Abstract Thinking of Beginning Electrical Engineering and Computer Science Students

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Abstract. Abstract thinking is the capability to deal with relevant information for a given phase while temporarily disregarding the irrelevant details for the current step. Abstract thinking is required in a wide variety of disciplines. It is of special importance in engineering, where examining many topics at different detail levels is needed. However, the literature implies that the abstract thinking of beginning students is insufficient. In light of the above, the research aimed to assess the abstract thinking of beginning electrical engineering and computer science students. The study used closed and open-ended instruments, and involved 64 undergraduate students at the Technion – Israel Institute of Technology. According to the findings, the average abstract thinking of the participants is moderate, with no significant difference between the two groups of students.

Keywords: Abstract Thinking · Electrical Engineering Students · Computer Science Students

1 Introduction

Abstract thinking is the capability to deal with relevant information for a given phase while temporarily ignoring the irrelevant details for the current stage [1]. Abstract thinking is needed in many disciplines, and it is of special importance in engineering, where examining many topics at different detail levels is required [2].

However, the literature implies that the abstract thinking of beginning engineering students is insufficient [3]. In light of the above, the present research aimed to assess the abstract thinking of beginning electrical engineering (EE) and computer science (CS) students and to examine a possible difference between the two groups.

The article is organized as follows. First, abstract thinking is reviewed. Then, the research goal and methodology are presented, followed by the results.

2 Abstract Thinking

As noted earlier, abstract thinking is the capability to deal with relevant information for a given phase while temporarily disregarding the less relevant details for the current step [1]. Thus, identifying the appropriate detail level (i.e., "level of abstraction") for a given step and shifting between several detail levels allow the individual to be more effective [4].

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Abstract thinking is an essential element of computational thinking, namely, the thought processes involved in problem-solving [5]. Therefore, abstract thinking is vital in engineering [2]. Indeed, the engineer is expected to use abstraction to identify, formulate and solve complex engineering problems and carry out engineering design [6]. For example, a chip designer is required to assign billions of components, and the only practicable approach to do this is by abstraction.

Yet, the abstract thinking skills of beginning engineering students are insufficient [3], and studies indicate that the more experienced the students, the higher their abstraction abilities [7].

The research literature offers ways to cultivate students' abstract thinking. For example, interdisciplinary methods based on heterogeneous teamwork [8], the use of visual tools [9], dedicated courses [10], and cooperative learning [11, 12].

Finally, it is worth mentioning that there are similarities between abstract thinking, systems thinking, i.e., a framework that examines the interrelationships between a system's components [2], and creative thinking, namely, approaching a challenge from innovative perspectives [13].

3 Research Objective and Methodology

3.1 Objective

The research aimed to assess the abstract thinking of beginning EE and CS students and to examine a possible difference between the two groups.

3.2 Participants

The research involved 64 undergraduate students at the Technion – Israel Institute of Technology. Twenty-nine were EE students (in their second semester) and 35 were CS students (in their third semester).

3.3 Methodology

The participants filled out a two-part anonymous questionnaire at the end of the relevant semester. The first part was closed-ended, and the second part was open-ended. Both parts were designed to assess the respondents' abstract thinking. The data obtained were statistically analyzed using unpaired *t*-tests.

3.4 Tools

As mentioned, the questionnaire consisted of two parts. The first part was a Likert-like scale, ranging from 1 ("strongly disagree") to 5 ("strongly agree"). This self-reporting tool was comprised of eight statements reflecting abstract thinking skills. Some of the statements expressed high abstract thinking and others – low abstract thinking. The statements were based on an instrument developed by the authors of [2]. Two experts in engineering education validated the statements, and Cronbach's alpha ($\alpha = 0.70$) indicated an acceptable internal consistency. Table 1 displays selected statements.

The second part of the questionnaire was open-ended. It consisted of a question in which respondents had to explain a mathematical (e.g., matrix) or physical (e.g., linear momentum) concept they knew well. The students had to provide an explanation at two levels of detail, i.e., for beginning students of EE or CS and for eighth graders. Two independent reviewers evaluated the answers on a scale extending from 1 (“low abstract thinking”) to 5 (“high abstract thinking”). The inter-rater reliability was found to be acceptable ($r = 0.70$).

Table 1. Likert-like scale – selected statements.

Abstract Thinking	Statement
High	When I am trying to solve a complex problem, it is easy for me to decide which details should be focused on at a given stage and which details are irrelevant
Low	It is difficult for me to describe the same system at different levels of detail

4 Findings

4.1 Self-reporting Survey

Table 2 shows the respondents’ abstract thinking (mean m, where $1 \leq m \leq 5$, and standard deviation s) based on the self-reporting questionnaire. According to the findings, the average abstract thinking of the participants is moderate, with no significant difference ($p > 0.05$) between EE and CS students.

Table 2. Students’ abstract thinking – self-reporting questionnaire.

Group	m	s
EE	3.55	0.45
CS	3.56	0.53

4.2 Open-Ended Question

Table 3 displays the respondents’ abstract thinking based on their answers to the open-ended question. Again, the average abstract thinking of the participants is moderate, and the difference between EE and CS students is non-significant ($p > 0.05$). Therefore, from here on, there is no distinction between the two groups.

Table 4 shows an example of a student’s response to the open-ended question that demonstrates high abstract thinking. The example deals with the explanation of the mathematical concept of “matrix”. The first explanation is intended for beginning students of

EE or CS and the second – for eighth-grade students. Both explanations were written by the same respondent. It is clear that although the explanations describe the same concept, they differ considerably in their levels of detail.

Table 3. Students' abstract thinking – open-ended question.

Group	*m*	*s*
EE	3.14	0.80
CS	2.90	0.81

Table 4. High abstract thinking – explanations of the mathematical concept of "matrix".

Target Audience	Explanation
Beginning students of EE or CS	A matrix over a field **F** is a rectangular array of elements of **F**
Eighth-grade students	A matrix is a table containing numbers (namely, information). The matrix is used by us to express sets of information and their interrelations, as opposed to "single" information – expressed by a single number that you already know

Table 5 displays an example of a student's response to the open-ended question that demonstrates low abstract thinking. The example focuses on the explanation of the physical concept of "magnetic field". As in the first example (Table 4), the first explanation is intended for beginning students of EE or CS and the second – for eighth-grade students. Both explanations were written by the same respondent. It is evident that the explanations do not differ considerably in their levels of detail.

Table 5. Low abstract thinking – explanations of the physical concept of "magnetic field".

Target Audience	Explanation
Beginning students of EE or CS	A magnetic field is a field created due to the flow of electrons. The field exerts a force called magnetic force on moving charged particles. It is possible to calculate the direction of the force by the cross product
Eighth-grade students	A magnetic field is created due to the movement of electrons in a certain direction. The field exerts a force on charged particles that are in motion

5 Discussion and Conclusions

The study reveals that the average abstract thinking of the participants is moderate, and the difference between EE and CS students is non-significant. These findings are consistent with those reported in the research literature, according to which the abstract thinking of beginning students of EE [3] and CS [11] is insufficient.

It should be noted, however, that the respondents' abstract thinking was higher in the self-reporting questionnaire (Table 2) than in the open-ended question (Table 3). This difference can be attributed to the documented phenomenon of measuring bias in self-reported tools, originating, among other things, from the participants' wish to "look good", even in anonymous surveys (as was the case in the present study) [14]. It is possible that the lack of significant difference between the two groups of students is because the respondents are at the beginning of their studies, so their program has not yet affected, if at all, their abstract thinking.

Based on the findings, it seems necessary to promote students' abstract thinking. Possible ways are courses that combine several levels of abstraction [15, 16] or that focus on cooperative learning [17].

The major limitation of the research relates to the relatively low number of respondents. To reduce it, both closed and open-ended instruments were used.

The contribution of the research is in the evaluation of the abstract thinking level of beginning EE and CS students. The relevance of this contribution is validated in light of the insufficient abstract thinking of these students [3, 11].

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