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Collaborative Problem-Solving Strategies and Cognitive Style: The Impact and Interaction on Students' Mathematical Reasoning Abilities

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ABSTRACT

This study aims at identifying the effect of collaborative problem solving (CPS) learning strategies on students' mathematical reasoning abilities with different cognitive styles, namely field-dependent (FD) and field-independent (FD). This study is a quasi-experimental study with a 2x2 factorial design. A total of 103 students of SMPN 3 Mesuji, Indonesia as research subjects. Mathematical reasoning ability data were obtained from essay tests and cognitive style data were obtained from the GEFT test. Data analysis used two-way analysis of variance (ANOVA) test. The results of this study are: 1) there were significant differences in mathematical reasoning abilities between students who received collaborative problem solving and direct instruction learning strategies, 2) there were significant differences in mathematical reasoning abilities between students who had field dependent and field independent cognitive styles, 3) there was no significant interaction between different learning strategies (collaborative problem solving and direct instruction) and cognitive styles (field dependent and field independent) on mathematical reasoning abilities.

Keywords
mathematical reasoning; cognitive style; collaborative problem solving

Introduction

Ability is a very important learning outcome for students. National Council of Teachers of Mathematics (2000) emphasizes the importance of reasoning and problem solving as a result of learning. Krulik, Rudnick, & Milou (2003) stated that the result of learning is to help students gain the ability to use facts, skills, and information in solving problems and develop their reasoning skills.

The results of the assessment PISA on 2015, Indonesia is ranked 63 out of 69 countries and is in the low material mastery group with an average score of mathematics (M = 386) (OECD, 2016), while in 2018 Indonesia continues to decline with an average score mathematics (M = 376) (OECD, 2018). Based on these assessments, it shows that students' mathematical abilities in solving math problems are still low. Reasoning ability is a very essential ability in mathematical problems solving.

According to Simatupang & Surya (2017) the thing that causes students to have low reasoning skills is an unsuitable learning strategy used by teachers to be able to explore students' reasoning abilities. The use of appropriate learning strategies can encourage students to feel happy about lessons and be able to achieve better learning outcomes (Ainurrahman, 2009).

To overcome these problems, an alternative solution is problem-based learning, namely the Collaborative Problem Solving (CPS) strategy. CPS is the individual's ability to be effectively involved in a process where two or more students try to solve problems by sharing their understanding and need to find solutions and accumulating knowledge, skills and abilities to reach solutions (Luckin et al., 2017; OECD, 2017).

Research on the effectiveness of the CPS strategy has focused more on student learning outcomes, so there have not been many studies examining high-level cognitive abilities in mathematics such as mathematical reasoning abilities. Research conducted by Fawcett & Garton (2005) found that students who studied in collaborative groups obtained better learning outcomes. Research by Lin, Mills, & Ifenthaler (2015) shows that CPS affects the problem-solving process. The higher the process of students collaborating, the higher they show the overall problem solving performance. CPS can improve the learning process and learning outcomes (Harding, Griffin, Awwal, & Scoular, 2017; Yin, 2015). Also concluded that CPS has an effect on learning outcomes (Lu & Lin, 2017).

Apart from learning methods, there are other factors that affect students' abilities. Bloom (1982) suggests that learning outcomes are related to two main factors, namely student characteristics and learning quality. The same thing was stated by Reigeluth (1999) the interaction between instructional strategies and instructional conditions related to the learning outcomes. One of the characteristics of students that affect learning outcomes is cognitive style. Dembo (1981) states that one of the most influential variables on learning outcomes is student characteristics, which appear in the cognitive style.

Cognitive style is a difference in cognitive behavior, thinking, and memory that will affect individual behavior and activities both directly and indirectly (Allinson & Hayes, 1996) and a psychological expression in information processing, which then affects how a person perceives and responds to events and ideas (H A Witkin, Moore, Goodenough, & Cox, 1977). Cognitive style refers to a person's characteristics in responding, processing, storing, thinking, and using information to respond to a task or various types of environmental situations and a person's typical way of solving problems, thinking, understanding and remembering (Bendall, Galpin, Marrow, & Cassidy, 2016).

Cognitive style categories discussed in this study are Field Dependent (FD) and Field Independent (FD) cognitive styles (H A Witkin et al., 1977). Several studies on cognitive style (FI and FD) conclude that cognitive style affects English learning outcomes (Khodadady, Gholami, & Bagheri, 2013), mathematics learning outcomes (Sudarman, Setyosari, Kuswandi, & Dwiyogo, 2016), learning outcomes of conceptual understanding and concept application (Susilowati, Degeng, Setyosari, & Ulfa, 2019).

Based on the explanation above, the CPS strategy has the potential to be a strategy that has a significant effect on improving students' mathematical reasoning abilities. Students who have different cognitive styles will get different learning outcomes so it is necessary to conduct research on cognitive styles. The influence of the cognitive style of FI and FD is very relevant to be explored because it has a strong correlation with cognitive processes in mathematical reasoning. Thus, it is important to investigate the main and interacting effects of CPS learning strategies and cognitive styles on students' mathematical reasoning abilities.

Literature Review

Collaborative Problem Solving is a collaboration carried out by two or more people who have the same goal, namely to solve a particular problem (Dillenbourg, 1999; Gokhale, 1995). CPS is the individual's ability to be effectively involved in a process where two or more agents try to solve problems by sharing their understanding and needs to find solutions and accumulating knowledge, skills and abilities to reach solutions (Wiltshire, Rosch, Fiorella, & Fiore, 2014).

Based on Reigeluth (1999) the steps in CPS learning in this study are: *Phase build a readiness* is to help the students' understanding what they are going to do and develop scenarios or to find problems that are authentic the level of complexity appropriate for the students (Wiggins, 2011). *Phase form a group* is one of the most important activities that is associated with the success of CPS. The heterogeneous formation of small study groups consists of three to six members (Slavin, 2015). *Phase identification of problems* have the meaning that all the members should understand the issues or problems. Furthermore, the group identifies the skills, knowledge, and information needed to start working on the initial problem-solving plan (Bransford, Brown, & Cocking, 2000). *Phase divide roles and tasks* means divide tasks among group members in problem solving sub-activities. By defining a task for each group member, students analyze what needs to be done and who will be responsible for doing it (Bridges, 1992).

Phase planning and problem solving is the heart of the CPS. This phase where the students will invest most of their time when they design and develop problem-solving solutions through activities such as refining and developing plans; identify and assign tasks; obtain the required information, knowledge and expertise; collaborate; disseminating information; engaged in the work of developing problem solving solutions; and participate in collaboration between

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groups (Reigeluth, 1999). *Phase implementation* is the group members will present the results of their work and other members provide responses, suggestions, or opinions and give a solution to solve the problem that have decided (Bridges & Hallinger, 1996). *Phase evaluation* means the teachers and students evaluate the results and the teachers have done processes of problem solving that (West, 1992). *Phase reflection* is final reflection for students to identify and discuss their learning outcomes.

Direct Instruction is a learning model that emphasizes the process of delivering material verbally from a teacher to a group of students with the intention that students can master the subject matter optimally (Sanjaya, 2010). Joice, Weill, & Calhoun (2015) suggest that there are five phases in direct instruction, namely: the *preparation and orientation*, phase in this phase the teacher determines the material and learning objectives. *In the presentation phase*, the teacher explains the material and exercises math problems. *The practice / practice phase under the guidance of the teacher*, the teacher guides and supervises students in working on questions. *The student's independent practice / practice phase, the* teacher provides opportunities for students to do exercises independently in class or at home. The teacher provides feedback at the end of a series of exercises / practices.

According to Witkin (1973) cognitive style is a form of function in a distinctive way based on a person's intellectual abilities which are displayed in perceptual activities and intellectual activities. Cognitive style is the way or habit of a person who is relatively fixed in selecting and remembering information to solve problems (Messick, 1976). Cognitive style categories discussed in this study are Field Dependent (FD) and Field Independent (FD) cognitive styles (Witkin et al., 1977). Field Dependent cognitive style tends to be less or unable to separate something part of a unit and tends to accept the dominant part or context, while Field Independent cognitive style can easily be free from organized perception and can immediately separate a part of the unit.

Some literature (Brodie, 2010), (Litner, 2000), (Fischbein, 1999) states that mathematical reasoning is reasoning about and with mathematical objects. Mathematical reasoning skills help students to conclude and prove a statement, build new ideas, to solve problems in mathematics. NCTM (2000) states that reasoning is: (1) observing patterns or regularities, (2) finding generalizations and conjectures regarding observed regularities; (3) assess / test conjectures; and (4) construct and assess mathematical arguments, and (5) describe logical conclusions and conclusions.

Methods

Research Design

This study is a quasi-experimental study with a 2x2 factorial design. The reason that quasi-experimental research is used is that the researcher does not allow it to control or manipulate all variables that are thought to affect the dependent variable (Tuckman, 1999). Meanwhile, a factorial design is used where two or more independent variables are confronted with each other to assess their effects independently and interactively on the dependent variable (Kerlinger & Lee, 2000).

Table 1. 2 x 2 factorial design

Cognitive style	Learning Strategy	
	Collaborative Problem Solving	Direct Instruction
Field Independent	Group 1	Group 2
Field Dependent	Goup 3	Group 4

Research Subject

This research was conducted at SMPN 3 Mesuji, Indonesia. The sampling technique was using cluster random sampling. A total of 103 grade VIII students were fully involved in this research. Details of the research subjects as in Table 2.

Table 2. Details of the research subjects

Treatment	Classes	Number Subject		
		Male	female	n
CPS	VIII C VIII E	13 11	13 14	26 25
Direct Instruction	VIII A VIII B	13 12	12 15	25 27
Total (N)		48	55	103

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Research Instruments

Test questions for students' mathematical reasoning abilities in the form of an essay test of 5 questions. The correlation score on the validity of the reasoning test is more than 0.30, so the test is valid and usable (Fraenkel, Wallen, & Hyun, 2014). The reliability test score using Cronbach's Alpha is (0.812> 0.70) so that the reasoning test has high reliability (Fraenkel et al., 2014).

The cognitive style test uses the Group Embedded Figure Test (GEFT) developed by Witkin, Oltman, Raskin, & Karp (1971). They used the Spearman-Brown formula to show that the reliability of the GEFT test was 0.82, while the validity was 0.82 for men and 0.79 for women (Davis, 2006).

Table 3. Details of subjects on cognitive style

Treatment	style		n
	FI	FD	
CPS	24	27	51
Direct Instruction	24	28	52
Total (N)	48	55	103

Data Analysis

Analysis in this study uses descriptive statistics and statistical software assisted inference. The normality test used the Kolmogorov-Smirnov test with a significance value ($p > 0.05$) and the homogeneity test used the Levene test with a significance value ($p > 0.05$). Hypothesis testing used two-way Analysis of Variance (ANOVA).

Results

Descriptive Statistics

The data analysis process in this study calculates the data description of the value of reasoning abilities based on learning strategies and cognitive styles using descriptive statistics consisting of the mean and standard deviation.

Table. 4. Results of descriptive statistical analysis

Instructional strategies	Cognitive style	Mean	Standard deviation	n
CPS	FI	72.92	9,315	24
	FD	61.48	10,814	27
	Total	66.86	11,574	51
Direct Instruction	FI	60.83	12,569	24
	FD	55.54	11,494	28
	Total	57.98	12,178	52

Statistical Inference

Table 5. Results of test for normality using the Kolmogorov-Smirnov

	Statistic	p
Reasoning mathematically	.200	.097

Based normality test results using the Kolmogorov-Smirnov test in Table 5, the value of the significance of 0.200 ($p > 0.05$), indicating that the data of mathematical reasoning abilities normally distributed. Furthermore, the homogeneity of the data was tested using the Levene test as in Table 6.

Table 6. Results of the homogeneity test used the Levene test

Levene statistic	df1	df2	p
.905	3	99	.442

Based on Table 6, the significance value was obtained 0.442 ($p > 0.05$) , shows that the mathematical reasoning ability data is homogeneous. The output of the hypothesis test results is as shown in table 7.

Table 7. Two-Path ANOVA Test Results

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4055.361[a]	1351.787	3	10 936	.000
Intercept	402885,127 3259,463	1		402885,127	.000
Instructional Strategy	2082,514 16,848	1		2082,514	.000
Cognitive Style	1793,813	1		1793,813	.000

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
	14,512				
Cognitive Style Instructional Strategy *	241,342.165	1		1,953	241,342
Error	12236.872	99	123 605		
Total	417075.000	103			
Corrected Total 16	292,233	102			

a. R Squared = .249 (Adjusted R Squared = .226)

Based on the results of the two-way ANOVA test in Table 7, there is a difference in mathematical reasoning ability between the CPS and DI strategies, evident in the significance value, namely ($F = 16.848$; $p < 0.05$). In the cognitive style, there are differences in mathematical reasoning abilities between FI and FD cognitive styles, as evidenced by the significance value ($F = 14.512$; $p < 0.05$). There is no interaction between learning strategies (CPS and DI) and cognitive styles (FI and FD) on mathematical reasoning abilities, proven at a significance value, namely ($F = 1.953$; $p > 0.05$).

Discussions

The first findings in this study indicated that students who received treatment used collaborative problem solving strategies with learning strategies direct instruction were significantly different. These results indicate that learning strategies are collaborative problem solving more effective than learning strategies direct instruction. Learning strategies are Collaborative problem solving effective in improving students' mathematical reasoning abilities.

The results of this study are in line with research that shows the superiority of the CPS strategy carried out previously (Lin et al., 2015; Lu & Lin, 2017; Setiawan, Degeng, Sa'dijah, & Praherdhiono, 2020). This strategy encourages students to cooperate more in more intensive groups. The CPS strategy includes several learning activities such as building readiness; forming small heterogeneous groups; identify problems; dividing tasks among group members into problem solving sub-activities; do problem solving together; presenting work results and other members providing suggestions until finally agreed upon and decided on a solution to solving the problem.

The second finding in this study shows that students who have FI and FD cognitive styles differ significantly. These results indicate that students with the FI cognitive style have better mathematical reasoning abilities than students with the FD cognitive style. The results of this study are in line with other studies which show that the field independent cognitive style is superior to field dependent (Sirin & Güzel, 2006; Sudarman et al., 2016), (Setiawan & Sa'dijah, 2020). Witkin et al., (1977) stated that FI students have analytical and synthetic properties in understanding problems. Students are able to abstract the elements into smaller and more independent parts. Meanwhile, individuals who have the cognitive style of FD have the following characteristics: tend to think globally; tend to accept existing structures. In the process of solving problems through the process of reasoning students must prove a statement, build new ideas, to solve problems in mathematics, take logical conclusions and draw conclusions (NCTM, 2000).

The third result of this study shows that there is no interaction between learning strategies (CPS and DI) and cognitive styles (FI and FD) on students' mathematical reasoning abilities. These results indicated that in the FI and FD cognitive styles, students who receive the CPS learning strategy have better reasoning abilities than students who receive the DI strategy. Furthermore, in the CPS and DI learning strategies, students with the FI cognitive style have better mathematical reasoning abilities than students with the FD cognitive style

Conclusion

This study found differences in mathematical reasoning abilities between students with cognitive styles (FI and FD). and between students who receive a defense strategy different lines (CPS and DI). The results of this study can be concluded that 1) the mathematical reasoning abilities of students who received treatment using collaborative problem solving strategies with direct instruction differed significantly. These results indicate that learning strategies are collaborative problem solving more effective in improving mathematical reasoning abilities than direct instruction, 2) mathematical reasoning abilities of students who have significant different FI and FD cognitive styles. These results indicate that students with the FI cognitive style have better reasoning abilities than students with FD cognitive styles, and 3) this study shows that there is no interaction between instructional strategies (CPS and DI) and cognitive styles (FI and FD) on mathematical reasoning ability.

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