The effectiveness of OR-IPA teaching model to improve students’ critical thinking skills on senior high school physics subject

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Abstract. The OR-IPA Teaching Model is a learning that has been developed specifically to improve students’ critical thinking skills in senior high school physics subject. The objective of this research is to analyse the effectiveness of OR-IPA Teaching Model towards the alteration of students’ critical thinking skills on senior high school physics subject. This research used one group pre-test and post-test from 150 students of the first grade of Cerme State Senior High School in 2017/2018 academic year which divided into 5 groups. Students’ critical thinking skill has been measured using Critical Thinking Skills Assessment Sheet (CTSAS) with critical thinking skill indicator. Wilcoxon test, n-gain, and Kruskal-Wallis tests are the techniques to analyse the data. The results of this research verified that: 1) There was an improvement in students’ critical thinking skills on α = 5%; 2) The average score of n-gain students’ critical thinking skills is .83 (high category), and 3) There was no significant difference (there was consistency) of n-gain students’ critical thinking skills on senior high school physics subject in all groups. Therefore, OR-IPA Teaching Model has proven its efficacy to improve students’ critical thinking skills on senior high school physics subject.

1. Introduction

Education has an important role in 4.0 industrial revolutions for developing the global economic community. Education is expected to provide skilful students to support them becoming success individually both in working life and society. Nowadays, to become success, students are required to have those skills such as critical thinking-problem solving, creativity-innovation, and communication-collaboration [1-9]. The development of students’ critical thinking regarded as one of the most important goals in the field of education [2,10-11]. Critical thinking is a thinking process to decide what is to be done and what is to be believed [12], the previous researchers also explained that students’ skill in solving the problem as cognitive skill reflected by formulating the problem, giving an argument, deciding, implementing, analysing, evaluating, inference, explaining, and self-managing [13-24]. Formulating the problem, giving an argument, making a decision, and analysing the results based on literary studies and preliminary studies by researcher are the five indicators of critical thinking that still
considered as a low-rank and needed to be improved in the case of senior high school student on physics subject.

Between 2012 and 2015, PISA (Program for International Student Assessment) and TIMSS (Trends International in Mathematics Science Study) showed the researches result that the science performance among 15 years old students have increased by 21 points [25-27]. Despite the increased data, the students have not been able to use various kinds of information, explanation of evidence and argument using critical analysis and to demonstrate or indicate the ability of thinking and giving a reason scientifically. The lack of students’ critical thinking skills on senior high school physics subject was also supported with preliminary study in State Senior High School 1 Cerme in 2017, this study found that; (1) the lack of exhaustiveness in students’ critical thinking skills on senior high school physics subject indicator (formulating problem 20%; giving an argument 28%; making a conclusion 20%; making a decision 22%; and analysing 17%); 2) the limitation of teacher to develop model and learning devices of physics subject which specifically designed to increase the students’ critical thinking skills on senior high school physics subject. In order increasing critical thinking skill on physics subject, a suitable learning model is urgently needed, the emerge of OR-IPA Teaching Model could be an alternative solution to increase the students’ critical thinking skills on senior high school physics subject [2,28].

OR-IPA Teaching Model is a model which specifically developed to improve students’ critical thinking skills on senior high school physics subject. OR-IPA Teaching has characteristics including problem-based mechanics learning through multi-representation approach based on the theory of multiple intelligences, theory of constructivist, theory of cognitive and theory of multi-representation [2,28-31]. Multi-representation-based teaching could stimulate the college student in critical thinking process [2,31]. It is also supported by some research [32-35] that multi-representation approach has three main benefits such as, the complement, interpretation delimiter, and building a more comprehensive understanding. This model has five syntaxes such as; 1) problem orientation, 2) problem representation 3) group investigation, 4) presentation, 5) analysis-evaluation and follow up. These have been proven effectively to improve the critical thinking skill of senior high school student and also the soon to be physics teacher [2,28]. This research is the continuation research based on recommendation [2,28] to see OR-IPA Teaching Model effectiveness towards other material and different level of physics such Work and Energy in 10th grade senior high school. The result of this research is expected to be the empirical proof in disseminate process of OR-IPA Teaching Model effectiveness to improve students’ critical thinking skills on senior high school physics subject.

2. Method

2.1. General background of research

This research is conducted in State Senior High School 1 Cerme (Gresik, Indonesia). The research’s scope is the senior high school students of 10th grade who took physics subject in school year 2017/2018. The aim was to analyse the effectiveness of OR-IPA Teaching Model which analysing the improvement of students’ critical thinking skills on senior high school physics subject before and after using OR-IPA Teaching Model. The effectiveness of OR-IPA Teaching Model will be determined based on; 1) significant improvement (statistically) on score between pre-test and post-test of students’ critical thinking skills on senior high school physics subject; 2) n-gain average determined at least on low improvement criteria; and 3) the existence of score average consistency n-gain students’ critical thinking skills on senior high school physics subject.

2.2. Sample of research

The samples of the research were 150 students of State Senior High School 1 of Cerme (Gresik, Indonesia) using purposive sampling technique, namely: group-1 (class X-MIA 1), group-2 (class X-MIA 2), group-3 (class X-MIA 3), and group-4 (class X-MIA 4), and group-5 (class X-MIA 5). Those classes have homogeneity of critical thinking skills. Each group consists of students on physics subject in academic year 2017/2018.
2.3. Instrument and procedures

The students’ critical thinking skills were measured by using Critical Thinking Skills Assessment Sheet (CTSAS) which had been declared valid and reliable [36]. CTSAS is formed based on the measurable critical thinking skills indicator such as: 1) formulating the problem, 2) giving an argument, 3) making a conclusion, 4) making a decision, and 5) analysing [2,15,36]. The materials of physics subject in this research were chosen according to OR-IPA Teaching Model characteristics which are Work and Energy. This research used one group pre-test and post-test design, O1 X O2 [37]. The initial learning has started with conducting the pre-test (O1). Every senior high school students are required to work CTSAS. After the pre-test, the teacher will apply OR-IPA Teaching Model and physics learning devices on each group (X). The implementation of OR-IPA Teaching Model has been conducted in five meeting on physics subject. OR-IPA Teaching Model in learning physics has 5 syntaxes such as: 1) problem orientation, 2) problem representation, 3) group investigation, 4) presentation, 5) analysis-evaluation and follow up. Learning devices of physics consist of syllabus, lesson plan, student work sheet, teachers’ textbooks, CTSAS, model observation sheets, students’ activity sheets, and questionnaires of respond (valid and reliable) [36]. Every phase of OR-IPA Teaching Model is designedly to train the critical thinking indicator on physics subject such as formulating the problem, giving an argument, making a conclusion, making a decision and analysing. After the implementation of OR-IPA Teaching Model ended by conducting the post-test (O2) using CTSAS, every student was required to finish CTSAS on the post-test.

2.4. Data analysis

The students’ critical thinking skills on senior high school physics subject is analysed based on a determined assessment before and after using OR-IPA Teaching Model. The students’ data on critical thinking skills pre-test, post-test and n-gain were analysed advance using inferential statistic with the help of SPSS software (IBM SPSS 16.0). The score of students’ critical thinking skills was based on these indicators; 1) formulating the problem, 2) giving an argument, 3) making a conclusion, 4) making a decision and 5) analysing [2,15,36]. N-gain was determined using this equation: n-gain = (score post-test - score pre-test) / (maximum score - pre-test score) [38], with the criteria: (1) if n-gain ≥ .7 (high), (2) if .3 <n-gain < .7 (moderate), and (3) if n-gain ≤ .3 (low). The selection of statistics testing methods depends on the assumptions of normality and the variants homogeneity for the score of pre-test, post-test and n-gain students’ critical thinking skills. The inferential statistical test is conducted using Wilcoxon test (analysis about the existence of the improvement statistically). Meanwhile, the analysis of n-gain consistency of the whole group of senior high school student after implementing OR-IPA Teaching Model is tested using Kruskal-Walls test.

3. Result and discussion

The result of the research showed on table 1, table 2, and table 3 with the explanation as follows:

Table 1. The average scores of pre-test, post-test and n-gain of students’ critical thinking skills on senior high school physics subject.

| Group   | Students’ critical thinking skills on senior high school physics subject. |         |         |         |
|---------|--------------------------------------------------------------------------|---------|---------|---------|
|         | Pre-test                                                                 | Post-test| N-gain  |
| 1 (XMIA1)| 1.07 Low                                                                | 3.55    | High    | 0.85    | High    |
| 2 (XMIA2)| 1.07 Low                                                                | 3.55    | High    | 0.85    | High    |
| 3 (XMIA3)| 1.07 Low                                                                | 3.55    | High    | 0.84    | High    |
| 4 (XMIA4)| 1.07 Low                                                                | 3.49    | High    | 0.82    | High    |
| 5 (XMIA5)| 1.07 Low                                                                | 3.55    | High    | 0.84    | High    |

Table 1 showed the average score of pre-test, post-test and n-gain of students’ critical thinking skills on senior high school physics subject. The entire group showed the pre-test average score was 1.07 (low category). This data is emerged because the students still had much difficulties and unfamiliar ideas to implement the critical thinking skill in physics problem-solving. Those finding was suitable with the
result of the early study conducted by the researchers that students’ critical thinking skills is still below the standard. This finding also supported by the research result [2,28,44] that college student also still had the difficulties in physics critical thinking skills and problem-solving. In contrary with the post-test’s score after implementing OR-IPA Teaching Model, in all group the data is as follows, 3.55; 3.55; 3.55; 3.49; and 3.55, all of them were in high category which shown in the table 1 that n-gain students’ critical thinking skills on senior high school physics subject in all group were .85; .85; .84; .82; and .84 in high category. The result of this research has proven that the implementation of OR-IPA Teaching Model was effectively proven to improve students’ critical thinking skills on senior high school physics subject. This is existed because OR-IPA Teaching Model has been developed to fulfil the validity (content and construction), practicality and effectiveness to improve students’ critical thinking skills on senior high school physics subject [2,28]. This is also supported by the research result [2,28,39-43,45] that the teaching model has been declared feasible by fulfilling the validity (content and construct), practicality and effectiveness will be able to improve and achieve the aim of the learning.

Table 2. The average scores of pre-test, post-test and n-gain of students’ critical thinking skills on senior high school physics subject.

| Groups | Scores | Students’ critical thinking skills on senior high school physics subject |
|--------|--------|--------------------------------------------------|
|        |        | FP                  | PA                  | C                  | MD                  | A                  |
| 1 (XMIA1) | O1 0.87 Low | 0.97 Low | 1.10 Low | 0.93 Low | 0.97 Low |
|         | O2 3.63 High | 3.57 High | 3.63 High | 3.50 High | 3.60 High |
|         | <g> 0.88 High | 0.86 High | 0.87 High | 0.84 High | 0.87 High |
| 2 (XMIA2) | O1 1.43 Low | 1.40 Low | 1.23 Low | 1.30 Low | 1.03 Low |
|         | O2 3.63 High | 3.53 High | 3.60 High | 3.67 High | 3.57 High |
|         | <g> 0.86 High | 0.82 High | 0.86 High | 0.88 High | 0.85 High |
| 3 (XMIA3) | O1 0.97 Low | 1.03 Low | 1.03 Low | 0.97 Low | 1.03 Low |
|         | O2 3.30 High | 3.63 High | 3.43 High | 3.37 High | 3.43 High |
|         | <g> 0.77 High | 0.88 High | 0.81 High | 0.79 High | 0.81 High |
| 4 (XMIA4) | O1 1.03 Low | 0.80 Low | 0.97 Low | 1.10 Low | 1.07 Low |
|         | O2 3.67 High | 3.50 High | 3.50 High | 3.40 High | 3.63 High |
|         | <g> 0.89 High | 0.84 High | 0.84 High | 0.79 High | 0.88 High |
| 5 (XMIA5) | O1 1.07 Low | 1.17 Low | 1.03 Low | 1.07 Low | 1.23 Low |
|         | O2 3.53 High | 3.53 High | 3.57 High | 3.50 High | 3.50 High |
|         | <g> 0.84 High | 0.84 High | 0.85 High | 0.83 High | 0.82 High |

Note: O1 (Pre-test); O2 (Post-test); <g> (N-gain); FP (Formulate the Problem); PA (Provide Arguments); C (Conclude); MD (Make Decisions); A (Analyse)

Table 2 showed that all of students’ critical thinking skills indicators on pre-test were on the low category, whereas after the implementation of physics learning with OR-IPA Teaching Model, it showed that all of the indicator of students’ critical thinking skills has improved. The general n-gain students’ critical thinking skills indicator was on the high category with the score above .77. The positive result is existed because the implementation of physics learning with OR-IPA Teaching Model has been improved the students’ critical thinking skills indicator consisting of: formulating the problem, giving an argument, making a conclusion, making a decision and analysing through five phases of OR-IPA Teaching Model such as: 1) problem orientation, 2) problem representation, 3) group investigation, 4) presentation 5) analysis-evaluation and follow up [2,28]. The prior researchers have also explained that the students’ skill in solving the problem as cognitive skill reflected by formulating the problem, giving an argument, deciding, implementing, evaluating, inferring, explanation, and self-management [13-24,45]. The result of normality test and homogeneity variants has informed that the score of pre-test, post-test and n-gain students’ critical thinking skills on senior high school physics subject is homogeneity and abnormally distributed for the whole group, except for group-3 who did not normally distributed in n-gain. Therefore, the effect of OR-IPA Teaching Model implementation toward the improvement of students’ critical thinking skills for the whole group used Wilcoxon test and consistency
test used Kruskal-Wallis test. The result of Wilcoxon test and Kruskal-Wallis test has showed in table 3.

**Table 3.** The result of Wilcoxon test and Kruskal-Wallis test students’ critical thinking skills for all groups.

| Wilcoxon test | Kruskal-Wallis test |
|---------------|---------------------|
| Group         | N      | Z      | p      | Group | N      | Chi square | df | p     |
| 1 (XMIA1)     | 30     | -4.80  | .00    | 1 (XMIA1) | 150    | 2.42       | 4   | .659  |
| 2 (XMIA2)     | 30     | -4.82  | .00    | 2 (XMIA2) | 30     | 4.80       |     |       |
| 3 (XMIA3)     | 30     | -4.82  | .00    | 3 (XMIA3) | 30     | 4.80       |     |       |
| 4 (XMIA4)     | 30     | -4.80  | .00    | 4 (XMIA4) | 30     | 4.80       |     |       |
| 5 (XMIA5)     | 30     | -4.83  | .00    | 5 (XMIA5) | 30     | 4.83       |     |       |

Note: *p < .05 (2-tailed)

Table 3 showed the average of students’ critical thinking skills for group 1, 2, 3, 4, and 5. Z score gave the score -4.80; -4.82; -4.82; -4.80; and -4.83. Each score were considered as significant, since the p is < .05. This was also indicated that there was an impact of OR-IPA Teaching Model’s implementation that could improve students’ critical thinking skills significantly in all groups. Table 3 also informed that the significance value is p = .659 > .05. This explained that there is no significant difference (consistency) of students’ critical thinking skills on senior high school physics subject improvement from the impact of OR-IPA Teaching Model application in physics learning in all groups. This was because OR-IPA Teaching Model were developed by design in improving students’ critical thinking skills with the following phases: (1) Problem Orientation to attract interest, and motivation in the learning process; (2) Representation of Problem to help understand the material and solve the problem through multiple representations; (3) Investigation to solve problems in students worksheet to build critical thinking skills of high school students; (4) Presentation to discuss the results of investigations in various representations and works; and (5) Analysis, Evaluation, and Follow-up aims to reflect on investigations and facilitate further structured tasks [2,28]. The results also reinforced with theoretical and empirical support that the OR-IPA Teaching Model was a problem-based learning model with a multi-representation approach to improve critical thinking skills based on motivational theory, social constructivist theory, multiple intelligence theory, cognitive psycho-theory, and multi-representation theory [2,28-31]. Therefore the OR-IPA Teaching Model is effective in improving students’ critical thinking skills on senior high school physics subjects.

4. Conclusion

OR-IPA Teaching Model is a specific model which developed to improve students' critical thinking skill of students in senior high school. This model has five syntaxes: 1) problem orientation 2) problem Representation of, 3) group Investigation of, 4) Presentation, 5) Analysis and follow-up. The results of the study prove that: 1) There is an improvement in critical thinking skills at α = 5%; 2) Average score of n-gain skills critical skills of high school students’ skills of .83 (high category); and 3) there is no significant (consistent) improvement in critical thinking skills in all groups. Therefore, the OR-IPA Teaching Model has been proven to be effective in improving students’ critical thinking skills on senior high school physics subjects. The implications of this research are an alternative in improving students’ critical thinking skills through physics-based problem-solving learning with multi-representation. Further research needs to replicate the OR-IPA Teaching Model in improving students’ critical thinking skills on senior high school physics subjects at various levels.

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References
[1] Kemdibud 2016 Salinan lampiran peraturan menteri pendidikan dan kebudayaan nomor 20 tahun 2016 tentang standar kompetensi lulusan pendidikan dasar dan menengah (Jakarta: Kemdibud)
[2] Griffin P and Care E 2015 Assessment and teaching of 21st century skills (New York: Springer)
[3] Jatmiko B, Prahani B K, Munasir, Supardi Z A I, Wicaksono I, Erлина N, Pandiangan P, Althaf R and Zainuddin 2018 J. Baltic Sci. Educ. 17 1
[4] Jatmiko B, Widodo W, Martini, Budiyananto M, Wicaksono I and Pandiangan P 2016 J. Baltic Sci. Educ. 15 441
[5] Pandiangan P, Sanjaya M, Gusti I and Jatmiko B 2017 J. Baltic Sci. Educ. 16 651
[6] Prahani B K, Winata S W and Yuanita L 2015 J. Penelit. Pend. Sains 4 503
[7] Prahani B K, Limatamu I, Nur M and Yuanita L 2016 Int. J. Educ. Res. 4 231
[8] Prahani B K, Nur M, Yuanita L and Limatamu I 2016 Vidhya Karya 31 72
[9] Suyidno, Nur M, Yuanita L., Prahani B K and Jatmiko B 2018 J. Baltic Sci. Educ. 17 136
[10] Thaïposri P and Wanapiroon P 2015 Procedia Soc. Behav. Sci. 174 2137
[11] Forawi S A, Almekhlafi A G and Al-Mekhlafi M H 2012 Online Submission 1 99
[12] Geertsen H R 2003 Teach. Sociology 31 1
[13] Ennis R H 1996 Critical thinking (The University of Illinois: Pretince Hall Inc)
[14] Burbach M E, Matkin G S and Fritz S M 2004 College Student J. 38 482
[15] Cheong C M and Cheung W S 2008 Australian J. of Educ. Technol. 24 556
[16] Ennis R H 2011 Inquiry 26 4
[17] Ernst J and Monroe M 2004 Environmental Educ. Res. 10 507
[18] Facione P A 2013 Insight Assessment 1 1
[19] Susantini E, Thamrin M H, Isnawati and Lisdiana L 2012 JPII 1102
[20] Miri B, David B C and Uri Z 2007 Res. Sci. Educ. 37 353
[21] Mundilarto and Ismoyo H 2017 J. Baltic Sci. Educ. 16 761-780
[22] Popil I 2011 Nurse Educ. Today 31 204-207
[23] Siew N M and Mapeala R 2016 J. Baltic Sci. Educ. 15 602-616
[24] Snyder L G and Snyder M J 2008 J. Res. Business Educ. 50 9
[25] OECD 2014 PISA 2012 results (Washington: OECD Publishing)
[26] OECD 2015 PISA 2015 (Washington: OECD Publishing)
[27] OECD 2016 PISA 2015 result in focus (Washington: OECD Publishing)
[28] Althaf R, Jatmiko B and Supardi Z A I 2013 Prosiding Seminar Nasional FMIPA Unesa Surabaya 22
[29] Moreno R 2010 Educational psychology (New York: John Wiley and Sons Inc)
[30] Arends R I 2012 Learning to teach (New York: Mc. Graw-Hill Companies)
[31] Slavin E R 2011 Educational psychology, theory and practice (Boston: Pearson)
[32] Maor D 2001 J. Com. Math. Sci. Teach. 20 75
[33] Ainsworth S 1999 Com. Educ. 33 131-152.
[34] Ainsworth S 2008 The educational value of multiple-representations when learning complexity scientific concepts (New York: Springer)
[35] Ciais P, Reichstein M, Viovy N, Granier A, Ogée J, Allard V and Carrara A 2005 Nature 437 529
[36] Sulistiyowarni P A D 2018 Pengembangan perangkat model pembelajaran orientasi ipa dengan laboratorium inkuiri untuk meningkatkan keterampilan berpikir kritis siswa sma (Pascasarjana Unesa: Surabaya)
[37] Fraenkel J R, Wallen N E and Hyun H H 2012 How to design and evaluate research in education (New York: McGraw-Hill)
[38] Hake R R 1998 Am. J. Phys. 66 64
[39] Limatamu I, Suyatno S, Wasis and Prahani B K 2018 J. Phys. Conf. Ser. 997 22
[40] Prahani B K, Suprapto N, Sulyianah, Lestari N A, Jauhariyah M N R, Admoko S and Wahyuni S 2018 J. Phys. Conf. Ser. 997 08
[41] Purwaningsih E, Suyatno S, Wasis and Prahani B K 2018 J. Phys. Conf. Ser. 997 32
[42] Sunarti T, Wasis, Madlazim, Suyidno and Prahani B K 2018 J. Phys. Conf. Ser. 997 13
[43] Madeali H and Prahani B K 2018 2018 J. Phys. Conf. Ser. 997 29
[44] Suprapto N, Suliyanah, Prahani B K, Jauhariyah M N R and Admoko S 2018 J. Phys. Conf. Ser. 997 11
[45] Hadi S A, Susantini E and Agustini R 2018 J. Phys. Conf. Ser. 947 63