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# Relationships Between Reflection Ability and Learning Performance of Junior Electronics Engineering Students*

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Modernization affects all areas of a company, including procedures, methods, instruments, and data flows, resulting in frequent and brief changes. New approaches and process improvements are essential in engineering projects. The reflection ability has been shown to improve processes by providing advantages for team performance and team invention as an ongoing interaction between thought and action. This quantitative study investigated the interrelationships between reflection ability and learning performance among 30 junior students enrolled in a microelectronics course using the reflection assessment, project assessment, and achievement test. The findings suggested a positive, moderate, and significant correlation between reflection ability and learning performance, with reflection ability significantly predicting performance. Therefore, reflection ability can be an effective instrument for assessing students' learning performance abilities throughout a course.

**Keywords:** reflection ability; learning performance; project-based learning; electrical engineering

## 1. Introduction

Reflection ability in project-based learning is an important skill for engineering students as it enables students to demonstrate their ability to reflect on their experiences during project-based learning. Through reflection ability, students can increase self-awareness, self-identity, and personal growth [1].

Modernization and computerization cause rapid changes in technology, the economy, organizations, and social systems. In terms of product development, these changes lead to increased system complexity, changing customer requirements, rapid technological development, and increased product and market uncertainties [3, 4]. As a result, engineering projects are more difficult to plan and frequently necessitate second-order iterations and changes to ongoing projects [2]. This implies that continual process improvement is a prerequisite for development organizations' business success [5]. In terms of adaptability, individual performance is a crucial success factor for dealing with change.

Despite the significance of reflection skills, students lack strategic and systematic approaches to reflection, and the literature indicates a dearth of relevant methodological approaches [2]. For reflection ability actions to be successful, it is necessary to reflect on the facts during the course of an action [6] and to interact with all parties involved in engineering projects in order to identify any changes and hazards in a timely manner in order to be able to respond appropriately [7].

The study described in this paper characterized the relationship between reflection ability and learning performance on a project assessment and achievement test among juniors in an electronics engineering program. The theoretical contribution of the study is the quantitative characterization of the interrelations between reflection ability and performance. The practical contribution is reflected in the development of educational activities to promote both of these skills in engineering education.

The paper opens with a review of reflection ability and learning performance. Next, the research goal and questions are formulated, and the research methodology is described. The main findings are then presented. The paper ends with a discussion and conclusions.

## 2. Theoretical Framework

### 2.1 *Reflection Ability*

Dewey discusses the importance of being open-minded and willing to listen to and act on criticism [8]. The key point to remember is that, although much of this reflection ability-related thinking and activity come from academia, this ability does not have to be academic thinking; it must be more than theoretical or hypothetical. Reflection on practice is such a potent instrument because it combines scholarly theoretical thought with practitioners' practical experiences and knowledge. The synergy created by combining sources is dependent on a variety of factors. Brockbank and McGill define this as an interaction among a practitioner's experiences, feelings, and emotions as well as their activities and accomplishments [9]. Ideally, reflective practitioners incorporate both the intellectual and


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the emotional into their operational activities. This catalyst will establish a continuing process in which thinking, acting, questioning, and collaborating are joined in a supportive manner, resulting in nuanced, intelligent replies and improved results, as opposed to a simple response.

Education has long realized and valued the benefits of students actively reflecting on their learning and education experiences. According to Dewey, individuals do not learn from their experiences, but rather from reflecting on their experiences. The Kolb learning cycle emphasizes reflection ability as a critical step in learning [10]. Thus, reflection ability involves looking back and analyzing the past in an effort to prevent the repetition of errors. The process is, however, increasingly associated with reflection ability on action [11] and also encourages exploring thoughts and feelings, seeking insights, and maximizing self-awareness, all of which contribute to the formation of identities [12]. This approach is most effective when it involves others, as it allows for collaboration, the sharing of ideas, and changes to be made [13]. Critical reflection ability and the sharing of findings can be difficult and can cause feelings of vulnerability in those exposing their thoughts; working in groups and networks with fellow students can provide the support and multiple inputs needed to deal with these feelings and show that the process is worthwhile, even if it seems intimidating at first [14]. Nonetheless, Spalding and Wilson argue that many students struggle with the concept of reflection ability, and most have never written or thought reflectively about their academic experience [15].

Engineering educators have also recently started to realize the vital role that reflection ability plays in student learning. Many engineering education-related studies that have examined student reflection ability have taken place in traditional classrooms.

Reflective skills are becoming increasingly important in academia [16, 17], after gaining a strong foothold in professions. Many university students in the United Kingdom are required to compose reflective essays, reports, journals, logs, and/or portfolios as part of their coursework [18]. Student handbooks, induction days, access to the successful reflective work of previous students, and sessions containing learning theories and styles, metacognition, self-analysis of strengths and weaknesses, and the writing of personal statements are frequently used to facilitate this ability [19].

### *2.2 Project-Based Learning*

In this article, we take a closer look at students' reflection ability in relation to a new context: project-based learning (PBL), which was first introduced in the 1980s in the context of medical education. Since then, PBL has been effectively used in many disciplines, including engineering, biology, law, chemistry, and physics. Therefore, project-based learning is a systematic approach to introducing student-centered active learning. Project-based learning consists of the following features [20]:

- Students learn through projects based on real-life problems.
- Students are not given all the information; they need to make assumptions and estimate some of the information.
- They acquire skills in identifying, searching for, and using information outside of textbooks.
- Learning is active and connected, with students working in groups.
- Faculty members serve as guides and mentors.

The projects in PBL courses are the focal point of student learning; students learn new material through these projects. In addition, good PBL projects cover course content naturally; are multi-staged, complex, and open-ended; and engage students at multiple levels [21]. With PBL, students engage in a more natural process of design and how engineering is carried out in the real world, where they face purposeful, open-ended, and ill-defined problems. The use of qualitative methods is crucial when analyzing concepts like self-directed learning and epistemological evolution, as well as changes in student attitude, especially if the course has a typical enrollment of less than a dozen students. Students' reflection ability and interviews give researchers plenty of material to analyze as well as key insights from their own perspectives.

### *2.3 Learning Performance*

There are numerous ways to define learning performance. For example, it can relate to students' exam results [22–24], learning satisfaction [22, 25], and even performance within the online learning system [26]. According to the Association for Educational Communications and Technology, learning performance is defined as a learner's ability to use recently gained knowledge or abilities. In essence, it entails not only the acquisition of basic knowledge and skills, but also the ability to apply them. A variety of factors influence learning performance [27–30].

Learners are expected to complete learning activities with the assistance of their personal learning environment [31]. Many learning tasks include a learning activity, and multiple learning activities can be arranged to represent a learning scenario. A learning task is a coordinated series of operations that must be completed in order to achieve a result. Typically, a learning activity requires mobilizing current resources and developing new ones. Learning performance is defined as the accomplishment of a learning task in a specific context. The learning performance is measured using two criteria: the outcome (what was produced) and the process (how it was produced). Learning performance is directly related to skill and serves as an indicator of skill acquisition. Currently, mainstream academic evaluations are still primarily concerned with the outcome of performance. In conventional other-regulated learning, the instructor often establishes the performance procedure just once for all students.

## 3. Research Purpose and Questions

This study explored the interrelations between reflection as expressed in the students' written self-reflection assessment after performing a project and between learning performance as expressed in the project execution and final semester achievement tests among junior students in an electronics engineering department. The following questions were derived from the research goal:

- What is the correlation between reflection ability and learning performance among junior students in the participating department of electronics engineering?
- What characteristics do these two skills have in common and what distinguishes them from one another?

## 4. Methodology

### *4.1 Participants*

Thirty juniors from an electronic engineering department in central Israel participated in the study. The participants reflected the distribution of ethnicity of the general population in their area. During the second semester, the students executed their project in teams and under the guidance of the course lecturers. The project focused on the design and implementation of a system that integrates digital and analog electronics components.

### *4.2 Procedure*

During the second semester, all students ($N = 30$) in a microelectronics course performed a hardware project using the LT-SPICE simulation. The students were required to build a project that is a successive-approximation (SAR) analog-to-digital converter (ADC) that needed to include hardware components (using LT-SPICE simulation), such as a digital-to-analog converter (DAC), sample and hold, shift register, comparator, and combinational logic. Students were required to build each of these from the bottom up using fundamental metal–oxide–semiconductor (MOS) transistor elements. After completing their projects, students took an achievement test focused on the course materials and wrote a self-reflection at the end of the semester. These three research tools were used to characterize students' performance. In addition, at the end of the semester, two experienced reviewers evaluated students' written reflections ($N = 30$) and projects ($N = 15$) completed by teams of two students each. The reviewers examined the extent to which the project reflected characteristics of performance.

The microelectronics course is a compulsory course for junior electrical engineering students in the electronic engineering department. Various DAC and ADC architectures were introduced at the beginning of the second semester. A top-down approach was presented to the class as it was announced that all basic digital building blocks would be introduced over the next few weeks. Indeed, each contained CMOS block was subsequently investigated and simulated, and students were instructed to save these fundamental subsystems created by them in order to design a complete ADC circuitry as their final design project. Among all structures, the chosen one, SAR ADC architecture, was also identified as a senior-level final project design comparable to other work [32]. A similar top-down approach was also presented at the senior-year level for analog designs with significant complexity [33].

As part of the quantitative analysis, a reflection questionnaire, achievement test, and project assessment rubric were separately performed, and the Pearson correlation coefficient among the reflection assessment scores, achievement test scores, and evaluated student project scores was calculated.

### *4.3 Instruments*

After students completed their projects in the course, they responded to a reflection questionnaire comprised of eight open-ended questions (see Appendix A). Two experts in engineering education validated each student's reflection ability.

Students also completed an achievement test (five open-ended questions) covering all course materials. Sample questions are provided in Appendix B.

The project assessment rubric, which dealt with the design and implementation of a system that integrates digital and analog electronic components, was also validated by two experts in engineering education. The assessment criteria were based on four categories of learning performance characteristics: problem solving, circuit design, component implementation, and presentation. All characteristics had an equal weight in the scoring.

The inter-rater reliability in evaluating reflection ability ($r$ = 0.845) and learning performance ($r$ = 0.855) was good. For data analysis purposes, the final score in each skill was determined as the average of the scores given by the two reviewers.

## 5. Findings

First, we present correlations between reflection ability scores and learning performance scores as measured by the various research instruments. Reflection ability scores are expressed by the reflection assessment, and learning performance is expressed by the achievement test and project assessment. We then describe the characteristics common to both skills (reflection ability and learning performance).

### *5.1 Correlation between Reflection Ability and Learning Performance*

Table 1 shows the mean score (M, ranging between 0 and 100) and standard deviation (SD) for reflection ability and learning performance as measured by the reflection assessment, achievement test, and project assessment. The mean scores were measured using three external assessment instruments (reflection assessment, achievement test, and final project assessment).

Table 2 shows that the Pearson correlation between reflection ability and learning performance was positive, moderate, and significant. The correlation coefficients calculated between reflection ability and learning performance according the three research tools based on external assessment (reflection assessment, achievement test, and project assessment) were close in value. Table 2 shows that the Pearson correlation between the two learning performance research tools (achievement test and project assessment) was positive, high, and significant.

**Table 1.** Descriptive statistics of reflection ability and learning performance (various tools)

| **Instrument ($N$ = 30)** | ***M*** | ***SD*** |
|---|---|---|
| Reflection assessment | 56.44 | 30.31 |
| Achievement test | 79.13 | 13.49 |
| Project assessment | 85.91 | 16.13 |

**Table 2.** Pearson correlation between reflection ability and learning performance (various tools)

| **Instrument ($N$ = 30)** | ***r*** | ***p*** |
|---|---|---|
| Reflection assessment–achievement test | 0.426 | <0.01 |
| Reflection assessment–project assessment | 0.459 | <0.01 |
| Project assessment–achievement test | 0.622 | <0.01 |

**Table 3.** Descriptive statistics of project assessment for different categories

| | **Project assessment ($N$ = 30)** | |
|---|---|---|
| **Category** | ***M*** | ***SD*** |
| Problem solving | 82.00 | 28.35 |
| Circuit design | 80.67 | 18.88 |
| Component implementation | 93.33 | 13.56 |
| Presentation | 92.22 | 14.34 |

### *5.2 Common and Distinctive Characteristics*

Table 3 displays, based on the analysis of the reflection assessment and project assessment, the mean score and standard deviation for learning performance according to project assessment in the following categories: problem solving, circuit design, components implementation, and presentation. Table 4 shows the correlation coefficients between reflection ability and learning performance categories. In each category, the corresponding correlation coefficient was positive and significant. In the problem-solving, circuit design, and component implementation categories the correlations were moderate, but in the presentation category the correlation was low.

Table 5 displays, based on the analysis of the reflection assessment and achievement test, the mean score and standard deviation for learning performance according to the five achievement test questions. Table 6 shows the correlation coefficients between reflection ability and the achievement test questions. In each question, the corresponding correlation coefficient was positive and significant; it was low in the first three questions but moderate in the last two questions.

### *5.3 Simple Linear Regression between Reflection Ability and Performance*

A simple linear regression was used to test if

**Table 4.** Pearson correlation between reflection ability and project assessment for different categories

| | **Reflection ability–Project assessment ($N$ = 30)** | |
|---|---|---|
| **Category** | ***r*** | ***p*** |
| Problem solving | 0.353 | <0.05 |
| Circuit design | 0.492 | <0.01 |
| Component implementation | 0.350 | <0.05 |
| Presentation | 0.234 | >0.05 |

**Table 5.** Descriptive statistics of achievement test questions

| | **Achievement test ($N$ = 30)** | |
|---|---|---|
| **Category** | ***M*** | ***SD*** |
| Question 1 | 83.33 | 17.23 |
| Question 2 | 78.00 | 24.79 |
| Question 3 | 75.42 | 21.24 |
| Question 4 | 82.50 | 16.84 |
| Question 5 | 74.83 | 20.89 |

**Table 6.** Pearson correlation between reflection ability and achievement test questions

| Category | Reflection ability–Achievement test ($N$ = 30) | |
|---|---|---|
| | $r$ | $p$ |
| Question 1 | 0.285 | =0.063 |
| Question 2 | 0.076 | >0.05 |
| Question 3 | 0.199 | >0.05 |
| Question 4 | 0.472 | <0.01 |
| Question 5 | 0.440 | <0.01 |

reflection ability significantly predicted learning performance in project assessment. The fitted regression model was: 72.111+0.244 · (project assessment). The overall regression was statistically significant ($R^2 = 0.211$, $F(1, 28) = 7.492$, $p \leq 0.05$). It was found that reflection ability significantly predicted learning performance in project assessment ($\beta = 0.459$, $p \leq 0.05$).

A simple linear regression was also used to test if reflection ability significantly predicted learning performance on the achievement test. The fitted regression model was: 68.426+0.190 · (achievement test). The overall regression was statistically significant ($R^2 = 0.182$, $F(1, 28) = 6.219$, $p \leq 0.05$). It was found that reflection ability significantly predicted learning performance on the achievement test ($\beta = 0.426$, $p \leq 0.05$).

## 6. Discussion

The present study measured reflection ability and learning performance among junior engineering students using three tools: a reflection ability evaluation, a project assessment, and an achievement test. The mean scores on the achievement test and final project assessment were close in value, but higher compared to those measured by the reflection assessment. This may be due to the fact that critical reflection ability and the sharing of findings can be challenging and can induce feelings of vulnerability in those exposing their thoughts [14]. Furthermore, many students struggle with the concept of reflection ability, and the vast majority have never written or thought reflectively about their academic experiences [15].

For the first time, to the best of the authors' knowledge, this study found a significant moderate positive correlation between reflection ability and learning performance in engineering education. These findings confirm the results of existing correlation research between reflection ability and learning performance in clinical learning environments [34–36]. In addition, the results emphasize the significance of written reflections as a method for evaluating professional learning performance [36]. Such a correlation was obtained between the reflection assessment and project assessment as well as between the reflection assessment and achievement test. The correlation coefficients measured using the instruments were found to have close values, despite the fact that the achievement test focused on the entirety of course materials, the project dealt with the design and implementation of a specific system (ADC converter), and the reflection abilities written by students focused on the project they performed. This result indicates that the correlation between reflection ability and learning performance is minimally influenced by the nature of the work at hand.

The study also shows that reflection ability has a moderate correlation with three categories of project assessment (i.e., problem solving, circuit design, and component implementation), but a low correlation with the category related to presentation. In addition, reflection ability has a moderate correlation with two questions (Questions 4 and 5) of the achievement test, but a low correlation on the other three questions (Questions 1–3), which were technically difficult. This finding might be explained as follows: Although both reflection ability and learning performance (project assessment and achievement test) have a partial common cognitive/metacognitive mechanism.

These findings imply that students' ability to reflect on how and what they have learned throughout learning in general and when performing projects (hands-on/simulation tasks) in particular has a quantifiable effect and contributes to enhanced academic performance. The results also support the literature's proposal to encourage students' introspective abilities from the earliest stages of their education [37]. According to the findings, reflection ability significantly predicted performance. As a result, reflection ability can be a useful tool for assessing students' learning performance abilities throughout a course.

The primary limitation of this study is its relatively small sample size. The theoretical contribution of this study is the quantitative characterization of the interrelationships between reflection ability and performance. This contribution is valid in light of the numerous efforts made to promote both types of capabilities.

In a proposed follow-up study, the relationship between reflection ability and learning performance among higher education students in general, and electrical engineering and computer engineering students in particular, will be investigated.

## 7. Conclusions

In conclusion, we discovered a significant moderately positive correlation between reflection ability and learning performance scores in the study when we looked at the adjusted correlations. In addition, the findings revealed that reflection ability significantly predicted performance. As a result, reflection ability can be a useful tool for evaluating students' learning performance abilities throughout a course. Thus, reflection appears to be an important component of professional competence. Further research could concentrate on the effect of reflection on performance in engineering students with varying levels of reflection ability and learning performance. Intervention studies could also be based on a differentiated approach of engaging students in reflective writing based on their learning performance. The results suggest that writing reflections throughout the learning process contribute to improved academic performance.

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## Appendix A

Reflection questionnaire:

Self-reflection on the projects process and outcome (reflection for every student). Following is a list of questions that encourage reflective thought:

1. What aspects of the project do you particularly enjoy?
2. Which aspects of the project did you dislike, and why?
3. During the execution of the project, what obstacles did you face? What precipitated the problem? How did you resolve the challenges?
4. What modifications will you make to this type of project?
5. What did the project teach you about yourself?
6. Did the work on the project reveal to you new facets in relation to the studied course material?
7. Which topics and their rationale should be specified in lectures?
8. Did the project influence your behavior or thoughts in the field in which the project was conducted?

## Appendix B

Two sample questions of the given achievement test:

Q2 – Dynamic Logic circuit analysis

The circuitry shown in Fig. A1, is to be analyzed using transistors model parameters, given in Table A1.

**Fig A1**

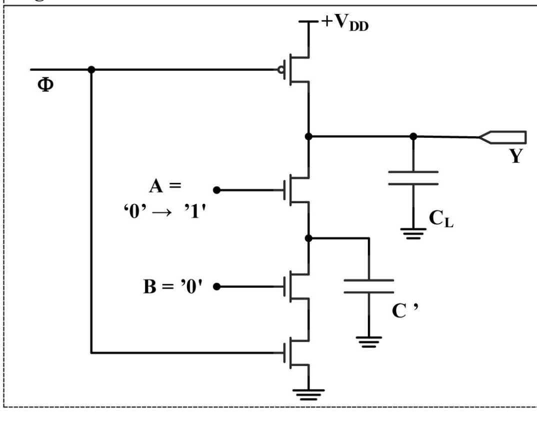


**Table A1**

$V_{DD} = 2[V]$

$V_{tn} = 0.4\ [V]$

$V_{tp} = -0.5\ [V]$

$k'_n = (\mu_e C_{ox}) = 500 \left[\frac{\mu A}{V^2}\right]$

$k'_p = (\mu_h C_{ox}) = 80 \left[\frac{\mu A}{V^2}\right]$

$\left(\frac{W}{L}\right)_n = 2$

$\left(\frac{W}{L}\right)_p = 4$

Assume that all MOSFET have the bulk connected to the source.

Load capacitance is $C_L = 35[fF]$, and overall parasitic capacitance at the node connecting transistors A and B value is $C' = 5[fF]$.

(1) Calculate the circuit Pre-charge time using the average current approximation.

(2) Assume that initially both digital inputs are set to $A = B = 0$ , the parasitic capacitance $C'$ is discharged and the output voltage is $V_O = +2[V]$. While at the evaluation stage and $\Phi = '1'$, it is given that the digital input A transitions, resulting: $B = 0, A = 1$ . Calculate the voltage drop at the output $\Delta V_O$ due to that.

Q5 – analysis of simple mixed signal circuit
The circuitry shown in Fig. A2, is to be analyzed using components values and voltage ratings described within the figure.

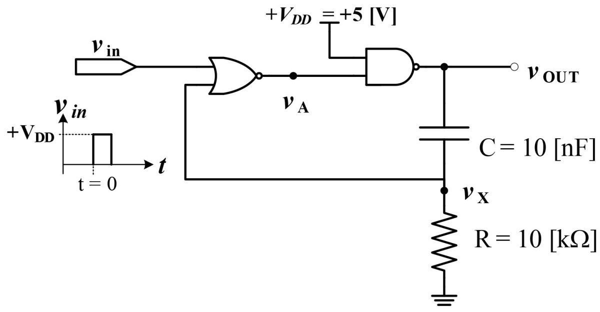


**Fig A2.**

The electrical inputs to the Boolean logic gates are assumed to include ideal over-voltage protection diodes, clamping the input voltage to the [0 +5V] range. While gate voltages are mapped into the digital domain as follow:

$$\textbf{Ideal '0' input:} \quad 0 < v_{in} < 2.5V$$
$$\textbf{Ideal '1' input;} \quad 2.5V < v_{in} < 5V$$

At time point $t = 0$, an ideal voltage pulse, is applied on the input node labeled as '$v_{in}$', having +5V voltage level and a temporal width much smaller than any time constant typical to the circuit.

(1) What are the voltages at the nodes labeled: $v_{in}, v_A, v_X$, both at $t = 0^-$ and $t = 0^+$, that is prior and immediately after the pulse is applied at $v_{in}$. Reason your answer.
(2) Draw time lined voltage traces for the following four (4) node voltages: $v_{in}, v_A, v_X, v_{OUT}$, starting at $t < 0$, till steady state is reached. Make sure you carefully mark voltage levels and temporal widths along each trace.

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