Pakistan Journal of Psychological Research, 2025, Vol. 40, No.4, 847-862

https://doi.org/10.33824/PJPR.2025.40.4.49

Self-Regulated Learning and Professional Competencies Among Engineering Graduates: Mediating Role of Self-Efficacy

Hormot Myllien, Friba Farhat Popal, and Vijay Kumar Chechi

Lovely Professional University, India

The success of any individual in engineering depends not only on their achievement and abilities but also on their self-belief and self-conviction that they can perform engineering studies and other related engineering tasks. Thus, this study tried to examine the role of self-efficacy in mediating the relationship between self-regulated learning and professional competencies among engineering graduates. The study sample was 416 engineering graduates of Lovely Professional University, Punjab, hailing from different parts of India. The streams covered were computer science engineering, mechanical engineering, electronics and mechatronics. The data were collected through a demographic questionnaire, a Self-Regulated Learning Questionnaire (Chakraborty & Chechi, 2021), Engineering Professional Competencies Scale (Motahhari-Nejad, 2021), and Engineering Self-Efficacy Scale (Mamaril et al., 2016). The results showed that self-regulated learning significantly impacted the professional competencies and self-efficacy of engineering graduates. Also, self-efficacy was found to be a significant predictor of professional competencies. Further, the results obtained through Structural Equation Modelling analysis manifested that self-efficacy partially mediated the relationship between self-regulated learning and professional competencies among engineering graduates. The study results were discussed in terms of how the role of teachers and other stakeholders is vital to developing and intensifying the self-belief and self-conviction of engineering students.

Keywords. Self-regulated learning, professional competencies, self-efficacy, higher education competencies, engineering graduates

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Hormot Myllien, Friba Farhat Popal, and Vijay Kumar Chechi, School of Education, Lovely Professional University, Phagwara, Punjab, India.

Correspondence concerning this article should be addressed to Vijay Kumar Chechi, School of Education, Lovely Professional University, Phagwara, Punjab, India. Email: chechivijay@gmail.com

Engineers play a critical role in the development of any nation's economy. If a country can increase the number of engineers it produces, it will benefit economically. Daily operations, encompassing construction, computing, technology, electrical systems, electronic devices, and manufacturing processes, constitute engineering activities (Aleta, 2016). Raising each nation's output of highly trained engineers has become a priority for every country. That is why various engineering institutions are being set up in different parts of the world, and these keep popping up daily to cater to society's demand for engineers. These engineering institutions are expected to teach pupils the necessary skills, abilities, and competencies.

Engineering students must also develop reasoning, problem-solving, and communication skills and apply engineering principles in practical work. They are also expected to master spatial ability, tinkering, and technical and engineering design (Mamaril et al., 2016). They need to be well-versed in engineering design, or the process of creating a system or component to address a specific problem (Carberry et al., 2010). Thus, Engineering educators should focus on helping them develop self-assurance in their ability to perform the tasks essential to the engineering career (Ponton et al., 2001).

However, it is sad that engineering students cannot continue and persist in their engineering programs, leading to a rise in the dropout rates of engineering graduates and the shortage of engineers worldwide (Gero & Friesel, 2020). As per the data compiled by the American Society for Engineering Education, there has been an increase in the number of engineering degrees conferred in 2011 in the USA compared to previous years. Despite this, a 4% decline was seen in the total number of engineering degrees conferred on US students (Aleta, 2016). The key to forming professional competencies is the ability and readiness for continuing education (Rusyn et al., 2021). According to Sáez-Delgado et al. (2020), many freshmen engineers show signs of academic failure and eventually drop out of their engineering studies. In light of the above, the engineering practice taxonomy, comprising 86 engineering activities paired with 17 engineering competencies and the 11 International Engineering Alliance graduate attributes, can help design a curriculum to reduce dropout rates in engineering education (Crossing et al., 2023). Barr et al. (2024) examined how students enrolled in a degree-level apprenticeship in software engineering developed their professional competencies in the workplace and reported that apprentices most often cited competencies relating to communication and interpersonal skills. However, competencies relating to responsibility, management, or leadership were less prevalent, with professional commitment proving to be the least commonly cited category of competencies.

A study on student teachers' Virtanen et al. (2017) reported that the Self-Regulated Learning (SRL) components were positively related to professional competencies. Student teachers who managed their learning had better professional competencies required in their future careers. Further, learners must develop self-regulated learning, to self-direct themselves and manage learning processes. It has been pointed out that educational institutions should emphasize the importance of developing engineering students in ICT-Work and using advanced ICT in the job. On a sample of 1,313 undergraduate engineering students from eleven universities in Thailand, he confirmed that self-esteem and SRL mediate the impact of ICT-Work on engineering competencies.

Regarding India, learning about engineers is especially important because the country is widely recognized as a hub in engineering education worldwide. Most high school students and their parents in India choose engineering as their ideal field of study even though engineering programs are somewhat expensive and threatened by a lack of guaranteed employability (Lathigara et al., 2021). Nevertheless, many of these students only show enthusiasm and confidence during the first semesters of the program; when the program is in full flow, many lose motivation, feel frustrated, and drop out of their studies altogether.

Several studies have linked engineering student dropout rates to low self-efficacy. It affects student's achievement, motivation, and persistence. It is crucial in helping engineers make decisions. Low self-efficacious engineering students doubt their ability to complete the courses or meet job requirements (Pajares & Urdan, 2006). However, highly self-efficacious students can make such a choice with less difficulty. Thus, understanding why engineering students are dropping out is crucial.

Self-efficacy is the belief in one's capabilities to organize and execute the courses of his action required to manage prospective situations (Bandura, 1995). According to previous studies, high self-efficacious pupils are more likely to use productive self-regulation tactics than their low-self-efficacious peers. For instance, Schunk and Ertmer (2000) discovered that students with high self-efficacy work hard and persist in completing assigned tasks while facing many challenges, while students with low self-efficacy do not control their learning behaviour. Learners with high self-efficacy demonstrate skill in directing their learning (Zimmerman, 2000). Usher and Pajares (2008) concluded that students' self-efficacy beliefs predicted their use of self-regulatory methods and actions. For Green et al. (2017), SRL was improved by higher levels of self-efficacy. Women entering college with more significant math preparation and high school GPA do not show stronger self-efficacy than their male peers but have greater coping self-efficacy and math outcome expectations.

According to Bandura (1989), people who are confident in their abilities are more likely to establish strategic plans that will lead them to success. Students with high levels of self-efficacy seek out and devote time to activities they perceive as complex and demanding to comprehend (Richardson et al., 2012). Jarwan and Al-Frehat (2020) reported that there was a statistically significant correlation between educational counsellors' self-efficacy and their actual level of professional competence. This suggests that self-efficacy is correlated favorably with professional competencies. A study conducted by Pendergast et al. (2011) indicated that self-efficacy is critical to the growth of teachers' effectiveness and skills.

SRL is a *key* that encourages students to take charge of their education (Zimmerman & Schunk, 2001). Professional competencies of student teachers are positively correlated with SRL components (Virtanen et al., 2017). SRL tactics, such as active learning approaches, according to Kramarski and Michalsky (2009), aid in the development of professional skills. Teachers are crucial in fostering SRL in their students (Karlen et al., 2020). Besides, students need to familiarise themselves with SRL and learn it properly (Kramarski & Kohen, 2017). Researchers have emphasized the critical role of competencies in SRL for achieving academic success, thriving in life, and pursuing lifelong learning (Dent & Koenka, 2016; Donker et al., 2014; Sitzmann & Ely, 2011). The competencies in SRL have been considered critical aspects of cross-curricular competencies and added to the latest curricula and educational standards (Organisation for Economic Co-operation and Development, OECD, 2019). Self-regulated learners actively participate in their learning process by continuously monitoring and adjusting their cognition, motivation, and behaviour to align with their learning goals and the context (Pintrich, 2000).

The studies above show evidence of the importance of SRL and its relationship with self-efficacy and professional competencies. The role of SRL in the educational outcomes of students has been pointed out. Besides, numerous studies investigating self-efficacy's mediatory role have also been found. The research is limited to school settings and general higher education students. Minimal studies are conducted on engineering students, which is crucial for national progress. The engineering students are expected to devise activities encompassing engineering construction, scientific inquiry, mathematical reasoning, artistic design, and technological skills (Dasgupta et al., 2019). An engineering design activity typically involves advanced skills such as observing, modeling, modifying, analyzing, and evaluating a project (Fan & Yu, 2017). These skills depend on students' SRL (Chiu et al., 2013). Therefore, the present study aims to understand the role of SRL in achieving professional competencies, which is vital to be explored in the Indian context.

Similarly, the study aimed to investigate the role of self-efficacy as a mediator between SRL and professional competencies, which has not been explored and not found in any published studies. Therefore, this study is needed to correctly grasp the function of self-efficacy in the relationship between SRL and professional competencies. The present study was inspired by the need to fill this knowledge gap.

Objectives of the Study

Engineering is a necessary discipline, and developing professional competencies among engineers is a core requirement for them to improve their careers functionally. SRL strategies play an essential role in the development of core competencies. Explicitly teaching students how to apply, monitor, and regulate their learning strategies has been proven to be highly effective in promoting SRL. Therefore, assessing their professional competencies and the engineering students' SRL strategies is essential to understand the curriculum change requirements in the Indian context. Lastly, the study aims to determine how self-efficacy is related to these variables and how it mediates the relationship between SRL and professional competencies. With this in mind, the researchers framed the following research questions, that is, what relationship exists between SRL, professional competencies, and self-efficacy? And will self-efficacy mediate the relationship between SRL and professional competencies? The results of this study would make teachers and other stakeholders responsible for engineers' learning. Full understanding of students’ self-efficacy is crucial if teachers want to transform them into professionally competent engineers.

Method

Sample

The participants for the current research involved 416 engineering graduates from various states of India pursuing their studies at Lovely Professional University, Punjab. The heads of the schools were approached for permission to carry out the survey. The purpose of the study was discussed with them. The section lists were taken from the respective schools, and data was collected from students during their scheduled class time after seeking cooperation from the sections in charge. The students explained the purpose of the research and asked for willing contributions to the study. Based on this, they supplied hard copies of the questionnaire, which included all three instruments. However, researchers established a good rapport with them before they filled out the questionnaire. The students completed the questionnaire, which ranged between 25 and 30 minutes. The final sample of the study included 253(60.8%) computer science engineering, 28 (6.73%) mechanical engineering, 73 (17.54%) electronic engineering, and 62 (14.9%) mechatronic engineering students. The gender-wise representation in the sample included 374 (89.9%) males and 42 (10.09%) females. The present sample comprised undergraduates in their first, second, and third years of engineering studies. Additionally, the average age of the sample is 19 years (*SD* = 2.03).

Measures

The following measures were used to assess the study variables.

Self-Regulated Learning Questionnaire

The self-regulated learning of engineering graduates was measured using the Self-Regulated Learning questionnaire developed and standardized by Chakraborty and Chechi (2021). The tool has 67 continuous items, measured using a 5-point Likert scale where 1 = *Strongly Disagree* and 5 = *Strongly Agree* (except for academic delay of gratification with four options) and high scores reflect better self-regulated learning strategies. Out of 67 items, 5 are fillers/ distractors belonging to unrelated variables like ‘emotional intelligence and dispositional optimism’ purposely included testing the sincerity of the respondents while giving their responses. In the current study, alpha coefficient above .70 was achieved thereby indicating adequate internal consistency of the scale.

Engineering Professional Competencies Scale

To measure Engineering Professional Competencies (EPC), the present research used the Engineering Professional Competencies scale developed by Motahhari-Nejad (2021). This scale has 24 items; measured using a five-point Likert scale ranging from 1 (*Very Low*) to 5 (*Very High*) and high scores indicate higher levels of engineering professional competencies. The professional competencies included in the scale include items on the five dimensions, namely knowledge and reasoning of technical and engineering; personal skills and attitudes; professional and ethical skills and attitudes; interpersonal skills and attitudes; and skills of developing a system, product, or process.

Engineering Self-Efficacy Scale

For measuring the Self-Efficacy of Engineering (ESE) graduates, the present research used the Engineering Self-efficacy scale, developed by Mamaril et al. (2016). This scale consists of two subscales: The General Engineering Self-efficacy scale and the Engineering Skills Self-Efficacy scale. The former has 5 items, whereas the latter has 12 items with 4 items measuring experimental skills self-efficacy, 4 items measuring tinkering self-efficacy, and another 4 items measuring engineering design self-efficacy. The 17 items of the scale are measured using a 6-point Likert scale ranging from 1 (*Strongly Disagree*) to 6 (*Strongly Agree*). In the current study, alpha coefficient above .70 was achieved thereby indicating adequate internal consistency of the scale.

Procedure

The investigators conducted this study at the Lovely Professional University, Punjab campus. More than 10000 students are pursuing engineering in the various branches of study. Students from all over India are admitted pursuing their engineering dreams at the university due to quality education being imparted and the university's rankings at the national level. Before surveying the selected sample, permission was obtained from the Heads of Schools of the four different engineering streams of Lovely Professional University, Punjab. The purpose was explained to them, and sections' incharge were approached through them. After checking the respective timetables of the engineering students, the investigators visited the respective sections for data collection. The students from all the years of study were approached. They were instructed to fill out the survey instruments after seeking their willingness to participate. In total, around 480 students were contacted, out of which 416 made it to the final sample after removing half-filled or wrong response questionnaires. The response rate of the selected questionnaires was 86.67%. The collected data was then subjected to data analysis to draw out the conclusions for the study objectives.

Results

Regression analysis is a commonly used technique in psychological research to explore the predictive power of independent variables on dependent outcomes. Multiple regression analyses were conducted to explore the relationship between SRL, EPC, and ESE. In line with research methodologies commonly employed, researchers used SPSS 16.0 to perform the regression analysis, ensuring the rigor of statistical processes. Table 1 presents the summary of the findings.

Table 1: *Summary of Regression Analysis (N = 416)*

Regression Model	Regression Weights	*R*	R^2	*β*	*F*	*p*
1	SRL→EPC	0.46	0.21	0.30	114.97	.000
2	SRL→ESE	0.67	0.45	0.72	347.07	.000
3	ESE→EPC	0.54	0.29	0.33	173.91	.000

Note. SRL = Self-Regulated Learning; ESE = Engineering Self-Efficacy; EPC = Engineering Professional Competencies.

SRL and EPC: Table 4.1, showed a moderate but significant correlation between SRL and EPC. The regression analysis indicates that SRL accounts for 21.7% of the variance in EPC this result, along with a significant *F* statistic confirms that SRL has a moderate but meaningful effect on EPC. This regression model also reveals that SRL significantly impacts EPC indicating that SRL plays a significant role in shaping EPC. These results directly affect the positive effect of SRL on EPC. Previous studies have also confirmed that SRL impacts student motivation (Zimmerman, 2002) or competency development (Bembenutty et al., 2015), demonstrating that self-regulated behaviors are a significant predictor of professional competencies in educational settings. Further, results suggest that for every unit increase in SRL, there is a corresponding positive and significant increase in EPC, highlighting the importance of fostering SRL to enhance professional competencies.

SRL and ESE: The relationship indicates strong and significant correlation between SRL and ESE. SRL explains 45.6% of the variation in ESE. Findings further revealed that positive impact of SRL on ESE. This high level of variance is consistent with findings in psychological research, where self-regulatory behaviors are seen as crucial in boosting self-efficacy (Bembenutty et al., 2015). The *β* coefficient of .72 shows a strong positive influence of SRL on ESE, suggesting that improving self-regulatory behaviors significantly enhances an individual's self-efficacy.

ESE and EPC: Findings show that the correlation between ESE and EPC is also significantly positive. The regression analysis revealed that ESE significantly predicts EPC accounting for 29.6% of the variance. This finding in line with the existing body of literature such as those dealing with performance-related outcomes (Bandura, 1997), self-efficacy often emerges as a strong predictor of competence and skill acquisition (Hutchison et al., 2006; Mamaril et al., 2016), especially in educational and professional development settings.

Structural Equation Modeling was used to address the second research question: Does ESE mediate the relationship between SRL and professional engineering competencies? This method is appropriate because it allows for simultaneously assessing multiple pathways and indirect effects (Kline, 2015). Figure 1 displays the path diagram representing the mediating role of ESE in the SRL-EPC relationship.

Figure 1: *Path Diagram Showing ESE as a Mediator in the Relationship Between SRL and EPC*

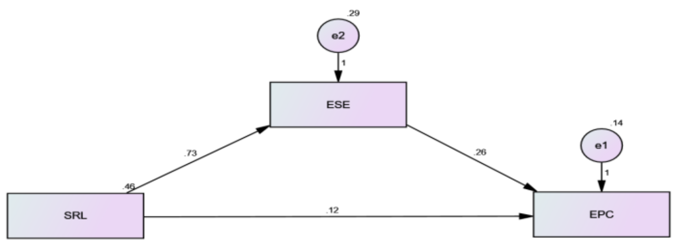


Table 2: *Summary of the Indirect Effects (N = 416)*

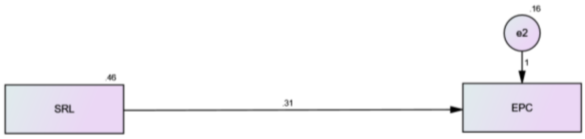
	Total Indirect Effects	Lower bounds	Upper bounds	Two-tailed Significance
	SRL	SRL	SRL	SRL
ESE	.00	.00	.00	.00
EPC	.18	.12	.25	.00

Note. SRL = Self-Regulated Learning; ESE = Engineering Self-Efficacy; EPC = Engineering Professional Competencies.

$p < .05$.

From Table 2 the total indirect effect of SRL on EPC through ESE is 0.18. However, to determine whether the indirect effect is significant, it is necessary to examine the lower and the upper bound confidence intervals. From the table, the lower bound confidence interval is 0.12, and the upper bound confidence interval is 0.25. The indirect effect is significant since there is no zero between the lower bound and upper confidence intervals. Additionally, the value of .00 at the intersection of SRL and EPC supports the mediation effect. This concludes that ESE mediates between SRL and EPC (Byrne, 2016). Figure 2 provides a path diagram that presents the direct relationship between SRL and EPC without including ESE.

Figure 2: *Path Diagram Showing the Direct SRL-EPC Relationship Without ESE.*



To determine the direct relationship between SRL and EPC without ESE was estimated (Figure 2). From Figure 2, the direct relationship between SRL and EPC without ESE was 0.30, as shown in Table 3.

Table 3: *Direct Effects*

Paths	Estimate	*p*
EPC ← SRL (without mediator)	.30	.00
ESE ← SRL (with mediator)	.72	.00
EPC ← SRL (with mediator)	.11	.00
EPC ← ESE (with mediator)	.25	.00

Note. SRL = Self-Regulated Learning; EPC = Engineering Professional Competencies.

In Table 3 the direct effects of SRL on ESE, SRL on EPC, and ESE on EPC were all significant. Findings further revealed that the estimate of the direct effect of SRL on EPC decreased from 0.31 to 0.12 when ESE was included. However, both direct relationships were significant. Thus, it is concluded that ESE partially mediates the relationship between SRL and EPC (Hayes, 2017; Preacher & Hayes, 2008).

Discussion

The findings that ESE partially mediate the relationship between SRL and Professional Competencies of Engineering Graduates. This partial mediation suggests that while SRL directly contributes to professional competencies, it also indirectly influences these competencies through its effect on self-efficacy. Partial mediation occurs when the direct relationship between an independent and dependent variable is reduced but still significant in the mediator's presence (MacKinnon, 2008). In this case, while the inclusion of ESE in the model reduced the direct effect of SRL on EPC, both direct and indirect effects remained statistically significant. This suggests that, although ESE explains part of the relationship between SRL and EPC, other factors also contribute to this relationship (Hair et al., 2017).

The significance of both the direct and indirect effects imply that fostering ESE could be an important strategy for enhancing the professional competencies of engineering students (Schunk & Pajares, 2005). Encouragement from parents, teachers, engineering educators, and other stakeholders can go a long way toward helping students develop a healthy sense of self-efficacy. Words of encouragement that would help increase engineering students' self-efficacy would be greatly appreciated. Once their confidence in themselves and their abilities is bolstered, they will enthusiastically take on any difficult job, leading them to transform into competent, professional engineers over time. This conclusion is consistent with existing literature on self-efficacy, which emphasizes the role of self-belief in influencing academic and professional outcomes (Bandura, 1997). In the present Global Engineering world, skills and competencies have become necessary criteria for recruitment into various engineering professions. Therefore, their engineering and related general competencies must be honed and improved. For this to happen, they should be provided with an environment to prove and manifest excellence in their various skills. Besides, all Educational Institutes should focus on providing them with strategies that will transform them into independent learners and lead them to excel in the various engineering fields.

Implications

Despite the abundance of literature on the mediating role of self-efficacy, no studies that explored ESE as a mediator in the SRL-EPC relationship have been found. So, the present research has filled a hitherto unfilled need in this area. Furthermore, as engineers are regarded as the assets of any country, the present study has demonstrated the factors contributing to a lack of qualified engineers and a rise in the dropout rates of those in the engineering field. Moreover, the Role of ESE as a critical factor in predicting both academic success and professional competency development have been already highlighted in terms that students with higher self-efficacy in engineering-related tasks are more likely to demonstrate competence in engineering problem-solving and teamwork, which are key components of EPC (Marra et al., 2009). Thus, in light of this, findings of the present study will be of tremendous use to engineering educators and future researchers as they strive to address the challenges faced by engineering students worldwide.

Limitations

In current study, it was not possible to acquire an equal representative sample size from each of the four engineering disciplines chosen during data collection process. The reason for this is that most engineering students concentrate on computer science engineering. In addition, only a tiny proportion of female students enrolled in undergraduate engineering programs, so the present research did not consider gender comparison in the analysis.

Recommendations for Future Research

To keep the sample as representative as possible, the present research focuses on the engineering students at Lovely Professional University. As a result, it was considered a good idea to expand the scope of future research to include additional engineering schools in Punjab or other states in India. The STEM community can also be studied in greater depth. In addition, the same research can be applied to MBBS students and pharmacists.

Conclusion

This study empirically supports the hypothesis that ESE mediates between SRL and EPC. This research underlined the importance of developing ESE and made engineering professors and other stakeholders better understand their student's abilities and areas for improvement. It brought to focus the implementation of the numerous strategies that may be helpful to engineer students and boost their self-confidence and self-conviction in their skills and abilities. By doing so, they can change a self-regulated engineer into a professional engineer.

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Received 12 October 2023

Revision received 24 September 2024