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Correlates of Logic Performance: The Relationship Between Logic Performance and General and Logical Reasoning Skills[1]

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The main purpose of this study is to explore the relationship between the 'logical reasoning skill' and performance in the logic unit that is part of the grade 9 syllabus in mathematics in Turkey. After the teaching of the logic unit, an achievement test, a general skills test and the test of logical reasoning were administered to the 80, 9th year high school students. Pearson Moments Correlation coefficient was used for the analysis of the data to determine the relations between the variables. In addition to that to obtain the most suitable regression explaining the students' performances in the logic unit, stepwise multiple regressions analysis was used. At the end of the study, statistically significant relations were found between the students' performance in the logic unit and their logical reasoning skills, their results of the shape recognition test from the general skills battery and their overall performance in the mathematics lesson.

Keywords: Logic, Logical Reasoning Skill, Mathematics Curriculum, Regression Analysis
ZDM Classification: E30, D40
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1. THE RESEARCH PROBLEM

Logic deals with concepts and propositions in terms of being able to make correct deductions by investigating the ways of reasoning. It puts forward and inspects the consistent and valid forms of reasoning (Yamanlar, 2001, p.120). The knowledge of logic is an effective tool in solving the daily problems and in clarifying some of the beliefs and assumptions through criticism which our behaviors depend on (Yamanlar, 2001, p.124). Therefore logic becomes a fundamental method for science as a discipline investigating the ways of reasoning because each discipline has to eliminate the mistakes in order to find the truth (Ozturk, 2001, p.106).

Mathematics, deals with numbers, shapes and patterns and the relations among themselves by using proof as a demonstrative tool. Mathematics does this through reasoning which is the common point between logic and mathematics. Mathematics uses the symbolism that logic provides both in its language and its methods. Mathematics, firstly, tries to find out and display a property or relationship that belongs to objects and secondly, tries to prove the existence of this relationship formally. To find a relationship is a psychological process which rather requires creative imagination, intuition and experience, but proving is a process which is based on formal reasoning whose rules are clearly stated (Yamanlar, 2001, p.117). This is the point where mathematics and logic meet.

Many studies suggest that the reasoning skill is one of the most important factors that affect performance in students' professional and social life after school (McCarthy & Tucker, 1998a; 1998b; Morris, 1984). The students who were taught logic have been found to be more successful at reasoning and critical thinking skills than those who weren't (Valanides, 1996; Miller, 1986). High levels of correlation has been detected between the performance in logic and in statistics (Harvey, 1985), geometry (Massachusetts Education Assessment Program, 1987), biology (Linn, 1989) and geology (Crow & Haws, 1985).

The relationship between the learning of mathematics and the improvement of logical reasoning skills has led to the tendency to accept mathematics teaching as a tool to improve logical reasoning skill in the Turkish curriculum as well as in almost all the mathematics education programs around the world. The statement that "the mathematics curriculum should provide experiences focused on improving logical analogies and skills" (NCTM, 1998) in the USA standards of mathematics teaching emphasizes this relationship. Likewise, the statement "improving the students' logical reasoning skills" takes the first place in the general aims of mathematics teaching in the Turkish National Education program (MEB, 2005).

Logic in the Turkish curriculum starts with the concept of 'proposition'. (Table 1) In the following section, *i.e.* the compound propositions, teachers, by giving examples, are advised to stress the fact that all statements that carry judgments are in fact propositions. In this section, teachers' explanations are enriched with activities that drive the students to think how the truth values of compound propositions which are made up with any combination of conjunctions change. The last section in the unit stresses the understanding of the proof methods. This section starts with a classification and followed by the definitions of all direct and indirect methods of proof Students, then, are asked to handle simple proofs (*e.g.* if $x\neq4$ then show that $4x+3\neq19$ with the proof by contradiction method).

Turkish high school mathematics curriculum is abstraction oriented and has a nature which makes little room for the applications of mathematics (Delice & Roper, 2006). Two evidences exist for this argument: Firstly, the statement "to teach the rules of reasoning correctly, to understand the concept of proof, to comprehend the difference between the demonstrable scientific results and dogmas, to get the students comprehend the necessity and importance of judgments and decisions to be demonstrable in every field (Baki & Bell, 1997; p.5.2)" comes second on the list of Turkish high school mathematics teaching aims stated by Turkish Ministry of Education. Apart from the fact that logic and algebra dominate first two years of Turkish high school mathematics curriculum, even in some of the topics in mathematics, such as Trigonometry, which is suitable for using real world applications, algebraic perspective dominates the teaching (Delice & Roper, 2006) (Table–1). Consequently, unlike the curricula of many other countries the fulfillment of the aim of "improving logical reasoning" has been uniformly distributed among the contents of mathematics, in the Turkish curriculum in order to accomplish the same aim, the burden seems to be imposed on certain areas. In this respect, "logic" becomes the most important topic in mathematics.

Table 1. The Distribution of Topics in the Turkish High School Mathematics Curriculum

Grade 9	Grade 10	Grade 10	Grade 10
Logic Algebra	Logic Probability and Statistics Trigonometry	Algebra Linear Algebra	Algebra Basic Mathematics

As a result of the emphasis laid on expressing propositions through symbols, on connecting propositions together appropriately and on the meaning of mathematical demonstration, there seems to be two skills which stand out in the logic unit of the Turkish mathematics curriculum: abstraction and deductive reasoning. Table 2 shows the complete list of learning areas and objectives in the logic unit in the Turkish curriculum. Moreover, in Box 1, a model question suggested for the assessment of objective B1.

explains the meaning of compound propositions, shows the characteristics of compound propositions made using 'and' & 'or' conjunctions and De Morgan Laws on a truth table" (MEB, 2005, p.73) are displayed.

Table 2. Logic Unit: Learning Areas and Objectives (TTKB, 2005, p.65).

A. Propositions 1. Explains the meanings of term, defined and undefined term with examples 2. Explains the meanings of proposition, truth value, equivalence of a proposition, and negation of a proposition.
B. Compound propositions 1. Explains the meaning of compound proposition, shows the characteristics of compound propositions made using 'and' & 'or' conjunctions and De Morgan Laws on a truth table. 2. Explains the meaning of a conditional, writes the converse, inverse, and contra positive of a conditional, shows the equivalent propositions using the truth tables. 3. Explains the meaning of two-way conditional, states the relationship between a two-way conditional and a conditional. 4. Finds the equivalents of compound propositions using the characteristics of conjunctions. 5. Explains the meanings of tautology and contradiction with examples.
C. Open propositions 1. Explains the meanings of open propositions and the truth set. 2. Explains the meanings of quantifiers (i.e. any & some), writes the negatives of propositions and compound propositions that include these quantifiers.
D. Proof methods 1. explains the meanings of definition, axiom and proof, states the hypothesis and judgment of a theorem 2. Using the proof method, does simple proofs.

Research suggests that there is a significant relationship between abilities of *deductive reasoning & abstraction* and skills in proving mathematical statements (Hadas, 1977; Sharlow, 1981; Alexander & DeAlba, 1997; Brown, 2004; Gutierrez, *et al.*, 2004; Heinze, Cheng & Yang, 2004). Hence it should not be surprising to find a positive correlation between students' performances in content areas in which abstraction and reasoning play a major role and their scores on a test measuring reasoning ability.

Box 1. A model Question for the Assessment of Objective B. 1. (Source: MEB[2])

Considering the compound proposition "Ali and Ayse stand up to the blackboard" it is possible to write the following propositions:

p: Ali stand up to the blackboard.
q: Ayse stand up to the blackboard.

Students are asked to judge the truth value of the compound proposition with respect to the realizations of the events stated in the p and q propositions and help them in deducing the following results.

If Ali and Ayse altogether went to the blackboard, the compound proposition is true.
If Ali went to the blackboard but Ayse did not, then the compound proposition is false.
If Ayse went to the blackboard but Ali did not, then the compound proposition is false.
If Ali and Ayse altogether did not go to the blackboard, the compound proposition is false.

1.1. The Aim of the Research

The main purpose of this study is to explore the relationship between the 'logical reasoning skill' that the students develop and their performances of logic that is part of the grade 9 syllabus in mathematics in Turkey. Here, the correlation between students' logic performance and their logical reasoning skill is taken as a measure for the nature of the relationship between the teaching of logic and the logical reasoning skill. More specifically, we wish to find out whether there is a significant correlation between the students' performance in the logic unit and their logical reasoning skills. The two additional foci in this paper are the relationship between the students' performance in the logic unit and students' general skills (Letter Series, Shape Recognition and Volume Surface Expansion) and overall mathematics performance.

2. METHODOLOGY

2.1. Research Design

This is a correlational study which aims to explain the relations of the students' performance in the logic unit to some mental factors. The term 'logic unit' in this manuscript refers to the content covered by the officially approved mathematics textbooks for teaching the concept of logic. The regulation that all contents should

[2] Ministry of National Education (Milli Eğitim Bakanlığı, 2005, p.73)

conform to the competencies defined explicitly by the Ministry of Education makes little room for the variation of content from one textbook to the other. Therefore, the small variations in the methods of teaching and assessment used in the teaching of the concept of logic are considered negligible

In the correlational design one of the variables is stated as the dependent variable and the others are specified as the independent variables. In the current study, the students' performance in the logic lesson is specified as the dependent variable and logical reasoning skills, general skills and the performance in the mathematics lesson are specified as the independent variables. The participants were 74 ninth grade students (34 girls and 40 boys) from TED Istanbul High School enrolled in three separate classes. The sample is purposefully chosen (Robson, 1993, p.141), as it is believed that it reflects the major characteristics of the average Turkish high school.

The data gathering tools used in the study are; the Logic Unit Achievement Test, General Skills Test Battery (Letter Series, Shape Recognition, Volume Surface Expansion) and The Test of Logical reasoning. The validity and reliability studies of these measurement tools are explained below.

The Logic Unit Achievement Test (LUAT) was developed by the school in order to specify the students' performance in the logic lesson. It is a multiple-choice test consisting of 30 questions. The validity and reliability studies of the LUAT were carried out again by the researchers. After the item analysis the following items were removed from the test; the 1st item, as its item difficulty value was too high, 3rd and 4th items, as their item discrimination values were too low and 10th, 11th and 16th items, as their item total-item remainder correlations were insufficient. At the end of the reliability analysis administered with the remaining 24 questions, the Cronbach Alpha internal consistency was found to be .82.

Table 3. Table of Specification for the Logic Unit*

Cognitive levels in Bloom taxonomy		Topics in the logic unit				Total
		Propositions	Compound propositions	Open propositions	Proof methods	
	Comprehension	2	3	3	0	8
	Application	3	4	4	0	14

	Analysis	0	3	3	5	8
Total		5	10	10	5	30

*Numbers in boxes show the number of test items that exist in the logic test.

The validity of a measuring instrument can be assessed by seeking evidence of its content and construct validity (Churchill, 1987, p.455). Content validity is defined as the agreement among professionals that the instrument logically appears to accurately reflect what it intends to measure (Zikmund, 1991, p.262). Construct validity, on the other hand, is used to assess how well the test links up with a set of theoretical assumptions about constructs the test intends to measure (Oppenheim, 1992; p.162). In order to establish the content and construct validity of the instrument, the specification grid (content by level matrix) showing the distribution of the questions with respect to the content and to the learning levels in Bloom taxonomy was assessed by five colleagues/experts (Table 3).

General Skills Test Battery (GSTB): The original form is in French and it has been adapted to Turkish by Ozcan (1985). The test measures analytic thinking, abstract thinking and spatial perception. It's a performance test and can be applied to individuals between 15-17 years of age. The test battery containing 113 items has three different dimensions which are; Letter Series (25 items), Shape Recognition (48 items) and Volume Surface Expansion (40 items) (Oner, 1996, p.183). The total score from the three different tests of the battery constitutes the students' general skills. The validity and reliability studies of the General Skills Test Battery were carried out again by the researchers on a dimensional basis and the results below were obtained.

The Test of Logical Reasoning (TOLT) which was designed by Tobin & Capie (1984) contains 10 questions. It measures the abilities to recognize and control variables, to proportion, to develop relations, to estimate and combine probability. TOLT is very useful in showing us to what extent one can see the cause & effect relations and use problem solving strategies for the problems that can be encountered especially in the areas of science and mathematics. The reliability of the TOLT was found to be .85 by Tobin and Capie (1981) and it was adapted to Turkish by Geban, Askar and Ozkan (1992). The validity and reliability studies were carried out again by the researchers and the Cronbach alpha reliability coefficient was found to be .76.

a. Letter Series Dimension: Based on the results of the item analysis the items 13, 16 18 and 23 were removed from the battery as their item total-item remainder correlations were weak. The latest version of the letter series test was found to have an internal consistency coefficient of .85.
b. Shape Recognition Dimension: Items 3, 42, 43, 45 and 48 were removed from the

shape recognition test because their item total-item remainder correlations were insufficient. The latest version of the test was found to have an internal consistency coefficient of .94.

c. Volume Surface Expansion Dimension: From the Volume Surface Expansion test the 5th, 7th, 10th, 31st, 36th and 38th items were removed as their item total-item remainder correlations were insufficient. The latest version of the test was found to have an internal consistency coefficient of .84.

2.2. Data Analysis

In order to specify the relations between the students' performance in the logic lesson and their general skills, logical reasoning skills and their overall mathematics performance Pearson Moments Correlation coefficient was used. In addition to that, to obtain the most suitable regression equivalent in explaining the students' performance in the logic lesson, stepwise multiple regression analysis was carried out. Multiple regression analysis provides a chance to interpret the total variance of the dependent variable explained by the independent variables and its statistical significance and a chance to comment on the direction of the relation between the independent variables and the dependent variable. In the current study the performance in the logic unit is adopted as the dependent variable and general skills, logical reasoning skills and the overall performance in mathematics as the independent variables. The significance level for all the statistical results in the study is accepted to be 0.05 and all the results were tested two-ways.

3. FINDINGS AND INTERPRETATIONS

The correlations obtained by using the Pearson Moments Correlation technique and the results from the multiple regression analysis are presented in Tables 3 and 4 respectively.

According to the data presented in Table 3 there are medium level but significant correlations between the students' performance in the logic unit and their logical reasoning skills and overall mathematics at the level of .01 (R: .608 & R: .550 respectively); and the shape recognition dimension of GSTB at the level of .05 (R: .416) (see Table 3).

Table 3. The Correlation Values between the Students' Performance in the Logic Unit and their Logical Thinking Skills, General Skills and Overall Mathematics Performance

		TOLT	Mathematics Performance	Letter Series	Shape Recognition	Volume Surface Expansion	General Skills
Logic Performance	***R***	*.608***	*.550***	*.199*	*.416**	*.355*	*.284*
	p	*.000*	*.002*	*.292*	*.022*	*.054*	*.129*

**: significant correlation at 0.01 level
*: significant correlation at 0.05 level

The findings provide clues for that the students who are better at logical reasoning skills, mathematics and shape recognition are also more successful at the logic unit. Hence, findings suggest that students who are successful at the logic unit will also improve their mental capacities.

Table 4. The Results of the Multiple Regression Analysis Regarding the Prediction of the Students' Performance in the Logic Lesson

	R^2	R^2 Conversion	B	Standard Error	β	T	p
TOLT	.370	.370	.734	.346	.382	2.118	.045
Mathematics Performance	.451	.082	.067	.043	.298	1.577	.128
Letter Series	.481	.030	.158	.426	.156	.370	.715
Shape Recognition	.484	.003	.200	.424	.364	.472	.641
Volume Surface Expansion	.485	.001	.154	.375	.228	.411	.685
General Skills	.487	.002	-.122	.382	-.440	-.319	.753
R: 0.698	R^2: 0.487						
F: 3.643	p: 0.11						

In order to specify the key predictors of the 9th year high school students' performance in the logic unit stepwise multiple regression analysis was used. As it appears from Table 4 positive correlations were detected between the students'

performance in the logic unit and their logical reasoning skills, general skills and overall mathematics performance. (R: 0.698, F: 3.643, $p<0.05$). Subsequently, the six independent variables mentioned above explain about 49% of the total variance of the performance in the logic unit. The only variable that predicts the students' performance in the logic unit significantly is found to be the logical reasoning skill. When the T-test results regarding the significance levels of the regression coefficients are examined, they show that the logical reasoning skill is a significant predictor of the performance in the logic lesson. ($T=2, 12$; $p<.05$). In the graphic displayed below, the dispersion diagram and the regression line for the performance in the logic lesson and the logical reasoning skills are presented.

TOLT alone explains 37% of the performance in the logic lesson. It's clear from Figure 1 that there is a linear relation between the performance in the logic lesson and TOLT and that the dots representing the values of the subjects regarding the two variables are accumulated around the line. The regression equation for predicting the students' performance in the logic lesson according to the results of the regression analysis is:

PLU[3]
= 2,099+0,734 LRS[4]+0,067 Mathematics+0,158 LS[5]+0,200 SR[6]+0,154 VSE[7]-0,122 GS[8]

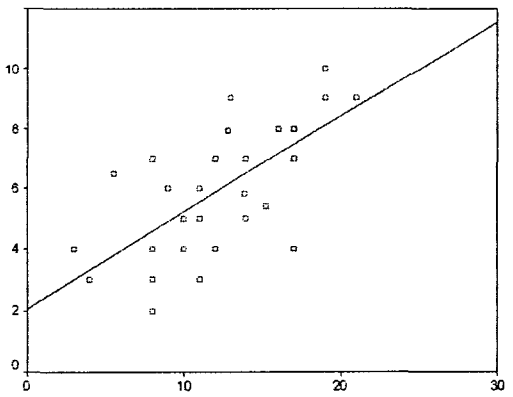

Figure 1. The Scatter Pilot Dispersion Diagram and the Regression Line for the Performance in the Logic Lesson and Logical Reasoning Skills.

[3] PLU: Performance in the Logic Unit
[4] LRS: Logical Reasoning Skills
[5] LS: Letter Series
[6] SR: Shape Recognition
[7] VSE: Volume Surface Expansion
[8] GS: General Skills

4. DISCUSSION

A positive correlation is detected between the students' performance in the logic lesson and their logical reasoning skills. The variance that can be explained by the logical reasoning skill is found to be 0.37 and TOLT is observed as a significant predictor of the performance in the logic lesson. This result supports the predictions which claim that there would be a high correlation between the logic lesson and the logical reasoning skill (Valanides, 1996; McCarthy-Tucker, 1998a; Braxton, 1993). It suggests that learning logic in high school helps to improve the "logical reasoning skills" which is one of the general aims of the mathematics education. The finding also corroborates the results of previous research which states that in order to improve the students' reasoning skills logic should be taught (Sharlow, 1981; Martin, 1983).

Mathematics is a compulsory almost in every high school curricula in Europe with varying degrees of content coverage and difficulty levels depending on the type of the emphasis. In Turkey, mathematics is compulsory in high school programs that follow social science based programs. Only a few of the students who are taught mathematics at high school specialize in mathematics or in the related fields of engineering or economics in their future lives. Major aims of mathematics education in most of the developed countries include equipping the students with the intellectual (*i.e.*, logical reasoning) skills, the ability to evaluate the circumstances in coming over everyday problems, intellectual independence and productivity and improving intuitive thinking and affective qualities (*i.e.*, being mentally open to different views and opinions and improving artistic values) (NCTM, 1998; DES/WO, 1982). These skills are primarily needed for average citizen to have a dignified and productive life after school. Given that the real purpose of mathematics education is to prepare the students for the real life (Mina, 2004), longitudinal studies are required in order to understand to what extent mathematics education programs are able to realize such aims. In the current study we tried to find out to what extent the teaching of logic, as applied in Turkey, contributes to the two of the skills (logical reasoning and general skills) the students will be using in their lives after they finish school.

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