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# Relationship of the cognitive functions of prospective science teachers and their knowledge, knowledge levels, success and success levels

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**This study reveals the transformation of prospective science teachers into knowledgeable individuals through classical, combination, and information theories. It distinguishes between knowledge and success, and between knowledge levels and success levels calculated each through three theories. The relation between the knowledge of prospective teachers and their cognitive functions is defined through the results gained from three theories, and a case study that collected data through problem solving techniques in the procedural knowledge of electricity. The results reveal that prospective teachers have problems with such knowledge, which may explain why cognitive automatism is not used. Since processes of understanding are not used in cognitive automatism, it appears that prospective teachers are individuals that may differ in terms of their learning but do not use their cognitive functions. The study suggests that if the knowledge levels of independent variables are increased, cognitive functions may develop.**

**Key words:** Classical calculation, cognitive automatism, cognitive functions, combination calculation, information calculation.

## INTRODUCTION

It is important to separate knowledge and a knowledge level, and success and a success level, in developing cognitive functions. Analysis of individual knowledge can be achieved through this separation. By using inference, the thinking and decision-making components of cognitive function procedures, individual knowledge can be developed. Success is based on the existence of procedural knowledge in terms of the structure of a cognitive domain. However, success is not merely based on the procedural knowledge of our cognitive domain.

External factors also affect success. Some studies show that teacher professional development (Franke et al., 2001; Roth et al., 2011; Saxe et al., 2001); teacher content knowledge (Heller et al., 2012; Hill et al., 2005; Kanter and Konstantopoulos, 2010); teacher pedagogical content knowledge (Heller et al., 2012); and teacher knowledge, skills, and practice (Cohen, 1990; Wilson and Berne, 1999) also influence success.

Although, researchers agree on this matter, there is a need for strong and clear evidence teacher professional

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development on specific effects. For instance, there is limited convincing proof of the influence of teacher professional development on success (Wayne et al., 2008).

For stronger evidence, knowledge, the knowledge level, success, and the success level must be precisely defined. In this way, strong proofs about the relations between dependent-independent variables can be obtained, which will lead to the development of cognitive functions. Knowledge can be analyzed by the knowledge level and symbolic level; however, when an individual acquires the data consisting of knowledge using his cognitive functions, do the knowledge level and symbolic level have effects? What is the meaning of the knowledge level and symbolic level during education-learning processes? In order to answer these questions, information theories should be used in the assessment and evaluation because the symbolic level involves the study subject of information theories.

Developments in neuroscience have brought innovations that help us understand the development of cognitive functions. Moreover, neuroscience also puts forward data about how educators should teach students. These data are more about the definitions of cognitive functions than effective learning (Oliver, 2011). The operation of memory is defined by the interaction of many cognitive functions, and yet it is not clearly defined by cognitive functions (Bledowski et al., 2010).

In creative thinking, the roles of various cognitive functions are important for learning. How the roles of a particular cognitive function can be included in problem solving is discussed in the literature (Gregory et al., 2013). Can knowledge, the knowledge level, success, and the success level be used in the development of cognitive functions? How each of these concepts can be developed by cognitive functions? Answering these questions requires not general descriptions but specific, specialized definitions.

The objective of this study is to reveal the knowledge of prospective science teachers that is the product of their cognitive functions, how this knowledge can be enhanced, and how these teachers can be transformed into knowledgeable individuals. In this study, the relations between knowledge, success, the knowledge level, and the success level and cognitive functions will be determined and suggestions will be made in order enhance knowledge of these future science teachers.

## THEORY

### Conceptual theories

In science teaching, the logical foundations of cognitive functions can be developed. “Understanding” has critical importance in defining cognitive functions, knowledge and thinking. Understanding, one of the cognitive function processes, is defined by Özenli (1999) as a part of cybernetic and mathematical logic. He writes:

*In the flow of input information or data, the conceptualization of the integration of cognitive modules that seem relatively independent from one another in the high structured semantic web and, therefore, solving the interpreted code in semantic memory unit by transforming “procedural knowledge” into declarative knowledge! Only if this is possible, does “understanding” occurs. Otherwise, this process/these processes create a “before understanding” state in order to understand the subject and this continues until the understanding occurs. Such scientifically structured understandings will remain within the frame of mental functions and the contemporary scientific-technologic structure (p. A7).*

The definition of understanding first requires dividing data into its cognitive modules, and then integrating them. This approach ensures measurable definitions of cognitive functions, knowledge, and thinking. The knowledge that is produced as a result of the understanding processes is declarative knowledge for the individual that produces it and data for other individuals.

Data, visual and tactual imprints are not the sole components of “knowledge.” “Knowledge” also includes inference, thinking, and decision-making components. Creating the semantic coordination among subunits of data using logic rules, mental mutation, and recombination produces “thinking” (Özenli, 1999). In order to use cognitive functions in thinking, data should be divided into its variables; these variables should be divided into their cognitive modules; and the possible states of each cognitive module should be determined. The possible states of cognitive modules will be called sub units. With the semantic coordination of the cognitive modules of variables, logic rules, and mental mutations, combinations among sub units will be constituted, and the cognitive modules of sub units decided by recombination will be knowledge. Such knowledge through cognitive functions is a product of thinking. This definition of knowledge can be called a “possibility-probability knowledge theory.”

If an individual can solve the problems that she confronts in the frame of the things learned during her formal learning process and can apply what she has learned, she is not knowledgeable according to the definition of knowledge aforementioned. In this case, individuals can be compared with other individuals based on “better or less educated” because education compulsorily provides what an individual should *already* know; therefore just because she knows what she should already know does not make that individual knowledgeable (Özenli, 1999). An individual’s application of what she has learned during her formal education process can be a result of cognitive automatism. For cognitive functions, cognitive automatism is necessary.

Understanding and cognitive automatism associates by Özenli (1999) are;

*The logical foundations of the cognitive functions of human beings represent the "operational concept of wisdom." There is no doubt that for the structure of this cognitive domain, the existence of a remarkable amount of procedural knowledge should be accepted. This information automatically emerges through books and publications that include graphic-pictorial, statistical, and semantic features and by reconciling cognitive actions. Subsequently, this cognitive automatism is always ready for action. When the circumstances that are necessary for them emerge (for instance, the emergence of a familiar concept or a word in a related field) can result independent images, intentions that are not realized by mind or conscious. Since this automatic processing is performed by sub units (or modules), it does not influence the operation of parallel sub units. Automatism gives us a holistic spectrum of possible interpretations or explanations of a circumstance and the related behaviors and is not yet related to understanding. However, when this broad spectrum created by cognitive modules, when related, can be degraded into a single understanding that includes maximum data with minimum terms, "understanding process" occurs and this defines the difference between cognitive automatism and understanding process (pp: A7-A8).*

In order to increase the knowledge of prospective teachers by transforming cognitive automatism into understanding, defining knowledge, the knowledge level, success, and the success level are important, since there might be differences in the measurement tools, objectives, and techniques of education. What really matters are determination through assessment-evaluation tools of whether feedback (knowledge) is sufficient and productive. This shows us where and how we are deficient. At the same time, right proofs lead us to solve problems.

## Mathematics-statistics theories

Cognitive function operations can be made by data or information cognitive modules and sub units. These modules and sub units represent knowledge and success. In his study, Yılmaz (2011) recommends defining and scoring cognitive modules of data or information as the smallest significant parts (akp). If data are used to produce knowledge, the $akp_B$ here represents knowledge. The $akp_b$ of result data represents success. Digitizing by scoring data and information enables us to assess mathematically understanding and cognitive function operations, and therefore analyze with "objective logical simplicity."

In this study, in order to determine knowledge, success, and the knowledge and success levels, the scoring system of akps of Yılmaz (2011) study will be used. After scoring, operations can be carried out by lowering them into two possibility cases (probability ½) in information and probability theories on "akp" in assessment-evaluation.

In this study, operations will be made for equal probability (1/2) cases and positive scores. In classical calculations, the definition and formulas of VDOİHİ combined the staging technique given below; it will be used. The definition and formulas of the VDOİHİ combined staging technique that will be used in the calculations of information and probability (combination) are given as follows:

## Classical calculation

### *Classical knowledge and success calculation*

VDOİHİ is a statistical technique that is based on comparing akps of theoretical and experimental data. Theoretical data are divided into its $akp_B$. After this division, each $akp_B$ is given a +1 score (GP). When these scores are added, the total $akp_B$ of the data (BGS) score is obtained. BGS score represents the cognitive modules that data and information includes, and the right knowledge.

$$BGS = \sum_{i=1}^{n} GP_i \qquad (1)$$

GP = +1 and n is the total akp number of data

Experimental data are divided into its $akp_B$ and compared to the $akp_B$ of theoretical data. If each $akp_B$ of experimental and theoretical data is semantically the same or similar, a +1 score (+PS) is added to the $akp_B$ of experimental data. These +PS scores are added, and the $akp_B$ score of experimental data (P) is obtained. The P point represents the cognitive modules and right knowledge in the data.

$$P = \sum_{i=1}^{r} +PS_i \qquad (2)$$

+PS= +1 and r; total number of $akp_B$ in experimental data ($r \leq n$)

Like knowledge calculations $akp_b$, in calculations of success, the result data are scored. Each $akp_b$ is given a +1 score (Cb). With the sum of $akp_b$ results that should be CB is calculated with the sum of existing $akp_b$ scores, GS is calculated. CB scores represent the expected success, whereas GS scores represent the existing success or $akp_b$ of CB, and GS represents the cognitive modules and success.

$$CB = \sum_{i=1}^{n} Cb_i \quad (3)$$

Cb =+1 and n is the total $akp_b$ number of the result data

$$GS= \sum_{i=1}^{r} Cb_i \quad (4)$$

r; is the total $akp_b$ number in the result of the experimental data (r ≤ n)

## *Classical level calculation*

In VDOİHİ statistics, the division of the sum of same type scores (positive, negative, positive in negative, zero, and irrelevant) of experimental data by the sum of same type theoretical data is called “level.” In the assessment and evaluation, the equivalence of levels in the system is mostly used. In this case, the level score is multiplied by the system score (100, 10, 5, and 4 point grading system and so on), and the system equivalence of level is calculated.

Level =existing scores/scores that should be (5)

In the calculations of the P and BGS scores, the possibility of the circumstance is not included. Calculations in which the possibility circumstances are not included will be called “classical” calculations. As both P and BGS scores represent “knowledge,” dividing the P score by the BGS score (APS) represents “the level of knowledge.” Therefore, the APS score will be called the “classical knowledge level.” If the scoring and calculations are the same, the obtained score (ASS) represents the “success level.” Therefore, the ASS score will be called the “classical success level.”

Classical knowledge level = P/BGS = APS (6)

Classical success level = GS/CB= ASS (7)

This calculation system will be called the “classical level calculation.” This definition of the classical calculation and the details of the formulas are explained in the study of Yılmaz (2011) and Yılmaz and Yalçın (2011). These definition and formulas will be used in the calculations of combinations and information.

## *Assessment-evaluation relation*

If the evaluation is done for equal scoring (probability), the ASP score is multiplied by the system score to obtain the system equivalent of classical knowledge level. The classical success level, however, is calculated by multiplying the ASS by the system score. For instance in a 100 point grading system, if we want to obtain classical knowledge and success levels,

100 point grading system knowledge level = APS.100 (8)

100 point grading system success level = ASS.100 (9)

The classical calculation technique depends on comparing the expected akp and the akp “that should be the cognitive module.” Therefore, in classical calculation, the “sub unit” does not pay attention to the possible circumstances of the data. This technique provides proof about cognitive functions but it does not deliver sufficient evidence of whether knowledge is a product of the thought that is created by the understanding processes or a product of cognitive automatism. In other words, the solely classical technique does not provide enough proof about whether inference is a product of thinking or deciding. When possibility circumstances are included, adequate proof is obtained. In order to determine whether knowledge is a product of thinking and deciding, combination and/or information theories should be used in evaluation-assessment. This proof also helps determine the understanding process or cognitive automatism.

## *Combination calculation*

**Terminology:** Case (n), concerns the circumstances that include a possibility that should take place in data. Existing (chosen) cases will be called as “r.” In VDOİHİ statistics, the case is akp. For knowledge, the $akp_B$ that exists in the data (total score P), is equal to “r” (r = P). The expected $Akp_B$ (total score GS) equals “n” (n = BGS). For success, the $akp_B$ that exist in the data (total score GS) equals to “r” (r = GS). The expected $Akp_B$ (total score CB) equals “n” (n = CB). In this case, “case” is the $akp_B$ of the data, and it does not include the possibility circumstances of $akp_B$.

Possibility (Pos(m)), concerns the circumstances of a case. For instance, the circumstances of a coin are heads and tails, and its numerical value is Pos(m) = 2. In VDOİHİ statistics, akp can be given -1, 0, +1, and other scores, and these scores represent the circumstances of akp. Determining the possibility circumstances of a case is a product of thinking. Choosing (making the right choice) between the cases is related to “decision-making.” Inference is the sample determined by thinking and deciding (cluster created with P possibilities).

Probability (Pro(A)) is the rate of actualization. For a coin Pro(A)=1/2.

$$Pro(A)=M_A/M \quad (10)$$

$$M_A = \sum_{i=1}^{a} 1_i \quad and \quad a \leq M \tag{11}$$

Number of samples (M) is the number of possibility distributions of a case or sum of case combination.

$$M = m^n = \sum_{i=0}^{n} \binom{n}{i} = \sum_{i=0}^{n} n!/(i!\,(n-i)!) \tag{12}$$

***Assessment and evaluation relation:*** When the possibility circumstances of the akp of the data are determined (Pos(akp)), all cognitive modules and sub units that are necessary for cognitive function operations are determined (akp and Pos(akp)). Pos and Pro ensures all sub units of data to be included in the assessment-evaluation. Therefore, knowledge, thinking and cognitive functions are identified by pos and pro.

***Combination knowledge and success calculations:*** In combination calculations, Pos(akp) cases of akp are included in the calculations. To achieve this, the Pos(akp)s of each akp is defined. In this study, the akp is defined and calculated based on two possible (Pos(akp) = 2) and equal Pro(akp) = 1/2 circumstances. Knowledge and success are calculated for certainty, certainty situations, total certainty, and (non)deficient akp. In these calculations, combination formulas are used. The combination definitions and formulas that are employed for knowledge will also be used for success.

Combination and certainty situations ($BD_B^K$) of $akp_B$ are the samples of last $akp_B$ values of knowledge (samples created by Pos(akp)s). Score is calculated by the combination of "r" of the circumstance,

$$BD_B^K = \binom{n}{r} = n!/(r!(n-r)!) \tag{13}$$

Pro of certainty situation is

$$Pro(BD_B^K) = BD_B^K/M \tag{14}$$

Combination certainty ($B_B^K$) of $akp_B$ is the sample created by Pos(akp) until the last $akp_B$ of knowledge,

$$B_B^K = \sum_{i=0}^{r-1} \binom{n}{i} = \sum_{i=0}^{r-1} n!/(i!\,(n-i)!) \tag{15}$$

$$Pro(B_B^K) = B_B^K/M \tag{16}$$

Total combination certainty ($TB_B^K$) of $akp_B$ are the samples of certainty and certainty situations. The score is the sum of certainty and certainty situations,

$$TB_B^K = B_B^K + BD_B^K \tag{17}$$

$$Pro(TB_B^K) = TB_B^K/M \tag{18}$$

Deficient combinations ($E_B^K$) of $akp_B$ are the samples created by the Pos (akp)s of $akp_B$ that do not exist in the data and are calculated by extracting $TB_B^K$ from the total combinations of a case.

$$E_B^K = OG_B^K - TB_B^K \tag{19}$$

$$Pro(E_B^K) = E_B^K/M \tag{20}$$

$Akp_B$ combination that should be ($OG_B^K$) is the number of samples and calculated by the sum of combination.

$$OG_B^K = M = m^n = \sum_{i=0}^{n} \binom{n}{i} \tag{21}$$

$$Pro(OG_B^K) = OG_B^K/M = 1 \tag{22}$$

***Combination level calculations:*** As in in classical calculations, the level is calculated by the ratio of certainty and total combination. In this study, the sampling ratio of total certainty will be used in level calculations. As the akp represents knowledge and success, the ratio calculations for knowledge give the knowledge level, and the ratio calculations for success give the success level.

Combination knowledge level ($APS^K$) is the division of certainty scores in knowledge by $OG_B^K$. As this study only deals with the division of $TB_B^K$ by $OG_B^K$,

$$APS^K \equiv Pro(APS^K) = TB_B^K/OG_B^K \equiv TB_B^K/M \tag{23}$$

In this case , pro$(APS^K)$ equals to pro$(TB_B^K)$ . Combination success level ($ASS^K$)

In this study, the success level is the division of total certainty score in the success ($TB_b^K$) by the success combination that should be ($OG_b^K$),

$$TB_b^K = \sum_{i=0}^{r} \binom{n}{r} \tag{24}$$

$$Pro(TB_b^K) = TB_b^K/OG_b^K = TB_b^K/m^n \tag{25}$$

n, total $akp_b$ scores of theoretical result data (n = CB). r, total $akp_b$ scores of experimental result data (r=GS) and Pos(m)=2

$$ASS^K \equiv Pro(ASS^K) = TB_b^K / OG_b^K$$

In this case, $Pro(ASS^K)$ equals to $Pro(TB_b^K)$

***Relation of evaluation-assessment*:** As all possible sub units of data are included in combination calculations, the results reveal more proof about both cognitive functions and whether knowledge is a product of understanding process or cognitive automatism.

***Information calculations***: Operations are done by possibility circumstances of data (akp and Pos(akp)) in information calculations. Definitions made for knowledge, success and level in combination calculations will be used in H function calculations in information theories. Both calculations (combination and information) will be done for the m=2 circumstance of possibility. In this case, "entropy" or "information content" of data is calculated by,

$$H(x) = -\sum_{i=1}^{M} \boldsymbol{P}(\boldsymbol{i}) \log 2^{\boldsymbol{P}(\boldsymbol{i})} \quad (27)$$

Equation

$$P(i) = \frac{1}{M} \quad (28)$$

$$H(x) = -M_A \left(\frac{1}{M}\right) \log 2^{\left(\frac{1}{M}\right)} = -M_A \left(\frac{1}{M}\right) \log 2^{\left(2^{\frac{1}{n}}\right)} = \quad (29)$$

The unit of H(x) is "bit." The more bit (information content) means the more uncertainty of the circumstance.

***Information calculations for akp:*** Information definitions and formulas made for knowledge will be used for success, as well.

***$akp_B$ information certainty situation ($BD_B^E$):*** It is the information content of possibility distribution of $r^{th}$ circumstance or information content of combination of $r^{th}$ circumstance.

$$H(BD_B^E) = -(BD_B^K/M)\log 2^{(1/M)} = -\left(Pro(BD_B^K)\right)\log 2^{(2^{1/BGS})} = Pro(BD_B^K).BGS \quad (30)$$

***$akp_B$ information certainty ($B_B^E$):*** It is the information content of possibility distribution until $r^{th}$ circumstance or information content of sum of combinations until $r^{th}$ circumstance.

$$H(B_B^E) = Pro(B_B^K).BGS \quad (31)$$

***$akp_B$ total information certainty ($TB_B^E$)***

It is the information content of possibility distribution including the $r^{th}$ circumstance or information content of sum of combinations including the $r^{th}$ circumstance.

$$H(TB_B^E) = Pro(TB_B^K).BGS \quad (32)$$

***$akp_B$ deficient information ($E_B^E$)***

It is the information content of possible circumstances of akp that does not exist in the data.

$$H(E_B^E) = Pro(E_B^K).BGS \quad (33)$$

$akp_B$ Information that should be ( $OG_B^E$ ): It is the information content of cases (data).

$$H(OG_B^E) = Pro(OG_B^K).BGS = BGS \quad (34)$$

***Information level calculations***

Just like in classical and combination calculations level is calculated by the ratio of certainty and $H(OG_B^E)$.

***Information knowledge level ($APS^E$):*** Knowledge level is the division of certainty scores in knowledge by $H(OG_B^E)$.

As this study only deals with the division of $H(TB_B^E)$ by $H(OG_B^E)$,

$$APS^E = H(TB_B^E)/H(OG_B^E) = Pro(TB_B^K) \equiv TB_B^K/M = APS^K \quad (35)$$

In this case, the combination and information levels are equal to each other, and they will be represented as $APS^{K,E}$.

***Information success level ($ASS^E$):*** If the operations done in information knowledge level are done for success level, it is obtained that $ASS^E$ is equal to $ASS^K$ and therefore will be shown as $ASS^{K,E}$.

***Evaluation-assessment relation***

As each possible sub unit of data is included in the calculations, as in those of combination, the results both give sufficient proof about cognitive functions and about whether knowledge is a product of a thought of the understanding processes or cognitive automatism. It also characterizes the uncertainty of the data (the expected and actual). Entropy and energy calculations can be done by the “bit” value obtained from such evaluation-assessment. For instance, by using the joule value, the energy that has been spent and that should be spent by a biological bit can be calculated.

### *General evaluation-assessment relation*

By using akp and Pos(akp)s with the classical, combination, and information theories of the VDOİHİ technique, knowledge, success, and the knowledge success levels can be calculated. The combination and information *levels* are equal to each other. However, the combination and information, knowledge and success values are different from each other. Moreover, classical values are different from the combination and information values. Their meanings become different for evaluation-assessment. The aim of the valuation-assessment can determine which calculations should be used.

In the VDOİHİ technique, the variables of the data are determined by the aim of the evaluation-assessment. For instance, if evaluation-assessment is performed by problem solving techniques, the given-asked of problem solving, free-body diagrams, definitions, formulas, operations, and separation techniques are considered as variables. Operations are carried out separately based on these variables. It is important to determine the variables that affect thinking in order to state whether knowledge or the knowledge level occurs as a result of the understanding processes or cognitive automatism. Subsequently, the knowledge level can be determined by taking all the sub units of these variables into consideration. After all, these detections are complete; by comparing the knowledge and success levels of variables, it is possible to determine if knowledge is a product of thinking. If a statistical relation is built between knowledge and success levels, it can be stated that knowledge is a product of thinking as a result of understanding processes. If a statistical relation is not built, knowledge is a product of cognitive automatism and can be called “memorization” knowledge.

## METHODOLOGY

This is a case study. The data of this study was collected by a single assessment tool, which consisted of 11 open-ended procedural knowledge problems that were related 2nd term physics lessons in electricity. The assessment tool was applied to 44 prospective science teachers, one week after teaching this subject. The prospective teachers knew how to solve a problem by using problem solving techniques (given-asked, free-body diagram, “SCD,” definition, formula, and operation).

Problem solving techniques were the *independent* variables of this study. Knowledge and knowledge levels will be defined by these independent variables. The result obtained by problem solving is the dependent variable. The success and success levels will be defined by these dependent variables. Classical, combination, and information theories will be used in definitions. In scoring data and classical calculations, the VDOİHİ combined staging technique, which is developed for 2-posibility circumstances, will be used (Yılmaz, 2011; Yılmaz and Yalçın2011).

In this statistics technique, the variable is divided into its significant smallest pieces (akp). The akp of experimental data is compared to the akp of theoretical data and given -1, 0 and +1 scores. Based on the scores +, -, or 0 for experimental data, different stages are defined. For each defined stage, calculations are performed only if a stage has its own score.

This reduces the possibility of stages down to 2, which will be accepted as an equal probability. In this study, calculations will executed based on the + values of the akp. With the sum of $akp_B$ scores of independent variables of theoretical data “BGS” scores will be calculated. With the sum of + $akp_B$ scores of independent variables of experimental data, the “P” score will be calculated. With the sum of + $akp_B$ scores of dependent variables of theoretical data, “CB” score will be calculated. With the sum of + $akp_B$ scores of dependent variables of experimental data, “GS” score will be calculated. These calculations will be called “classical calculations”.

In this study, the akp will be accepted as the cognitive modules of data. Therefore, “understanding” can be associated with the akp. The akp and Pos(akp)s (akp+Pos(akp)) will be accepted as the sub units of data. In this case, thinking or knowledge can be associated with akp+Pos(akp)s. In the classical, combination and information calculations, definitions and formula given in the theory part of this study will be used. The calculations for dependent and independent variables will be done separately. The P, BGS, GS, and CB scores of variables will be calculated by averages. The first scores (P, BGS, GS, and CB) of each variable of specific data (data obtained from one prospective teacher) in 11 questions will be determined. The same operations will be done for all data. Scores of the same question of the data will be added and averaged. Scores calculated for each question will be added and then divided by the number of questions to obtain result scores.

The calculated scores will be transformed into “whole numbers” by rounding up, in order to use them in combination and information calculations. With this whole number, value combination and information combinations will be done. *Packaged software program* developed for VDOİHİ technique will be used in calculations. The data will be analyzed by the knowledge, success, and knowledge and success level scores obtained via classical, combination, and information calculations of variables in problem solving of procedural knowledge. The analysis done by these scores will include the cognitive functions, inference, thinking, and decision making situations of prospective science teachers.

## RESULTS

The data were collected through the solutions of procedural knowledge problems which were about the electricity subjects of a science physics lesson. By applying the VDOİHİ technique to the data, the results of cognitive functions were obtained. Electricity subjects were preferred, since they include more than one law, and the applications of these laws are suitable to define cognitive functions and consist of scientific knowledge. Procedural knowledge was preferred as it is the first step in understanding.

Moreover, as the rights and wrongs in procedural knowledge will affect all cognitive function stages, cognitive function situations were determined by three different theories-- based on knowledge, success, and knowledge level and success levels--in order to make the

**Table 1.** Classical, combination and information knowledge values in independent variables.

| Variable | Level/ variable* | Given-asked | Free-body diagram | Definition | Formulas | Operations | Variables of average |
|---|---|---|---|---|---|---|---|
| Classical | P | 2 | 2 | 5 | 2 | 7 | 4 |
| | BGS | 11 | 6 | 18 | 6 | 20 | 12 |
| Combination | $B_B^K$ | 12 | 7 | 4048 | 7 | 60460 | 299 |
| | $BD_B^K$ | 55 | 15 | 8568 | 15 | 77520 | 495 |
| | $TB_B^K$ | 67 | 22 | 12616 | 22 | 137980 | 794 |
| | $E_B^K$ | 1981 | 42 | 249528 | 42 | 910596 | 3302 |
| | $OG_B^K$ | 2048 | 64 | 262144 | 64 | 1048576 | 4096 |
| Information (bit) | $B_B^E$ | 0.06 | 0.66 | 0.28 | 0.66 | 1.15 | 0.88 |
| | $BD_B^E$ | 0.30 | 1.41 | 0.59 | 1.41 | 1.48 | 1.45 |
| | $TB_B^E$ | 0.36 | 2.06 | 0.87 | 2.06 | 2.63 | 2.33 |
| | $E_B^E$ | 10.64 | 3.94 | 17.13 | 3.94 | 17.37 | 9.67 |
| | $OG_B^E$ | 11 | 6 | 18 | 6 | 20 | 12 |

right detection and solution suggestions. The VDOİHİ technique, which separates data into its akps, provides an objective logical simplicity of measurement for knowledge and success.

In this study, independent variables that affect problem solving are given-asked, SCD, definition, formula, and operation variables. Knowledge in the independent variables is defined by three different theories, which are given in Table 1. In Table 1, the average of five variables is given in the last column. The values in the BGS, $OG_B^K$, and $OG_B^E$ lines show the $akp_B$ values that should be in the independent variables, and the other lines show the existing $akp_B$ values of prospective science teachers.$BD_B^K$ and $BD_B^E$ are the value of the last unascertained $akp_B$ (the last P). $B_B^K$ and $B_B^E$ are the value of conclusive $akp_B$ ("P-1") and can be interpreted as highly permanent learned knowledge. $TB_B^K$ and $TB_B^E$ are the expected $akp_B$ value in the $akp_B$. $E_B^K$ and $E_B^E$is the value of insufficient $akp_B$ (BGS-P) in the expected $akp_B$.

As the akp of independent variables represents the smallest significant pieces of knowledge, the values in table 1 will be interpreted as knowledge values. Knowledge was determined by three different theories for five independent variables, and it was concluded that the prospective teachers' knowledge certainty (knowledge "P," certainty state. The meanings of the variables can be found in Mathematics-statistics theory section.

"Unascertained knowledge," certainty "conclusive knowledge," and total certainty "existing knowledge) were significantly lower than what it should be. It was deduced that the conclusive knowledge calculated for independent variables via the combination and information theories was higher than high the permanent knowledge.

This result shows that, prospective teachers will have difficulty in declaring procedural knowledge or solving procedural knowledge questions. The fact that the deficient knowledge level was higher than the knowledge level in five different variables revels that the prospective teachers have learning and educational problems. The difference (deficient knowledge) between the knowledge levels that should exist and the knowledge level in five independent variables provides information about must be addressed in teaching and education.

The fact that the deficient knowledge levels of the last column of Table 1 are almost four times bigger than the average of knowledge levels proves the necessity of reform in these areas. Certainty, certainty situation, total certainty, and deficient knowledge situations calculated via combination and information theories cannot be calculated via classical theory because Pos(akp)s must be included for these calculations.

The difference of combination and information theories for assessment-evaluation is that in information theories, H represents the uncertainty of a situation; however, combination theories allow us to define the uncertainty of information theories as certainty, certainty situation, total certainty, deficient akp (knowledge), or akp that should be. The results calculated via combination and information theories are equal to each other. As in knowledge calculations, the values obtained from the calculations scoring $akp_b$ of the result data (dependent variable) are given in Table 2. The $akp_b$ of dependent variables represents the smallest significant piece of success; the values in Table 2 will be interpreted as the success value.

The success of prospective teachers was found to be closer to the expected success, based on knowledge

**Table 2.** Classical, combination and information success level of dependent variable.

| Variable | Level/variable* | Akp/ Bit |
|---|---|---|
| Classical | GS | 6 |
| | CB | 11 |
| Combination | $B_b^K$ | 1024 |
| | $BD_b^K$ | 462 |
| | $TB_b^K$ | 1486 |
| | $E_b^K$ | 562 |
| | $OG_b^K$ | 2048 |
| Information (bit) | $B_b^E$ | 5.50 |
| | $BD_b^E$ | 2.48 |
| | $TB_b^E$ | 7.98 |
| | $E_b^E$ | 3.02 |
| | $OG_b^E$ | 11 |

* The meanings of the variables can be found in mathematics-statistics theory section.

levels. This shows that prospective teachers think in a result-oriented way and that they know the problem solving techniques well. The fact that conclusive success is higher that unascertained success demonstrates that success is repeatable.

That the existing success level is higher than the deficient success level proves that formal education process is supporting success. The fact that existing success is closer to expected success than to knowledge levels shows that prospective teachers have knowledge problems.

Knowledge and success levels based on the calculations of values given in Tables 1 and 2 are shown in Table 3. Here, APS levels are knowledge levels. The classical knowledge level has been calculated by dividing the P value in Table 1 by the BGS value. The combination and information knowledge levels have been calculated by dividing the existing knowledge ($TB_B^{K,E}$) by the expected knowledge. ASS values in Table 3 represent the success level. Classical success level has been calculated by dividing the GS level in Table 2 by the CB level. The combination and information success levels have been calculated by dividing the existing success ($TB_b^{K,E}$) by the expected success . Though the same assessment tool and the same akp values have been used, classical and combination-information knowledge and success levels are rather different from one another (except from the knowledge level of SCD and the formula variable).

However, in all levels with the calculations by three different theories, the knowledge levels are lower than success levels. These results prove that prospective teachers thing in a result-oriented way or do not know problem solving techniques; it is also possible that the knowledge level of the independent operation variable is close to success level, which would prove that the success of prospective teachers might be the result of correct operations. That the knowledge level of the SCD and formula variables is close to success level supports this conclusion. The knowledge level of this variable, which is determined by the SCD drawings of correct formula or formulas, shows that the success level value can be obtained through correct operations.

However, the difference between the knowledge level of the independent operation level, which is obtained via combination-information calculations, and the success level is quite high, and they are not at the closest levels. The closest values to success level are the other variables that *may* affect the success. In classical calculation, the knowledge levels of independent variable SCD and formula. This proves that prospective teachers arrived at their results with correct formulas and through correct mental processes. The difference between these two knowledge levels and the success level is almost two time higher and success level; its being as high as 0,73 shows that prospective teachers have reasoned well. The meanings of the variables can be found in Mathematics-statistics theory section.

In two different level calculations in which the cognitive modules and sub units of a problem are defined and the need for a structural model of problem solving is determined for the independent given-asked variable, the APS and $APS^{K,E}$ levels are much lower than those of the ASS and $ASS^{K,E}$'. This result proves that prospective teachers have completed problem solving without employing *understanding processes* and procedures. As a result, it can be deduced that the

ASS and $ASS^{K,E}$' values of the independent operation variable decreases. One of the structural models of problem solving is that the solution is done by the independent variable of this study. The fact that although prospective teachers know this model and that their knowledge level is low reveals that they inadequately structure models. The second structural model can be used in problem solving with the independent SCD variable. The knowledge level of this variable is equal to the average knowledge level of the five variable values (Table 3, last column) in classical calculations and is higher than the average values in the combination-information calculations; these results show that the prospective teacher preparation can be improved. The fact that the knowledge level was lower than the success level demonstrates that prospective teachers have difficulty in the analysis of a problem. However, the fact that success level are higher than the knowledge level proves that the problem synthesis and prediction states of prospective teachers are better than their understanding, modeling, and analysis states.

Since the knowledge levels of prospective teachers are

**Table 3.** Classical, combination and information knowledge and the success levels of dependent and independent variables.

| Variable | Level/ variable* | | Given-asked | Free-body diagram | Definition | Formulas | Operations | Variables of average |
|---|---|---|---|---|---|---|---|---|
| | APS | - | 0.18 | 0.33 | 0.28 | 0.33 | 0.35 | 0.33 |
| Classical | ASS | 0.54 | - | - | - | - | - | - |
| | $APS^{K,E}$ | - | 0.03 | 0.34 | 0.05 | 0.34 | 0.13 | 0.19 |
| Combination and information | $ASS^{K,E}$ | 0.73 | - | - | - | - | - | - |

lower than their success levels, it is clear that their inference and decision-making is relatively good. However, the classical value of the success level is 0.54 (%54), although the classical value of knowledge level of independent operation variable, which determines a decision, is 0.35 (%35); this result shows the uncertainty in the decision-making processes. The fact that combination-information value of the success level is 0.73, while the combination-information knowledge level of the operation variable is 0.13 reveals that uncertainty in the decision making-process has increased. The combination-information success level value of 0.73 and the classical success level value of 0.54 prove that inference is better in combination-information calculations.

Since thinking is about dividing data into its sub units and building semantic coordination among these units, using logic rules, mental mutation, and the recombination of all these abilities, the division of data into sub units is the first step. This is achieved by determining the akp and Pos(skp)s via VDOİHİ technique. Since in problem solving technique sub units are determined in the given-asked variable, knowledge level of this variable provides information about how thinking emerges. The knowledge level of this variable is 0.18 in classical calculations and 0.03 in combination-information calculations, which demonstrates that prospective teachers do not employing *understanding processes*. In this case, the other variables might be the result of *cognitive automatism*, which is always ready for knowledge and the success level actions and occurs when the circumstances are ready.

In both level calculation techniques, the knowledge level of prospective teachers is low for the cognitive domain structure, which reveals that procedural knowledge is below a significant level or with significant features. According to classical calculations, the success level value (ASS=0.54) indicates that the teachers can solve procedural knowledge problems about electricity within the scope of what they have learned; according to the knowledge level values (average APS 0.33), they can apply what they have learned with faults. According to combination-information success level values, they can solve procedural knowledge problems about electricity well within the scope of what they have learned ($ASS^{K,E}$=0.73), whereas according to their knowledge level values they cannot apply what they have learned (average $APS^{K,E}$ =0,19). In this case, the prospective teachers include those who have learned well or less well, but do not possess firm knowledge.

## DISCUSSION AND CONCLUSION

The VDOİHİ technique was applied to the sample group of this study via problem solving techniques about procedural knowledge of Newton's law of motion and the results were low (Yılmaz, 2011; Yılmaz and Yalçın, 2012b ), as in this study.

Thus, prospective science teachers have procedural knowledge problems for cognitive domain structures. Moreover, in the same sample group, classical knowledge, he knowledge levels, and the success level obtained with for problem solving techniques about declarative subjects on Newton's law of motion was low (Yılmaz, 2011; Yılmaz and Yalçın, 2012a, 2012c); consequently, procedural knowledge problems in cognitive domain structure cause declarative knowledge problems. The fact that prospective teachers use cognitive automatism in problem solving might be a cause of the procedural and declarative knowledge problems. In a study, Heller et al. (2012) state that item scores might be affected by selected-responses. Selected-responses are a product of cognitive automatism. Prospective teachers may use cognitive automatism because of selected-responses.

Mathematical logic structure of scientific knowledge might be effective in degrading a single meaning with minimum terms, including maximum data in the spectrum obtained by cognitive modules from data through the understanding processes. In the analysis of the sample group of this study, mathematical logic, classical knowledge, and success levels aboutelectricity and magnetism were lower than the classical values of this study (Yılmaz, 2012, 2014). The fact that mathematical knowledge and success levels are low might be the reason why prospective teachers *do not use* their understanding processes. Consequently, in-class practices of teachers and teacher professional development affect student learning (Garet et al., 2001; McCutchen et al., 2002; Roth et al., 2011). Problems generated by teachers might cause students to employ cognitive automatism instead of the understanding processes.

The result that the knowledge, success, the knowledge level, and the success level of this study are low might be related both to the learning of prospective teachers and also to their teaching. Studies show that student success is founded on teacher content knowledge, skills, and practices (Desimone, 2009; Heller et al, 2012; Hill et al., 2008; Scher and O'Reilly, 2009; Wilson and Berne, 1999).Science content knowledge can increase skills and practices (Cohen, 1990; Desimone, 2009; Heller et al, 2012). Students reflect their knowledge levels in biology class success (Wadouh et al, 2014).

However, this study demonstrates a relation between the knowledge and success levels of students; the fact that their knowledge levels are lower than their success levels proves that their knowledge level is not well reflected in their success levels, a result which conforms to those of earlier studies (Yılmaz, 2012, 2014; Yılmaz and Yalçın, 2012a, 2012b, 2012c). Moreover a significant correlation has been found between student interest in electricity and student achievement in electricity (Sencar and Eryilmaz, 2004). Low success might be a result low student interest. Motivation can be used in knowledge level mechanisms (Di Sessa, 2014). The low level of knowledge might be a result of low teacher motivation.

In literature on the symbolic level, the organization of a knowledge base focuses on how a user expresses information in a representation language. Though the knowledge level can be described as the symbolic level (Newell, 1982, 1993; Stephens and Chen, 1996), it is not possible to say that human brain thinks in symbols. They think in "words or significant pieces (akp)" instead of symbols. The symbol level description shows how knowledge level behavior is attained (Newell, 1993). In this study, classical, combination, and information calculations performed with akp reveals that the knowledge and symbol levels can be expressed as a single level.

In prospective teacher problem solving about the procedural knowledge subjects of electricity, knowledge and success levels can be improved. However, increasing continuity and productivity is related to increasing the knowledge level of independent variables of the research. These improvements can help prospective teacher scientific knowledge become a product of thought based on cognition. Knowledge as a product of thinking affects success and success levels positively.

The prospective teachers' use of the understanding processes is determined by their solutions for open-ended questions with problem solving techniques. In order to obtain more information whether "understanding process," which means degrading whole spectrum that emerges through thinking or cognitive automatism into a single meaning with possible minimum terms and maximum meaning has occurred or not, the solution for the question can be given and the question is asked or similar techniques can be used. If the Pos(akp)s of cognitive modules are included in assessment-evaluation, results obtained for cognitive functions and thinking might differ, as Table 1, Table 2 and Table 3.

Classical calculations are essential when quantity is important, whereas combination or information calculations come into play when quality is important. If control gains in important in the assessment-evaluation, they should be calculated, such as with energy levels. If learning is not accidental, the energy that is required for learning is determined and should be supplied. Energy can be determined through information calculations.

## CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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