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UNDERGRADUATE STUDENTS' MISCONCEPTION ON ACID-BASE AND ARGENTOMETRIC TITRATIONS: A CHALLENGE TO IMPLEMENT MULTIPLE REPRESENTATION LEARNING MODEL WITH COGNITIVE DISSONANCE STRATEGY

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Abstract

The study was conducted to map the misconception pattern of chemistry prospective teachers who learned acid-base and argentometric titration. Further, it attempts to minimize misconception through a multiple representation model of learning chemistry with cognitive dissonance strategy. The first treatment was done on acid-base titration and the second treatment on argentometric titration materials. The multiple choice test with open reasons was administered to 30 undergraduate students. The finding shows that 28.6% students have the same pattern of misconception while learning in both of the courses. After the treatment, misconception decreased to 9.5% on the first treatment, and 9.4% on the second treatment. The model was found to be suitable to decrease the misconception, but could not change the misconception into "zero misconception", especially for microscopic and symbolic representations.

Keywords: acids base titration; argentometric titration; misconception; multiple representations

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INTRODUCTION

Misconception that occurs among undergraduate students is one of the major influential factors in inhibiting the understanding of a certain concept. Misconception is the concept of students that is incompatible with the concepts of the expert (Clement, 1987). Misconception can also be said as an inconsistency in comprehension between students' and experts' (Luoga et al., 2013). According to Pinarbasi et al. (2009) misconception or alternative conception is an inconsistency in students' concept with scientific concept. Misconception is difficult to change, although it has been attempted so through learning process. Most undergraduate students have their own concepts of basic chemistry, which were obtained in high school before they study in university. This prior knowledge makes students often relate their prior knowledge to the current knowledge inaccurately, which creates misleading concepts compared to experts' concepts. Some researchers from educational background have realized that misconception is one type of inaccuracies that often occurs among students. Students' daily experiences, creativity, perception, and textbooks can cause misconception. Moreover, misconception is deeply rooted in students' mind so that it may affect their learning activity.

Gurel et al. (2015) have reviewed and compared diagnostic instruments to identify students' misconceptions in science. They reported that there are a variety of methods for diagnosing misconceptions. However, most researchers have not reached a consensus regarding the best method for identifying misconceptions. It depends on the context of the topic to be investigated, the characteristics of the intended subjects to be investigated, and the ability and resources of the researcher or the teacher. However, it is well known that a combination of many methods is better than a single method (Gurel et al., 2015). As reported by Rahayu et al. (2011), the teaching innovation in their study was effective in improving students' understanding, especially about acid-base concept. Innovations in teaching can improve students' understanding and overcome misconceptions.

Acid-base and argentometric titrations are part of Analytical Chemistry course, specifically in quantitative analysis. The subject of acid-base and argentometric titrations involves abstract and complex concepts, such as determining samples' concentrations, pH, and ions in titration. Thus, there are still many students who get difficulties in understanding Fundamentals of Analytical Chemistry course, particularly in the volumetric analysis, which may cause the misconception.

Misconception in chemistry courses, particularly in Basic Analytical Chemistry for undergraduate students who learn acid-base and argentometric titrations, is the issue that needs to be solved. The occurrence of misconception will become a problem because if it is not treated, it may affect the processing concept. Other studies that relate to chemistry misconceptions have been done by some experts. Research on chemistry misconceptions in acids-bases has been done by Pinarbasi (2007), showing that Turkey undergraduate students have some general misconceptions on the concept of acid and base. Another similar misconception of acid-base has also been found by Cros et al. (1986, 1988); Nakleh and Krajcik (1994); Kala et al. (2013); Damanhuri et al. (2016); and Tumay (2016). In this regard, Ozmen and Yildirim (2005) argued that Chemistry includes a number of abstract concepts; therefore, most students have difficulties in understanding and learning these concepts.

Acid and base concepts are two of the most important concepts in both primary and secondary curricula. There have been numerous studies on these concepts in the literature. These studies show that learners at all levels have common misconceptions (Ozmen and Yildirim, 2005). Ozmen and Yildirim (2005) show that work sheets are more effective teaching materials than traditional teaching methods. Traditional instructional methods may have a significant effect on students' misconceptions, but they are far from being sufficient in remediation of students' misconceptions that are resistant to change. For this reason, alternative teaching strategies that make students active in learning activities should be developed and used in classroom teaching.

A teacher needs to implement suitable learning strategies, so that misconceptions can be identified and reduced. Misconceptions in learning acid-base and argentometric titrations will destroy the system of student understanding of the analytical chemistry course as a whole, considering the concepts of acid-base titration and argentometric titration are related to each other. Here, we report the use of a learning model with multiple representations with cognitive dissonance strategy to reduce undergraduate students' misconception of acid-base and argentometric titration.

LITERATURE REVIEW

Misconceptions of Acid-base and Argentometric Titration

Acid-base titration is a titration using acid and base standard solution, while argentometric titration uses a standard solution of silver nitrate. The endpoint of both titrations is usually signaled by a sharp change in the color of the solution. The titer volume obtained can be used to calculate the concentration of the sample. As a common characteristic of chemical concepts in general, titration provides many abstract and complex concepts. This characteristic causes many students to get into difficulty and even to hold misconception.

The concept that is considered difficult by students includes the species of ions involved in the titration process (before, during and after the endpoint of titration), titration curve, equation, and stoichiometry. One of the solutions to overcome this issue is that a lecturer is expected to provide macroscopic, submicroscopic, and symbolic representations when giving explanation. This effort can improve students' understanding of the concepts and reduce students' misconception.

Multiple Representation Learning Model with Cognitive Dissonance Strategy

Wandersee et al. (in Chiu & Wu, 2009) stated that representation is a way to express phenomena, object, abstract concepts, idea, mechanism or process, and system. The use of various ways (representation modes) to represent a phenomenon is called multiple representations. In the same way, Waldrip et al. (2006) confirmed that multiple representation is re-representing the same concept using various forms of descriptive representation modes (verbal, graphic, table), experimental, mathematical, figurative (pictorial, analogy, and metaphor), and axial-operational modes.

Cognitive dissonance is a disagreement of people's beliefs, ideas, and values with the existing beliefs, ideas, and values (Festinger, 2014). In the learning process, students can experience a cognitive dissonance when they get a piece of information which is different from their beliefs. According to Lee et al. (2003) cognitive dissonance has a practical implication in many disciplines, such as cognitive conflict in learning. Dreyfus et al. (1990) explained that the cognitive conflict strategy can facilitate students' conceptual change. This conceptual change can in turn facilitate the change of students' misconceptions towards students' scientific understanding. The scientific understanding will eventually improve student learning achievement.

Previous studies confirmed that students' misconception is resistant and difficult to be eliminated. Therefore, teachers are highly suggested to implement a learning strategy in order to identify and eliminate students' misconception. Multiple representations by cognitive dissonance (MRCD) is a recommended strategy to address the issue. MRCD model is conducted by providing two different representations in order to generate a cognitive conflict within students' mind. The rise of cognitive dissonance will change students' behavior to be more motivated for understanding the concept. Therefore, it is important that cognitive dissonance strategy is implemented by asking-question method. The questions provided in implementing the method should be presented in various representations of chemical concepts. This strategy is expected to facilitate students' cognitive change towards misconception elimination as well as understanding improvement.

METHOD

This study used a descriptive method. The participants of this study were undergraduate students in chemistry education from batch 2014 to 2015 in State University of Malang (UM). There were 30 students enrolled in Fundamentals of Analytical Chemistry class. The instrument used in this study was a multiple choice test with reasons. The test consisted of 18 questions: 10 questions of acid-base titration and 8 questions of argentometric titration. The reasons given by students were reflected from their processing ability and their understanding of the concepts that they have learned. Based on their answers and reasons, whether students' perspective on any concept is in line with the exact scientific concept can be identified.

Misconception identification was done by using the CRI scale to measure students' confidence in answering each question. The CRI scale used in this study was a modification from Hasan et al. (1999), performed by Potgieter et al. (2005) with four scales: 1 = Guessing; 2 = Unsure; 3 = Sure; 4 = Very Sure. Low CRI level (1-2) shows students' hesitancy in answering the questions. CRI level of 3-4 shows students' great confidence in answering the questions. Students' hesitancy in answering the questions was caused by the limited confidence in dealing with the answers given. Kurbanoglu & Akin (2010) reported that students who fully understand a concept will have high confidence. From this statement, it can be interpreted that the students who answer the question with a lower CRI value (1-2) lack concept understanding. High CRI value (3-4) shows that students have more confidence to answer the questions. This shows that the students will perform based on the concept of competence in answering questions.

The CRI level criteria developed by Hasan by adding the reasons had been modified due to problems occurred in their implementation in Indonesia, in which most Indonesian students are always not sure with their reasons in selecting answers from the given questions. This constraint has been addressed by Hakim et al. (2012). He reported that if students answer correctly and the reasons are also true, despite the low level of confidences, it can be concluded that those students understand the concepts but are not confident enough in answering the given questions. The CRI classification modified by Potgieter et al. (2005) and Hakim et al. (2012) can be seen in Table 1.

Table 1. The criteria of misconception identification based on CRI

Answers	Reasons	CRI value	Description
True	True	> 2	Understand the concept of well
True	True	< 2	Understand the concept but are not confident with the answers given
True	False	> 2	Misconceptions
True	False	< 2	Do not know the concept
False	True	> 2	Misconceptions
False	True	< 2	Do not know the concept
False	False	> 2	Misconceptions
False	False	< 2	Do not know the concept

RESULTS AND DISCUSSION

The initial study of students enrolled in the Fundamentals of Analytical Chemistry course found misconception on the volumetric analysis material or topic, which is still related to the acid-base and argentometric titration materials. The average results of both of the materials can be seen in Table 2.

Table 2. The average result of undergraduate students' comprehension in the initial study

Concepts	Average score of students' comprehension of each concept					
	Misconception (M)		Lack of knowledge (L)		Correct concepts (C)	
	Total	%	Total	%	Total	%
Acid-base Titration	22	31.4	15	21.4	33	47.2
Argentometric Titration	18	25.7	20	28.6	32	45.7
Average Percentage		28.6		25.0		6.4

Based on the data presented in Table 2, there were misconceptions: 31.4% in acid-base titration and 25.7% in argentometric titration. The average misconception among students in both of the materials was 28.6%. Thus, an attempt to overcome this situation is needed.

Concept comprehension is a group of changes in the behavior of students who are affected by the intellectual capability that includes several levels; remembering (C1), understanding (C2) apply (C3), analyzing (C4), evaluating (C5), and creates (C6) (Anderson & Krathwohl, 2001). Every student has different levels of ability in understanding concepts, even if they learn the same material and from the same lecturer. This difference results in the various skill levels among students, which can create misconception toward the concept that is being learned. In fact, the acid-base and argentometric titrations have been learned by students in high school and Basic Chemistry course. However, it does not guarantee that there will not be misconceptions. Thus, conducting a test using multiple choices with reasons was done to identify whether there was any misconception among students. The eighteen questions given were categorized into two different groups, as can be seen in Table 3.

The number and percentage of students' answers to each item can be seen in Table 4 and Table 5; meanwhile, the overall picture of students' levels of comprehension before and after the treatment on both materials is shown in Figure 1.

Table 4 and Table 5 show the tendency of undergraduate students' misconceptions on questions number 3, 4, 7, 9, 14, 15 and 18. The percentages of the tendencies and misconceptions of undergraduate students on the acid-base and argentometric titrations materials can be seen in Table 6.

Table 3. Questions categorized based on sub-concepts and competencies

No	Sub concept	Competencies	Questions number	Cognitive level
1	Acid-base titration	• Applying the concept of acid-base titration	1	C3
		• Interpreting the pH value and specie that exist in solution in the titration curve of acetic acid with NaOH	2, 3, 4,5, 6	C5
		• Describing species that exist in the titration process of the ammonia solution with HCl	7	C3
		• Selecting appropriate indicators in acid-base titration	8	C5
		• Calculating the concentration of acid-base titration of the sample	9	C3
		• Determining the type of acid-base titration	10	C4
2	Argento-metric Titration	• Calculating the concentration of sample by argentometric titration	11	C3
		• Distinguishing the types of argentometric titration	12	C2
		• Interpreting the value of PAg/PX and species that exist in the solution based on the curve between NaCl with $AgNO_3$	13, 14, 15, 16	C5
		• Interpreting the titration curve between $AgNO_3$ solution with NaCl	17	C5
		• Determining Br^- purity by argentometric titration	18	C3

Table 4. The number and percentage of undergraduate students' answers of acid-base titration

Question number	**Number and Percentage of Student**					
	Misconception (M)		**Lack of Knowledge (L)**		**Correct Concepts (C)**	
	Total	**%**	**Total**	**%**	**Total**	**%**
1	0	0	0	0	30	100
2	0	0	9	30	21	70
3	5	17	9	30	16	53
4	5	17	8	27	17	56
5	2	7	15	50	13	43
6	2	7	1	3	27	90
7	5	17	8	27	17	56
8	3	10	2	7	25	83
9	5	17	16	53	9	30
10	1	3	3	10	26	87
Average		9.5		23.7		66.8

Table 5. The number and percentage of undergraduate students' answers of argentometric titration

Question number	Number and Percentage (%) of Student					
	Misconception (M)		Lack of Knowledge (L)		Correct Concepts (C)	
	Total	%	Total	%	Total	%
11	0	0	9	30	21	70
12	0	0	3	10	27	90
13	2	7	0	0	28	93
14	6	20	2	7	22	73
15	5	17	2	7	23	76
16	2	7	6	20	22	73
17	3	10	0	0	27	90
18	4	14	1	3	25	83
Average		9.4		9.6		810

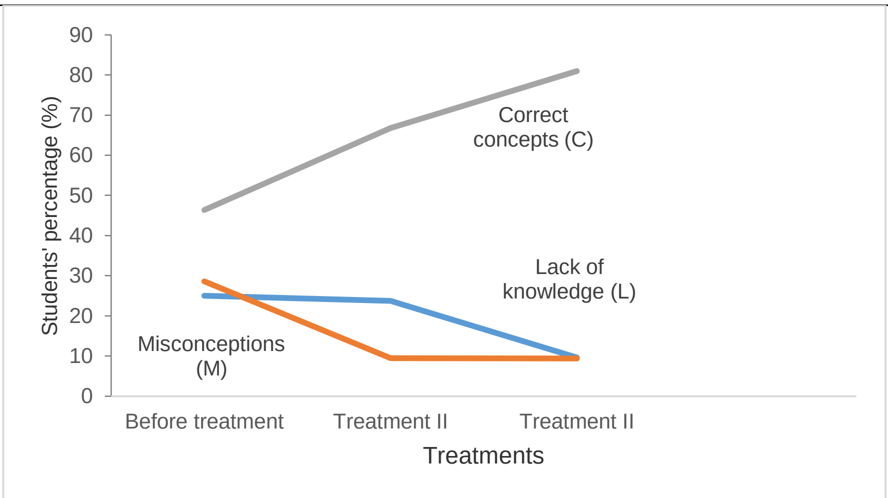

Figure 1. Students' levels of comprehension on several treatments

Note: 0 = before the treatment which was done in an initial study, 1 = treatment I on acid-base titration, and 2 = treatment II on argentometric titration.

Table 6. The Percentage of the tendencies of misconceptions of undergraduate students on acid-base and argentometric titrations (N = 30)

No.	Misconceptions	Percentage
3	Assuming at point L (25 mL NaOH) there is only speci-speci H^+ and CH_3COO^-	17
4	Calculating pH at the point L, a student calculating pH from the CH_3COOH (a weak acid)	17
7	Relating microscopic appearance titration process ammonia solution to HCl, the undergraduate students mentioning the H_3O^+ ion before the equivalence point	17
9	Calculating the number of moles without going through the equation that occurs between NH_3 with H_2SO_4 to find the content of NH_3	17
14	Assuming at point L (10 mL $AgNO_3$) there is only species of Na^+ and Cl^-.	20
15	Relating microscopic appearance of NaCl to $AgNO_3$ titration process, students assuming there is only the equivalence point of Na^+ and NO_3^- in the solution.	17
18	Calculating the mass by multiplying the number of moles of Br with the relative atomic mass of Br without involving the number of the moles of KSCN	14

According to Table 6, misconceptions still appear in several other essential concepts, including the microscopic concept about species that exist in the solution before the equivalent point and the calculation of pH (acid-base titration). The same can be seen in the argentometric titration. Students also experienced misconceptions when asked to determine the species that exist before the endpoint and to determine stoichiometric bromide ion. They generally stated the number of moles of KSCN as a determining factor in the assays of bromide. This is reflected in the equation which they wrote that did not involve KSCN. Actually, in cognitive dissonance strategy, this misconception is already anticipated by providing questions, such as how the reaction occurs and how to compare the number of moles in the equation. However, in its application to the problem, many students in the research still ignored it. Therefore, although the rates were not too high, in fact, misconceptions still occurred.

In general, the concepts of chemistry, including those of acid-base and argentometric titrations, are relatively complex, difficult and abstract. Therefore, it is necessary to develop a learning strategy for making students easily understand the concepts. Furthermore, Sirhan (2007) reported that chemistry has to be taught in a simple way. The key lies in seeing chemistry from the point of view of the students to avoid confusion and misunderstanding.

According to education experts, misconceptions can be overcome by using an innovative learning model; for example, adapting a syllabus with students' thinking ways, cognitive conflict, analogy, couple interaction, metacognition, and demonstration. In the lecture, it can be applied, for example, by using multiple representations. This condition is in line with Hand and Chio's (2010). They reported that multiple representations give positive impacts on students' ability in constructing arguments in lab classes. Similarly, McDermott and Hand (2013) stated that the use of multiple representations supports the task of writing-to-learn as a pedagogical tool in enhancing chemistry teaching at schools. Domin and Bodner (2012) also reported that the use of multiple representations help students in chemical concepts problems solving. A study on cognitive dissonance in chemistry through multiple representations has been reported by Linenberger and Bretz (2012). They stated that the combination of representations encourages students to try to make connections between representations. Barke (2009) analyzed the relationship levels of representation in chemistry among macro, submicro and representational levels. Macroscopic levels are real, can be observed directly, and may be seen by students in everyday life. Submicroscopic level describes the phenomenon that cannot be seen by the naked eye. For example, atoms, molecules, and ions, where representation is needed to understand concepts more clearly. Meanwhile, representational level states various types of representations in the form of symbols, images, chemical formula, equation, tables, graphs and figures. Barke (2009) reported that teachers tended to teach from macro level directly to representational level, so students cannot understand the concept of chemistry as a whole. The main obstacle in understanding chemical concept is not the existence of third-level representations, but the understanding of chemistry concept must be more emphasized on the abstract and symbolic levels.

In this study, cognitive dissonance strategy was employed as a support in the lecture by using multiple representations on the materials of acid-base and argentometric titrations. It is hoped that cognitive conflicts that arose during the lecture cause students to be more challenged to figure out the correct concepts. The results showed there are changes related to the students' misconceptions after learning. However, although two treatments had been applied in learning activity, apparently, misconception could not be completely eliminated. This phenomenon is in line with the argument of some experts in educational backgrounds, which stated that misconception is really difficult to change, although it has been addressed through learning (Pinarbasi et al., 2009). Based on the observation, the misconception which was not eliminated was found in abstract concepts that needed pictures to make students better understand the concepts. Most of the misconceptions experienced by students appeared during the process of understanding microscopic pictures of ions in titration process and microscopic symbols related to chemical equation on reaction. On acid-base titration, the highest misconception appeared in the determination of pH and species in liquid before reaching out the equivalent point (number 3 and 4), microscopic description of species in the process of titration of a weak acid and strong base (number 7), and the content sample (number 9). Meanwhile, on argentometric titration material, the highest misconception appeared in the determination of species before the equivalent point (number 14), microscopic description of species in the process of NaCl with AgNO3 titration (number 15), and in the determination of content sample (question 18). Based on the findings, it can be concluded that both treatments have the same misconception pattern. The results also showed that misconceptions are more prevalent on questions applying cognitive levels (C3).

The similarity between misconception patterns on acid-base and argentometric titrations before the equivalent point can be seen in the questions number 3 (17%), 4 (17%), and 4 (20%). On the acid-base titration on Question 3, students mentioned that the species existing in the solution before reaching the equivalent point were the H+ and CH3COO- ions. A salt should also be formed from CH3COONa, which is the result of the reaction. This answer had an impact on the determination of pH on Question 4. Students calculated the pH from the weak acid that should be the buffer pH from the solution because the species that exist in the solution are actually H+, CH3COO-, and CH3COONa, which is a mixture of a weak acid with its salt. On the argentometric titration (question 14), most students incorrectly identified the ions in the liquid. Before the equivalence on NaCl and AgNO3 titration, the species on the solution should be Na+, Cl-, NO3- ions, and solid AgCl. Most of the students did not know about this and assumed that there were only Na+ and Cl- in the liquid.

Similar misconception also appeared in the questions number 7 (17%) and 15 (17%), which are related to microscopic pictures in titration process. Question 7 and 15 are related to microscopic description of dominant species in solution before the addition of titrant, before the equivalence point is reached, when the equivalent point is reached, and after the equivalent point is reached. In question number 7, before the equivalent point there were still students who mentioned the H3O+ in solution. Supposedly, H3O+ was up to react with OH- and species that exist in the solution should be NH4+, Cl-, and NH3. The reason of that condition is because students' lack of understanding in the chemical reactions that occur during the titration process, so that students experienced misconceptions about the species that exist in solution. The same case occurred for question number 15, which is related to the microscopic description of NaCl of titration with AgNO3. Before the equivalent point, the species present in the solution are ion Na+, Cl-, NO3-, and AgCl. There were some students who still chose image A as the answer before the equivalent point and the species that exist in the solution to be Na+, Cl-, Ag+, and AgCl. Actually, the species Ag+ should no longer be there because it was completely reacted with Cl-. From both of these answers, there were still students who had misconceptions related to the species' microscopic appearance on the titration process.

Similar misconception pattern appeared for questions number 9 (17%) and 18 (14%), which are related to the calculation of sample rate. On the acid-base titration, when calculating the number of remaining moles of H2SO4 after reacting with NaOH, most of the students only used the number of the moles to calculate NH3 rate without considering the chemical reaction between NH3 and H2SO4. Hence, there was miscalculation of the needed moles in determining the content of NH3. In the argentometric titration, most of the students experienced misconception in determining Br rate, which is related to the titration. It was because they calculated the mass by multiplying the number of Br mole with atomic relative mass of Br- only without including KSCN mole number.

The same pattern also occurred in comprehending the concept of calculating sample rate. On the acid-base titration, the highest incomprehension was found in the questions number 9 (53%), and number 11 (30%) on the argentometric titration. With regard to undergraduate students' concept comprehension on the acid-base titration, the greatest percentage was for question number 1 (100%), which was about the identification of pH at an equivalent point. Meanwhile, the greatest percentage of concept comprehension on the argentometric titration was for the question number 13 (93%), which is related to the identification of pAg and species in solution before the addition of titrate. The great percentages were obtained because the concepts often do not need complex calculation and the species in the liquid are already obvious.

According to Figure 1, it can be seen that the misconception was significantly decreased after treatments were applied, where treatments I and II did not give similar results. The misconception decreased, starting from 28.6% to 9.5% (treatment I) and 9.4 % (treatment II). The misconception on treatment I (acid-base titration) was greater than that in treatment II (argentometric titration). It occurred because the materials were more complex and varied. From Figure 1, it also can be seen that there was a decrease in the incomprehension before (25.0%) and after treatment I was applied (23.7%) as well as treatment II (9.6%). This condition gave impacts to the undergraduate students' increased comprehension before and after the treatment, which were 46.4% to 66.8% (after treatment I) and 81.0% (after treatment II), respectively. In other words, those treatments were not able to overcome misconception. However, those treatments have changed concepts' incomprehension into comprehension.

CONCLUSION

The present study has attempted to help students overcome misconceptions on acid-base and argentometric titrations by employing a learning model with multiple representations and dissonance strategy. Similar misconception patterns were mapped in the pre-service students' comprehension of acid-base and argentometric titrations. It was shown that for the topic of acid-based nitration most of the students had the highest misconception in the determination of pH and species in liquid before reaching out the equivalent point, microscopic description of species in the process of titration of a weak acid and strong base, and the content sample. Meanwhile, on argentometric titration material, the highest misconception was found in the determination of species before the equivalent point, microscopic description of species in the process of NaCl with AgNO3 titration, and determination of content sample. The learning model employing multiple representations with cognitive dissonance could not fully eliminate students' misconceptions; however, the learning model successfully changed students' incomprehension to comprehension.

Preservice teachers as the future teachers should be able to eliminate their own misconceptions in order to help their future students. Applying multiple representations in learning with dissonance strategy can be one of the alternatives to overcome this problem.

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