | Not reported | | Yes | Chemical engineering | | No |
| 2006 | Schmitz, Bernhard; Wiese, Bettina S. | Switzerland | Quantitative | 40 | Causal or(quasi) experimental or intervention research | Yes | Civil engineering | | No |
| 2005 | Tynjala, Paivi; Salminen, Risto T.; Sutela, Tuula; Nuutinen, Anita; Pitkanen, Seppo | Finland | Quantitative | 394 | Correlational/ regressional research | No | Engineering in general | | No |
| 2001 | Case, Jennifer; Gunstone, Richard; Lewis, Alison | South Africa | Qualitative | 90 | | Yes | Chemical engineering | | No |
| 2000 | Hativa, Nira; Birenbaum, Menucha | Israel | Quantitative | 175 | Correlational/ regressional research | No | Engineering in general | | No |

Note. Due to limited space, full references of the included articles are upon request.