Implementation of cooperative integrated reading and composition (CIRC) to enhance mathematical argumentation ability of mathematics teacher students

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Abstract. This study aims to analyse whether there are differences in the enhancement of mathematical argumentation ability between students who received Cooperative Integrated Reading and Composition (CIRC) learning and students who received conventional learning. The research method chosen is quasi-experiment using non-equivalent control group design. Data analysis techniques used are descriptive statistics and inferential statistics. The results show that the average enhances the ability of students’ mathematical argumentation who received CIRC learning are better than students who received conventional learning. When reviewed based on PMK (Prior Mathematical Knowledge), a mathematical argumentation ability of upper and middle PMK group students in CIRC learning classes are better than students' mathematical argumentation in conventional learning. Nevertheless, students' mathematical argumentation ability in the lower PMK groups between the CIRC learning class and the conventional learning class is not different.

1. Introduction
The student's skill in communicating the results of their thinking correctly and full of responsibly is one of the indicators of student's success in picking up the knowledge and skills taught in the college. The student’s should to develop their abilities and interests to use precise language, reason carefully, solve problems effectively, and use mathematics to advance arguments and enhance understanding [1]. The success of students in solving a problem is not only based on the amount of knowledge already possessed but the quality of the knowledge it is a very important part. The quality of student knowledge will be better when they are given some opportunist to think and reason so that students can develop their understanding. These activities are part of mathematical argumentation activities.

The term of argumentation refers not only to an activity called debate, although it is one form of argumentation. Golanics and Nussbaum [2] view argumentation as a process of social thought and interaction in which individuals construct and criticize arguments. According to Toulmin [3], argumentation is a process of making claims and justifying those claims by fact. The other definition of arguments as the rational way used to solve questions, problems, disagreements and solve problems [4]. The most important of the three opinions above about argumentation is an attempt to influence or
convince others by rationally arguing which aims to support (justify) or refute something. When it is related to mathematics learning, the opinions above conclude that argumentation is the ability of students to provide mathematical explanations based on sufficient evidence/facts in inferential process.

Toulmin states that there are six elements to build a strong argument [4]. The six elements in question are a claim, data, warrant, backing, qualifier, and rebuttal, as shown in Figure 1 below.

![Toulmin's model of argumentation](image)

**Figure 1.** Toulmin's model of argumentation

A claim (standpoint) is defined as a statement expressing a person's "opinion" or "stand" about something you want to prove. Data is evidence in the form of certain facts that support claims. A warrant can be expressed as a principle, a rule, and the like. The role of a warrant as a bridge between the data elements and claims. Furthermore, backing, qualifier, and rebuttal are additional elements that may be needed in constructing an argument [5].

A good argument is an argument that meets the specified criteria. According to Blair and Johnson [4], a good argument must contain all three criteria: relevance, sufficiency, and acceptability. Relevance implies that in an argument there is a sufficient relationship between the content of a premise and its conclusion, the meaningful sufficiency of the argument contains a premise that provides sufficient evidence/fact for inference process, and acceptability is the reality of the premises being constructed.

The basic argumentation is critical and logical thinking [6], while the argument from the side of psychological development as a process that allows the need for an understanding of concepts and the ability to think critically [2]. This is in line with other statement that critical thinking is part of mathematical thinking ability, in which there is the ability to argue, to use syllogism, to inference, to evaluate, and the ability to create something in the form of new products or knowledge that possess the characteristics of originality [7]. Critical thinking can be viewed as a careful determination of whether to accept, reject, or postpone a decision to accept a statement. Therefore, critical thinking requires listening skills, reading carefully, searching for and determining hidden assumptions, and investigating the consequences of a statement.

Based on the above description, the aspect of mathematical argumentation skills used in this research is derived from three qualitative argument traits namely relevance, sufficiency, and acceptability. Aspects of these skills are analysis, evaluation, interpretation, and inference. The four skills aspects are operationalized into (1) can examine the similarities and differences of strategies used including identifying data, warrant, and claim, (2) can assess the truth of an argument including evaluating claims based on acceptable data and warrants, (3) can clarify statements by providing necessary and sufficient conditions, (4) can compile an explanation based on relevant and irrelevant data, and (5) can apply the principle by presenting sufficient data, relevant warrant, and acceptable claim in making a decision.

Although the ability of mathematical argument has an important role in developing the quality of students' mathematical understanding, it is not fully mastered by the students. The low level of mathematical argumentation is still a major problem in the implementation of current learning, this has been shown by some previous research results that illustrate the low ability.
The results of the study of several experts with the subject of mathematics preservice teachers concluded that the causes of most students can’t do mathematical argument well are their mistake in interpreting a premise so that they are mistaken to build a mental model and difficulties in translating the conclusion of a premise [8]. The research results of Cerbin show that the student's inhibition of problem-solving is specifically due to their weakness in relating evidence with claims when thought processes are important during problem-solving [3]. Meanwhile, the results of Reznitskaya, Anderson, McNurlin, Nguyen-Jahiel, and Archodidou [4] concludes that students' weaknesses in writing argument structures, selecting concepts or supporting theorems, and setting up counter examples are major factors that hinder students in constructing a valid argument. The other result of the study shows that most students though produce the correct solution of a problem but the solution is still based on false conceptions. Thus, the success of students in solving numerical problems does not necessarily reflect the quality of their understanding of related mathematical concepts and principles [9].

Mathematics learning involves the activities of students and teachers, much like the learning process in general. Therefore, certain learning activities play a role in improving students' mathematical argumentation skills. Based on several studies applying a variety of approaches or learning models, it is shown that students who have active learning can achieve better mathematical argumentation skills compared to students with conventional learning.

Richart states that in order for students to learn effectively and their argumentation skills are develop, they need to be motivated to get used to using their thoughts. The form of motivation can be the habituation of students involved with the task, construct knowledge, build meaning, build solutions, and communicate solutions to others. In simple terms, the process can be done by applying cooperative learning [10]. One of the cooperative learning models is Cooperative Integrated Reading and Composition (CIRC). CIRC is a cooperative learning technique originally intended for elementary school, junior high and high school in reading and writing [11]. CIRC is developed based on the research and analysis of traditional problems practically on the teaching of reading, writing, and language arts that produce a significant influence on improving students' reading and writing skills. In this study, the authors have experimented the CIRC model on the application of mathematics learning at the college level because it assumes that the ability to read and write mathematics is closely related to the ability of mathematical argumentation.

Learning using the CIRC model consists of three main phases of learning: the concept introduction phase, the exploration-application phase, and the publication phase. In the introduction phase of the concept, students present the material through text reading that is interpretative reading that is reading that requires students to draw conclusions from the text content either expressed or implied. During this phase, students are given the opportunity to conduct reading activities to interpret and construct the meaning contained in the text and writing activities to compile summaries and questions. During the process of interpretation and the formation of the ideal meaning occurs also the process of association with ideas and other mathematical ideas from learning resources outside the text, translation of mental symbols of mathematics, identification, evaluation, clarification and compilation of explanations.

The exploration-application phase provides students with the opportunity to uncover the interpretation and meaning outcomes that have been formed in the first phase, to develop new knowledge with a team and minimal mentoring from the teacher. This leads to cognitive conflicts in themselves and attempts to test and discuss to explain the results of his observations. The lecture given by the lecturer in this second phase is more critical reading through the problems and material issues because basically the purpose of this phase is to raise interest, curiosity and apply the student's early conception to the learning activities.

The third phase of the CIRC learning model is publication. This phase trains students' ability to communicate ideas embodied in texts, solutions to problems or problems provided, to prove, and to re-demonstrate the material under discussion. The publication of this idea can be either something new or simply prove its interpretation to be known by their classmates. In this stage, the students are trained to be ready to accept criticism and suggestions or even to argue with each other. Therefore, the CIRC
learning model is considered appropriate to motivate students to do activities that can develop the ability of mathematical argumentation.

2. Methods
Based on the consideration of problem formulation and research objectives to be achieved, the type of research chosen is a quasi-experiment. In addition, consideration of the selection of research subjects is also the reason why the type of research is used. The research design used was non-equivalent control group design were subjects in the experimental group or control group were not randomly selected.

The population in this research is all students of the candidate of mathematics pre-service teacher who enrolled in subject of Number Theory in one of Private University in Region III Cirebon, West Java, Indonesia, as many as 120 students. Samples from the population were taken based on a purposive sampling of 80 students grouped into two groups are 40 students joined the group who got the CIRC learning and 40 other students joined the group who got the conventional learning.

Data analysis techniques used are descriptive statistics and inferential statistics. To analyse descriptive argumentation enhancement data through normalized gain analysis. Meanwhile, the inferential analysis was conducted to analyse statistically the enhancement of students' mathematical argument ability that got CIRC learning compared to students who received conventional learning. The statistical test used is the parametric statistical test (t-test or t'-test) if each group of data comes from a normally distributed population, whereas if there is one group of data that is not normally distributed then the test using non-parametric statistical test, in this case, Mann-Whitney U test.

3. Results and Discussion

3.1. Results
The average data of mathematical argumentation ability (MAA) of students based on learning model and a group of PMK is presented in Table 1.

| A Group of PMK | Descriptive statistics | Conventional | CIRC |
|----------------|------------------------|--------------|------|
|                |                        | Pretest | Posttest | N-gain | Pretest | Posttest | N-gain |
| Upper          | N                      | 7       | 7        | 10     | 10      |          |       |
|                | Max. Score             | 6       | 32       | 0.87   | 8       | 30       | 0.81   |
|                | Min. Score             | 4       | 12       | 0.25   | 4       | 18       | 0.44   |
|                | Mean                   | 5.14    | 21.14    | 0.52   | 5.00    | 26.00    | 0.68   |
|                | SD                     | 1.07    | 5.98     | 0.19   | 1.41    | 3.53     | 0.11   |
|                | N                      | 27      | 27       | 24     | 24      |          |       |
|                | Max. Score             | 8       | 32       | 0.88   | 8       | 28       | 0.75   |
|                | Min. Score             | 0       | 10       | 0.19   | 0       | 0        | -0.2   |
|                | Mean                   | 4.74    | 16.82    | 0.39   | 4.33    | 23.04    | 0.59   |
|                | SD                     | 1.58    | 4.79     | 0.15   | 1.74    | 6.22     | 0.21   |
|                | N                      | 6       | 6        | 6      | 6       |          |       |
|                | Max. Score             | 6       | 32       | 0.87   | 8       | 26       | 0.69   |
|                | Min. Score             | 2       | 12       | 0.27   | 4       | 8        | 0.07   |
|                | Mean                   | 4.67    | 19.67    | 0.48   | 5.67    | 18.67    | 0.42   |
|                | SD                     | 1.63    | 7.74     | 0.24   | 1.97    | 7.34     | 0.26   |
|                | N                      | 40      | 40       | 40     | 40      |          |       |
|                | Max. Score             | 20      | 96       | 2.62   | 24      | 84       | 2.25   |
|                | Min. Score             | 6       | 34       | 0.71   | 8       | 26       | 0.31   |
|                | Mean                   | 4.85    | 19.21    | 0.46   | 5.00    | 22.57    | 0.56   |
|                | SD                     | 1.43    | 6.17     | 0.19   | 1.71    | 5.70     | 0.19   |

Table 1. The average data of students' MAA based on learning and PMK
In Table 1, it can be seen that either overall or by PMK group, the average of MAA pretest students who received conventional learning is relatively the same as the average pretest of MAA students who received CIRC learning. The average enhance of MAA score based on N-gain for the group of students who get conventional learning is 0.46 while the N-gain for a group who get CIRC learning is 0.56. However, when viewed based on the N-gain criteria, the mathematical argumentation ability between the students in the experimental group and the control group is on the same criteria of medium criteria. In the meantime, the enhance in MAA of students in upper and middle PMK groups who received CIRC learning was higher compared to those in the upper and middle PMK groups who received conventional learning, whereas the mean enhancement of the MAA students in lower PMK groups who received conventional learning was relatively the same as the CIRC learning group.

To determine whether the descriptive conclusions can be generalized or not, then the inferential statistical test is analyzed. The result of normality test of data enhancement of mathematical argument ability using Kolmogorov-Smirnov test shows that the value of sig. in the normality data test the average of enhancement in MAA students less than \( \alpha = 0.05 \) so it can be concluded that the average of enhancement of MAA in both groups of learning comes from the population that is abnormal distribution. Therefore, to examine the difference of the average of students' mathematical argumentation enhancement in both learning groups, the Mann-Whitney U test. The formulation of the hypothesis tested is:

\[
H_0: \mu_1 = \mu_2
\]

There is no difference of mathematical argumentation enhancement between groups of students who received CIRC learning and a group of students who received conventional learning

\[
H_1: \mu_1 > \mu_2
\]

The overall enhancement of students' mathematical argumentation who received CIRC learning is better than the group of students who received conventional learning

The testing criteria: If the value of sig. (1-direction) is higher than \( \alpha = 0.05 \), \( H_0 \) is accepted and in the other cases, \( H_0 \) is rejected. The testing results are given in Table 2.

| MAA Test          | Group of Learning | U Mann Whitney | Z    | sig. (1-direction) | Marks       |
|-------------------|-------------------|----------------|------|--------------------|-------------|
| Enhancement       | Conventional      | 337.5          | -4.457 | 0.000              | H. is rejected |
|                   | CIRC              |                |      |                    |             |

The results of the difference test above show the sig value. (1-direction)<0.05 which means the \( H_0 \) is rejected. Therefore, it can be concluded that the overall, the average of enhancement in the mathematical argumentation ability of students who received CIRC learning is better than the conventional group of students. The recapitulation of the difference test of the average of enhancement mathematical argumentation ability based on the upper and lower PMK groups is presented in Table 3. While the results of difference test of middle PMK group students are being given in Table 4.

| MAA Test | Group of PMK | Group of Learning | \( t_m \) | df | \( t_m \) | \( \text{sig.} \) (1-direction) | Marks       |
|----------|--------------|-------------------|--------|----|--------|---------------------------|-------------|
| Enhancement | Upper   | Conventional      | -2.226 | 15 | -2.131 | 0.021                    | H. is rejected |
|          | CIRC      |                    |        |    |        |                           |             |
|          | Lower    | Conventional      | 0.416  | 10 | 2.228  | 0.343                    | H. is accepted |
|          | CIRC      |                    |        |    |        |                           |             |
Table 4. The results of the mann-whitney u test in the middle PMK group on both learning groups

| MAA Test | Group of PMK | Group of Learning | U Mann-Whitney | Z     | sig. (1-direction) | Marks |
|----------|--------------|------------------|----------------|-------|--------------------|-------|
| Enhancement | Middle       | Conventional     | 95.5           | -4.321| 0.000              | H_0 is rejected |

Based on the results of inferential statistical tests it can be concluded that overall, the average of enhancement the ability of students' mathematical arguments who received CIRC learning is better than students who received conventional learning. Based on PMK group category, it can be concluded that in learning of CIRC, students in upper and middle PMK groups have an average of enhancement in mathematical argumentation ability is better than students who received conventional learning, whereas in PMK group below the average of enhancement in the ability of mathematical argumentation between on both learning groups is not different.

3.2. Discussion

Based on the average difference test using Mann-Whitney U statistic test, the result shows that overall enhancement of MAA students who received CIRC learning is better than MAA students who received conventional learning. It is related to the result in which CIRC learning can enhance students' mathematical connection ability [12]. In addition, the result of other study also showed similar problems of connection ability and mathematical problem solving of students who received CIRC learning higher than students who received conventional learning [13].

Based on the results of study about implementation of approaches and learning models can affect an enhancement of mathematical ability studied, it can be said that student activities during CIRC learning are also contributed to the enhancement of MAA students. CIRC learning is a learning that combines the activities of reading and writing in groups. The three main phases of CIRC learning have provided space for students to develop their mathematical argumentation ability. In the phase of concept introduction, learning begins by training students reading a theorem and definitions relating to the concept being studied in groups. During this phase, students are given the opportunity to do reading activities to interpret and build the meaning contained in a definition or theorems of mathematical concepts. The task of constructing the knowledge given to the students through reading activities makes the thinking process of students more developed and the student experience in connecting the concept with one another increases. The meaningful learning experience for students can be given the assignment of a more oriented thinking ability of students, and students who also do the thinking process [14]. This repetitive learning experience led to the enhancement of students' mathematical argumentation ability in the CIRC class better than the conventional class.

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The second phase of CIRC learning are the exploration-application phase. It is giving a positive influence on enhancing the ability of mathematical argumentation. During this phase, students reveal some results of interpretation and meaning that has been formed in the first phase. The process of revealing interpretation and construction of the meaning of some theorems and definitions by the students also fostered the mental activity higher than the previous stage. In-group discussion activities are the focus of learning in the exploration-application phase. The interaction of students with their study groups while trying to understand the meanings contained in a theorem and the definition affects the quality of mathematical argumentation. Through CIRC learning, each student is responsible for group work. Each member of the group exchanged ideas to understand a concept and complete the task, so that formed the understanding and experience of learning a long time. It is related to Vygotsky's opinion that interaction in a class is a fertile ground to explore the mathematical comprehension of learners more developed [9]. Meanwhile, students' comprehension of a concept also influences the resulting mathematical argumentation. This is related to the study of Lampert, Rittenhouse, and Crumbaugh [2] which shows that the quality of the learners' argument correlates with the understanding of their mathematical concepts.
The last phase of the CIRC learning is the publication phase. This phase trains students to communicate mathematical ideas that have been acquired and discussed in the first and second phases. When students publish what they have acquired, they are learning to compose an explanation based on relevant data so that what they believe will be accepted by others. At this stage, students are also trained to be ready to accept criticism and suggestions from all classes. Thus, the ability of students to explain, clarify, evaluate, and make inference more be sharpened.

Furthermore, the difference in MAA enhancement of students who received CIRC learning with students who received conventional learning also occurs when reviewed based on the PMK of students. In the upper and middle PMK groups between the both learning, the mathematical argumentation ability of the CIRC learning group is higher than that of the conventional learning group. Meanwhile, in the lower PMK group the enhancement in MAA students on both learning groups, there is no different. Based on this, it is can be said that a quality of the students' PMK will be effect to their mathematical argumentation.

While solving mathematical problems, students adapt and extend their existing understanding by both connecting new information to their current knowledge and constructing new relationship within their knowledge structure. Thus, the conceptual framework of prior knowledge must be better and integrated in order to accommodate various perspectives, methods, and solutions through synthesis and conflict processes in students' cognitive structures.

4. Conclusion
The average of enhancement in the ability of students' mathematical arguments who received CIRC learning is higher than students who received conventional learning. When reviewed based on groups of prior mathematical knowledge (PMK), the mathematical argumentation ability of upper and middle PMK group students in CIRC learning is higher than students' mathematical argumentation in conventional learning. Nevertheless, students' mathematical argumentation ability in the lower PMK groups between the CIRC learning and the conventional learning did not differ.

Relating to the results of research that has been obtained, it can be said that in addition to the stages of learning that must be implemented properly, teachers should still pay attention to the students' prior mathematical knowledge. This can be reflected in the task given at the time of learning. The effective tasks are tasks that can motivate and guide students to learn well in accordance with their prior mathematical knowledge.

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