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AN ANALYSIS OF PRESERVICE CHEMISTRY TEACHERS' MISCONCEPTIONS OF REDUCTION-OXIDATION REACTION CONCEPTS

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Abstract

This article describes a study of 149 preservice chemistry teachers' misconceptions of concepts related to a reduction-oxidation reaction. A mixed-method approach was used to obtain data through the ROXCI (Redox Concept Inventory) instrument and interviews. Result indicated that the highest misconceptions were for item number 10 (4.03% or only 6 of 149 students answered correctly) and the lowest misconception occurred on item number 1 (94.63% or 141 of 149 students answered correctly). These results were supported by the analysis of the interviews where the respondents produced misconceptions when explaining the process of electron transfer in redox reactions. The highest percentage of consistent answers in the six ROXCI categories was obtained in the surface feature concept category (6.71% or 10 out of 149 respondents consistently answered correctly). This shows that preservice chemistry teachers are not able to connect the three levels of chemical representation, macroscopic, microscopic, and symbolic in studying chemistry, especially for the redox concept. Analysis of the relationships between misconceptions and average student confidence shows that every distractor chosen by the respondents at every level was followed by a degree of confidence of between 50%-70%, indicating that misconceptions became stronger because the preservice chemistry teachers did not realize that a concept believed to be true is wrong.

Keywords – Misconceptions, Oxidation-reduction reactions, Preservice chemistry teachers.

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1. Introduction

Chemistry is a subject that involves learning abstract concepts, meaning that they cannot be seen directly by the naked eye. Chemistry topics require students to visualize concepts and explanations of submicroscopic processes. The chemistry topics that often cause misconceptions are chemical bonds, chemical equilibrium, and oxidation-reduction reactions (Barke, Hazari & Yitbarek, 2009). An oxidation-reduction reaction in chemistry is abstract because students are required to understand the occurrence of reduction and oxidation without seeing the actual transfer process of electrons. In an oxidation-reduction reaction, there is a link between concepts where students need to understand the concept of determining oxidation numbers in order to determine oxidation-reduction reactions. Indirectly, the determination of oxidation numbers requires the mastery of numeracy skills. Oxidation-reduction is a large subject area requiring multilevel understanding, where students must first understand about ions and how to write using correct scientific terms. This complex level of understanding can lead students to develop misconceptions about redox reaction concepts. A study by Hono, Yuanita and Suyono (2014), aimed at preventing the occurrence of students' misconceptions of redox reactions concepts, shows that all concepts in redox reaction material have the potential to cause misconceptions. The answer to overcoming it, is to uncover and find the cause of it. One way that can be used to detect it is a diagnostic test.

Multiple choice tests were widely used as diagnostic tests before concept maps, guessing, observations and explanations, research, concept phase diagrams, V diagrams, question formation, two-tier tests, and other new research were developed as alternatives to detecting misconceptions (Tuysuz, 2009). When a two-tiers test is compared with a multiple-choice test, a two-tier test is more effective at detecting misconceptions in subjects and for revealing whether meaningful learning occurs (Treagust, 1995). A two-tiered test is as easy to evaluate as a multiple-choice test whilst also providing the added advantage of being more effective than other tests because a student can explain why a particular answer has been given (Peterson, Treagust & Garnett, 1989). Two-tiered questions have two main advantages over conventional tiered questions. The first is a decrease in measurement errors. In a one-tier multiple choice question with 5 possible options, there is a 20% chance of students guessing the answer correctly. These random and correct guesses must be considered in measurement errors. The two-tier question is considered correct only if both levels are answered correctly. As a result, a student who answers a question with 5 choices in the first level and 5 in the second level has only a 4% chance of randomly guessing.

In this study, the Redox Concept Inventory (ROXCI) instrument, developed by Brandriet and Bretz (2014), was used to measure students' symbolic and particulate understandings of redox reactions. The Instrument can be used to quickly and efficiently measure students' understandings, and their confidence about those understandings. ROXCI consists of 18 questions, 12 of which are single questions and the remaining 6 are two-tier questions where the student chooses the answer to the first question and then elaborates with their reasoning in the second question. Each of the 18 items also ask students to show confidence in their answer from 0 (just guessing)) to 10 (certain). The confidence scale was added to help instructors understand the robustness of student misconceptions and to indicate whether students were thoughtfully choosing distractors that represented their ideas (*Ibid.*). The total score is calculated from 0 to 180.

Misconceptions in chemistry can be problematic because chemistry concepts are related to each other whereby errors at the onset of learning will have an impact on subsequent learning, resulting in a low and incomplete level of understanding (Nazar, Sulastri, Fitriana, 2010). Revealing preservice teachers' conceptual understanding is important because their knowledge has a significant impact on their competence as a teacher. This study used the Redox Concept Inventory (ROXCI) instrument to focus on misconceptions as the initial foundation of ongoing research into preservice teacher competency.

2. Research Methode

2.1. Research Methodology

A post-positive research paradigm and a mixed-methods approach with an explanatory design underpinned this research project. An explanatory design (two-phase model) is a mixed methods design undertaken by collecting quantitative data from the ROXCI (Redox Concept Inventory) instrument and qualitative data from individual interviews of preservice chemistry teachers. Research was conducted by collecting, analyzing, and combining quantitative and qualitative data.

2.2. Participants

The participants in the study were 149 preservice chemistry teachers in levels I-IV, level I are preservice chemistry teachers in year I, Level II are preservice chemistry teachers in year II, Level III are preservice chemistry teachers in year III, and Level IV are preservice chemistry teachers in year IV, V, and VI as follows: level I (n=40), level II (n=35), level III (n=25), and level IV (49). The preservice chemistry teachers had previously learned Redox material in high school (for level I preservice chemistry teachers) and in high school and University (for level II-IV preservice chemistry teachers).

2.3. Data Collection

The data in this study were obtained through interviews and the ROXCI (Redox Concept Inventory) instrument developed by Brandriet and Bretz (2014). The Redox Concept Inventory (ROXCI) measures students' symbolic and particulate understandings of redox reactions. The Instrument was used to quickly and efficiently measure preservice chemistry teachers' understandings, and the confidence they had in those understandings. Of the 18 items, 12 were single-tiered items such as question 16 (Figure 1). The remaining 6 items were two-tiered where respondents choose an answer for the first question and then elaborated with their reason in the second question such as in question 3 and 4 (Figure 2).

DIRECTIONS: Below is an oxidation-reduction reaction. Use this reaction to answer questions 9, 10,and 11.

$$Fe(s) + CdSO_4(aq) \rightarrow FeSO_4(aq) + Cd(s)$$

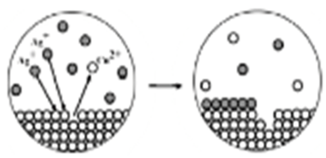
10. How do the electrons transfer in this reaction?

a. The bond between cadmium and sulfate breaks, and the iron bonds with sulfate.
b. The electrons travel freely through solution.
c. The sulfate carries the electrons from one metal to another.
d. Cadmium deposit onto the solid iron atoms.

How confident are you about your response?

1	2	3	4	5	6	7	8	9	10

Not Confidence (Just guessing) — Confident (absolutely Certain)



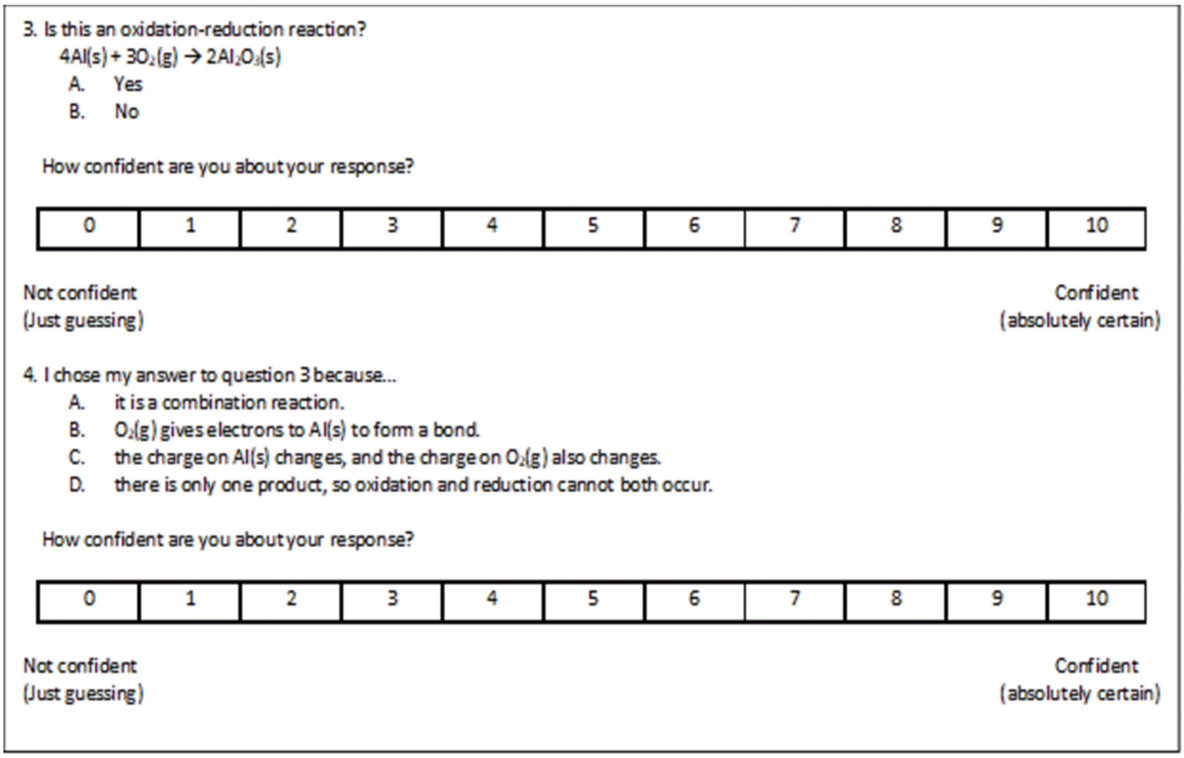
16. Which statement best describes silver in this reaction?
A. Two Ag+ push Cu^{2+} off the solid and into the solution.
B. Two Ag+ replace the charge that is missing on the solid when Cu^{2+} leaves.
C. Two Ag^{+} are attracted to the electrons that are left on the solid when Cu^{2+} leaves.
D. Two Ag^{+} receive electrons from the Cu solid.

How confident are you about your response?

0	1	2	3	4	5	6	7	8	9	10

Not confident (Just guessing) — Confident (absolutely certain)

Figure 1. A one-tier item with the confidence scale on the Redox Concept Inventory


3. Is this an oxidation-reduction reaction?

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$

A. Yes
B. No

How confident are you about your response?

0	1	2	3	4	5	6	7	8	9	10

Not confident (Just guessing) — Confident (absolutely certain)

4. I chose my answer to question 3 because...

A. it is a combination reaction.
B. $O_2(g)$ gives electrons to Al(s) to form a bond.
C. the charge on Al(s) changes, and the charge on $O_2(g)$ also changes.
D. there is only one product, so oxidation and reduction cannot both occur.

How confident are you about your response?

0	1	2	3	4	5	6	7	8	9	10

Not confident (Just guessing) — Confident (absolutely certain)

Figure 2. A two-tier item with the confidence scale on the Redox Concept Inventory

The ROXCI instrument was translated into Indonesian and distributed using Google Forms. Interviews were conducted individually through a video conference Zoom meeting using questions and answers from the ROXCI instrument that students had previously filled out. 10 participants who had filled out the ROXCI instrument were initially chosen for interviews based on their total score high (score 130-180), medium (score 70-120), and low (0-60). Of that number, 7 participants were willing to be interviewed.

2.4. Data Analysis

The ROXCI instrument was used to measure the preservice chemistry teachers' understandings, and their confidence about those understandings of Redox concepts. Data from the six ROXCI concept categories were analyzed to identify any alternative conceptions that would appear to be limiting the participants' understanding of the concepts. The relationships between misconceptions and average student confidence was also analyzed. Three stages of data analysis; preparation, implementation and final were undertaken to extract the research results. The preparation stage included: (a) Determining the selected diagnostic instrument; (b). Interpreting the selected diagnostic instrument; (c). Expert judgment validity test; (d). Revise the instrument. The implementation stage included: (a). Providing and spreading ROXCI online test instruments; (b). Reliability test using Re-test method by 30 preservice chemistry teachers; (c). Interviews; (d). Quantitative and qualitative data processing. The final stage included the results and discussion.

3. Results and Discussions

The ROXCI instrument was translated from English to Indonesian and validated by two lecturers who provided expert judgment in the fields of organic chemistry, and analytical chemistry to ensure that the translation did not change the meaning or content of the instrument. The experts examined each test item in terms of language and conformity with the concepts on the original instrument. The reliability of the instrument was tested using the test–retest method which requires the researcher to use the assessment tool twice at different times. To calculate the correlation between the results of the first test assessment and the second Spearman's rank order correlation technique was used. Table 1 shows the scores of tests 1 and 2 for the same 30 respondents. The value of rho obtained (ϱ_{count}) is compared to the rho value table (ϱ_{table}) with a sample count (N) is 30. The -value table at a significant level of 5% with sample count (N) of 30 is 0.364, it turns out that obtained from the calculation is 0.809 (ϱ_{count} = 0.809) greater than the table ($\varrho_{count} > \varrho_{table}$), meaning between the first test and the second test a significant positive correlation occurred. Based on these results, it can be concluded that the translated ROXCI instrument has high reliability (reliable).

The data for this study were obtained from the responses of preservice teachers to 18 multiple choice questions classified into six main concept categories and analyzed to each class level, namely level I, II, III, and IV (class of 2021, 2020, 2019, and 2018-2014). The results were obtained by analyzing the number of correct answers in each category with the percentage of each class in each item. The percentage of correct answers on questions in tier 1 accompanied by reasons in tier 2 for storied problem items (questions no. 1-6) and single problems (numbers 7-18). The main category of misunderstandings, noted by the ROXCI, can be seen in Table 2.

No. Respondents	Test Score 1	Test Score 2	No. Respondents	Test Score 1	Test Score 2
1	140	150	16	80	110
2	130	150	17	80	80
3	120	120	18	80	90
4	120	90	19	80	90
5	120	90	20	70	70
6	120	120	21	70	80
7	110	120	22	60	100
8	110	130	23	60	40
9	110	120	24	40	50
10	100	120	25	30	20
11	90	110	26	30	20
12	90	80	27	90	80
13	80	50	28	100	90
14	80	70	29	80	60
15	80	80	30	70	70

Table 1. Comparison of Test Scores 1 and 2

ROXCI Categories	Description of Categories	Items
Oxidation numbers	Application and/or understanding of charges and/or oxidation numbers	1/2, 3/4, 5/6, 7, 8, 9, 13, 14, 15
Surface features	Using the surface features of chemical equations to identify whether a reaction is a redox reaction	1/2, 3/4, 5/6, 9, 12, 14
Electron transfer	Role of electron transfer in redox reactions	3/4, 9, 10, 16, 17, 18
Spectator ions	Role of spectator ions in single-displacement redox reactions	9, 10, 11, 17, 18
Dynamics reaction process	Dynamic nature of particles	10, 11, 16, 17, 18
Electrostatics and bonding	Bonding, charge attractions, or replacing charge between charged species in a redox reaction	10, 11, 16, 17, 18

[a] point 1−6 is a two-tiered answer /reason paired item. The answer/reason pairs are 1/2, 3/4, and 5/6.

Table 2. Major Misconceptions Categories Assessed by The ROXCI

Analysis of the suitability and consistency of answers was undertaken to find out the extent to which students understood concepts. The consistency of answers to the question point (1-6) can be seen in Table 3 and the answers to the single item (7-18) can be seen in Table 4. In addition, analysis was also conducted to compare the consistency of answers related to the respondents' understanding of the categories of concepts indicated by Table 5. The results of the analysis are summarized as follows.

3.1. Analysis of Preservice Chemistry Teachers' Answers on Question 1-6 Paired Answers/Reasons Two-Tier.

The analysis of consistency of answers to questions 1-6 paired answers/reasons is shown in Table 3. The table summarizes the percentage of respondents' answers to 6 multiple-choice questions. Conceptual understanding among the preservice chemistry teachers proved to be less precise when related to the reasons they provided. Most respondents provided correct answers in the first tier, as shown by the high percentage proportion in Table 3, however, some respondents gave incorrect reasons in the second tier. Data on the first and second-tier options is shown below.

Questions Number (Correct Answer)	Preservice Teacher Student Level				Sum
	I	II	III	IV	
	N=40	N=35	N=25	N=49	N=149
1 (A)	90.00 (36)	97.14 (34)	96.00 (24)	95.92 (47)	94.63 (141)
2 (D)	85 (34)	94.29 (33)	84 (21)	91.84 (45)	82.26 (133)
3 (A)	65.00 (26)	77.14 (27)	56.00 (14)	83.67 (41)	72.48 (108)
4 (C)	55 (22)	62.86 (22)	56 (14)	59.18 (29)	58.39 (87)
5 (A)	22.50 (9)	22.86 (8)	36.00 (9)	57.14 (28)	36.24 (54)
6 (D)	45 (18)	22.86 (8)	40 (10)	57.14 (28)	42.95 (64)

Table 3. Percentage of preservice teachers' answers correctly in the first tier (questions 1, 3, and 5) and the second tier (questions 2, 4, 6) consistently

When comparing the frequency of correct responses to the first 3 tier questions, the above data shows there is a difference between first-tier answers and the reasons given in the second tier, where the two-tier question items are paired in numbers 1 and 2, 3 and 4, and 5 and 6. From the details of the given items, there are different results for all categories represented.

Table 3 shows a difference in results for numbers 1 and 2. However, the difference was not highly significant, where 141 preservice chemistry teachers agreed that question number 1 was the reduction-oxidation reaction, and 133 preservice chemistry teachers responded accordingly that the reason number 1 was the reduction-oxidation reaction was because the zinc charge increased, while the copper charge decreased. Misconceptions demonstrated by an inconsistency between answers in the first and second-tier scored at 5.67%. The difference between the two values indicates that most preservice chemistry teachers understood oxidation numbers. Interviews conducted with the respondents who experience misconceptions on question number 2 are as follows:

> *If they swapped places yes as well, but (I feel) more confident (on change) the charge. Zinc on the left 1, the right I forgot, I think it increases*

(Participant 01, Monday, 18 October 2021)

Participant 01 agreed that the problem at number 1 was a redox reaction but at the second tier, on question number 2, the reason given was because zinc and copper exchanged places.

Question number 3 asked whether the reaction presented was a reduction-oxidation reaction or not. At this point, there was a decrease in the number of correct responses, at 72.48%, when compared to number 1. There was a corresponding decrease in correct answers to question number 4 with only 58.39% of respondents answering with the correct reason, that the charge of Al(s) changed and the charge of O_2(g) also changed. 19.44%. percent of preservice chemistry teachers experienced misconceptions demonstrated by inconsistencies between answers in the first and second tiers, indicating that although the questions were similar and represent the same category of concepts, some participants' understanding was incorrect. The conceptual errors were explained as follows:

I don't know why I answered the combination reaction, when I was working on it, I was serious and used scribbles to calculate

(Participant 05, Monday, October 18, 2021)

Participant 05 agreed that the question at number 3 was a redox reaction but at the second tier, on question number 4, the reason given was because the reaction was a combination reaction. The student questioned their reasoning for number 3, but was nevertheless able to give the correct reason that there was a change in the aluminum and oxygen charge. The student realized their mistake as they pressed the answer button on question number 4, option A, a combination reaction. This shows that the concept of redox reactions understood by this preservice chemistry teacher is not good enough, because it can be confused by looking at the reaction equation displayed.

The data obtained from numbers 5 and 6 is unique. Respondents were given a picture of H2O as a reactant and were asked to choose a product if H_2O experienced a redox reaction. However, only 36.24% chose option A (reactants dissociated to H2 and O_2) correctly.. The uniqueness occurred where the percentage of correct answers for number 6 (42.95%) that provided the reason for the answer was greater than the answers at number 5. Participant 07 explained their reasoning as follows.

H_2O becomes hydrogen (H_2) and oxygen (O_2). (I am) a bit confused, (I have been) learning about redox only through reaction equations, not images. Answer A is more illustrates what might happen because H can't be alone

(Participant 07, Saturday, 16 October 2021)

The student was not used to learning about redox with images, which they considered made it more difficult to interpret reaction equations. The results further show that preservice chemistry teachers were not consistent in answering the first six questions.

Analysis of answers to paired questions (no. 1-6) show that the percentage of correct answers on tier 1 was 94.63% for item number 1 and 36.24% for item number 5. While the percentage decreased for tier 2, ranging from 82.26% for item number 2 to 42.95% for item number 6, see Table 3). The participants at each level scored the lowest percentage for items number 5, 36.24%, and 6 42.95%. In general, for paired questions, all participants had difficulty working on question number 5.

3.2. Analysis of Preservice Chemistry Teachers' Answers to The Single Question Number 7-18

An analysis of correct answers to the single question items numbers 7-18 is shown in Table 4. These results are a summary of the percentage of preservice chemistry teachers' answers to 12 multiple-choice questions.

The lowest percentage was scored on question number 10 with only 6 respondents out of 149 or 4.03% answering correctly. This suggests that the students were unable to explain the process of electron displacement in a redox reaction (bonding, charge attractions, or the replacing charge between charged species in a redox reaction). Interviews revealed the following:

Cadmium sulfate electrons moved first, continued to bind to iron

(Participant 02, Saturday, October 16, 2021)

While learning, (I) do not think there is an explanation of the transfer of electrons, only changes

(Participant 04, Saturday, 16 October 2021)

Because I remembered (the process) in organic chemistry that there is a bond that broke first ($CdSO_4$) to bind to $FeSO_4$

(Participant 06, Saturday, 16 October 2021)

Questions Number (Correct Answer)	Preservice Teacher Student Level				Sum
	I	II	III	IV	
	N=40	N=35	N=25	N=49	N=149
7 (B)	40.00 (16)	60.00 (21)	56.00 (14)	75.51 (37)	59.06 (88)
8 (C)	7.50 (3)	17,14 (6)	20.00 (5)	14.29 (7)	14.09 (21)
9 (B)	15.00 (6)	17,14 (6)	4.00 (1)	51.02 (25)	25.50 (38)
10 (D)	7.50 (3)	5.71 (2)	0.00 (0)	2.04 (1)	4.03 (6)
11 (B)	40,00 (16)	65,71 (23)	40,00 (10)	63,27 (31)	53,69 (80)
12 (D)	17.50 (7)	40.00 (14)	24.00 (6)	55.10 (27)	36.24 (54)
13 (A)	15.00 (6)	25.71 (9)	16.00 (4)	40.82 (20)	26.17 (39)
14 (A)	55.00 (22)	62.86 (22)	68.00 (17)	69.39 (34)	63.76 (95)
15 (C)	57.50 (23)	77.14 (27)	80.00 (20)	87.76 (43)	75.84 (113)
16 (D)	7.50 (3)	5.71 (2)	8.00 (2)	24.49 (12)	12.75 (19)
17 (B)	22.50 (9)	25.71 (9)	36.00 (9)	38.78 (19)	30.87 (46)
18 (C)	20.00 (8)	22.86 (8)	16.00 (4)	20.41 (10)	20.13 (30)

Table 4. Percentage of preservice teachers' answers correctly on question no. 7-18

86 preservice chemistry teachers answered A, the bond between cadmium and sulfate is broken, and iron binds to sulfate. The answer assumes that a new bond is formed if there is a previously broken bond. However, the concept that in solution, cadmium and sulfate are in the form of ions instead of molecules, is lost.

An analysis of the single test items (no. 7-18) show that the highest percentage of correct answers was 75.84% (on item number 15) and the lowest percentage of correct answers was 4.03% (on item number 10). When asked about the process of electron transfer in redox reactions all respondents had difficulty answering questions with similar numbers. However, correct answers increased according to the level of the respondents.

Data analysis was also carried out by calculating the discrimination and difficulty of all items, the graph was obtained as shown by Figure 3.

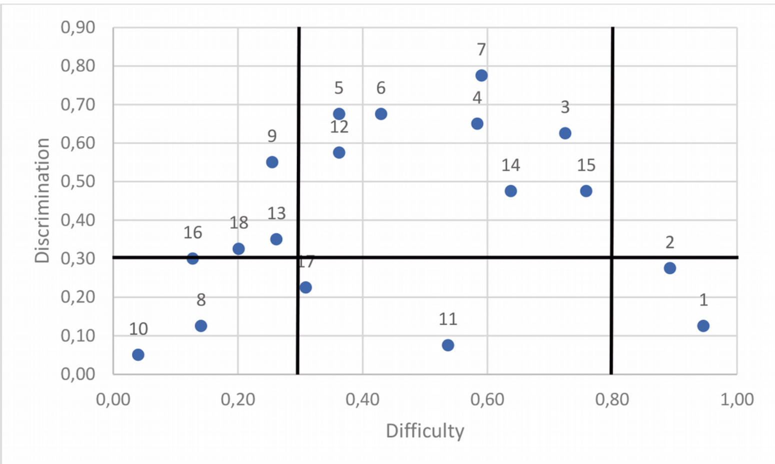


Figure 3. Difficulty and discrimination indices for each of the 18 items for all student sample with numerical values indicating item numbers

As shown in Figure 3, most of the ROXCI items have discrimination indices above 0.30. Item discrimination is the extent to which an item distinguishes between strong and weak students. It can be calculated from the difference in percentages of correct responses between the students who scored at the top and bottom 27% of the 149 sample students distribution. Values above 0.30 are considered to highly discriminate between high and low achieving students. Some items cluster in the bottom left-hand corner of the figure, suggesting low discrimination but also high difficulty. This means that not only the low achieving students but also the high achieving students find these items to be difficult (thus, low discrimination). Items did not discriminate adequately because both strong and weak students got the wrong answers. For this study, there are items number 8, 10, and 16.

3.3. Analysis of Preservice Chemistry Teachers' Understanding in Six Concept Categories

An analysis was conducted to compare the conceptual understanding of the respondents from the 4 levels of preservice chemistry teacher education in the six categories of concepts indicated on Table 5.

No.	Concept Category	Question Number	Preservice Teacher Student Level				Sum
			I	II	III	IV	
			N=40	N=35	N=25	N=49	N=149
1	Oxidation numbers	1	90.00 (36)	97.14 (34)	96.00 (24)	95.92 (47)	94.63 (141)
		3	65.00 (26)	77.14 (27)	56.00 (14)	83.67 (41)	72.48 (108)
		5	22.50 (9)	22.86 (8)	36.00 (9)	57.14 (28)	36.24 (54)
		7	40.00 (16)	60.00 (21)	56.00 (14)	75.51 (37)	59.06 (88)
		8	7.50 (3)	17,14 (6)	20.00 (5)	14.29 (7)	14.09 (21)
		9	15.00 (6)	17,14 (6)	4.00 (1)	51.02 (25)	25.50 (38)
		13	15.00 (6)	25.71 (9)	16.00 (4)	40.82 (20)	26.17 (39)
		14	55.00 (22)	62.86 (22)	68.00 (17)	69.39 (34)	63.76 (95)
		15	57.50 (23)	77.14 (27)	80.00 (20)	87.76 (43)	75.84 (113)
		Average	40.83	50.79	48.00	63.95	51.98
2	Surface Features	1	90.00 (36)	97.14 (34)	96.00 (24)	95.92 (47)	94.63 (141)
		3	65.00 (26)	77.14 (27)	56.00 (14)	83.67 (41)	72.48 (108)
		5	22.50 (9)	22.86 (8)	36.00 (9)	57.14 (28)	36.24 (54)
		9	15.00 (6)	17,14 (6)	4.00 (1)	51.02 (25)	25.50 (38)
		12	17.50 (7)	40.00 (14)	24.00 (6)	55.10 (27)	36.24 (54)
		14	55.00 (22)	62.86 (22)	68.00 (17)	69.39 (34)	63.76 (95)
		Average	44.17	52.86	47.33	68.71	54.81
3	Electron Transfer	3	65.00 (26)	77.14 (27)	56.00 (14)	83.67 (41)	72.48 (108)
		9	15.00 (6)	17,14 (6)	4.00 (1)	51.02 (25)	25.50 (38)
		10	7.50 (3)	5.71 (2)	0.00 (0)	2.04 (1)	4.03 (6)
		16	7.50 (3)	5.71 (2)	8.00 (2)	24.49 (12)	12.75 (19)
		17	22.50 (9)	25.71 (9)	36.00 (9)	38.78 (19)	30.87 (46)
		18	20.00 (8)	22.86 (8)	16.00 (4)	20.41 (10)	20.13 (30)
		Average	22.92	25.71	20.00	36.73	27.63
4	Spectator ions	9	15.00 (6)	17,14 (6)	4.00 (1)	51.02 (25)	25.50 (38)
		10	7.50 (3)	5.71 (2)	0.00 (0)	2.04 (1)	4.03 (6)
		11	40.00 (16)	65.71 (23)	40.00 (10)	63.27 (31)	53.69 (80)
		17	22.50 (9)	25.71 (9)	36.00 (9)	38.78 (19)	30.87 (46)
		18	20.00 (8)	22.86 (8)	16.00 (4)	20.41 (10)	20.13 (30)
		Average	21.00	27.43	19.20	35.10	26.85

No.	Concept Category	Question Number	Preservice Teacher Student Level				Sum
			I	II	III	IV	
			N=40	N=35	N=25	N=49	N=149
5	Dynamics Reaction Process	10	7.50 (3)	5.71 (2)	0.00 (0)	2.04 (1)	4.03 (6)
		11	40.00 (16)	65.71 (23)	40.00 (10)	63.27 (31)	53.69 (80)
		16	7.50 (3)	5.71 (2)	8.00 (2)	24.49 (12)	12.75 (19)
		17	22.50 (9)	25.71 (9)	36.00 (9)	38.78 (19)	30.87 (46)
		18	20.00 (8)	22.86 (8)	16.00 (4)	20.41 (10)	20.13 (30)
		Average	19.50	25.14	20.00	29.80	24.30
6	Electrostatics and Bonding	10	7.50 (3)	5.71 (2)	0.00 (0)	2.04 (1)	4.03 (6)
		11	40.00 (16)	65.71 (23)	40.00 (10)	63.27 (31)	53.69 (80)
		16	7.50 (3)	5.71 (2)	8.00 (2)	24.49 (12)	12.75 (19)
		17	20.00 (8)	25.71 (9)	36.00 (9)	38.78 (19)	30.20 (46)
		18	22.50 (9)	22.86 (8)	16.00 (4)	20.41 (10)	20.81 (30)
		Average	19.50	25.14	20.00	29.80	24.30

Table 5. Percentage of preservice teachers who answered correctly in six concept categories

3.3.1. Concept of Oxidation Numbers

Results show that the percentage of preservice chemistry teachers who answered 9 questions about the concept of Oxidation Numbers, at numbers 1, 3, 5, 7, 8, 9, 13, 14, and 15, correctly achieved 51.98% of the total respondents or samples. However, respondents scored different percentages at all four levels of teacher education. The highest score was achieved by level IV respondents with a percentage of 63.95% while the lowest score was obtained by level I respondents with a percentage of 40.83%. This demonstrates an increased understanding of the concept of energy, and/or of charge ,and/or oxidation from level I to level IV.

3.3.2. Concept of Surface Features

50% of preservice chemistry teachers correctly answered 6 questions about surface features, at numbers 1, 3, 5, 9, 12, and 14, with a noticeable difference in the scores of all four levels. The highest percentage was achieved by Level IV with a score of 68.71% while the lowest percentage was obtained by Level I with a score of 44.17%. This suggests that understanding of the concept of the surface features of chemical reaction equations to identify whether a reaction is a redox increases from level I to level IV.

3.3.3. Concept of Electron Transfer

Only 27.63% of the total respondents correctly answered 6 questions about the concept of Electron Transfer at numbers 3, 9, 10, 16, 17, and 18. Level IV achieved the highest percentage 36.73% with the lowest score of 20% obtained by level III. These results indicate a lack of understanding by the respondents at every level. A misconception regarding the role of electron transfer in redox reactions was evident in the responses. A deviation occurred in these results where level III preservice chemistry teachers scored a lower percentage of correct answers than respondents at level I and II.

3.3.4. Concept of Spectator Ions

Of the respondents who answered 5 questions about the concept of Ion Spectator, at numbers 9, 10, 11, 17, and 18, 26.85% identified the correct answer. Level IV preservice chemistry teachers achieved the highest score of 35.10% with the lowest score obtained by level III at 19.20%. This result indicates that respondents at every level hold misconceptions regarding the spectator ion in a single displacement redox reaction. A deviation also occurs in this category where level III preservice chemistry teachers scored lower than those at level I and II.

3.3.5. Concept of Dynamics Reaction Process

Of the 5 questions about the concept of Reaction Process Dynamics, at numbers 10, 11, 16, 17, and 18, only 24.30% of the total respondents answered correctly. The Level IV preservice chemistry teachers achieved the highest score of 29.80% with the lowest score of 19.50% obtained by Level I respondents. This result indicates that the respondents, across all levels, hold misconceptions regarding dynamic particles.

3.3.6. Concept of Electrostatics and Bonding

The percentage of preservice chemistry teachers who correctly answered the 5 points about the concept of Electrostatics and Ties, at numbers 10, 11, 16, 17, and 18, achieved only 24.30% of the total score. The difference between the four Levels was not significant. At Level IV the respondents achieved the highest score of 29.80% while the lowest score was obtained by Level I with a percentage of 19.50%. The respondents' ability to choose the correct answer in category 6 was the same as category 5, indicating that the preservice chemistry teachers also lack knowledge and understanding of Electrostatics and Bonding.

Analysis shows that the respondents' understanding of the six concept categories was highest for the concept of surface features at an average of 54.81%, meaning that they could use the surface features of chemical equations to identify whether a reaction is a redox. The lowest average percentage was 24.30% for the concepts of dynamics reaction processes and electrostatics and bonding, meaning that preservice chemistry teachers experienced misconceptions in understanding the dynamic nature of particles, bonds, the attraction of charge, or charge replacement between charged species in redox reactions.

3.4. Analysis of Preservice Chemistry Teachers' Answers Consistency in Six Concept Categories

In addition to analyzing preservice chemistry teachers' understanding of the six concept categories by calculating the percentage who answered correctly on each number of questions at each level, an analysis of answer consistency in the six concept categories was also carried out. The purpose of this analysis was to reveal the level of understanding of each concept. Results were calculated by identifying the number of preservice chemistry teachers who answer all the questions in each concept correctly. The results of analysis are shown in Table 6.

No.	Concept Category	Preservice Teacher Student Level				Sum
		I	II	III	IV	
		N=40	N=35	N=25	N=49	N=149
1	Oxidation Numbers	0.00 (0)	2.86 (1)	0.00 (0)	4.08 (2)	2.01 (3)
2	Surface Features	0.00 (0)	2.86 (1)	0.00 (0)	18.37 (9)	6.71 (10)
3	Electron Transfer	0.00 (0)	0.00 (0)	0.00 (0)	2.04 (1)	0.67 (1)
4	Audience Ion/Ion Spectator	0.00 (0)	0.00 (0)	0.00 (0)	2.04 (1)	0.67 (1)
5	Reaction Process Dynamics	0.00 (0)	0.00 (0)	0.00 (0)	2.04 (1)	0.67 (1)
6	Electrostatics and Bonding	0.00 (0)	0.00 (0)	0.00 (0)	2.04 (1)	0.67 (1)

Table 6. Percentage Consistency of Preservice Chemistry Teachers' Answers in Six Concept Categories

Table 6 shows that out of a total of 149 respondents who answered the ROXCI questions 1, 3, 5, 7, 8, 9, 13, 14, and 15, only 2.01% were able to answer all 9 questions correctly. The respondents who answer correctly were from Level II and Level IV. For numbers 1, 3, 5, 9, 12, and 14, only 6.71% were able to correctly answer all 6 questions on the surface feature concept. The respondents who answered correctly were also at Level II and Level IV. For numbers 3, 9, 10, 16, 17, and 18, only 0.67% were able to correctly answer all 6 questions on electron transfer concept. These respondents were all from Level IV. Only 0.67% respondents were able to correctly answer all 5 questions on the concept of spectator ions correctly at numbers 9, 10, 11, 17, and 18. The student who answered correctly was at Level IV of their education. For numbers 10, 11, 16, 17, and 18, only 0.67% of respondent correctly answered all 5 questions on the concept of dynamics reaction process, electrostatic and bonding. These respondents also came from Level IV.

The consistency of answers to questions in the six categories was low with the highest percentage obtained for the surface feature concept category (only 6.71% or 10 out of 149 preservice chemistry teachers consistently answer correctly for all questions). This result indicates that preservice chemistry teachers do not understand the concepts completely and deeply. The analysis of Tables 5 and 6, that show the respondents' teachers' understanding and answer consistency on the six concept categories, also show that Level IV respondents have a better understanding than those at Levels I-III. Understanding improves from the Level I to Level IV in relation to the efficacy of learning experiences However, there were some deviations from the norm in that no Level III preservice chemistry teachers consistently answered questions in the six categories correctly.

3.5. Alternative Concepts of Preservice Chemistry Teachers

Based on the analysis of preservice chemistry teachers' understanding and answer consistency in the six concept categories, several alternative concepts were identified where at least 10% of the total number of respondents chose those alternative concepts (see table 7). The value of 10% was chosen as the minimum value to be able to eliminate students' alternative conceptions (Peterson, et al., 1989). The answers to six two-tier questions from item no. 1-6 and single questions from 7-18) indicate that respondents had different conceptual understandings. Tables 7 and 8 show that alternative conceptions were provided by respondents to the paired two-tier and single questions. The data about alternative conceptions can be useful information for lecturers planning classroom instruction. Alternative conceptions were given by respondents on all questions as shown in Table 7.

This table shows that the least alternative conceptions were for item number 2 where only 1 alternative conception was provided, which is only 8.05% in total, although the total percentage does not reach 10%, there are 12.5% of level I preservice chemistry teachers who choose the answer as an alternative concept,, indicates that the answer is quite believed to be correct. While in item number 4 and 6 the variation of answers is still spread for different reasons with the highest percentage, respectively, 18.79% and 24.83%.

Question Number (Correct Answer)	Alternative Concepts	Preservice Teacher Student Level (%)				Sum
		I	II	III	IV	
		N=40	N=35	N=25	N=49	N=149
2 (D)	The charges on zinc, copper, and nitrate do not change (2A)	12.5	5.71	8	6.12	8.05
4 (C)	It is a combination reaction (4A)	15	2.86	0	12.24	8.72
	$O_{2(g)}$ gives electrons to Al(s) to form a bond (4B)	5	11.43	16	22.45	14.09
	There is only one product, so oxidation and reduction cannot both occur (4C)	25	22.86	28	6.12	18.79
6 (D)	Oxidation and reduction cannot occur with uncharged reactants (6A)	2.5	20	4	10.2	9.4
	Oxidation and reduction cannot occur when there is only one reactant (6B)	32.5	11.43	36	16.33	22.82
	The oxidation numbers change from 0 to -2 for oxygen and from 0 to +1 for hydrogen (6C)	20	45.71	20	16.33	24.83

Table 7. Percentage of Alternative Concepts of Preservice Chemistry Teachers on Redox Concepts in Two-tiered Answer/Reason Paired item

Question Number (Correct Answer)	Alternative Concepts	Preservice Teacher Student Level (%)				Sum
		I	II	III	IV	N=149
		N=40	N=35	N=25	N=49	
7 (B)	NO_3^- is oxidized and N is reduced (7C)	25	28.57	24	12.24	21.48
	NO_3^- is oxidized and H^+ is reduced (7D)	25	5.71	12	8.16	12.75
8 (C)	A charge is assigned to an entire compound, while an oxidation number is assigned to an individual element (8B)	27.5	31.43	40	34.69	32.89
	A charge represents the number of valence electrons, but an oxidation number represents the number of bonding electrons (8D)	55	42.86	40	46.94	46.98
9 (B)	from cadmium to sulfate and from sulfate to iron (9C)	35	37.14	52	30.61	36.91
	from iron to sulfate and from sulfate to cadmium (9D)	37.5	37.14	24	16.33	28.19
10 (D)	The bond between cadmium and sulfate breaks, and the iron bonds with sulfate (10A)	65	60.00	56	51.02	57.72
	The electrons travel freely through the solution (10B)	7.5	8.57	4	24.49	12.75
	The sulfate carries the electrons from one metal to another (10C)	20	25.71	40	42.86	32.21
11 (B)	The aqueous cadmium and iron are charged because sulfate exists (11A)	27.5	20.00	44	18.37	25.50
	Sulfate bonds with cadmium and with iron (11C)	22.5	14.29	8	10.20	14.09
12 (D)	Only I. Oxidation can happen without reduction (12A)	52.5	42.86	52	18.37	39.60
	Only II. Metal must be a reactant (12B)	15	14.29	16	12.24	14.09
	Both I and II Oxidation can happen without reduction and A metal must be a reactant (12C)	15	2.86	8	14.29	10.74
13 (A)	I and IV (Sulfur has an oxidation number, but no charge, and Sulfate has both a charge and an oxidation number) (13B)	45	34.29	28	12.24	28.86
	II dan III (Sulfur has both an oxidation number and a charge and Sulfate has a charge, but no oxidation number) (13C)	10	14.29	12	24.49	16.11
	II dan IV (Sulfur has both an oxidation number and a charge and Sulfate has both a charge and an oxidation number) (13D)	27.5	25.71	44	22.45	28.19
14 (A)	This is a combustion reaction, not an oxidation-reduction reaction (14D)	25	28.57	32	18.37	24.83
15 (C)	changes from +2 to 0 (15B)	25	14.29	16	8.16	15.44
16 (D)	Two Ag^+ push Cu^{2+} off the solid and into the solution (16A)	30	20.00	20	12.24	20.13
	Two Ag^+ replace the charge that is missing on the solid when Cu^{2+} leaves (16B)	32.5	40.00	40	28.57	34.23
	Two Ag^+ are attracted to the electrons that are left on the solid when Cu^{2+} leaves (16C)	30	34.29	32	34.69	32.89
17 (B)	Cu^{2+} must leave to create a space for Ag^+ to deposit (17A)	17.5	17.14	8	14.29	14.77
	Cu^{2+} has a greater charge than the Ag^+, so Cu^{2+} is attracted into the solution by NO_3^- (17C)	47.5	42.86	36	32.65	39.60
	When Cu^{2+} leaves the solid, two electrons remain behind (17D)	12.5	14.29	20	16.33	15.44

Question Number (Correct Answer)	Alternative Concepts	Preservice Teacher Student Level (%)				Sum
		I	II	III	IV	N=149
		N=40	N=35	N=25	N=49	
18 (C)	NO_3^- receives the electrons from one metal and passes them to the other (18A)	15	17.14	20	22.45	18.79
	The negative charge on NO_3^- attracts the metal into the solution (18B)	47.5	42.86	56	40.82	45.64
	NO_3^- is irrelevant for the reaction because it cancels out in the net ionic equation (18D)	17.5	17.14	8	16.33	15.44

Table 8. Percentage of Alternative Concepts of Preservice Chemistry Teachers on Redox Concepts on Single Item (7-18)

Table 8 shows questions number 14 and 15 provide the least alternative conceptions for a single item where only 1 alternative conception was provided. The lowest percentage of alternative conceptions was for questions 15 at 15.44% of respondents who answered the choice as an alternative concept, while for other questions the variation of answers was spread across different reasons. The highest percentage of alternative concepts was for question number 10 at 57.72%. This was the highest percentage for both pair and single questions. Analysis shows that question number 10 scored the highest number of misconceptions.

3.6. Analysis of the Relationships between Misconceptions and Average Student Confidence Based on Six Concept Categories

Table 9 shows that every distractor chosen by respondents at all level was always followed by a high degree of confidence of between 50%-70%. For example, the misconception of the 8D and 10A distractor are selected by approximately 50% of preservice chemistry teachers at all levels with an average confidence of more than 70%, meaning that this distractor was chosen with very strong confidence. Analysis shows that misconceptions increased because respondents did not realize that what they believed to be true was the wrong concept.

Misconceptions	Preservice Teacher Student Level							
	I (N = 40)		II (N = 35)		III (N = 25)		IV (N= 49)	
	% of preservice chemistry teachers	Average of Confidence (%)	% of preservice chemistry teachers	Average of Confidence (%)	% of preservice chemistry teachers	Average of Confidence (%)	% of preservice chemistry teachers	Average Confidence (%)
Oxidation numbers The charge states the number of valence electrons, but oxidation numbers state number of bonding electrons (8D)	55.00% (22)	76.82%	42.9% (15)	73.33%	40.00% (10)	75.00%	46.94% (23)	70.87%
Surface features Fe(s)+ $CdSO_4$ (aq) $FeSO_4$(aq)+Cd(s). electrons move from cadmium to sulfate and from sulfate to iron (9C)	35.00% (14)	70.00%	37.14% (13)	66.92%	52.00% (13)	53.85%	30.61% (15)	61.33%
Electron transfer Fe(s)+ $CdSO_4$(aq) $FeSO_4$ (aq)+ Cd(s) The process of electron transfer occurs when the bond between cadmium and sulfate breaks, and iron binds to sulfate (10A).	65.00% (26)	73.85%	60.00% (21)	69.52%	56.00% (14)	73.57%	51.02% (25)	66.00%

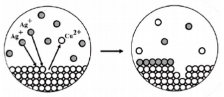
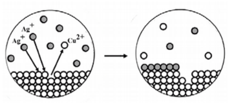
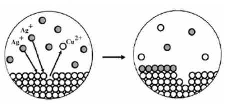
Misconceptions	Preservice Teacher Student Level							
	I (N = 40)		II (N = 35)		III (N = 25)		IV (N= 49)	
	% of preservice chemistry teachers	**Average of Confidence (%)**	**% of preservice chemistry teachers**	**Average of Confidence (%)**	**% of preservice chemistry teachers**	**Average of Confidence (%)**	**% of preservice chemistry teachers**	**Average Confidence (%)**
Spectator ions The image below shows a cross-sectional view for oxidation-reduction reactions from $Cu(s)$ with$AgNO_3(aq)$. Nitrates are **not** shown in the image  The statement that **best** describes nitrate in this reaction is the negative charge at NO_3^- pulling the metal into the solution (18B)	47.50% (19)	71.58%	42.86% (15)	66.67%	56.00% (14)	51.43%	40.82% (20)	62.00%
Dynamics reaction process The image below shows a cross-sectional view for oxidation-reduction reactions from $Cu(s)$ with$AgNO_3(aq)$. Nitrates are **not** shown in the image  The statement that best describes **silver** in this reaction is that the two Ag^+ replace the charge lost on the solid when Cu^{2+} leaves (16B).	32.50% (13)	71.54%	40.00% (14)	63.57%	40.00% (10)	61.00%	28.57% (14)	48.57%
Electrostatics and bonding The image below shows a cross-sectional view for oxidation-reduction reactions from $Cu(s)$ with$AgNO_3(aq)$. Nitrates are **not** shown in the image  The **statement** that best describes copper in this reaction is that Cu^{2+} has a charge greater than Ag^{+}, so Cu^{2+} is pulled into solution by NO_3^- (17C)	47.50% (19)	63.16%	42.86% (15)	70.00%	36.00% (9)	58.89%	32.65% (16)	60.00%

Table 9. Examples of Misconception Percentage and Average Student Confidence Based on Six Concept Categories

Overall, the analysis of answers on the ROXCI instrument showed that the preservice chemistry teaching involved in this study had limited understanding of the Redox concept. Analysis of answers to paired questions (no. 1-6) showed that the percentage of correct answers in tier 1 was 94.63% (in item number 1) and 36.24% (in item number 5). The percentage decreased for the answers in tier 2, , ranging from 82.26% for item number 2 to 42.95% for item number 6. Respondents at each level scored the lowest percentage on items number 5 and 6 with the percentage of correct answers 36.24% for number 5 and 42.95% for number 6. Generally, on the paired questions, All level had difficulty working on question number 5. Meanwhile, analysis of answers on single items (no. 7-18) showed that the highest percentage of correct answers was 75.84% on item number 15, and the lowest percentage of correct answers was 4.03%, on item number 10. On average, the preservice chemistry teachers of all levels had difficulty working on question number 10. When asked about the process of electron transfer in redox reactions they had difficulty answering questions of similar numbers, with a tendency for respondents a higher the level increasingly answering correctly. The highest percentage of alternative concepts, equal to 57.72%, was also scored on question number 10, the highest percentage for both pair and single questions. Analysis of the tests and the results of the respondents' qualitative answers, show that question number 10 scored the highest percentage of misconceptions.

The consistency of answers to questions in each of the six categories was very low with the highest percentage obtained for the surface feature concept category where only 6.71% or 10 out of 149 respondents answered correctly. This result shows that preservice chemistry teachers do not understand the concept completely and deeply. Analysis of Tables 5 and 6 also show that Level IV preservice chemistry teachers had a better understanding than preservice chemistry teachers at Levels I-III, where understanding improved from the first to fourth level, according to the respondents learning experience. However, there were deviations at Level III where none of the respondents at that level consistently answered correctly for the six categories.

Analysis of answers related to the preservice chemistry teachers' understanding of concepts in the six concept categories show that the highest average percentage of 54.81%, was scored for the concept of surface features, meaning that respondents were able to use the surface features of chemical equations to identify whether a reaction is a redox. The lowest average percentage was 24.30. % for the concepts of dynamics of reaction processes and electrostatics and bonds, meaning that the preservice chemistry teachers held misconceptions about the dynamic nature of particles, bonds, the attraction of charge, or charge replacement between charged species in redox reactions. Analysis of the relationships between misconceptions and average student confidence showed that every distractor chosen by respondents at every level was always followed by a high average of confidence of between 50%-70%, a result that shows how misconceptions become stronger because the preservice chemistry teachers did not realize that what they believed to be true was the wrong concept.

4. Conclusion

Based on the results of this study, it appears that preservice chemistry teachers have not connected the three levels of macroscopic, microscopic, and symbolic chemical representation in studying the redox concept. 54.81% of respondents were able to use the surface features of chemical equations to identify whether a reaction is a redox. The results indicate that the symbolic representation, which involves symbols, formulas, equations, models, and symbols of chemical substances used to represent macroscopic phenomena are understood quite well. However, microscopic (molecular) representations, explanations of phenomena at the particle level (atoms, molecules, ions), in particular, the dynamic properties of particles, bonding, the attraction of charge, or charge switching between charged species in redox reactions are not well understood. According to Treagust, Jacobowitz, Gallagher and Parker, 2003, the three levels of chemical representation are an integrated and inseparable part of understanding chemical concepts and must be understood as one whole. All three levels are essential for describing and explaining interrelated phenomena to facilitate student understanding. An incomplete understanding of the three levels of representation can lead to misconceptions. Misconceptions can be described as beliefs built from one's experience that provide an incorrect understanding of ideas, objects, or events (Martin, Sickson & Lime, 1998). Misconceptions generally occur because preservice chemistry teachers do not understand concepts completely and deeply, thus creating incomplete views regarding the material they are studying. It is a student's view that causes differences in perception between the concept and their understanding, resulting in misconceptions.

Redox topics can cause problems for preservice chemistry teachers regardless of the number of chemistry lessons in a course. Therefore, it is necessary to revisit the concepts at all level of preservice chemistry teacher to strengthen their conceptual understanding using appropriate learning strategies. In addition, lecturers must be familiar with how preservice chemistry teachers develop their understanding of redox topics. However, knowledge of the alternative conceptions held by preservice chemistry teachers can be useful information for lecturers planning classroom instruction. Various scientific concepts have been developed over the past two decades (Chandrasegaran, Treagust & Mocerino 2007). This instrument serves as an easy-to-use tool to identify misconceptions of the redox concept and student confidence about the concept, but changes are needed for several items such as numbers 8, 10, and 16 because based on this studies, the items was low discrimination and high difficulty, which indicates the item was not discriminated adequately because both strong and weak students got the wrong answers. Items that can detect misconceptions in both strong and weak students are important for educators, especially if the educators believe that the students hold a strong grasp of the concept. The data from this research can be used by lecturers to develop appropriate learning methods so that students can construct scientific concept knowledge correctly.

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