# A Study On Prospective Science Teachers' Knowledge And Achievement Levels In Mathematical Logic In Electricity-Related Subjects

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**ABSTRACT**

*The purpose of this case study is to reveal prospective science teachers' knowledge and achievement levels in electricity-related subjects. The data for the study were collected from 44 prospective teachers using three measurement tools. The data were then analyzed using software developed for the Probability and Possibility Calculation Statistics for Data Variables method, developed by Yılmaz (2011). It was concluded that prospective science teachers' achievement levels in mathematical logic in electricity-related subjects are influenced by their achievement levels in physics and basic mathematical procedures, as well as their knowledge levels. However, it was observed that the main influence on their achievement level in mathematical logic is the logical structure of knowledge, and not the knowledge level in the variables "given-asked" and "operations." Based on the findings of this study, it is recommended that both the methods of teaching knowledge and teaching the logical structure of knowledge be incorporated into the educational-instructional process. The study emphasizes that it would be optimistic to expect that individuals who learn without an awareness of the logical structure of knowledge will reach their potential.*

**Keywords:** Factors in Achievement; Mathematical Logic; Prospective Science Teachers' Knowledge and Achievement Levels; Variables in Achievement

## INTRODUCTION

Students studying science teaching at universities are taught physics, including electricity-related subjects and, therefore, the laws of physics. As a result, the logical structure of electricity-related subjects is "mathematical logic," which constitutes the logical structure of science.

George Boole found that, by adequately representing logic, it became a branch of algebra in a precise sense: all known results in logic (and some unknown) could be obtained by the use of standard mathematical techniques. Two facts were crucial to Boole's discovery: (i) the change from a philosophical view of logic as an enormous complex structure of syllogisms and conditional statements to a view of it as (possibly) fitting the general scheme for any branch of algebra; (ii) the successful application of the method of separation of symbols (MSS) to logic, which meant that a subset of the properties of the operations on numbers held for logic as well. These two facts made it possible to use the powerful tools of mathematics on this new domain of Logic (Ledesma et al., 1997).

Frege also wished to make reasoning about human affairs more rigorous by applying logic. Indeed, Leibniz was explicit about his goal of replacing argument with calculation. However, expressing knowledge and reasoning about the commonsense world in terms of mathematical logic has proven difficult and requires extensions to basic logic concepts. These extensions are only beginning to develop (McCarthy, 1988).

When some logicians began to shake of the Aristotelian and scholastic chain of formal reasoning in the 19th century, none could have imagined that logic would become one of the fastest growing fields of mathematics in the following century, attracting more researchers than there were for the entire field of mathematics in the 19th century in the Western hemisphere. Formal logic would also become one of the most important theoretical bases for what, at the time, were known as calculating machines (Wagner-Döbler, 1997). However, interest in mathematical logic grew slowly, before growing exponentially during the 1940s and 1950s in terms of the number of participators and papers (Wagner-Döbler & Berg, 1993).

Whatever the choice of symbols, all types of mathematical logic share two ideas. First, the strings of symbols considered to be formulae of the logic must be mathematically definite. Second, inferences of new formulae derived from existing formulae must be allowed and mathematically definite. These ideas enable computer programs to decide what combinations of symbols are sentences and what inferences are allowed in a particular logical language (McCarthy, 1988). The term "mathematical logic" is understood in a broad sense. In this sense, it, like Gallia in Caesarian times, is divided into three parts: 1) mathematical logic in the strict sense, i.e., the theory of formalized languages, including deduction theory; 2) the foundations of mathematics; and 3) the theory of algorithms (Uspensky, 1992).

The history of modern logic is included within the history of mathematics or, more generally, symbolic logic. Modern logic is also called "new logic," "mathematical logic," or "symbolic logic." In fact, it is mathematicians who founded modern logic. The pioneer of this logic is George Boole. The ideas presented by Boole are related to the algebraic expression of the laws of thought. In addition to the ideas presented by Boole, Gottlob Frege, Hermann Rudolf Lotze, and Ernst Schröder also stated similar opinions on the "algebraic expression of the logic" (Peckhaus, 1999).

Although logic and mathematics started approaching each other with Newton's and Leibnitz's differential calculus and integral calculus, it was Boole and Frege who combined the two. Boole and Frege attempted to provide a final and clear form for formal deduction, which in turn resulted in mathematics and logic becoming closer as disciplines. Boole developed a symbolic system for Aristotle's rules of deduction. Even though Aristotle had articulated his rules of deduction in a clear way, they were expressed in natural language (verbal). Boole managed to develop a symbolic system by extending Aristotle's rules beyond this natural language expression. Frege, in turn, improved on Boole's "symbolic system for rules of deduction," and came up with "predicate calculus (open-ended propositions)," laying the foundations for mathematical logic (Ozenli, 1999, s: R1; Heijenoort, 1970, pp: 1–2; Corcoran, 2003). Currently, this calculus constitutes a significant part of the logical basis of the whole of mathematics (Ozenli, 1999). Mathematical logic is not a formulated abstract logic. Instead, it expresses content using symbols in a more definitive and decisive way (Gözkan, 2008, p: 20).

Mathematical logic has a wide range of meanings, which can be grouped into three stages. The first stage refers to a language that includes making deductions during the process of developing theories. The second stage refers to the foundations of mathematics. The third stage refers to algorithm theories (Uspensky, 1992). These studies not only contribute to the development of mathematical logic, but also successfully prove to be areas in which it can be applied and practiced.

There are two opinions on selecting symbols for applications of mathematical logic. According to the first opinion, logical formulations should be taken into account and mathematically defined using a series of symbols. The second opinion stipulates that deducing new formulae from existing formulae should be mathematically defined. In both cases, symbol combinations are sentences; they allow for deductions in similar logical languages, as well as for writing computer software (McCarthy, 1988). A successful use of mathematical logic should include propositions presented through mathematical symbols. It is essential that these symbols be universal and can be used for identifying other laws (Ledesma et al., 1997).

Scientific theory is an "interpreted axiomatic system." It refers to the entire body of logical terms, such as →, V, ↔, Λ, Э, etc., as well as the theoretical and observational terms from which the concepts and theories required by a scientific discipline are derived through descriptions and deductions (Ozenli, 1994, pp: 35–38). Mathematical logic constitutes the logical structure of science in an adequate manner (Ryall, 1958, p: 1; Gözkan, 2008, pp: 180–185; Heijenoort, 1970, pp: 1–2).

The purpose of this study is to reveal prospective teachers' knowledge and achievement levels in mathematical logic within electricity-related subjects. The study attaches importance to the logical structure of knowledge, as well as the methods in an educational-instructional process. A further objective is to determine the effects that variables and prospective teachers' knowledge of procedures have on their achievement level. In order to teach students to become "learning individuals," one of the fundamental objectives of education is to teach the logical structure of any given subject. It would be optimistic to expect learning individuals to comprehend a subject without an awareness of its logical structure. The reason why knowledge and achievement levels in mathematical logic were chosen as the subject of this study is that the logical structure of "electricity-related subjects," which constitutes the knowledge subject of the study, is based on mathematical logic.

## METHODOLOGY

The data for the study were collected from a total of 44 first-grade prospective science teachers who took theoretical and experimental lessons in electricity-related subjects using case studies. The data were collected using three measurement tools. The first tool consisted of questions about the students' knowledge and achievement levels in mathematical logic. The second and third measurement tools contained questions on the procedures that the students used to provide answers to the questions in the first measurement tool.

The first measurement tool (MT1) contained five semi-structured open-ended questions about the students' knowledge and achievement levels in mathematical logic. In the first two questions, the prospective science teachers were presented with a mathematical logical proposition concerning the electricity-related subjects that they had covered in theoretical and experimental lessons. Afterwards, they were asked to comment on whether the formulae for electricity-related subjects could prove the logical propositions. In the next two questions, they were provided with another mathematical logical proposition regarding the same subjects and asked to comment on whether the formulae for electricity subjects that were given in the items could prove the mathematical logical propositions. In this way, the first four questions, in which the students were asked to comment on whether 14 formulae for electricity-related subjects could prove the given propositions, revealed the students' knowledge and achievement levels in the first stages of the logical structures of the formulae for physics. The Probability and Possibility Calculation Statistics for Data Variables method (or Veri Değişkenlerinin Olasılık ve Ihtimal Hesaplama Istatistiği, or VDOIHI), developed by Yılmaz (2011), was used to determine the students' knowledge and achievement levels.

Two variables were specified for this measurement tool, namely "asked-given" and "operation." The prospective science teachers' knowledge and achievement levels were revealed through the operations specified in the VDOIHI method (Yılmaz, 2011; Yılmaz and Yalçın, 2011) considering the collective effects of the two variables on the result. In this method, the knowledge level is revealed through the P score (or APS score). The achievement level is determined using the ASS score. The APS score is the total number of the smallest meaningful elements in the variable(s); that is, the total number of the "pieces of true knowledge" that students have concerning any given subject. Therefore, the APS score reveals the students' knowledge level. The ASS score is related to the answers students provide to the questions and therefore reveals their achievement level.

In the last question in the MT1 tool, students were asked to provide a mathematical logical proposition, similar to those presented in the first four questions regarding the electricity-related subjects. Afterwards, they were asked to write down the formulae for electricity that could prove or disprove their own proposition. Furthermore, they were asked to justify why the formulae they had written could prove or disprove their proposition. In this way, the students' knowledge and achievement levels in mathematical logic about electricity-related subjects were revealed. The first four questions included in the MT1 tool determined the students' knowledge and achievement levels by asking them to prove whether the fourteen different formulae could fit the given proposition. In contrast, the fifth question revealed students' knowledge and achievement levels across all electricity-related subjects.

The second measurement tool (MT2) was comprised of 21 semi-structured questions. These questions were based on the procedures for the electricity-related subjects in the questions in MT1. Each question presented the formula/equation that physics students were required to use to answer the questions in MT1. In this measurement tool, students were asked whether they knew a given formula/equation. They were asked to write the name of the formula/equation, as well as the name of the law or subject to which the formula/equation was related. These three pieces of knowledge were assigned "1 point" in each question. In this measurement tool, 13 questions contained the formulae the students were required to use to answer the first question in MT1. Therefore, a student was expected to get 39 points in MT2 for the first question in MT1. The students' scores were calculated and divided by 39. In this way, their achievement level in the procedures for the first question was determined by percentage. For the other four questions in MT1, students were presented with a total of 21 questions aimed at revealing whether they knew the procedures that had an influence on their knowledge and achievement levels in mathematical logic about electricity-related subjects. The remaining questions in MT2 were broken down as follows: 18 for the second question in MT1; 18 for the third question in MT1; 16 questions for the fourth question in MT1; and 21 questions on the procedures for the fifth question in MT1. The same grading system was used for each collection of questions in MT2 to reveal the students' achievement level by percentage.

The third measurement tool (MT3) contained 50 questions on the students' achievement level in the procedures for basic mathematics. Each question presented a basic mathematical equation that should be known. One part of each equation was purposely left blank and students were expected to complete it. Each correctly completed equation was assigned 1 point. The students points were divided by 50 (the maximum score that could be taken from the questions). This revealed the students' achievement levels in procedures for basic mathematics that they were required to use to provide answers to the questions in MT1.

The formulae/equations in the questions included in MT2 and MT3 reflected the procedures for "the mathematical logical structure of electricity-related subjects" in MT1. These procedures were also the factors in the students' knowledge and achievement levels. Other factors in their knowledge and achievement levels were the variables and the N, NP, IP or ANS, NAPS, IS and SS scores in the variables. The students' knowledge and achievement levels in MT1, MT2, and MT3 were determined using the VDOIHI software developed as part of this study.

## FINDINGS AND CONCLUSION

Table 1 presents the results of MT1 (the prospective science teachers' knowledge and achievement levels in mathematical logic about electricity-related subjects), MT2 (the extent to which the students knew the procedures for electricity that influenced their knowledge and achievement levels), and MT3 (the extent to which students know the procedures for basic mathematics that influenced their knowledge and achievement levels.

As shown in Table 1, the effects of the variables measured by the "ASS" results are as follows.

It is thought that the students' knowledge in the positive stages of the variable "given-asked" for question 1 has an effect of 44% on the ASS value. Students' unconnected knowledge cannot affect the ASS value (0%). Their negative knowledge is thought to affect the ASS value negatively by 1%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 55% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" for question 1 has an effect of 27% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 27%. Their negative knowledge is thought to affect the ASS value negatively by 9%. Their positive knowledge in the negative stages might have an influence of 4% on the ASS value. It is thought that a zero score has an effect of 60% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "variables" for question 1 has an effect of 36% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 13%. Their negative knowledge is thought to affect the ASS value negatively by 5%. Their positive knowledge in the negative stages might have an influence of 2% on the ASS value. It is thought that a zero score has an effect of 57% on the ASS value. Their knowledge about MT2 is thought to have an effect of 55% on the ASS value, whereas their knowledge about MT3 is believed to have an effect of 77% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "given-asked" for question 2 has an effect of 19% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 6%. Their negative knowledge is thought to affect the ASS value negatively by 8%. Their positive knowledge in the negative stages might have an influence of 5% on the ASS value. It is thought that a zero score has an effect of 67% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" for question 2 has an effect of 15% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 33%. Their negative knowledge is thought to affect the ASS value negatively by 13%. Their positive knowledge in the negative stages might have an influence of 6% on the ASS value. It is thought that a zero score has an effect of 67% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "variables" for question 2 has an effect of 17% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 19%. Their negative knowledge is thought to affect the ASS value negatively by 10%. Their positive knowledge in the negative stages might have an influence of 5% on the ASS value. It is thought that a zero score has an effect of 67% on the ASS value. Their knowledge about MT2 is thought to have an effect of 56% on the ASS value, whereas their knowledge about MT3 is believed to have an effect of 77% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "given-asked" for question 3 has an effect of 2% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 3%. Their negative knowledge cannot have an influence on the ASS value (0%). Similarly, their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 98% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" for question 3 has an effect of 22% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 19%. Their negative knowledge is thought to affect the ASS value negatively by 5%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 72% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "variables" for question 3 has an effect of 12% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 11%. Their negative knowledge is thought to affect the ASS value negatively by 3%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 85% on the ASS value. Their knowledge about MT2 is thought to have an effect of 54% on the ASS value, whereas their knowledge about MT3 is believed to have an effect of 77% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "given-asked" for question 4 has an effect of 2% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 1%. Their negative knowledge cannot have an influence on the ASS value (0%). Similarly, their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 98% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" for question 4 has an effect of 11% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 9%. Their negative knowledge is thought to affect the ASS value negatively by 6%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 82% on the ASS value.

**Table 1: Prospective Science Teachers' Knowledge and Achievement Levels in Mathematical Knowledge (MT1, MT2, and MT3)**

| | 1. Question | | | 2. Question | | | 3. Question | | | 4. Question | | | 5. Question | | | Sum of Questions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MT1 (Points/ Variable)** | **Given-Asked** | **Operation** | **Variables** | **Given-Asked** | **Operation** | **Variables** | **Given-Asked** | **Operation** | **Variables** | **Given-Asked** | **Operation** | **Variables** | **Given-Asked** | **Operation** | **Variables** | **Given-Asked** | **Operations** | **Variables** |
| **P** | 3,09 | 3,82 | 6,91 | 1,30 | 1,68 | 2,98 | 0,07 | 2,18 | 2,25 | 0,16 | 1,20 | 1,36 | 0,30 | 0,39 | 0,69 | 4,91 | 9,27 | 14.18 |
| **BGS** | 7,00 | 14,00 | 21,00 | 7,00 | 11,00 | 18,00 | 3,00 | 10,00 | 13,00 | 7,00 | 11,00 | 18,00 | 1,68 | 1,68 | 3,36 | 25,00 | 47,00 | 72,00 |
| **İS** | 0,00 | 0,27 | 0,13 | 0,06 | 0,33 | 0,19 | 0,03 | 0,19 | 0,11 | 0,01 | 0,09 | 0,05 | 0,02 | 0,10 | 0,06 | 0,02 | 0,19 | 0,11 |
| **APS** | 0,44 | 0,27 | 0,36 | 0,19 | 0,15 | 0,17 | 0,02 | 0,22 | 0,12 | 0,02 | 0,11 | 0,07 | 0,10 | 0,13 | 0,11 | 0,15 | 0,18 | 0,16 |
| **ANS** | –0,01 | –0,09 | –0,05 | –0,08 | –0,13 | 0,10 | 0,00 | –0,05 | –0,03 | 0,00 | –0,06 | –0,03 | 0,00 | –0,01 | –0,01 | –0,02 | –0,07 | –0,04 |
| **NAPS** | 0,00 | 0,04 | 0,02 | 0,05 | 0,06 | 0,05 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,01 | 0,02 | 0,02 |
| **SS** | 0,55 | 0,60 | 0,57 | 0,67 | 0,67 | 0,67 | 0,98 | 0,72 | 0,85 | 0,98 | 0,82 | 0,90 | 0,90 | 0,87 | 0,88 | 0,81 | 0,74 | 0,77 |
| **MT2** | | | 0,55 | | | 0,56 | | | 0,54 | | | 0,51 | | | 0,55 | | | 0,54 |
| **MT3** | | | 0,77 | | | 0,77 | | | 0,77 | | | 0,77 | | | 0,77 | | | 0,77 |
| **ASS** | | | 0,37 | | | 0,25 | | | 0,45 | | | 0,27 | | | 0,13 | | | 0,30 |

It is thought that the students' knowledge in the positive stages of the variable "variables" for question 4 has an effect of 7% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 5%. Their negative knowledge is thought to affect the ASS value negatively by 3%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 90% on the ASS value. Their knowledge about MT2 is thought to have an effect of 51% on the ASS value, whereas their knowledge about MT3 is believed to have an effect of 77% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "given-asked" for question 5 has an effect of 10% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 2%. Their negative knowledge cannot have an influence on the ASS value (0%). Similarly, their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 90% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" for question 5 has an effect of 13% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 10%. Their negative knowledge is thought to affect the ASS value negatively by 1%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 87% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "variables" for question 5 has an effect of 11% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 6%. Their negative knowledge is thought to affect the ASS value negatively by 1%. Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that a zero score has an effect of 88% on the ASS value. Their knowledge about MT2 is thought to have an effect of 55% on the ASS value, whereas their knowledge about MT3 is believed to have an effect of 77% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "given-asked" across all questions has an effect of 15% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 2%. Their negative knowledge is thought to affect the ASS value negatively by 2%. Their positive knowledge in the negative stages might have an influence of 1% on the ASS value. It is thought that a zero score has an effect of 81% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" across all questions has an effect of 18% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 19%. Their negative knowledge is thought to affect the ASS value negatively by 7%. Their positive knowledge in the negative stages might have an influence of 2% on the ASS value. It is thought that a zero score has an effect of 74% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "variables" across all questions has an effect of 16% on the ASS value. Students' unconnected knowledge is thought to affect the ASS value negatively by 11%. Their negative knowledge is thought to affect the ASS value negatively by 4%. Their positive knowledge in the negative stages might have an influence of 2% on the ASS value. It is thought that a zero score has an effect of 77% on the ASS value. Their knowledge about MT2 is thought to have an effect of 54% on the ASS value, whereas their knowledge about MT3 is believed to have an effect of 77% on the ASS value.

## DISCUSSION AND IMPLICATIONS

In the first four questions in MT1, the prospective science teachers' achievement levels in mathematical logic ranged between 25% and 45%, whereas their achievement level in the procedures for physics they needed to answer these questions varied from 51% to 56% (Table 1). This finding suggests that prospective teachers do not know the procedures for electricity-related subjects (memorized knowledge) properly. It also shows that their achievement level in the procedures supports their achievement level in mathematical logic, but not to a satisfactory extent. Furthermore, the students' achievement level in the procedures for mathematics, measured using MT3, was 77%, the highest value of all the knowledge and achievement levels revealed by the study. This finding suggests that the students' achievement level in mathematical logic (25%–45%) is only slightly correlated with their achievement level in the procedures. In addition, it shows that there is a very slight correlation between the students' awareness of the logical structure of the electricity-related subjects and their knowledge of the procedures. These findings are supported by the fact that the students had an achievement level of 13% in the fifth question of MT1, in which they were asked to produce a mathematical logical proposition and to write down examples that could prove or disprove it. In other words, they were unable to establish a correlation between the proposition concerning the logical structure of the subject and the examples that could prove or disprove it, although their achievement level in the procedures varied between 55% and 77%. Based on these findings, it can be argued that the students have a higher achievement level when providing physics formulae for a given proposition than they do when producing a proposition.

The students' knowledge level in the first four questions of MT1 (the APS score) was lower than their achievement level in the same questions (Table 1). In fact, this is a result of their achievement level in the procedures, which is associated with their overall achievement level. Furthermore, the students' knowledge level in the fifth question was lower than those in the first four questions, which suggests that they do not know the logical structure of electricity-related subjects.

The last column of Table 1 presents the students' achievement level for the variables, namely the sum of the variables and procedures. These figures reveal that the students' achievement level for procedures (MT2 for their achievement level in the procedures for physics, and MT3 for their achievement level in the procedures for basic mathematics) was higher than their achievement level in the first measurement tool, which suggests that the study is reliable and that a correlation can be established between their achievement level in the procedures for electricity-related subjects and their achievement level in logic. It can be concluded that the knowledge level in the procedures for physics is more important/influential in such a correlation than the knowledge level in the procedures for mathematics.

The prospective teachers had a knowledge level (the APS score) of 16% in the five questions on electricity-related subjects included in MT1. This knowledge level was influenced by the variables "given-asked" and "operations" by 15% and 18%, respectively. Their knowledge levels in these two variables were low and similar to each other, which is the reason why they had a low achievement level (30%). These findings suggest that the achievement level is influenced by the knowledge level in the variables. Even so, it can be argued that the main influence on the achievement level is not the variables "given-asked" and "operations." Based on the findings of the study, it can be concluded that the main influence is related to the logical structure of knowledge. The uncorrelated score, IS (19%), specified for the variable "operations" for the five question included in MT1 was higher than the APS score (18%), the knowledge level for the same variable. This finding suggests that the prospective teachers made an effort to improve their achievement levels (ASS = 30%). Nevertheless, they attempted to compensate for their lack of knowledge with misinformation, for their knowledge level was insufficient and they could not establish correlations concerning the subject. Based on these findings, it can be argued that prospective teachers' knowledge levels in mathematical logic does not represent their achievement level, which is also supported by the findings of the studies conducted by Yılmaz (2011) and Yılmaz and Yalçın (2012a, 2012b) on Newton's laws of motion. These studies found that prospective teachers' knowledge levels do not represent their achievement level. These results are not surprising, since the logical structures of knowledge are not included in the educational-instructional process, and students can only learn the logical structure of a subject through their own personal efforts. Learning individuals cannot be expected to comprehend concepts without an awareness of the logical structure on which the knowledge is based. Therefore, it is essential that both the methods of teaching knowledge and the logical structure of knowledge should be incorporated into the educational-instructional process. It would be optimistic to expect the knowledge levels of individuals who learn without an awareness of the logical structure of knowledge to represent their achievement levels.

## AUTHOR INFORMATION

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**NOTES**