The profile of prospective physics teachers’ conceptual change based on cognitive style dimensions through collaborative learning on electricity and magnetism topic

R Rahmawati¹*, N Y Rustaman², I Hamidah², D Rusdiana²

¹Program Studi Pendidikan Fisika, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Makassar, Jl. Sultan Alauddin No. 259, Makassar 90222, Indonesia
²Program Studi Pendidikan IPA, Sekolah Pascasarjana, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia

*rahmawatisyam@unismuh.ac.id

Abstract. This study aims to explore conceptual changes of prospective physics teachers on electricity and magnetism topic based on the different of their cognitive style dimension through collaborative learning. The research method used was pre-experiment with pre-test and post-test designs. The sample in this study was 30 prospective physics teachers at a university in Makassar for the first year of the 2018/2019 academic year. Conceptual changes of prospective physics teachers were measured by the four-tier test. The analysis of conceptual changes was divided into three categories, namely not understanding, understanding, and misconceptions. Cognitive style were divided into Field Independence (FI) and Field Dependence (FD) which were measured using the Group Embedded Figure Test (GEFT) standard test. The results showed that there were no FI students who had misconceptions both on the initial and final test but decreased in the category of not understanding (1%), and increased in the category of misconceptions (1%). Meanwhile, FD students experienced misconceptions both on the initial test (34%) and the final test (20%) but decreased in not understanding (2.7%) and increased in understanding (17.7%). The results also provided collaborative learning contributed to improve students’ conceptual changes from misconceptions and not understanding concepts to be understanding concepts.

1. Introduction

Conceptual change is a condition in which students change their initial conceptions and beliefs that are caused by new concepts that students acquire during the learning process [1]. Conceptual changes can occur when there is student dissatisfaction with the concepts that already exist in themselves, the existence of new concepts that are clearer and easier to understand, and new concepts can help solve the problem at hand logically [2,3]. Furthermore, conceptual change is defined as a change in a conception that exists in students such as beliefs, ideas, or ways of thinking from students’ initial conceptions to scientific conceptions [4].

The process of changing student conceptions could be influenced by several factors, both external and internal factor [5-7]. One of the internal factors that influence the process of changing the conception is related to cognitive aspects. The results of previous research revealed that students who
had good initial knowledge and perseverance in learning would find it easier to understand the concepts taught [8]. Conceptual changes also involve a conceptual understanding process which causes students to construct their understanding of conceptual changes [9]. Two main components used in the process of changing conceptions were the individual circumstances that provided the necessary context and conditions for conceptual changes to occur [2,3,10]. Cognitive factors are very influential in terms of their relationship with the individual's circumstance of conceptual change because cognitive is a thinking tool to construct internal knowledge based on external information received. The cognitive variables that can affect the process of changing one's conception are the dimensions of cognitive style [11].

Cognitive style describes how a person acts in different situations [11]. The term of cognitive style is more defined as "personal style" in terms of the way each individual is unique in understanding and deciding something [12]. Some cognitive psychologists pointed out several dimensions of cognitive style. There were nine dimensions of cognitive style, among them: 1) field dependence independence, 2) scanning, 3) breadth of categorizing, 4) conceptualizing, 5) cognitive complexity, 6) reflectiveness versus impulsivity, 7) leaving versus sharpening, 8) constricted versus flexible control, and 9) tolerance for incongruous or unrealistic experiences [11,13]. The study of the cognitive style in this paper was more focused on field dependence independence (FDI) of cognitive style dimensions.

There were several characteristics that could differentiate between learners who had the dimensions of Field Dependence (FD) and Field Independence (FI) cognitive style. Individuals with FI cognitive style characteristics had a higher intellectual and analytic level than FD individuals. The cognitive style dimension had a role in the way a person views the concepts they get, accepts the concept, even changes the initial concept with a new concept based on the results of the analysis of thinking. Thus, FI individuals were superior and easy to carry out the concept change process based on their fundamental rationality [14]. The study of conceptual change and its relation to the cognitive style dimensions showed a mutually supportive relationship with one another. Thus, the variable cognitive style became one of the parts reviewed for students' conceptual change on electricity and magnetism topics in this study.

As for external factors that could influence the process of changing a person's concept, the teacher's teaching method was also an external factor that could affect changes in student conceptions [5,7,15-17]. Monotonous teaching caused students to face difficulty in understanding concepts. For this reason, the use of a variety of conceptual teaching methods was highly recommended, for example through practicum activities [7]. The results of preliminary observations on first-year prospective physics teachers at a university in Makassar for the 2017/2018 academic year showed that the conceptual knowledge of prospective physics teachers was still in the low category on electricity and magnetism topics. The highest percentage was in the category of incomplete (68.7%) and incomplete partially (25.8%). Meanwhile, the lowest percentage was in the category of complete partially (2.8%) and complete (2.7%) [18]. This situation showed the importance of being selective in choosing learning strategies that can fix the conceptions of prospective physics teachers so that they can reduce misconceptions or not understanding concepts of prospective physics teachers.

Various research on how to improve students' conception has been done by providing innovations in learning [19-22]. One of the learning strategies that can fix prospective physics teachers' concepts was a collaborative learning strategy with practicum. Collaborative learning in small groups has been a pedagogical tool in physics education for a long time in order to give opportunities for the students to express themselves with newly accessed knowledge in a relevant context [23-26]. A meaning-making of concepts, their relations and also limitations of models used is facilitated if you are allowed to discuss them in a social context [15,23,24,26]. Research also shows that active learning, including collaborative learning, leads to improved results for several learning outcomes compared to passive learning, such as traditional lectures without interaction [23,27]. However, it is also demonstrated that it is not necessarily the case that the more collaborative learning there is the better. A combination of different methods might be the best [23,27]. Based on this description, a collaborative learning strategy with practicum activities was expected to be able to assist students in building their knowledge based on a
strong knowledge structure so that it can help correct student conceptions from misconceptions or not understanding concepts to the understanding concepts.

Electrical and magnetics material is an important concept that must be taught to students in training their problem solving skills because the interaction of electrical material and the Magnetics plays a central coordination in determining the structure of life and become a foundation of important technological developments in life [18,28]. The abstract nature of electricity and magnetism topics made this material difficult to understand from the elementary school [29–33], junior and senior high school [34–40], the university level [41–43], until teachers [34,44,45]. To overcome difficulties in understanding the concepts of electricity and magnetism, various efforts have been made by educators, both single and multi-strategy or approaches to learning. Although not all efforts can be successful in changing some of the difficulties in understanding the concepts of electricity and magnetism for the better due to other factors that influenced the level of one's success in understanding these concepts. The factors causing the incompatibility of students' concepts with the concepts possessed by scientists can be internal or external factors. Therefore, it was important to provide electricity and magnetism in order to improve the conceptions of prospective physics teachers.

Based on the results of related research by previous researchers, learning with a collaborative model in small groups was able to improve students' physics conceptions. The difference in this study with previous research was that this study focused on improving student conceptions reviewed based on the dimensions of cognitive style through collaborative learning with practicum activities in learning electricity and magnetism topics. Furthermore, students were given a conception test in the four-tier test form to measure conceptions based on the cognitive style dimensions of prospective physics teachers.

2. Methods
Metode yang digunakan in this study is pre experiment with one group pre-test-post-test design with using 30 prospective physics teacher in 2018/2019 academic year as sample in this study. The data analysis technique used is descriptive-quantitative based on test result. Instruments used in this research are four-tier test and Group Embedded Figure Test (GEFT). Four-tier test is used to measure conception of prospective physics teachers which consist of fourty multiple-choice with four-tier form. Each question contains question, answer-choice, certain-level choice of answer-choice, reason-choice of answer-choice, and certain-choice of reason-choice. Furthermore, GEFT test standardized is used to measure prospective physics teachers’ cognitive style dimension. 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.

Analysis of four-tier test result is start to 1) determining answer-pattern of prospective physics teachers; 2) grouping answer pattern into three categories, namely not understanding, understanding, and misconception; and 3) calculating percentage of each category of answer. Furthermore, analysis of GEFT test is quantitative description with determining test scoring of GEFT. Students 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].

3. Results and Discussions
The results and discussions of this research consist of 1) description about prospective physics teachers’ cognitive style and 2) description of prospective physics teachers’ conceptual change based on their cognitive style.
3.1. Description about 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 [18,46]. 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 [47]. There are 12 prospect physics teachers who have FI cognitive style (40%) and 18 prospect physics teachers who have FD cognitive style (60%) from 30 prospect physics teachers.

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 learning strategy with our student characteristic to improve problem solving skills of prospective physics teachers.

3.2. Description about conceptual change of prospective physics teachers based on their cognitive style.

Table 1 showed result of descriptive-quantitative analysis about percentage of categories of conceptual change based on prospective physics teachers’ cognitive style through collaborative learning with small-group (each group consist of two FI students and three FD students) in physics course.

| Topics                        | Dimension of Cognitive style | Number of samples \( (n) \) | Test | Categories of conceptual change |
|-------------------------------|-------------------------------|-----------------------------|------|---------------------------------|
|                               |                               |                             |      | Not understanding (%) | Understanding (%) | Misconception (%) |
| Electric current              | FD                            | 18                          | U1   | 15.6 | 34.4 | 50.0 |
|                               |                               |                             | U2   | 30.0 | 51.1 | 18.9 |
| Electric force and voltage    | FD                            | 18                          | U1   | 50.8 | 14.3 | 34.9 |
|                               |                               |                             | U2   | 49.2 | 31.0 | 19.8 |
| Resistance                    | FD                            | 18                          | U1   | 58.3 | 11.1 | 30.6 |
|                               |                               |                             | U2   | 61.1 | 16.7 | 22.2 |
| Energy and electric power     | FD                            | 18                          | U1   | 65.3 | 5.6  | 29.2 |
|                               |                               |                             | U2   | 76.4 | 9.7  | 13.9 |
| Direct current                | FD                            | 18                          | U1   | 50.0 | 27.8 | 22.2 |
|                               |                               |                             | U2   | 11.1 | 88.9 | 0.0  |
| Kirchhoff Law                 | FD                            | 18                          | U1   | 8.3  | 91.7 | 0.0  |
|                               |                               |                             | U2   | 8.3  | 91.7 | 0.0  |
| Magnetic field                | FD                            | 18                          | U1   | 55.6 | 7.4  | 37.0 |
|                               |                               |                             | U2   | 62.0 | 15.7 | 22.2 |
| Magnetic force                | FD                            | 18                          | U1   | 50.0 | 12.5 | 37.5 |
|                               |                               |                             | U2   | 69.4 | 18.1 | 12.5 |
Table 1 provided information about the percentage in the three categories of conceptual change in each student group of the FD and FI cognitive style. Table 1 showed that all FI students did not experience misconceptions on all topics of electricity and magnetism both on the first (U1) and the second test (U2). Furthermore, the percentage of not understanding decreased and increased in the understanding category from the first test to the second test for all subjects. In not understanding category, the largest percentage decrease was in the topic of electric current (15%) and constant on the topic of electric force and potential difference, resistance, energy and electric current conductivity, Kirchhoff's law, and magnetic fields (0%). Meanwhile, the topic of direct current (dc) increased by 11.9%. For the understanding category, the highest percentage increasing occurred in the electric current topic (15%) and was constant (0%) on the electric force and potential difference topics, resistance, energy, and electric current conductivity, Kirchhoff's law, and magnetic fields.

The percentage of the misconception category decreased from the first test (U1) to the second test (U2) in the FD student group on all topics. The largest percentage decreasing in not understanding category was found in Kirchhoff's Law (31.1%) and the smallest was in electric force and potential difference topics (8.3%). The largest percentage decreasing in not understanding category was found in Kirchhoff's Law (38.3%) and increased in magnetic force (19.4%). Meanwhile, the highest percentage in the understanding category increased in Kirchhoff's Law (61.6%) and the lowest was in energy & electric current conducting power (4.2%). For the misconception category, the largest percentage decreasing occurred in the electric current topic (31.1%) and the smallest was in the resistance topic (8.3%). Further information was that all students with the FI cognitive style do not experience misconceptions both on the first test results (U1) and the second test results (U2). Meanwhile, most FD students experienced misconceptions on the first test but experienced a decrease in the second test. Both FD and FI students experienced an increase in the understanding category and a decrease in not understanding category.

The result of this research related to the data on conceptual changes of the FD and FI students showed that collaborative learning contributed to change students' conceptions from not understanding concepts and misconceptions to understanding concepts. Another finding was that cognitive style was a variable that affects the categories of students' conceptual change on electricity and magnetism topics. This description was indicated by the percentage of conceptual change in the misconception category that was higher for FD students than FI students. On the other hand, the percentage of FD students' concept understanding category was lower than FI students. Likewise, in not understanding category, FD students were higher than FI students.

4. Conclusions
Based on the result of study above, it can be concluded that 1) collaborative learning can improve conceptual change of prospective physics teachers based on their cognitive style; 2) conceptual change
of FI prospective physics teachers in understanding category were higher percentage than percentage of FD prospective physics teachers on electricity and magnetism topic.

Acknowledgement
This study is supported by Department of Physics Education, Fakultas Keguruan dan Ilmu Pendidikan, Universitas Muhammadiyah Makassar. We also are grateful to the participants who have been contributed in this study.

References
[1] Thong W M and Gunstone R 2008 Some Student Conceptions of Electromagnetic Induction *Res. Sci. Educ.* 38, 1 p. 31–44
[2] Posner G J, Strike K A, Hewson P W, and Gertzog W A 1982 Accommodation of a Scientific Conception: toward a Theory of Conceptual Change *Sci. Educ.* 66 p. 211–227
[3] Strike K and Posner G 1985 *A Conceptual Change View of Learning and Understanding. In L. West & R. Hamilton (Eds.), Cognitive Structure and Conceptual Change* (London: Academic Press)
[4] Davis J 2001 Conceptual Change: The Problem-Solving Process in Physics as Observed when Engineering Students at University Level work in Groups *Eur. J. Eng. Educ.* 40, 4 p. 380–399
[5] Kang H 2010 Investigating Conflict and Situational Interest as Factors Influencing Conceptual Change *Int. J. Environ. Sci. Educ.* 5, 4 p. 383–405
[6] Fulmer G W 2013 Constraint on Conceptual Change: How Elementary Teachers’ Attitudes and Understanding of Conceptual Change Relate to Changes in Students’ Conceptions *J. Sci. Teach. Educ. Res. Sci. Educ.* 34, 1 p. 113–133
[7] Durmus J and Bayraktar 2010 Effect of Conceptual Change Texts and Laboratory Experiments on Fourth Grade Students’ Understanding of Matter and Change Concept *J. Sci. Educ. Technol.* 19 p. 498–504
[8] Hadijiachelos S, Valanides N, and Angeli C 2013 The Impact of Cognitive and Affective Aspect of Cognitive Conflict on Learners’ Conceptual Change about Floating and Sinking *J. Res. Sci. Technol. Educ.* 31, 2 p. 133–152.
[9] Wittrock M C 1986 *Handbook of Research on Teaching* (London: Collier Macmillan Publishers)
[10] Hewson M G and Hewson P W 1999 Effect of Instruction Using Students’ Prior Knowledge and Conceptual Change Strategies on Science Learning *J. Res. Sci. Teach.* 20 p. 731–743
[11] Saracho O N 1997 The Relationship between Matching Teachers’ and Students’ Cognitive Styles and the Students’ Academic Achievement *Early Child Dev. Care* 137, 1 p. 21–29
[12] Witkin H. A., Goodenough D. R., and Cox C A M P. W 1977 Field-Dependent and Field-Independent Cognitive Styles and Their Educational Implications *Rev. Educ. Res.* 47, 1 p. 1–64.
[13] Witkin H A 1973 The Role of Cognitive Style in Academic Performance and Teacher-Student Relations *Proc., Symp., on Cognitive Styles, Creativity, and Higher Education (the Graduate Record Examination Board)* (Canada: New Jersey/Princeton)
[14] Saracho O N 1997 *Teachers and Students Cognitive Styles in Early Childhood Education* (London: Bergin & Garvey) p. 220
[15] Gänswein W 2011 *Effectiveness of Information Use for Strategic Decision Making* (Netherlands: Gabler)
[16] Chiu M S 2012 Identification and Assessment of Taiwanese Children’S Conceptions of Learning Mathematics *Int. J. Sci. Math. Educ.* 10, 1 p. 163–191.
[17] McCormick R 1997 Conceptual and Procedural Knowledge *Int. J. Technol. Des. Educ.* 7, 1–2 p. 141–159.
[18] Rahmawati R Rustaman N Y Hamidah I and Rusdiana D, 2019 The Profile of Cognitive Style,
Logical Thinking Ability, and Conceptual Knowledge of Electricity and Magnetism Topic based on Prospective Physics Teachers’ Grade Level J. Phys. Conf. Ser. 1157, 3 p. 5–12.

[19] Binkley M, Erstad O, Herman J, Raizen S, Ripley M, Miller-Ricci M, Rumble M 2012 Assessment and teaching of 21st century skills (New York: Springer)

[20] Costa A L 1985 Developing Minds: A Resource Book for Teaching Thinking (Alexandria, Virginia: Association for Supervision and Curriculum Development)

[21] Koenig J A, Elliott S, Hilton M, and Iverson K 2011 Assessing 21st Century Skills Summary of a Workshop (Washington D.C: The National Academies Press)

[22] McGregor D 2007 Developing Thinking Developing Learning: A Guided to Thinking Skills in Education (USA: Education Press)

[23] Gustafsson P, Jonsson G, and Enghag M 2015 The Problem-Solving Process in Physics As Observed when Engineering Students at University Level Work in Groups Eur. J. Eng. Educ. 40, 4 p. 380–399

[24] Leach J and Scott P 2003 Individual and Sociocultural Views of Learning in Science Education Sci. Educ. 12, 1 p. 91–113

[25] Cakir M 2008 Constructivist Approaches to Learning in Science and Their Implication for Science Pedagogy: A literature review Int. J. Environ. Sci. Educ. 3, 4 p. 193–206

[26] Redish E F 1994 Implications of Cognitive Studies for Teaching Physics Am. J. Phys. 62, 9 p. 796–803

[27] Prince M 2004 Does Active Learning Work? A Review of the Research J. Eng. Educ. 93, July p. 223–231

[28] Rahmavati R, Rustaman N Y, Hamidah I, and Rusdiana D 2018 The Development and Validation of Conceptual Knowledge Test to Evaluate Conceptual Knowledge of Physics Prospective Teachers on Electricity and Magnetism Topic J. Pendidik. IPA Indones. 7, 4 p. 483–490

[29] Shipstone D M 1984 A study of Children’s Understanding of Electricity in Simple DC Circuits Eur. J. Sci. Educ. 6, 2 p. 185–198

[30] Shipstone D 1988 Pupils’ Understanding of Simple Electrical Circuits: Some Implications for Instruction Phys. Educ. 23, 2 p. 92–96

[31] Arnold M and Millar R 1987 Being Constructive: An alternative Approach to The Teaching of Introductory Ideas in Electricity Int. J. Sci. Educ. 9, 5 p. 553–563

[32] Osborne R 1983 Towards Modifying Children’s Ideas about Electric Current Res. Sci. Technol. Educ. 1, 1 p. 73–81

[33] Osborne R J and Cosgrove M M 1983 Children's Conceptions of the Changes of State of Water J. Res. Sci. Teach. 20, 9 p. 825–838

[34] Hekkenberg A, Lemmer M, and Dekkers P 2015 An Analysis of Teachers’ Concept Confusion Concerning Electric and Magnetic Fields African J. Res. Math. Sci. Technol. 8457, January 2016 p. 34–44

[35] Borges A T and Gilbert J K 2010 Mental Models of Electricity Int. J. Ment. Model. Electr. January 2015 p. 37–41

[36] Cosgrove M, 1995 A Study of Science-in-The Making As Students Generate An Analogy for Electricity Int. J. Sci. Educ. 17, 3 p. 295–301

[37] Cohen R, Eylon B, and Galen U 1983 Potential Difference and Current in Simple Electric Circuits: A Study of Students’ Concepts Am. J. Phys. 51, 5 p. 407–412

[38] Paat R, Ryder J, Schwedes H, and Scott P 2004 A Case Study: Analysing The Process of Analogy based Learning in A Teaching Unit about Simple Electric Circuits Int. J. Sci. Educ. 26, 9 p. 1065–1081

[39] Psillos D, Koumaras P, and Valassiades O 1987 Pupils’ Representations of Electric Current before, during, and after Instruction on DC Circuits Res. Sci. Technol. Educ. 5, 2 p. 185–199

[40] Engelhardt P V and Beichner R J 2004 Students’ Understanding of Direct Current Resistive
Electrical Circuits *Am. J. Phys.* 72, 1 p. 98–115

[41] Finkelstein N 2005 Learning Physics in Context: A Study of Student Learning about Electricity and Magnetism *Int. J. Sci. Educ.* 27, 10 p. 1187–1209

[42] Zacharia Z C and de Jong T 2014 The Effects on Students’ Conceptual Understanding of Electric Circuits of Introducing Virtual Manipulatives within A Physical Manipulatives-Oriented Curriculum *Cogn. Instr.* 32, 2 p. 101–158

[43] Stocklmayer S M and Treagust D F 1996 Images of Electricity: How do Novices and Experts Model Electric Current? *Int. J. Sci. Educ.* 18, 2 p. 163–178

[44] Heller P M and Finley F N 1992 Variable Uses of Alternative Conceptions: A Case Study in Current Electricity *J. Res. Sci. Teach.* 29, 3 p. 259–275

[45] Heywood D and Parker J 1997 Confronting The Analogy: Primary Teachers Exploring The Usefulness of Analogies in The Teaching and Learning of Electricity *Int. J. Sci. Educ.* 19, 8 p. 869–885

[46] Rahmawati R, Rustaman N Y, Hamidah I, and Rusdiana D 2017 The Use of Classroom Assessment to Explore Problem Solving Skills Based on Pre-Service Teachers’ Cognitive Style Dimension in Basic Physics Course in *IOP Conf. Series: Journal of Physics: Conf. Series* 812 (2017) 012047 p. 012047.

[47] Gordon H R D and Wyant L J 1994 Cognitive Style of Selected International and Domestic Graduate Students at Marshall University, China, 027 596.