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Culturally Responsive Teaching in Differentiated Learning to Improve Mathematical Communication Ability

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Abstract

This study was motivated by the low mathematical communication ability observed among students, which is partly due to teaching approaches that have not fully accommodated students' diverse cultural backgrounds and learning needs. The purpose of this classroom action research is to improve students' mathematical communication ability in differentiated learning through Culturally Responsive Teaching (CRT). The data were collected using questionnaires, observation sheets, and tests in statistics topic, and were analyzed by comparing data from pre-test and post-test results. This study was conducted in 2 cycles in a class of Grade X students at SMAN 14 Semarang with procedures: (1) planning, (2) action, (3) observation, and (4) reflection. The first cycle is related to differentiated-process learning based on learning interests through CRT with the theme of Semarang City Culture, while the second cycle is related to differentiated-process learning based on learning styles through CRT with the theme of Javanese Culture. The results showed that CRT in differentiated learning can improve mathematical communication ability by 29% in the first cycle and 53% in the second cycle. The learning process became more inclusive, with students showing greater confidence in communicating mathematical ideas and engaging more actively in class discussion. This study contributes to the field of mathematics education by integrating cultural responsiveness with differentiated instruction, which can address diverse student needs, foster a meaningful learning environment, and improve mathematical competencies.

1. Introduction

Education has an important role in the development of a nation. Education is the first step to developing human resources. In this 21st century, the education system emphasizes 4C abilities in learning that is critical thinking, communication, collaboration, creativity (Saimon et al., 2023). The 4C abilities are needed to develop students' quality to face the global world. One of the 4C's capabilities is communication.

Communication is the process of conveying thoughts either verbally or non-verbally. Verbal communication is in the form of verbal and written, while non-verbal communication is in the form of motion, images, and gestures (Lanani, 2013). Communication ability is the ability to conveying thoughts either verbally or non-verbally, while mathematical communication ability is the ability to connect real objects and images into mathematical language (Tong et al., 2021). Mathematical communication ability in this study is the abilities to develop thinking structures to solve mathematical problems through mathematical languages and symbols. According to Tupamahu et al. (2023) research, mathematical communication ability in this study are: (1) communicating ideas using mathematical languages and symbols appropriately, (2) modeling situations into various forms of mathematical representations such as pictures, tables, diagrams, or graphs, and (3) presenting well-structured problem solving.

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Communication is an important part of mathematics and mathematics education (National Council of Teachers of Mathematics, 2000). In mathematics education, communication abilities are very important to be optimized so that the learning process can run smoothly (Setiyani et al., 2020). In mathematics learning, there are several mathematical problems that need to be solved to get solutions. Studies conducted by Rohid et al (2019) showed that mathematical communication abilities play a major role in the mathematical problem-solving processes. The attention of these mathematical communication abilities is irrelevant to the ability that students have.

Based on the formative assessment results of measures of data location material, the communication abilities of tenth 5 grade students aren't optimal. From 34 students, 3 students (9%) reached the 3s indicators of mathematical communication ability, 6 students (18%) reached 2 indicators, and 6 students (18%) reached 1 indicator, while the remaining 19 students didn't reach all the 3s indicators. One of the formative assessment questions to measure the 3s indicators of mathematical communication ability is shown in Figure 1.

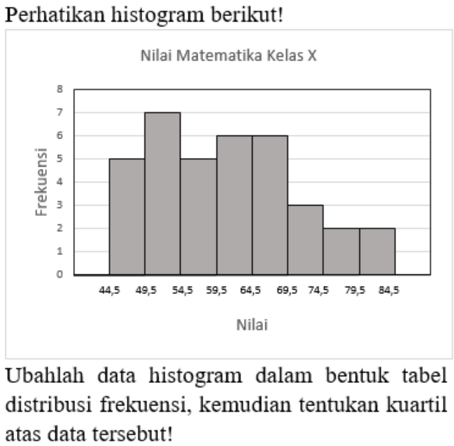
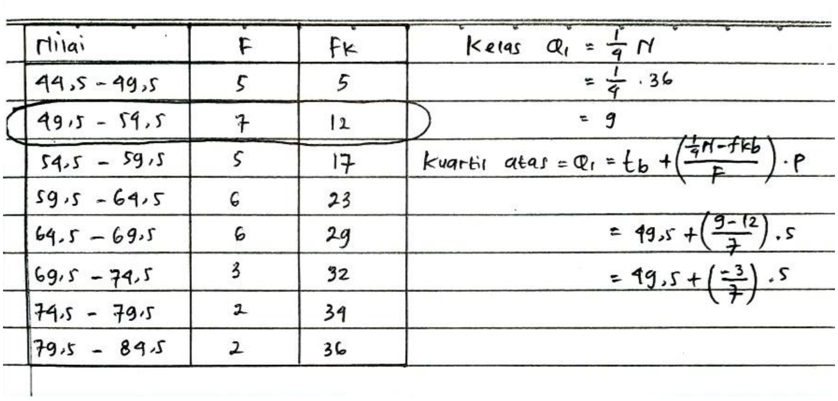


Figure 1. Pre-test Question.

The pre-test questions in Figure 1 is to measure the 3s indicators of mathematical communication abilities. Students are asked to represent the data on the histogram to the form of frequency distribution table (Indicator 1 and Indicator 2), then determine the upper quartile of the data (Indicator 3). The following is one of the student's answers.



Nilai	F	Fk
44,5 – 49,5	5	5
49,5 – 54,5	7	12
54,5 – 59,5	5	17
59,5 – 64,5	6	23
64,5 – 69,5	6	29
69,5 – 74,5	3	32
74,5 – 79,5	2	34
79,5 – 84,5	2	36

Kelas $Q_1 = \frac{1}{4} N$

$= \frac{1}{4} \cdot 36$

$= 9$

kuartil atas $= Q_1 = t_b + \left(\frac{\frac{1}{4}N - fkb}{F}\right) \cdot p$

$= 49,5 + \left(\frac{9-12}{7}\right) \cdot 5$

$= 49,5 + \left(\frac{-3}{7}\right) \cdot 5$

Figure 2. Example of Pre-test Answer.

In Figure 2, students create a table containing 3 columns that is value, frequency, and cumulative frequency. Students recognize that the symbol of writing frequencies, cumulative frequencies, and number of data is f, f_k, and n, in contrast it isn't correct in writing, because it has been written in capital letters. This shows that students do not reach Indicator 1 because they do not communicate ideas using mathematical languages or symbols appropriately. Furthermore, students are able to determine the number of classes, which is 8 classes, but can't determine the lower and the upper class limits in each class. Students immediately write the lower and the upper class edges as a class, for example in the first class which is written with $44{,}5 - 49{,}5$. On the histogram, each class is written using the lower and the upper class edges so that the lower class limits is gotten by adding the lower class edges by $0{,}5$ while the upper class limits is gotten by subtracting the upper class edges by $0{,}5$. On the histogram, it can be seen that the first class has the lower class edge of $44{,}5$ so the lower class limit is $44{,}5 + 0{,}5 = 45$, while the upper class edge of $49{,}5$ so the upper class limit is $49{,}5 - 0{,}5 = 49$. Hence, students do not reach Indicator 2 because they do not model situations into various forms of mathematical representations such as pictures, tables, diagrams, or graphs. In addition, students can't determine the upper quartile is the Q_3. Students mistakenly think that the upper quartile is Q_1 hence the formula used is the formula to determine Q_1. Students also look for the Q_1 class. In the section substituting the value of f_{kb}, the cumulative frequency before the quartile class, students write the frequency in the quartile class (frequency of Q_1 class). The students' work was stopped because of the negative values. This shows that students aren't able to present well-structured problem solving, hence Indicator 3 has not been reached.

The mathematical communication abilities of tenth 5 grade students have not been optimal, encouraging teachers to reflect on the learning activities that have been carried out. Based on the results of the observation for one semester, the mathematical communication ability is not optimal due to the implementation of an inappropriate differentiated learning approach, by grouping students' cognitive abilities based on high, medium, and low abilities. This resulted in a low level of confidence in medium and low ability groups that were seen when discussed in completing students' worksheets (i.e. Lembar Kerja Siswa) and presenting the discussion results in front of the class. Therefore, it is necessary to differentiate learning based on learning interests and learning styles so that students remain confident.

The other thing to reflect on is the context of learning that is still abstract. This abstraction process is considered difficult for students, especially for students who are not interested in learning mathematics, therefore, a learning approach is needed to bring students closer to real life in their living environment (Afni & Hartono, 2020). One of the learning approaches that brings students closer to the surrounding environment is Culturally Responsive Teaching (CRT) (Murti, 2023). CRT syntax is (1) developing students' self-identity in different cultural backgrounds (2) constructing understanding of local culture (3) collaboration in groups (4) critical thinking to reflect and (5) transformative construction by presenting collaboration results (Patras et al., 2025). The first and second syntax of CRT can improve the first indicator of mathematical communication abilities. By developing their self-identity and constructing understanding of their local culture, students are facilitated to communicating ideas using mathematical languages appropriately. The third and fourth syntax of CRT can improve the second indicator of mathematical communication abilities. By collaborating with peers in groups and thinking critically, students are helped to modeling situations into various forms of mathematical representations. The last syntax of CRT has similar process with the third indicator of mathematical communication ability that is presenting well-structured collaboration results as transformative construction. Each learning step uses CRT, students are directed to learn mathematical concepts that are linked to their culture, thus facilitating the process of building student knowledge and fulfil students' learning needs as differentiated learning implementation.

According to this problem description, this classroom action research was carried out to improve students' mathematical communication ability by applying differentiated learning based on students' learning interests and learning styles through CRT.

2. Methods

2.1. Research Design

The classroom action research aims to solve real problems that occur in the classroom as well as find scientific answers as to why they can be solved through actions to be taken (Cholifah et al., 2019). Classroom Action Research (CAR) is not only supported but also mandated by Permendikbud Nomor 22 Tahun 2006 as part of Indonesian teachers' professional duties. The regulation defines CAR as a scientific approach to address classroom issues, test interventions, and improve teaching practices through recursive cycles of planning, action, observation, and reflection. The widely CAR cycle described by Kemmis et al. (2014) consists of four stages : planning, action, observation, and reflection. Planning stage to identify a classroom problem and plan an intervention, action stage to implement the planned intervention, observation stage to collect data on the effects of the action, and reflection stage to analyze to determine if the problem has been resolved and plan progress for the next cycle. This CAR use spiral model of 2 cycles which described in Figure 3.

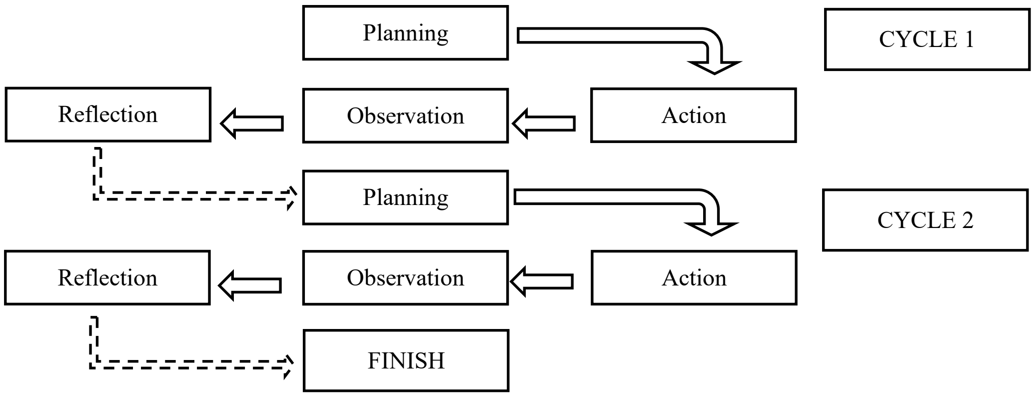


Figure 3. Research Design.

The first cycle uses differentiated-process learning based on learning interests through CRT with the theme of Semarang City Culture that is Dugderan Culture. As Maulana et al. (2024) described, learning interests are categorized as high, medium, or low. **First**, at the planning stage, prepare teaching modules, learning interest questionnaire, pre-test, and post-test 1. **Second**, at the action stage, it consists of 3 activities, which is the initial, core, and closing activities. The initial activity began with the provision of pre-test and learning interest questionnaire. In the core activity (first action), the differentiated learning based on learning interests (high, medium, low) through CRT Dugderan Culture. In the closing activity, it contains conclusions and assignments. **Third,** in the observation stage, the teacher gives post-test 1 after the first action. Post-test 1 score was compared with the pre-test score to determine the improvement of mathematical communication abilities. **Fourth**, at the reflection stage, evaluate whether the achievement indicators have been reached or not. If not, then the reform learning is necessarily needed, both in differentiation and in CRT.

Table 1. Implementation Time.

	Week							
	1		2		3		4	
	Meeting							
	1	2	1	2	1	2	1	2
Cycle 1								
1. Planning	√							
2. Action		√	√	√				
3. Observation				√				
4. Reflection					√			
Cycle 2								
1. Planning					√			
2. Action						√	√	√
3. Observation								√
4. Reflection								√

The second cycle uses differentiated-process learning based on learning styles through CRT with the theme of Javanese Culture that is Wayang Orang Culture. As Munahefi et al. (2024) described, learning styles are categorized as auditory, visual, or kinesthetic. **First**, at the planning stage, prepare teaching modules, learning style questionnaires and post-test 2. **Second**, at the learning action stage, it consists of 3 activities, which is the initial, core, and closing activities. The initial activity began with the provision of learning style questionnaires. In the core activity (second action), the differentiated learning based on learning styles (auditory, visual, kinesthetic) through CRT Wayang Orang Culture. In the closing activity, it contains conclusions and assignments. **Third,** at the observation stage, the teacher gives post-test 2 after the second action. The post-test 2 score was compared with the score of post-test 1 to find out the improvement of mathematical communication abilities. **Fourth,** at the reflection stage, evaluate whether the achievement indicators have been reached or not. If so, then the study can be stopped and then disseminate the research results at Unnes Journal of Mathematics Education. The implementation time is explained in Table 1.

2.2. Participant and Data Collection

This research subject is 34 students in tenth five grade of SMAN 14 Semarang. The data collection technique uses questionnaires, observations, and tests. Questionnaire method is a method of collecting data through submitting written questions to research subjects and the answers are also given in writing (Krosnick, 2017). This questionnaires are used to identify students' learning interests in the first action, and learning styles in the second action. Observation is a method of data collection in which researchers make explorations on the subject of research both directly and indirectly (Ciesielska et al., 2017). The learning process in cycle 1 and cycle 2 was observed directly using observation sheets that had been adjusted to CRT-differentiated learning syntax. Test is a method of data collection that confronts a number of questions to research subjects either individually or in groups where the responses can be categorized into true or false responses (Budiyono, 2017). This tests consists of pre-test, post-test 1, and post-test 2. Pre-test is given before any action, while post-test 1 and post-test 2 is given after the first action (cycle 1) and the second action (cycle 2). Each pre-test and post-test is in the essay form descriptive questions in statistics topic, each of which is arranged based on mathematical communication ability indicators.

2.3. Data Analysis and Instruments Validity

This research instrument includes questionnaires, observation sheets, and test questions that have been validated with fellow teachers using expert judgement (Werner et al., 2017). The data analysis technique used is comparative descriptive analysis, which is comparing data from pre-test, post-test 1, and post-test 2 results. The achievement indicator in this study is the improvement of students' mathematical communication ability based on the indicators of at least 50% of the total students.

3. Results & Discussions

3.1. Cycle 1

This first cycle of this classroom action research consists of the following four stages.

Planning stage : compiles the learning tools include teaching modules that contain indicators and objectives learning, data dispersion measure materials (range, spread, average deviation, variance, and standard deviation), differentiated learning approaches based on learning interests (high, medium, low), teaching media (discussion sheets with the theme of Dugderan Culture), differentiated learning process design (based on mathematics learning interests) through CRT Dugderan Culture, and learning resources (students' worksheet and YouTube). Besides that, the teacher also compiles the learning interest questionnaires, pre-test, and post-test 1.

Action stage : learning action consists of the following 3 activities. The initial activity began with the pretest provision to measure students' initial abilities and the provision of learning interest questionnaires. In addition, the teacher provides an apperception and motivation to study. The core activity, the teacher design differentiated learning based on learning interests in high, medium, and low categories. There're 34 students in the class, divided into 6 groups. Based on the average and deviation standard, the results are obtained from group 1 in high category, group 6 in low category, and the remaining group 2 until group 5 in medium category. The CRT Dugderan Culture approach is integrated on the discussion sheets which are done in groups. The closing activity, teacher together with students deducted the material that had been learnt, that is data dispersion measures. Teacher also gives students' assignments related to data dispersion measures.

Observation stage : post-test 1 given to measure students' mathematical communication abilities after being given the first action. Post-test 1 results are assessed based on the score guidelines. Data of the post-test 1 score is compared to the pre-test score, which determines the number of students who have reached each mathematical communication ability indicator. The comparison of the results is given in Table 2.

Table 2. Comparison of Mathematical Communication Ability after the First Action.

Indicator Mathematical Communication Ability	Before Action *(pre-test)*	Cycle 1 *(post-test 1)*
Communicating ideas using mathematical languages and symbols appropriately.	23 students (68%)	31 students (91%)
Modelling situations into various forms of mathematical representations such as pictures, tables, diagrams, or graphs	14 students 41%)	23 students (68%)
Presenting well-structured problem solving.	3 students (9%)	10 students (29%)

Table 2 explains that the students' mathematical communication abilities, which have reached Indicator 1 before the action, is about 68%, 23 students only. By developing their self-identity and constructing an understanding of Dugderan culture (first and second CRT syntax), 31 students communicated ideas using mathematical language appropriately, which means that students have reached Indicator 1 of mathematical communication abilities, increase into 91%. Students' mathematical communication abilities, which have reached Indicator 2, before the action is, about 41% but increase to 68% after the first action. By collaborating with peers in groups and thinking critically about data dispersion measure which are presented in Dugderan culture (third and fourth CRT syntax), students model situations into various forms of mathematical representations, that is distribution table and statistical symbols. Students' mathematical communication abilities, which have reached Indicator 3, before the action, is about 9% but increase to 29% after the first action. By transformative construction (fifth CRT syntax), 10 students presented well-structured collaboration results. Mathematical communication ability indicators are a sequence of abilities, so that students who have reached Indicator 3 must have reached the two indicators before, there are Indicator 1 and Indicator 2. As a consequence, the calculation of the improvement of mathematical communication abilities is seen from the number of students who have reached Indicator 3. Based on the achievement indicator that has been decided before, the 29% improvement has not been said to be successful, so the following action is necessarily needed.

Reflection stage : the first action resulted in no significant improvement of mathematical communication abilities, so a reform learning is necessarily needed, both in differentiation and in CRT which is used. After the cycle 1, the reflection findings are design differentiated learning based on learning styles through CRT Wayang Orang Culture.

3.2. Cycle 2

This second cycle of this classroom action research consists of the following four stages.

Planning stage : compiles the learning tools include teaching modules that contain indicators and objectives learning, materials such as boxplot, scatter plot, statistics report evaluation in the media, differentiated learning approaches based on learning styles (auditory, visual, kinesthetic), teaching media (discussion sheets with the theme of Wayang Orang Culture), differentiated learning process design (based on mathematics learning interests) through CRT Wayang Orang Culture, and learning resources (students' worksheet and YouTube). Besides that, the teacher also compiles the learning style questionnaires and post-test 2.

Action stage : the initial activity began with the provision of learning style questionnaires. In addition, teacher provides an apperception and motivation to study. The core activity, teacher design differentiated learning based on learning styles in auditory, visual, and kinesthetic categories. There're 34 students in the class, divided into 6 groups. Group 1 and group 2 in auditory category, group 3 and group 4 in visual category, and group 5 and group 6 in kinesthetic category. The CRT Wayang Orang Culture approach is integrated on the discussion sheets which are done in groups. The closing activity, teacher together with students deducted the material that had been learnt, that is data dispersion measures. Teacher also gives students' assignments related to boxplots and scatter plots.

Observation stage : post-test 2 given to measure students' mathematical communication abilities after being given the second action. Post-test 2 results are assessed based on the score guidelines. Data of the post-test 2 score is compared to the pre-test score, which determines the number of students who have reached each mathematical communication ability indicator. The comparison of the results is given in Table 3.

Table 3. Comparison of Mathematical Communication Ability after the Second Action.

Indicator Mathematical Communication Ability	Before Action *(pre-test)*	Cycle 1 *(post-test 1)*	Cycle 2 *(post-test 2)*
Communicating ideas using mathematical languages and symbols appropriately.	23 students (68%)	31 students (91%)	32 students (94%)
Modelling situations into various forms of mathematical representations such as pictures, tables, diagrams, or graphs	14 students 41%)	23 students (68%)	26 students (76%)
Presenting well-structured problem solving.	3 students (9%)	10 students (29%)	18 students (53%)

Table 3 explains that students' mathematical communication abilities increase from 29% to 53% after the second action. By implementing Wayang Orang Culture in the data dispersion measures materials (CRT), 18 students solved the problems and presented the collaboration results well (Indicator 3 of mathematical communication abilities). Based on the achievement indicator that has been set, it can be said that this study was successful.

Reflection stage: second action resulted in an improvement of students' mathematical communication abilities, with more than 50% students in the class reached all mathematical communication ability indicators. Furthermore, teachers disseminate the classroom action research findings at Unnes Journal of Mathematics Education (UJME). The comparison of cycle 1 and cycle 2 is shown in Table 4.

Table 4. Comparison of Cycle 1 and Cycle 2.

Procedure	Cycle 1	Cycle 2
Planning	Differentiated learning design based on learning interests through CRT Semarang City Culture. Learning interest questionnaires, pre-test and post-test 1.	Differentiated learning design based on learning styles through CRT Javanese Culture. Learning style questionnaires and post-test 2.
Action	Differentiated learning design based on learning interests (group 1 in high category, group 2 until group 5 in medium category, and group 6 in low category). CRT with the theme of Semarang City Culture (Dugderan Culture at the kirab procession) integrated in discussion sheets.	Differentiated learning design based on learning styles (group 1 and group 2 in auditory category, group 3 and group 4 in visual category, group 5 and group 6 in kinesthetic category). CRT with the theme of Javanese Culture (Wayang Orang performance) integrated in discussion sheets.
Observation	Comparative descriptive analysis, comparing data from pre-test and post-test 1: the improvement of students' mathematical communication abilities less than 50%.	Comparative descriptive analysis, comparing data from post-test 1 and post-test 2: the improvement of students' mathematical communication abilities more than 50%.
Reflection	Design differentiated learning based on learning styles (auditory, visual, kinesthetic) through CRT with the theme of Javanese Culture.	Dissemination of study results in Unnes Journal of Mathematics Education (UJME).

The results of this research show that the implementation of CRT led to greater student engagement and confidence in communicating mathematical ideas. This improvement occurred because CRT contextualized learning by connecting mathematical content with students' cultural backgrounds which increase engagement. Student are more expressing ideas using appropriate mathematical language and symbols when learning is grounded in their lived realities. This aligns with findings by Hutchison & McAlister-Shields (2020), who reported that culturally responsive teaching fosters deeper learning. The effectiveness of the differentiated approach can be seen in its capacity to accommodate varying levels of learning interests and learning styles. Differentiated content and process could engage meaningfully with the material, leading to more inclusive and effective group discussion. These findings suggest that a cultural approach that combines with a differentiated approach can be applied to lead to miscommunication in other subjects or classrooms with diverse student needs, engaging more actively in class discussion, foster a meaningful learning environment, and improving mathematical competencies.

4. Conclusion

In the first cycle, differentiated-process learning by grouping students based on learning interests (high, medium, low) through CRT with theme of Dugderan Culture at the Kirab procession as Semarang City Culture, which integrated in discussion sheets, can improve students' mathematical communication abilities by 29%, while in the second cycle, differentiated-process learning by grouping students based on learning styles (auditory, visual, kinesthetic) through CRT with theme of Wayang Orang as Javanese Culture, which integrated in discussion sheet, can improve students' mathematical communication abilities by 53%. It can be concluded that CRT in differentiated learning is effective in improving students' mathematical communication abilities.

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