

## Defining Operational Equivalent of Classic and Combination-Information Mental Function of Prospective Science Teacher Knowledge of Electricity Procedural Knowledge Subject by Comparing Theoretical and Experimental Data

### Fen bilgisi öğretmen adaylarının elektriğin prosedürel bilgi konularında klasik ve kombinasyon-enformasyon akılsal fonksiyon işlem karşılıklarının teorik ve deneysel olarak belirlenmesi

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**Abstract.** By comparing theoretical and experimental data, we aim to improve the learning and mental functions of prospective science teachers. Accordingly, mental function operations are defined by a qualitative study to ensure the establishment of a "bijective mental" level. Combination-information (CI)-level intervals of mental function operations are determined by knowledge and success. These are defined by the relation between the procedural knowledge in the cognitive domains of solutions and possible cases of data (questions) through an assessment tool. This tool includes open-ended questions for assessing the procedural knowledge of electricity of prospective science teachers. By employing these level intervals and comparing the obtained CI knowledge and success levels through problem-solving, the CI mental function operation equivalencies of prospective-teacher knowledge levels of electricity are established. To determine the equivalencies of classic mental function operations, an equal level interval is used. By comparing classic knowledge and success levels with these interval values, classic mental function operation equivalencies are determined. Using these equivalencies, learning and mental functions are improved. Based on the results, we provide suggestions on maintaining bijective mental levels.

**Keywords:** Bijective mind, mental function operation, procedural knowledge, mental function

**Öz.** Fen bilgisi öğretmen adaylarının öğrenme ve akılsal fonksiyonlarının geliştirilerek bijektif akıl seviyesinin sağlanabilmesi için öğretmen adaylarının akılsal fonksiyon işlemleri nitel durum çalışmasıyla, teorik ve deneysel dataların karşılaştırılmasıyla belirlenmiştir. Veriler öğretmen adaylarından elektriğin prosedürel bilgi konularında açık uçlu sorularla hazırlanan ölçme aracının problem çözüm teknikleriyle çözümlerinden toplanmıştır. Toplanan verilerden öğretmen adaylarının prosedürel bilgileri arasında kurabildikleri ilişkilerle belirlenen bilgi ve başarı düzeyleriyle, akılsal fonksiyon işlemlerinin kombinasyon-enformasyon düzeyleri belirlenmiştir. Bu düzeylerle, problem çözümlerinden elde edilen kombinasyon-enformasyon bilgi düzeyi ve başarı düzeylerinin karşılaştırılmalarıyla öğretmen adaylarının elektriğin prosedürel bilgi konularında kombinasyon-enformasyon akılsal fonksiyon işlem karşılıkları belirlenmiştir. Klasik akılsal fonksiyon işlem karşılıklarının belirlenmesinde eşit düzey aralığı kullanılmıştır. Klasik bilgi ve başarı düzeylerinin bu aralık değerleriyle karşılaştırılmasından, klasik akılsal fonksiyon işlem karşılıkları belirlenmiştir. Belirlenen işlem karşılıklarıyla, öğrenme ve akılsal fonksiyonların geliştirilerek bijektif akıl seviyesinin sağlanabilmesi için öneriler geliştirilmiştir.

**Anahtar Kelimeler:** Bijeaktif akıl, akılsal fonksiyon işlemleri, prosedürel bilgi, akılsal fonksiyonlar.

#### Public Interest Statement.

By using the classification method used in many aspects of science; Learning of the human brain can also be improved. By comparing theoretical and experimental data, we aim to improve the learning and mental functions of prospective science teachers

#### Toplumsal Mesaj.

Bilimin birçok alanında kullanılan sınıflandırma yöntemiyle; insan beyninin öğrenmesi de geliştirilebilir. Bu nedenle, fen bilgisi öğretmen adaylarının öğrenme ve akılsal fonksiyonlarının geliştirilerek bijektif akıl seviyesinin sağlanabilmesi amacıyla akılsal fonksiyon işlemleri nitel durum çalışmasıyla, teorik ve deneysel datalar karşılaştırılmıştır.

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## 1. INTRODUCTION

Learning is related to cognitive function and can be improved through mental function operations. Use of mental function operations in learning processes can improve mental functions. Scientific knowledge can be expressed as procedural knowledge, which is the starting point of understanding. To improve learning by applying mental function operations to procedural knowledge, learner mental function operations should be determined and application procedures should be improved. Effective use of mental functions in learning requires applicable definitions.

Various fields in psychology strive to explain mental functions in units, such as sense, cognition, and perception, according to mental approaches. However, in the context of terms that are used to explain mind organization, mental functions do not align with the literature (e.g., Lindquist & Barrett, 2012). Subsidiary mental functions are stated to support effective and cognitive understanding and improvement of attention (Borrachero et al., 2014; Desbordes et al., 2012). However, mental function operations require greater substantiation to be used to improve individuals' procedural knowledge, mental understanding, attention, mental models, and so on within education and teaching processes.

The human mind is the arena of conscious thoughts and mental activities. According to the human reference system, the capacity of the mind is complete and eternal. Being "intelligent" requires understanding. Understanding requires consciousness. Both intelligence and understanding are non-algorithmic. The "genetic mind" is the same in all individuals as a *potential talent*; that is, all individuals are equal in terms of having a genetic mind (except those with genetic disorders). Mental functions are *not genetic* but are rather *epigenetic*, and they are acquired within the development process. Individuals are separated from one another in terms of *mental functions* and *their quality*. Mental functions separate not only the individual from others but also the individual from himself/herself within the process. It is the individual's duty to improve, shape, and upgrade this genetically existing mental talent. As a control process in the development of mental talent, education is responsible for the maximization (through control theories) of functional behaviors, the quality of the production, and the rate of output (Özenli, 1999, pp: R39-T3).

In the development of mental functions, the related operations should be well defined for maximizing the functional behavior, production quality, and output rate. In addition, techniques should exist that apply these definitions. Such a technique could be effectively initiated by using the smallest significant parts (akp) and Pos (akp) of the VDOİHİ statistical method (see e.g., Yılmaz, 2011; Yılmaz & Yalçın, 2011; Yılmaz, 2017).

In this paper, we conduct a statistical comparison of theoretical data akp and individual knowledge (experimental data). From the results, mental function operation equivalencies of prospective science teachers' problem-solving techniques—included in procedural knowledge types—is defined to improve their mental functions and learning. With these defined equivalencies, procedures are recommended for developing, shaping, and upgrading the capacity of the mind.

### 1.1 Theory

#### 1.1.1 Mental function operations

The logical bases of cognitive functions are called mental functions. These comprise the operational concepts of intelligence or cognitive functions. In teaching and learning, mental functions can be improved by mental function operations, which are summarized as follows from Özenli's study (1999):

- Essential Principle: *Primordial Obscurity (inability of the mind to reach the actual truth (GG))*
- Axiomatized Individual Knowledge Sets: *Knowledge Set A, Knowledge Set B,...(in finite numbers; this number can be increased as much as possible)*
- Structure of Knowledge Set: *Set A = ("What we understand" in A) U ("What we do not understand" in A)*
- Kernel of the Set (=Ker Set): *This principle set is the "subset of what we understand"*
- Complement of the Set: *(Set) - (Ker Set)*
- Data Analysis: *a) Effective Mind; b) Non-Effective Mind*

- A) Effective Mind
- A1) Quadratic Injective Mind (Quadratic Reliable Mind): The mind that projects an incoming data mind spectrum onto knowledge set kernels one by one and correlates other related Ker sets
  - A2) First Order Injective Mind: The mind that manages to partially cover one to one
  - A3) Surjective Mind: The mind that manages to fully cover
  - A4) Functor Mind: The mind that easily works by projecting both Individual Knowledge Sets and Possibility Space on the axis of projection
- B) Non-Effective Mind: The mind that works only by projecting an Individual Knowledge Set on the Complement of Set
- C) Description of the Intelligent: Having a Bijective Mind (= Injective Mind + Surjective mind) (pp: R39-T3)

### 1.1.1.1 Determining mental function operations

Mental function operations can be determined by the procedural knowledge type that forms at the start of understanding. This can take place for the subject of electricity, which is a fine application field of science. Mental function operations can be determined by comparing theoretical and experimental data by using the VDOİHİ statistical technique developed by Yılmaz (2011). This technique is based on performing statistical operations by separating theoretical and experimental data into the respective akp (e.g., Yılmaz, 2012, 2014; Yılmaz & Yalçın, 2011, 2012a, 2012b, 2012c, 2012d). Mental function operations can be determined by two different statistical calculations: classic and combination-information (CI).

### 1.1.2 Classic-level calculations of mental function operations

In determining the theoretical and experimental data of mental function operations by comparisons in classic calculations, experimental or theoretical admissions can be performed. As given in this paper, five mental function operations can be defined by equal-level intervals by theoretical acceptance. In this case, mental function operation equivalencies of the given levels can be calculated by accepting  $0 \leq B < 0.20$ ,  $0.20 \leq A1 < 0.40$ ,  $0.40 \leq A2 < 0.60$ ,  $0.60 \leq A3 < 0.80$  and  $0.80 \leq A4 \leq 1.00$  level values as the beginning point. With the help of the following studies, these intervals can be optimized. In determining mental function operations through classic methods, the evaluation tools and professionalism of the evaluator become more important than identifying the objective operations.

### 1.1.3 Combination-information-level calculations of mental function operations

Mental-function operations can be determined by CI-level calculations through the ratio of sample space, which defines the projection and coverage (akp of experimental data) for the number of samples (akp of theoretical data). Projection and coverage can be defined by setting a relation between the procedural knowledge state in the structure of the individual's cognitive domain and the possible cases of data. The correlated state can be defined as 1) a projection if it exists in the sample only once, 2) partial coverage if it exists in the sample more than once, 3) full coverage if a maximum state exists, 4) unprojected if there is no state existing, or 5) a total sample space, which can be defined as a projection depending on the states of the case and possibility space. Samples represent mental function operations. Samples that include a correlated true case only once represent A1 mental function operations. Except for samples that include maximum true cases, samples that include more than one true case represent A2 mental functional operations. Samples that are formed by maximum true cases represent A3 mental function operations. A sample set represents an A4 mental function operation. Samples that do not include true cases represent B mental function operations.

The level of mental function operations represented by the sample is calculated through the ratio of samples (CI values) to the number of samples. When  $Pos(m) = 2$ , as a sample set, along with A3, is represented by mental function operations, only A4 cannot be determined. In the case of  $Pos(m) = 2$ , A4 can be determined by a second calculation. Mental function operation equivalencies of experimental data can be determined by comparing experimental levels to CI-level calculations

that are obtained by the ratio of sample spaces to the number of samples. The number of mental function operation samples is determined by the number of events that should take place in the experimental data. Therefore, mental function operations are determined that are particular to the event and experiment.

## 2. METHODOLOGY

This is a qualitative study. The data of this study was collected from prospective science teachers. The data was collected after the electricity topics were taught to prospective science teachers. In addition, prospective science teachers were informed about procedural knowledge. Included in the study were 44 prospective science teachers, who were asked 11 open-ended procedural knowledge questions. Measurement tool was applied the following week after the electrical teaching. Data were collected based on the solutions they reached by using problem-solving techniques. The prospective science teachers knew how to solve a problem by using problem-solving techniques. Solving a problem through the given-asked, free-body diagram (SCD), definition (scientific theoretical definition), the formula and operation variables is called a problem-solving technique. These variables are the independent variables of the study. Knowledge and knowledge levels will be defined by these independent variables. Success and success levels will be defined by dependent 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. The VDOİHi technique is used in scoring the variables (Yılmaz, 2011). This is a probability and possibility technique. The data are digitized so that this technique can be used. Two possibilities are used in digitization. The data are theoretical and experimental. Theoretical and experimental data are digitized and compared with VDOİHi technique. In scoring data and classical calculations, the VDOİHi combined staging technique, which is developed for 2-possibility circumstances, will be used in Yılmaz, 2017 (Yılmaz, 2011; Yılmaz & Yalçın, 2011). The operations are performed with positive scores and the two cases of Pos(akp). The total score of independent variables is the knowledge score, and the score calculated through the ratio of knowledge scores is the knowledge level. The result is called the dependent variable, which is scored in a way similar to the independent variables. The total score of the result is the success score, while the score calculated through the ratios of success scores is the success level.

In calculating the levels of the VDOİHi-combined stage, classic theories (Yılmaz, 2011; Yılmaz & Yalçın, 2011) and CI theories are used. With the knowledge and success scores, the CI-level intervals of the mental function operations in this study are determined. In determining the classic calculations of mental function operations, theoretical equal-level intervals are used ( $0 \leq B < 0.20$ ,  $0.20 \leq A1 < 0.40$ ,  $0.40 \leq A2 < 0.60$ ,  $0.60 \leq A3 < 0.80$  versus  $0.80 \leq A1 < 1.00$ ). In determining the CI-level intervals of mental function operations, we use the knowledge score that should be (BGS), which is given in Table 1 in Yılmaz, 2017, and the success score that should be (CB), which is given in Table 2. Two fractional stages (.00) are obtained from the calculated levels. If the fractional stages are more than two, then they are mathematically rounded up. As a result, to create an interval, one or two are added to or subtracted from these two-stage levels if no interval emerges on account of this rounding up. This operation creates a maximum 2% error. By comparing the mental function operation level intervals of knowledge and success (given in Yılmaz, 2017, Table 3) to the knowledge and success scores (knowledge scores are given in Yılmaz, 2017, Table 1; success scores are given in Table 2) individual mental function operations of the prospective science teachers that participated in the study are determined.

### 3. RESULTS

Experimental CI knowledge level intervals of mental function operations that are calculated through knowledge scores that should be (BGS) given in Yılmaz, 2017, Table 1 are given in Table 1. After rounding up the two stages after the commas of some values, some knowledge level intervals did not emerge. Therefore, 0.01 or 0.02 were added to or subtracted from the values shown as  $\pm$  in Table 1 to create knowledge-level intervals. This created a 1% or 2% error. To determine the mental function operation equivalencies of classic knowledge levels of prospective science teachers, equal-level intervals are used. Moreover, to determine the mental function operation equivalencies of CI knowledge levels, the experimental level intervals given in Table 1 are used.

**Table 1.** CI Knowledge Level Intervals of Mental Function Operations Calculated by BGS Scores (+ denotes that the result was obtained through an addition to the last stage of the numerical value; \_ denotes that the result was obtained by subtracting from the last stage of the numerical value)

	Level/ Variable	Given- Asked	Free-Body Diagram	Definition	Formulas	Operations	Variables of Average
Classical	BGS	11	6	18	6	20	12
	<i>low level</i> $\leq B \leq$	0.00	0.00	0.00	0.00	0.00	0.00
	<i>high level</i>	0.01 <sup>+</sup>	0.02	0.01 <sup>+</sup>	0.02	0.01 <sup>+</sup>	0.01 <sup>+</sup>
Combination-Information Knowledge-Level Intervals	<i>low level</i> $< A1 \leq$	0.01	0.02	0.01	0.02	0.01	0.01
	<i>high level</i>	0.02 <sup>+</sup>	0.11	0.02 <sup>+2</sup>	0.11	0.02 <sup>+2</sup>	0.02 <sup>+2</sup>
	<i>low level</i> $< A2 \leq$	0.02	0.11	0.02	0.11	0.02	0.02
	<i>high level</i>	0.97	0.88	0.97 <sup>-</sup>	0.88	0.97 <sup>-</sup>	0.97 <sup>-</sup>
	<i>low level</i> $< A3 \leq$	0.97	0.88	0.97	0.88	0.97	0.97
	<i>high level</i>	0.99	0.98	0.99	0.98	0.99	0.99
	<i>low level</i> $< A4 \leq$	0.99	0.98	0.99	0.98	0.99	0.99
	<i>high level</i>	1	1	1	1	1	1

Table 2 presents the experimental CI success level intervals of mental function operations that are calculated by success scores that should be (CB), which are given in Yılmaz, 2017, Table 2. After mathematically rounding up the numbers, the two success level intervals did not emerge. Therefore, the values shown with the + in Table 2 were added to 0.01 to create the knowledge-level intervals. This created a 1% error. To determine the mental function operation equivalencies of classic success levels of prospective science teachers, equal-level intervals are used. In determining mental function operation equivalencies of CI success levels, the experimental level intervals given in Table 2 are used.

**Table 2.** CI Success Level Intervals of Experimental Mental Function Operations Calculated by CB Scores (+ denotes that the result was obtained through addition to the last stage of the numerical value; \_ denotes that the result was obtained by subtracting from the last stage of the numerical value)

	Level/ Variable	Success Level
Classical	CB	11
	$low\ level \leq B \leq high\ level$	0.00 0.01 <sup>+</sup>
	$low\ level < A1 \leq high\ level$	0.01 0.02 <sup>+</sup>
	$low\ level < A2 \leq high\ level$	0.02 0.97
	$low\ level < A3 \leq high\ level$	0.97 0.99
	$low\ level < A4 \leq high\ level$	0.99 1

Mental function operations are obtained by comparing classic equal-level intervals of mental function operations to the CI knowledge and success levels of mental function operations given in Tables 1 and 2. Prospective science teachers' knowledge and success levels obtained through experimental data are compared to the values given in Yılmaz, 2017, Table 3. The determined operations are given in Table 3.

**Table 3.** Classic and CI Mental Function Operation Equivalencies of Prospective Science Teachers (APS = knowledge level; ASS = success level)

Through the above analysis, a maximum 2% of error occurred on account of the regulations in the

	Level/ Variable	Given- Asked	Free-Body Diagram	Definition	Formulas	Operations	Variables of Average
Classic	APS	B	A1	A1	A1	A1	A1
	ASS	A2					
Combination- Information	APS <sup>K,E</sup>	A2	A2	A2	A2	A2	A2
	ASS <sup>K,E</sup>	A2					

CI-level intervals of mental functions given in Tables 1 and 2. These caused no errors in

determining mental functions because the related values given in Yılmaz, 2017, Table 3 did not occur in the intervals that emerged on account of the regulations in Tables 3 (Yılmaz, 2017) and 1. If the related values of Table 3 (Yılmaz, 2017) had occurred in the intervals that emerged on account of the regulations, they would have caused a discrepancy in the equivalencies of mental function operations. No errors occurred in determining the mental function operations because the related values of Table 3 (Yılmaz, 2017) did not occur in these intervals.

The classic knowledge levels of the participants in the study showed that they could only project incoming data flux spectra in the given-asked variables onto the components of the individual knowledge set. The average knowledge level of the other four variables and that of the five variables in the one-to-one projected the incoming data flux spectra onto the principal knowledge set kernel. These results can be correlated to other related Ker sets. The classic and CI success levels show that they managed one-to-one projected by partially addressing the asked-knowledge data spectrum. The classic results prove that, in determining the individual mental functions of prospective science teachers, the success levels are better than knowledge levels; i.e., those who use their minds are more success-oriented.

Based on CI knowledge and success levels, the prospective science teachers can manage to partially cover one-to-one incoming data or the asked data spectra. The fact that they can perform the same mental function operations for both dependent and independent variables (a first-order injective mind) shows that their success levels and knowledge levels are related.

#### 4. DISCUSSIONS AND SUGGESTIONS

Both learning and mental functions of prospective science teachers can be improved in the field of electricity, which serves as a good example of scientific knowledge. Learning relates to the mind; moreover, within educational and teaching processes, mental functions can be consciously improved and controlled through mental function operations. The capacity of the mind is complete and adequate according to the human reference system. Therefore, the differentiation of one individual from another in the process of improving, shaping, and upgrading the capacity of the mind in education and teaching processes can be assured by real, applicable knowledge procedures that are developed by strong and correct proofs. Intelligence requires understanding and understanding requires a transition from procedural knowledge to declarative knowledge. Therefore, use of an inductive approach to improving applicable knowledge procedures should begin from procedural knowledge.

A problem-solving technique to improve procedural knowledge and understanding processes is based on strong, true proofs. According to the results herein, prospective science teachers know how to maximize one-to-one projected to partially cover their knowledge and success in data and cognitive domains. They are expected to provide one-to-one full cover of intelligence at a bijective mind level. The knowledge levels of prospective science teachers can be a good starting point for upgrading them to a bijective mind level. This is because success levels and permanent success levels relate to knowledge levels. Classic results show that to reach the surjective mind level by increasing the knowledge level, the beginning point should be the given-asked variable.

The fact that these individuals can provide one-to-one partial coverage in mental function operations separates prospective science teachers from one another and from themselves within the process. However, this separation is not sufficient. To ensure a subjective mind level, the following conditions should be met. 1) First of all, noteworthy, characteristic procedural knowledge should exist for the structure of the cognitive domain. 2) This knowledge should be separated into its cognitive modules, and possible cases of each cognitive module should be determined. 3) Variables of late-in coming or perceived data should be separated into their cognitive modules, and possible cases should be determined. 4) Then, possible cases of cognitive modules of knowledge existing in the cognitive domain structure should provide one-to-one coverage of the

possible causes of cognitive modules of incoming or perceived data. 5) Set kernels should be created by the possible causes of cognitive modules associated with one-to-one coverage. 6) By associating elements of the set kernel and set component elements, partial coverage should be provided. 7) Finally, by determining the relation between set kernel elements and set complement elements, accurate decision making should be assured and complete coverage should be achieved between accurate decisions and set kernel elements (surjective mind). Therefore, by improving mental functions, three mind levels can be achieved; accordingly, the bijective mind—intelligence—can be formed.

To ensure complete one-to-one coverage by separating variables into their cognitive modules and possible cases, semiotic knowledge model, mental models, and others can be used. On the other hand, with mental function operations existing between cognitive modules and possible cases, the way that transitions between different levels may be possible can be defined, and applications of these models can be enhanced. For instance, Keselman's (2003) suggestion of explaining the nature of (mental) model transitions can be presented as follows: Separate the variables into their cognitive modules and possible cases. Then, with mental models, first ensure one-to-one coverage, then ensure partial coverage, and, finally, ensure full coverage between procedural knowledge that exists in the cognitive domain structure and cognitive module and possible cases of the data. Accordingly, that suggestion can likewise be made for this present study. Wang and Barrow's (2011) definitions of thinking skills through a mental model of university students as being low, average, and high in the subject area of chemistry can be expanded into the five mental function operations given in this paper. Furthermore, semeiotic knowledge models can be developed that facilitate learning through knowledge success levels or mental function operations.

The conclusions supporting the classical results of this research have also been reached in the subjects related to the magnetism of Yilmaz (2016a, 2016b) prospective science teachers. In these studies, the APS and ASS values of the variables that are collected from the prospective science teachers by the case study are similar. These similarities show that prospective science teachers are in similar mental functioning. The results of this study and the results of Autor's work show that the mental functions of prospective science teachers should be raised. Teaching programs that develop these mental functions can be applied, taking into account the mental functions of the prospective science teachers.

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