The profile of cognitive style, logical thinking ability, and conceptual knowledge of electricity and magnetism topic based on prospective physics teachers’ grade level

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Abstract. One of the efforts that can be done in designing classroom assessment is to mapping a number of variables that affect the physics learning process, especially on electricity and magnetism. In this research, mapping of cognitive style, logical thinking ability, and conceptual knowledge of electrical and magnetism topics aimed to know the pattern of change of three variables owned by prospective physics teachers based on grade level. This study is descriptive research with 95 respondents taken from one class for each level by random sampling. The results showed that cognitive style, logical thinking ability, and conceptual knowledge variables changed with linear pattern. This finding becomes one of the next considerations to design electricity and magnetism learning assessment in universities.

1. Introduction
The study of cognitive variables has been widely practiced in the world of science education researches [1]. This study was part of cognitive psychology studies, a study of cognitive processes involved in influencing the senses associated with the environment and the surrounding interactions [2]. This definition described a person's ability to process the amount of information which they receive and then with their thinking ability to connect a series of information so that it has value or meaning. The level of ability to process information can differ between individuals. This difference can be caused by external and internal factors. External factors can be caused by the circumstances surrounding the environment, for example learning process that was often and even always given with a monotonous or varied learning styles, the quality of people around who interact with students, and habit factors in the care of parents in their family. While, the internal factors related genes offspring which is related to brain development, for example cognitive styles [3]. The cognitive style demonstrated a stable attitude, preference, or custom strategy that distinguished individual styles in perceiving, remembering, thinking and solving problems [4]. Furthermore, cognitive styles can influence the outcome of thought processes, like problem solving [5]. As an individual characteristic in processing information, cognitive style is in the trajectory of ability and personality, and manifested in some activities. In addition, cognitive style concerns the characteristics of an individual in learning,
both related to the acceptance and processing of information, attitudes toward information, and habits associated with the learning environment [6]. Based on its dimensions, the cognitive styles are divided into two dimensions namely the Field Dependence (FD) and Field Independence (FI) cognitive style [7]. The fundamental difference between the two dimensions of cognitive style is the way in processing information. Another difference is that individual FI have more analytical skills compared to individual FD [4]. It means that cognitive style is one of variables that influences prospective physics teachers’ thinking process in learning that leads to level of academic achievement. Therefore, the cognitive style becomes one of the variables in the initial study and the foundation in developing an integrated assessment model in the learning process.

Study of other cognitive variables in science education is logical thinking. Logical thinking plays an important role for students’ success in learning [8]. According to Piaget’s cognitive development theory, reasoning levels are closely related to one’s cognitive development. There are four stages of cognitive development experienced by a person, namely sensorimotor (0-2 years), pre-operational (2-7 years), concrete operational (7-11) years, and formal operational (11-16 years) stage [9]. The fundamental thing that distinguishes each stage is type of thinking. Individuals at the formal operational stage are able to think logically with abstract problems and be able to systematically test the hypothesis [10]. One of test types that can measure logical thinking ability is Test of Logical Thinking (TOLT). This test can categorize one's logical thinking ability into concrete, transitional, or formal operation categories. TOLT measures 5 types of reasoning, namely proportional, variable control, proportional, correlation, and combinatorial reasoning [11]. This explanation provides an assumption that logical thinking ability is also important to conduct initial assessment as basic in developing assessment types and forms integrated in learning process which can facilitate all students who are varied.

One of the important components in the learning process is teaching materials. Determination of the material in subsequent research design is done through identification of materials that are perceived difficult by the students. Furthermore, based on the results of these perceptions developed a test instrument that can identify the conceptual knowledge students related to the material in the second basic physics course. In addition, the purpose of this test was to confirm the truth of materials in the second basic physics course which is perceived difficult by students.

Based on the above description, this paper focus to describe cognitive style, logical thinking, and conceptual knowledge of electricity and magnetism based on grade level. The aims of this research is to observe the pattern of each variable difference based on prospective physics teachers’ grade level which will become basic of consideration of further research in designing learning assessment form in basic physics course.

2. Method
This study used non-experiment research with descriptive research type in which whole data were analysed by using descriptive statistic to make conclusion. The participants of this research was 95 freshmen (age 18-21) who have taken basic physics course in the first year for each academic year 2015/2016, 2016/2017, and 2017/2018. The instruments used in this research were GEFT, TOLT, and CKEM test (Conceptual Knowledge of Electricity and Magnetism).

**GEFT:** Participants’ FDI cognitive style was assessed by a version of the Witkin, Olman, Raskin, and Karp (1971) Group Embedded Figure Test (GEFT) [12]. GEFT is a psychometric measure whose reliability and validity has been supported by a growing body of studies and then the reliability coefficient of test was 0.82 [3, 4, 5, 6]. It consists of three sections; each section has simple figure embedded in large complex figures, which had to be traced. The first section which has a time limit of 2 minutes includes 7 items. This section is only as a warm-up to make them ready but the items in this section were not included in the total score. The real task began at the second section and into the third one. The second and the third section included a total of 18 items, 9 items for each section, which had to be traced in 12 minutes set within time limit of 6 minutes for each. These sections were given score 0 for the false answers and score 1 for the true answers so that the maximal score is 18 and the
minimum is 0. After the second section had been administered, students stopped for more instruction on the third section and then went on. Those whose score above 12 out of 18 were labelled FI persons and those with score of 11 and less than 11 were branded as FD cognitive stylists [13].

**TOLT:** Measuring participants’ logical thinking ability, we used Test of Logical Thinking (TOLT) which was developed by Tobin and Capie version whose coefficient reliability (α) = 0.85, high significant level (p < 0.0001), mean value $M = 2.94$, and deviation standard = 2.94 [11]. The test consists of the 10 items to measure five modes of formal reasoning: controlling variables, proportional reasoning, combinatorial reasoning, probabilistic reasoning, and correlational reasoning. Each of the 10 items requires participants to select a correct response and justification from a number of alternatives. The categorization of students’ logical thinking ability is divided over three. There are concrete, transition, and formal operational categorize. Students whose score 0-1 were labelled concrete operational category, those with score 2-3 were called transition operational category, and they whose score above 4 were branded as formal operational category.

**CKEM test:** Conceptual Knowledge of Electricity and Magnetism test (CKEM-test) is an instrument to measure participants’ conceptual knowledge category about electricity and magnetism concepts. The instrument consists of multiple-choice option 40 items whose reliability and validity has been obtained from a study in which 65 prospective physics teachers from the second grade. The coefficient reliability of test (α) = 0.556 [14]. The categorization of students’ conceptual knowledge is divided over four. There are perfect, two middles, and not perfect [15]. Student’ conceptual knowledge were perfect if their answer choice are correct, reason is correct, and then answer choice and reason is interconnection. They are in the middle if students whose answer choice are correct, reason is correct, but answer choice and reason is not interconnection or if students whose answer choice or reason are correct, and not interconnection. If their answer choice and reason are incorrect, they are categorized as not perfect.

3. Results and discussions

3.1. Description of prospective physics teachers’ cognitive style

Result of the last field study explained that the participants’ score related with GEFT test was ranged 0-16. Dominant scores obtained by whole students were score 4, 8, and 9 [16]. The Gordon and Wyant analysis model describes that persons who get scores between 0 and 11 are labeled FD cognitive style and they who get score more than 11 until maximum score are called FI persons. Using this analysis model, student’s cognitive style based on each student grade level can be shown in Table 3.

Analysis result about obtaining test score of GEFT showed that the number of students who had FD cognitive style was more than the number of FI cognitive style students. Based on this result, we can conclude that every student has cognitive style to get and process more information in the class. Therefore, it is important to consider the use of appropriate assessment and learning strategy with our student characteristic.

3.2. Description of prospective physics teachers’ logical thinking

Data of prospective physics teachers’ logical thinking based on their grade level was shown in table 1. The highest average score of logical thinking was in the third grade students ($M = 4.20$; $SD = 2.13$). While, the lowest average score was in the second grade student ($M = 2.35$; $SD = 1.89$). Proportional reasoning was the highest average score ($M = 1.13$; $SD = 0.77$) and dominated all of five reasoning forms from all students. Then, the lowest average score was in correlational reasoning ($M = 0.19$; $SD = 0.40$). The average score of students’ logical thinking reasoning overall was 3.10 from maximal score 10 with deviation standard (SD) is 1.91. Prospective physics teachers’ formal reasoning can be categorized into three types based on Tobin and Capie theory [17], namely concrete, transitional, and formal reasoning. Based on the result of administrating test to prospective physics teachers, we obtained data about them which was shown by Table 3. Table 3 shows that students’ type of logical thinking which the highest percentage was obtained by students at the third grade level (61%), then the
first grade students (30%). The lowest percentage was obtained by the second grade students (only 29%). It means that students in the second grade dominated concrete reasoning type. Actually, we hope that the higher grade level, the more student whose operational formal reasoning.

Table 1. Descriptive statistic and different test of prospective physics teachers’ logical thinking.

| Variables of Logical Thinking | Grade Level | N  | M   | SD  | Different test of Kruskal Wallis |
|-------------------------------|-------------|----|-----|-----|----------------------------------|
|                               |             |    |     |     | Asymp. Sig | Significance |
| LTh 1                         | 1st         | 30 | 0.97| 0.85| 0.002       | Significant  |
|                               | 2nd         | 31 | 0.87| 0.85|             |              |
|                               | 3rd         | 34 | 1.56| 0.61|             |              |
| LTh 2                         | 1st         | 30 | 0.83| 0.70| 0.095       | Not Significant |
|                               | 2nd         | 31 | 0.51| 0.77|             |              |
|                               | 3rd         | 34 | 0.85| 0.78|             |              |
| LTh 3                         | 1st         | 30 | 0.10| 0.31|             |              |
|                               | 2nd         | 31 | 0.09| 0.30|             |              |
|                               | 3rd         | 34 | 0.38| 0.60|             |              |
| LTh 4                         | 1st         | 30 | 0.37| 0.56| 0.162       | Not Significant |
|                               | 2nd         | 31 | 0.26| 0.44|             |              |
|                               | 3rd         | 34 | 0.53| 0.61|             |              |
| LTh 5                         | 1st         | 30 | 0.50| 0.57| 0.113       | Not Significant |
|                               | 2nd         | 31 | 0.61| 0.71|             |              |
|                               | 3rd         | 34 | 0.88| 0.77|             |              |
| LTh-tot                       | 1st         | 30 | 2.77| 1.70| 0.001       | Significant  |
|                               | 2nd         | 31 | 2.35| 1.89|             |              |
|                               | 3rd         | 34 | 4.20| 2.13|             |              |

LTh 1 = proportional reasoning; LTh 2 = controlling variable reasoning; LTh 3 = correlational reasoning; LTh 4 = probabilistic reasoning; LTh 5 = combinatorial reasoning; LTh-tot = total of logical thinking reasoning

3.3. Description of prospective physics teachers’ conceptual knowledge on electricity and magnetism topic

Table 2 shows the comparison of three grade levels on eight electricity and magnetism sub topic. The highest average score was in the third grade level students ($M = 2.99$; $SD = 1.29$). There is amazing data that the first grade level students had the highest score average ($M = 1.67$; $SD = 0.67$) than students’ score average at the second grade level ($M = 1.27$; $SD = 0.55$). The third grade level students had the highest on seven sub topics, namely electric current ($M = 7.68$; $SD = 2.90$), electromotive force ($M = 3.74$; $SD = 2.57$), resistance ($M = 0.82$; $SD = 1.31$), energy and power of electric ($M = 1.74$; $SD = 2.09$), direct current & Kirchhoff rules ($M = 4.71$; $SD = 2.26$), magnetic force acting on a current carrying conductor ($M = 2.15$; $SD = 2.16$), and coil carried a steady current ($M = 1.15$; $SD = 1.26$). The first grade level students have gotten the highest score on force of charge particles moving in a magnetic field ($M = 1.19$; $SD = 2.01$).
Table 2. Descriptive statistic and different test average of prospective physics teachers’ conceptual knowledge on electricity and magnetism topic.

| Electricity& Magnetism Topics | Grade Level | N   | M    | SD   | Different Test | Kruskal Wallis |
|-------------------------------|-------------|-----|------|------|----------------|----------------|
|                              |             |     |      |      | Asymp. Sig     | Significance   |
| CKEM1                        | 1<sup>st</sup> | 30  | 2.03 | 2.33 | 0.000          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 2.42 | 2.20 |                |                |
|                              | 3<sup>rd</sup> | 34  | 7.68 | 2.90 |                |                |
| CKEM 2                       | 1<sup>st</sup> | 30  | 2.70 | 2.53 | 0.000          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 1.13 | 1.12 |                |                |
|                              | 3<sup>rd</sup> | 34  | 3.74 | 2.57 |                |                |
| CKEM 3                       | 1<sup>st</sup> | 30  | 0.47 | 0.68 | 0.347          | Not Significant|
|                              | 2<sup>nd</sup> | 31  | 0.35 | 0.66 |                |                |
|                              | 3<sup>rd</sup> | 34  | 0.82 | 1.31 |                |                |
| CKEM 4                       | 1<sup>st</sup> | 30  | 1.23 | 0.90 | 0.020          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 0.74 | 0.89 |                |                |
|                              | 3<sup>rd</sup> | 34  | 1.74 | 2.09 |                |                |
| CKEM 5                       | 1<sup>st</sup> | 30  | 2.43 | 1.43 | 0.000          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 3.23 | 1.65 |                |                |
|                              | 3<sup>rd</sup> | 34  | 4.71 | 2.26 |                |                |
| CKEM 6                       | 1<sup>st</sup> | 30  | 2.13 | 2.10 | 0.027          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 1.16 | 1.39 |                |                |
|                              | 3<sup>rd</sup> | 34  | 2.15 | 2.16 |                |                |
| CKEM 7                       | 1<sup>st</sup> | 30  | 1.80 | 1.42 | 0.001          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 0.74 | 1.00 |                |                |
|                              | 3<sup>rd</sup> | 34  | 1.19 | 2.01 |                |                |
| CKEM 8                       | 1<sup>st</sup> | 30  | 0.57 | 0.82 | 0.009          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 0.35 | 0.61 |                |                |
|                              | 3<sup>rd</sup> | 34  | 1.15 | 1.26 |                |                |
| CKEM-tot                     | 1<sup>st</sup> | 30  | 1.67 | 0.67 | 0.000          | Significant    |
|                              | 2<sup>nd</sup> | 31  | 1.27 | 0.55 |                |                |
|                              | 3<sup>rd</sup> | 34  | 2.99 | 1.29 |                |                |

CKEM1 = Electric current; CKEM2 = GGL Electromotive force; CKEM3 = Resistance; CKEM4 = Energy & Power of electric; CKEM5 = Direct current & Kirchhoff Rules; CKEM6 = Magnetic force acting on a current carrying conductor; CKEM7 = Force of charge particles moving in a magnetic field; CKEM8 = Coil carried a steady current; CKEM-tot = All sub topics.

Only one sub topic was improving average score (direct current and Kirchhoff rules) based on grade level. Improving average score for each grade level (1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup>) on current electric was 2.03 (SD = 2.33), 2.42 (SD = 2.20), and 7.68 (SD = 2.90). On the sub topic of direct current and Kirchhoff rules, improving average score for each grade level was 2.43 (SD = 1.43), 3.23 (SD = 1.65), and 4.71 (SD = 2.26). There were six sub topics whose score average reduced from the first grade level to the second grade level, and then increased from the second grade level to the third grade level. Those were electromotive force, energy and power of electric, resistance, force of charge particles moving in a magnetic field, magnetic force acting on a current carrying conductor, and coil carried a steady current. The Kruskal Wallis different test aimed to draw significant differentiation of average score on each concept based on students’ grade level. The significant differentiation could be found on seven sub topics. Students’ answer can be categorized into four types which is shown in Table 3.
Table 3. The percentage of category on prospective physics teachers’ logical thinking, cognitive style, and conceptual knowledge on electricity and magnetism based on grade level.

| Grade level | Categorization of Logical Thinking (%) | Dimension of Cognitive style (%) | Categorization of Conceptual Knowledge on Electricity and Magnetism (%) |
|-------------|---------------------------------------|---------------------------------|-----------------------------------------------------------------------|
|             | C   | T   | F   | FD  | FI  | 1   | 2   | 3   | 4   |
| 1st         | 30  | 40  | 30  | 80  | 20  | 73.6| 23.4| 0.8 | 2.3 |
| 2nd         | 52  | 19  | 29  | 87  | 13  | 79.1| 19.5| 1.0 | 1.4 |
| 3rd         | 15  | 24  | 61  | 76  | 24  | 53.4| 34.6| 6.5 | 5.5 |

C = Concrete; T = Transitional; F = Formal; FD = Field Dependence; FI = Field Independence
1 = Not perfect; 2 = middle; 3 = middle; 4 = perfect

Table 3 showed dominant categorization of prospective physics teachers’ conceptual knowledge on electricity and magnetism was type 1 or not perfect. It indicates that almost all students have difficulty in electricity and magnetism concepts. Therefore, these concepts will be considered as topic which will be discussed in designing next research.

4. Conclusions
Based on the result of study above, it can be concluded that cognitive style and logical thinking are cognitive variables that have changed based on the length of time in obtaining learning experiences. And then, electricity and magnetism are the topic perceived difficult by prospective physics teachers. Therefore, electricity and magnetism are the important topic to be discussed in designing next research.

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