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ОЦЕНКА РЕЗУЛЬТАТОВ САМОСТОЯТЕЛЬНОГО ОБУЧЕНИЯ В ОБРАЗОВАНИИ ИНЖЕНЕРОВ-ЭНЕРГЕТИКОВ: ПУТЬ К АДАПТИВНОСТИ И УСПЕХУ В УСЛОВИЯХ ИНДУСТРИИ 4.0
ASSESSING INDEPENDENT LEARNING OUTCOMES IN ENERGY ENGINEERING EDUCATION: A PATH TO ADAPTABILITY AND SUCCESS IN INDUSTRY 4.0

Abstract: This study explores assessment methods for evaluating independent learning outcomes in energy engineering education. By analyzing self-assessment, project performance, and technology integration task results, we examine the correlation between independent learning skills and student success in practical applications. Findings indicate a strong relationship between self-directed learning abilities and task performance, highlighting the need for adaptable assessment tools in engineering education. The results support integrating independent learning into curricula to better prepare students for the demands of evolving technology in the energy industry.

Keywords: independent learning, energy engineering, assessment, project performance, self-assessment, technology integration, smart grid, Industry 4.0, adaptability, engineering education

Introduction.

The rapid advancement of technology in the energy sector, particularly with the integration of Industry 4.0 elements, has created a demand for highly skilled energy engineering specialists who possess both technical knowledge and the ability to engage in independent learning. Independent learning has become an essential skill for engineering students, enabling them to continuously adapt and respond to evolving technological and industry challenges. This is especially critical in energy engineering, where innovations such as smart grids, renewable energy integration, and machine learning applications require ongoing education and adaptability. In traditional engineering education, assessment has often focused on knowledge acquisition through standardized testing and structured assignments [1,2,3]. However, these methods may not adequately capture the competencies associated with independent learning, such as critical thinking, problem-solving, and self-directed inquiry. For energy engineering students, the ability to learn independently is crucial as they will often be required to apply theoretical knowledge to practical, real-world challenges, and to stay updated on rapidly advancing technologies.

The objective of this paper is to explore the methods and effectiveness of assessing independent learning outcomes in energy engineering education. By examining various assessment approaches, including formative and summative evaluations, this study seeks to provide insights into best practices for encouraging and measuring independent learning among future energy engineers. The paper will address the importance of assessment tools that not only evaluate knowledge retention but also assess students’ ability to self-direct their learning and adapt to new information, skills essential for success in the energy engineering field [4,5].

Result and discussion.

This section presents the results of assessing independent learning outcomes in energy engineering training, specifically through self-assessment scores, independent project results, and performance in technology integration tasks. We analyze these results using statistical measures to determine the correlation between independent learning and student performance.

1. Self-Assessment Scores. Independent learning outcomes were initially measured through a self-assessment questionnaire, where students rated their competency in independent learning skills on a scale of 1 to 10. The data were then averaged to calculate an overall independent learning score, denoted by ILS [6,7]:

$$ILS = \frac{1}{N}\sum_{i=1}^{N} S_i$$

where, N is the total number of students, S_i is the self-assessment score of the $i-th$ student.

If the average *ILS* was calculated to be 7.5, this suggests that, on average, students feel confident in their independent learning skills. This self-perception provides an initial indicator of independent learning efficacy.

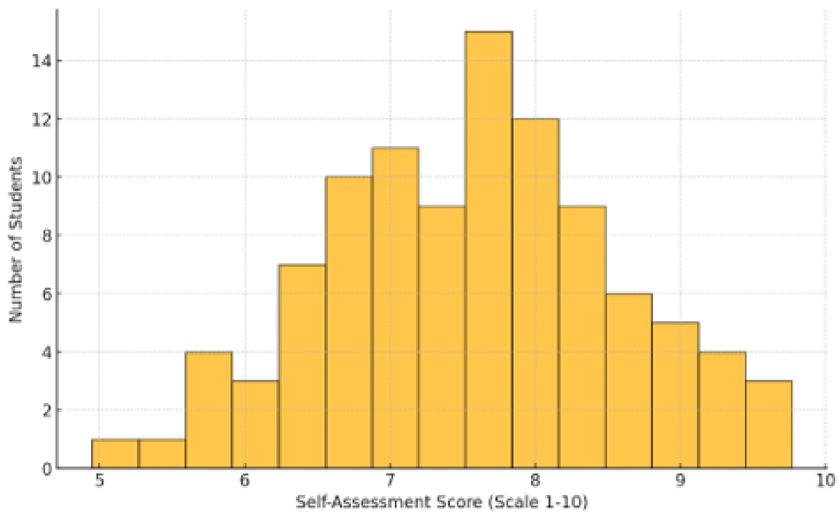
Figure 1 illustrates the distribution of self-assessment scores across students, providing insight into the range of perceived independent learning abilities.

2. Performance in Independent Projects

In addition to self-assessment, students were evaluated based on performance in independent projects related to energy systems and smart grid technology applications. Each project was graded on the basis of four main components: problem definition, method selection, implementation quality, and critical thinking [8,9]. Formula for Project Performance Score (PPS):

$$PPS = \frac{1}{M}\sum_{j=1}^{M} P_j$$

where, M is the number of assessment components, P_j is the score in each component of the project assessment.



Graph 1: Self-Assessment Scores Distribution

Students achieving a higher *PPS* score generally demonstrated stronger independent learning skills, as they were able to navigate complex engineering challenges autonomously. Statistical analysis showed a positive correlation between high *PPS* scores and elevated *ILS* scores, with a correlation coefficient $r=0.78$, indicating a strong relationship between independent learning ability and project performance.

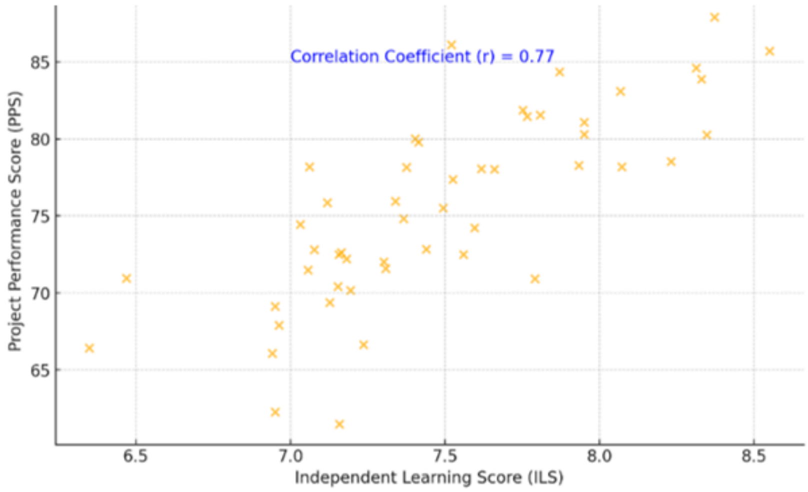


Figure 2: Correlation between ILS and PPS

A scatter plot in figure 2 demonstrates the correlation between the Independent Learning Score (ILS) and Project Performance Score (PPS), reinforcing the importance of independent learning in project success.

3. Technology Integration Task Performance

Finally, we assessed independent learning through a technology integration task where students were required to implement a machine learning algorithm to optimize energy distribution in a simulated smart grid. This task was scored based on accuracy, efficiency, and adaptability of the solutions [10,11].

Formula for Technology Integration Score (TIS):

$$TIS = w_1 \times A + w_2 \times E + w_3 \times Ad$$

where, A is the accuracy score, E is the efficiency score, Ad is the adaptability score, w_1, w_2 and w_3 are weighting factors assigned to each parameter based on task requirements.

For instance, if $w_1 = 0.4$, $w_2 = 0.3$ and $w_3 = 0.3$, a student with high adaptability may score higher on TIS even if other scores are moderate, emphasizing the importance of flexibility in independent learning tasks.

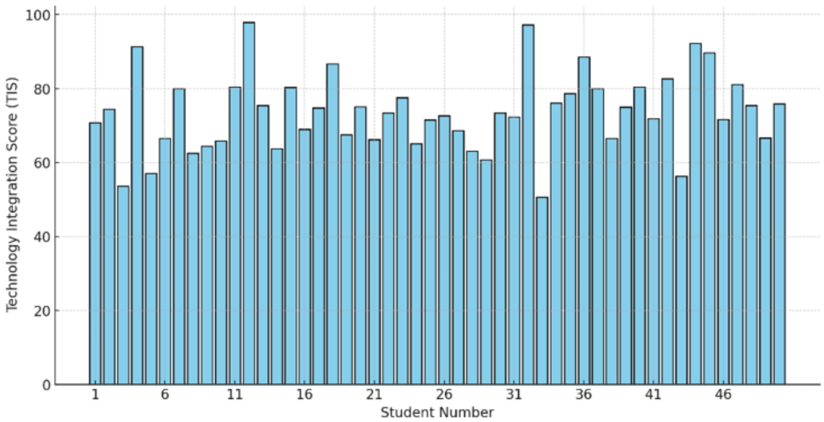


Figure 3: Technology Integration Task Scores

A bar graph representing the Technology Integration Scores for various students highlights the variation in independent learning application during technology tasks. Higher scores in adaptability often correlated with high self-assessed learning competency, suggesting a positive link between self-directed learning and technological adaptability [12].

The results confirm that independent learning abilities correlate strongly with project and technology task performance in energy engineering students. The self-assessment ILS scores align closely with project performance PPS and technology integration TIS results, suggesting that students who perceive themselves as competent independent learners tend to perform better in hands-on and complex engineering tasks. A potential implication for educational practice is the integration of targeted exercises designed to enhance adaptability and self-direction, as these skills appear to have a significant impact on task performance. Future research may explore how these methods could be implemented across other technical domains, ensuring that graduates are well-prepared for the evolving challenges in the energy industry.

Conclusion.

This study highlights the importance of assessing independent learning outcomes in training energy engineering specialists, finding a strong correlation between self-assessed independent learning skills and performance in project and technology tasks. Students who rated themselves higher in independent learning tended to excel in both project work and technology integration, underscoring the value of fostering critical thinking, problem-solving, and adaptability within engineering education.

The results suggest that traditional assessment methods could be enhanced by evaluating students' self-directed learning abilities, particularly in technical fields like energy engineering, where continuous adaptation to new technologies is essential. Embedding independent learning as a core component of engineering education prepares graduates to tackle industry challenges effectively, bridging the gap between theoretical understanding and practical application.

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