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THE COMPARISON OF OR-IPA TEACHING MODEL AND PROBLEM BASED LEARNING MODEL EFFECTIVENESS TO IMPROVE CRITICAL THINKING SKILLS OF PRE-SERVICE PHYSICS TEACHERS

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Abstract. *Critical thinking skills are one of the 21st century skills that are effectively trained by using the OR-IPA and Problem Based Learning (PBL) Model, therefore this research aims to compare the effectiveness of both. Research design used True Experiment with Randomized Subject Control-group Pre-test and Post-test with 94 pre-service physics teachers. Data collected using the critical thinking skills test and the student response sheet, and then analyzed using t-test and N-gain. The results showed: (1) the teaching instruments of OR-IPA and PBL Model have fulfilled the validity requirements (ra ~ .26) and reliability (α = .96 - .99). (2) Each of OR-IPA, PBL, and Conventional Model can significantly increase critical thinking skills at α = 5%, respectively with average N-gain: medium (.60), medium (.48), and low (.14); with the student response of: very positive, very positive, and less positive. (3) The OR-IPA and PBL Model are effective to improve critical thinking skills, while the Conventional Model is ineffective, and the OR-IPA Model is more effective compared to the PBL Model. Implication of this research is that the OR-IPA Model can be an innovative solution to improve critical thinking skills, but there is still a need for repetitive research like this.*

Keywords: *basic physics, critical thinking skills, OR-IPA model, pre-service physics teachers, and PBL model.*

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Introduction

In this 21st century, education has an important role in producing Human Resources (HR) that has the needed skills to work. Meanwhile, the demands of the curriculum and the development of globalization era require educational institutions to do beneficial innovations for the 21st century skills-based educational world (Griffin & Care, 2015; Turiman, Omar, Daud, & Osman, 2012). Permendikbud No.73 of 2013 on the Indonesian National Qualification Framework in the field of higher education requires universities to prepare curriculum for pre-service physics teacher to have superior competence with various skills that are in line with 21st century demands, among them are: critical thinking skills, skills to utilize Information and Communication Technology (ICT), and skills to solve problems (Griffin & Care, 2015; Jatmiko, Widodo, Martini, Budiyanto, Wicaksono, & Pandiangan, 2016; Kemdikbud, 2013; Pandiangan, Sanjaya, & Jatmiko, 2017). The 21st century educational process requires human resources with competence and the achievement of pre-service physics teachers are directed to skills and learning innovations, among others are: Critical thinking skills, problem solving skills, decision making, creative thinking, responsibility, and ability to learn independently (Griffin & Care, 2015; Pandiangan, Sanjaya, & Jatmiko, 2017; Suyidno, Nur, Yuanita, Prahani, & Jatmiko, 2018).

The development of critical thinking skills is considered as one of the most important goals of education for over a century (Forawi, Almekhlafi, & Al-Mekhlafy, 2012; Geertsen, 2003). Critical thinking has been defined and measured in a number of ways, but it usually involves an individual's ability to identify central issues and assumptions in arguments, recognize important relationships (Mason, 2017, Moon, 2007), make correct conclusions from data, infer provided information or data, interpret whether the conclusion is guaranteed or not based on the data provided (Facione, 2013; Mulnix, 2012). Furthermore, previous researchers explain that critical thinking is cognitive skills, it includes activities of interpretation, analysis, evaluation, inference, explanation, and self-management in problem solving (Bean, 2011; Cheong & Cheung, 2008, Dam & Volman, 2004; Ennis, 2011; Ernst & Monroe 2004; Jenicek, 2006; Marin & Halpern, 2011; Miri, David & Uri 2007; Mundilarto & Ismoyo, 2017; Popil, 2011; Siew & Mapeala, 2016; Snyder & Snyder, 2008; Womack & Jones, 2010). In this research, critical thinking skills is a cognitive process which is carried out as a thinking guide by using reason judgments against evidence, context, standard, method, and conceptual structure by performing concepts, application, synthesis and information obtained from observation, experience, reflection, thinking, or communication as a basis for believing and doing an action and focusing on what to do. The critical thinking skills' indicators in this research are analysis, evaluation, interpretation, and inference based on the results of literature research and preliminary study by the investigator, these indicators are still low and need to be accelerated in pre-service physics teachers.

In connection with the improvement of the teaching process and outcomes quality mentioned above, there are important problems faced by the world of education today, which is how to strive pre-service physics teachers' critical thinking skills through teaching (Krulik & Rudnick, 1996; Marzano, 1993). This needs to be done because there are many students who do not have critical thinking skills (Brookfield, 2017). Critical thinking skills are important thinking skills and should be taught, but there are still many lecturers who do not understand how to teach critical thinking skills. The results of Patrick's, Fallon, Campbell, Cretchley, Devenish, & Tayebjee (2014) and Pithers & Soden (2000) showed that critical thinking skills should be taught, but there are still some lecturers who do not know how to teach critical thinking skills effectively (Brownlee, Walker, Lennox, Exley, & Pearce, 2009; McPeck, 2016).

Martin, Mullis, Foy, & Stanco (2012) showed that most of Indonesian students are only able to recognize a number of basic facts and have not been able to communicate and relate various topics of science, especially in applying complex and abstract concepts. This fact is in line with the results of Rosyid, Jatmiko, & Supardi (2013) research, which indicated that the physics teaching process is still and more emphasized on the process of knowledge transfer, so it has not been able to make students able to construct knowledge. The low critical thinking skills of pre-service physics teachers are suspected to have something to do with the teaching process being implemented (Browne, & Meuti, 1999; Staib, 2003; Wlodkowski, & Ginsberg, 2017). The implemented teaching model, which is the Conventional Teaching Model (i.e. Conventional Model) cannot facilitate in developing students' critical thinking skills, resulting in low learning achievement (Hammond, Barron, Pearson, Schoenfeld, Stage, Zimmerman, & Tilson, 2015; Mann & Kaitell, 2001). Therefore, to improve the quality and facilitate the development of pre-service physics teachers, it is necessary to find out alternative solutions. The alternative solutions include implementing the OR-IPA Teaching Model (i.e. OR-IPA Model) and Problem Based Learning Model (i.e. PBL Model). The results of previous research conducted by Rosyid, Budi, & Supardi (2013) showed that OR-IPA Model and PBL Model with supporting teaching instruments can improve high school students' learning outcomes in Kabupaten Jember, East Java significantly at $\alpha = 5\%$ with moderate N-gain.

The OR-IPA Model is a problem-based teaching model through a multi-representation approach based on the theory of multiple intelligences, constructivist theory, cognitive theory, and multi-representation theory. Multi-representation teaching can stimulate students to perform analysis, synthesis, and evaluation, so that students can build their own understanding (Damon, 2015, Maor, 2001). This was also applied to Ainsworth's (2008, 1999) and Ciais, Reichstein, Viovy, Granier, Ogée, Allard & Carrara (2005) studies which suggested that multi-representation learning has three main functions: complementary, interpretive, and can build a more comprehensive understanding. In this research, the OR-IPA Model has five syntaxes, namely: (1) **O**rientation of Problem, (2) **R**epresentation of Problem, (3) **I**nvestigation, (4) **P**resentation, (5) **A**nalysis, Evaluation and Follow-up (Rosyid, Budi, & Supardi, 2013). The interactive tasks in applying this OR-IPA Model to grow up the ability of critical thinking skills are referred to the phases in the syntax, namely: (1) **O**rientation of Problem, which is aimed to attract the students, focus the students, and motivate them to take an active role in the teaching process; (2) **R**epresentation of Problem, which is aimed to assist students in understanding the material and solving the problems that will be discussed through various approaches that can be adapted to the objectives of teaching and the presented material characteristics; (3) **I**nvestigation, which is aimed to collect information with the help of Student Worksheet, then the lecturer guides to carry out step-by-step investigations, explores the explanation, and solutions to build the critical thinking skills which includes (a) formulating the problem; (b) formulating the hypothesis; (c) identifying variables; (d) writing the operational variables definition; (e) writing down the experimental tools and materials; (f) conducting

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experiments; (g) organizing experiment data; (h) analyzing experimental data; and (i) making a conclusion; (4) **P**resentation, which is aimed to guide students in making conclusions and discussion of the investigation results in various representations, and assisting in the planning, preparing and presenting the works; and (5) **A**nalysis, Evaluation and Follow-up, which is aimed to analyze and evaluate the problem-solving process of inquiry and process in various forms of representation, observe the students' work as the learning evidence, and facilitate follow-up learning through the assignment of structured tasks.

The PBL Model has five syntaxes, namely: directing students to problems, organizing students to learn, helping independent and group investigations, developing and presenting artifacts and exhibits, and analyzing and evaluating problem-solving processes (Arends, 2012). Characteristics of the PBL Model are designed to help students improving their inquiry skills and problem-solving skills, social behavior and skills according to the role of adults, as well as independent learning skills for the investigation of everyday life issues (Arends, 2012; Arizaga, Bahar, Maker, Zimmerman, & Pease, 2016; Nilson, 2016). The PBL Model begins with a complex real life (Ledesma, 2016), unstructured, and involves interdisciplinary content (Loucky, 2017), engages in collaborative teaching to manage an increasingly diverse student population (Guilherme, Faria, & Boaventura, 2016; Kang, Kim, & Lee, 2015). PBL is an important practice that provides a suitable learning environment for students (Caesar, Jawawi, Matzin, R., Shahrill, Jaidin, & Mundia, 2016; Nuninger & Châtelet, 2017). The PBL Model also regulates a student-centered learning environment that is not viewed as an empty vessel but is capable to bring its own distinct framework and learning (Chakravarthi, 2010; Efendioglu, 2015). The PBL Model can enhance self-study skills and provide a more realistic picture of higher academic challenges, more confidence, better problem-solving skills, critical thinking skills, and provide the improvement of communication skills (Malan, Ndlovu, & Engelbrecht, 2014; Méllesis & Hurren, 2011; Williams, 2005). The application of PBL Model will promote students to have motivation, confidence in learning and able to improve students' ability to solve more complex problems (Caesar et al., 2016; Nilson, 2016; Sern, Salleh, Mohamad, & Yunos, 2015; Tracey & Morrow, 2017). However, the PBL Model is still weak in terms of inquiry orientation components, alternative solutions, and difficult in formulating problems and preparing hypotheses (Ates & Eryilmaz, 2010; Chakravarthi, 2010). Although the research shows that the PBL Model supports self-study and communication skills, critical skills improvement, creative thinking skills and problem-solving skills (Ates & Eryilmaz, 2010; Malan, Ndlovu, & Engelbrecht, 2014; Prahani, Nur, Yuanita, & Limatahu, 2016), however PBL's weaknesses are lack of initiation and timing, lack of student discipline, and more challenging authentic issues are needed (Ates & Eryilmaz, 2010; Thompson, McInerney, Manning, Mapukata-Sondzaba, Chipamaunga, & Maswanganyi, 2012).

The State University of Surabaya (Unesa) as an institution of higher education has facilitated its lecturers with various teaching models that can be integrated with information and communication technology. However, the reality shows that there are still many lecturers who have not conducted the lesson by utilizing the facilities to provide learning experiences for pre-service physics teachers. Most of the lecturer facilities provided by Unesa are only used as teaching tools and have not been utilized to produce teaching models. The teaching models gained through a series of research are less useful and ineffective because they have not been optimally utilized by lecturers at Unesa as it is in other higher education institutions, lecturers should be responsible for developing models, strategies, approaches, methods or instructional techniques in the era of the 21st century (Huba & Freed, 2000; Richards & Rodgers, 2014). OR-IPA Model and PBL Model are very useful to improve lecturers' competence in teaching. This is because the teaching becomes more interesting, more challenging, and better suited to the needs of students. The results of previous research indicate that the OR-IPA Model and PBL Model are effective and practical in improving critical thinking skills of Senior High School students in Jember Regency (Rosyid, Jatmiko, & Supardi, 2013).

Referring to the effectiveness of OR-IPA Model and PBL Model in improving the students' critical thinking skills, it needs to be reviewed and tested for further consistency in improving the critical thinking skills of pre-service physics teacher from Unesa. This research is very important in order to develop models and learning theories that are able to answer the challenges and skills needs in the 21st century. The low critical thinking skills are theoretically caused, among other things, by: poor motivation and responsibility, poor analytical skills, and less discipline in teach (Adebayo, 2014). This is also due to the lack of ability to organize time, lazy to learn, and less supportive learning environment (Chakravarthi, 2010; Eaton, 2015). Therefore, it is necessary to compare the effectiveness between OR-IPA Model and PBL Model in improving student critical thinking skills. In order to be able to compare the effectiveness of the two models, then the preparation of teaching instruction of OR-IPA Model and PBL Model was done firstly which is designed to be able to increase critical thinking skills of pre-service physics teachers.

Problem of Research

The problem of this research is how to analyze the effectiveness of teaching in the basic physics course with the OR-IPA Model and PBL Model to get more effective teaching model to improve the critical thinking skills of pre-service physics teacher. In addition, also how to get examples of teaching instruments that are valid and reliable with an effective teaching model in improving the critical thinking skills of pre-service physics teachers. In detail, the focuses of this research were: (1) how is the validity and reliability of teaching instruments in basic physics course with OR-IPA Model and PBL Model to improve the critical thinking skills of pre-service physics teachers, which includes: Semester Teaching Plan, Lesson Plan, Student Teaching Materials, Student Worksheet, and Student Critical Thinking Skills Test of pre-service physics teachers? (2) how is the effectiveness of teaching process with OR-IPA Model, PBL Model, and Conventional Model in improving the critical thinking skills of pre-service physics teachers? and (3) which teaching model is the most effective to improve the critical thinking skills of pre-service physics teachers?

Research Focus

During this time, the way to get the student's critical thinking skills is done by teaching with PBL Model, but the previous research conducted on senior high school students in Jember, Indonesia by using teaching with OR-IPA Model, which is a correction of the PBL Model to improve students' critical thinking skills showed results that are also effective and practical (can be applied). On the other hand, many students do not have critical thinking skills, so there are many lecturers who still do not understand how to teach critical thinking skills effectively to the pre-service physics teachers. The focus of this research was to compare the effectiveness of teaching in basic physics courses with OR-IPA Model and PBL Model in improving the critical thinking skills of pre-service physics teacher. This research used control variables; it was the Conventional Model.

Methodology of Research

General Background

This research was conducted at State University of Surabaya in June - December 2017. The scope of this research is the first-year students who took Basic Physics course in academic year 2017/2018. This research is True Experiment with Randomized Subject Control-group Pre-test and Post-test Design. This research is emphasized on the analysis of the OR-IPA Model, PBL Model, and Conventional Model effectiveness by analyzing the increase of critical thinking skills of pre-service physics teachers before and after following the process of physics teaching with CRBT model. The Conventional Model in this research was lecturer-centered teaching model, which includes lecture, presentation, and discussion. The teaching instruments and research instruments are said to be valid if $r_a >$ r table and invalid if $r_a \leq$ r table. Physics teaching process with OR-IPA Model, PBL Model, and Conventional Model are said to be effective if: (1) there is a significant increase of critical thinking skills of pre-service physics teachers at $\alpha = 5\%$, (2) the minimum N-gain is categorized as moderate, and (3) students' responses are at least positive.

Sample

The research was conducted to 94 students of Physics Education Study Program, Unesa, Indonesia, which came from a population of 123 students in three groups (experimental group-1 / OR-IPA Model, experimental group-2 / PBL Model, and control group / Conventional Model). The calculation of the sample number was based on the Slovin formula, that was the sample = [population / (1 + $e^2 \times$ population)] with error tolerance e = 5% (Sevilla, Ochave, Regala, & Uriarte, 1984; Tejada, & Punzalan, 2012). This research took three groups, namely: group of: experiment group-1 came to 31 students; experiment group-2 came to 30 students; and control group came to 33 students, each of them was statistically in the same level of critical thinking skills.

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Instrument and Procedures

This research is True Experiment with Randomized Subject Control-group Pre-test and Post-test Design (Fraenkel, Wallen, & Hyun, 2012).

O_1	X_1	O_2
O_1	X_2	O_2
O_1	C	O_2

With: O_1: Pre-test score, O_2: Post-test score, X_1: OR-IPA Model, X_2: PBL Model and C: Conventional Model

Prior to the research, firstly the researchers set up teaching instruments that covered these components: (1) Semester Teaching Plan, (2) Lesson Plan, (3) Student Teaching Materials, (4) Student Worksheet, and (5) Critical Thinking Skills Test of pre-service physics teacher, respectively for the OR-IPA Model and PBL Model. The data were collected by using the research instruments, which consisted of the following components: (1) Teaching Model Implementation Sheet and (2) Student Response Sheet. The validity of those teaching instruments from both OR-IPA Model and PBL Model was then assessed by the physics education experts in terms of the content and construct. In order for the teaching instruments to be able to be implemented, the leaning instruments have to meet the valid and reliable requirements.

The research began by giving the critical thinking skills pre-test (O_1) by using the critical thinking skills test of pre-service physics teacher to each group of students, then providing teaching with different models, namely: OR-IPA Model, PBL Model, and Conventional Model. Finally, after the entire teaching process has been completed, all groups of students are awarded a post-test (O_2) of the critical thinking skills with the same materials and problems as in the pre-test.

Data Analysis

In order to get the validity of contents and construct for the teaching instruments of the OR-IPA Model and PBL Model as well as the research instrument, the assessment of those instruments was done by the physics education expert based on the content and construct validity. Content validity is a description of needs and novelty, while construct validity is a description of the consistency of teaching instruments of OR-IPA Model and PBL Model with theory/empirical and consistency between the instrument components (Plomp, 2013). The data was analyzed by reliability test; each of them was analyzed by using Cohen's Kappa, single measure interrater coefficient correlation (r_a) and Cronbach's alpha (a). The teaching instruments and research instruments are said to be valid if $r_a > r_{table}$ and invalid if $r_a \leq r_{table}$. Meanwhile, the teaching instruments and research instruments are said to be reliable if $.6 \leq α \leq 1.0$ and not reliable if $α < .6$. In order to analyze physics teaching with a more effective teaching model, an "effective" operational definition is required. Physics teaching process with OR-IPA Model, PBL Model and Conventional Model are said to be effective if: (1) there is a significant increase of critical thinking skills of pre-service physics teachers at $α = 5\%$, (2) the average N-gain at least in moderate category, and (3) students' responses are at least positive. In this research, the pre-test and post-test results were analyzed as follows: when the normality assumption for the achieved score is fulfilled, the Paired t-test will be applied. If it is not fulfilling, non-parametric analysis will be used. In order to get increasing level of student's critical thinking skills score, the calculation was done by using N-gain with equation: N-gain = (Post-test score - Pre-test) / (maximum score - Pre-test) (Hake, 1998). By the criteria of: (1) N-gain > .70 (height); (2) .30 < N-gain < .70 (medium); and (3) N-gain < .30 (low). In order to test whether the improvements on students' critical thinking skills existed or not with the OR-IPA Model, PBL Model, and Conventional Model, Paired t-test against the pre-test score and post-test by using IBM SPSS Statistic 16 software was done. Meanwhile, to get more effective model in improving students' critical thinking skills after being given lessons, researchers compared the effectiveness of the three models by using Independent t-test. In order to see the responses of pre-service physics teachers toward teaching with OR-IPA Model, PBL Model, and Conventional Model, student responses data was analyzed by using qualitative descriptive (Prahani, Winata, & Yuanita, 2015; Riduwan, 2010). With the criteria of: (1) Response ≥ 75% (very positive); (2) 50% ≤ Response < 75% (positive); (3) 25% ≤ Response < 50% (less positive); and (4) Response < 25% (not positive).

Results of Research

Validity of Teaching Instruments and Research Instruments of OR-IPA Model and PBL Model

Before the research is done, teaching instruments and research instruments that have been compiled must meet the requirements of validity and reliability. The validity of teaching instruments of OR-IPA Model and PBL Model, and research instruments were assessed by two physicists of Unesa. The results of the validity assessment of the teaching instruments and research instruments for OR-IPA Model and PBL Model, respectively, are shown in Table 1 and Table 2.

Table 1. The result of teaching instruments and research instruments validity of OR-IPA model.

Components	The Validity of OR-IPA Model Instruments											
	Construct Validity						Content Validity					
	Cohen's kappa	R	r_α	V	α	R	Cohen's kappa	R	r_α	V	α	R
Semester Teaching Plan	1.00	Reliable	.26	Valid	.99	Reliable	.97	Reliable	.26	Valid	.99	Reliable
Lesson Plan	.87	Reliable	.25	Valid	.97	Reliable	.87	Reliable	.25	Valid	.97	Reliable
Student Worksheet	1.00	Reliable	.26	Valid	.99	Reliable	.96	Reliable	.25	Valid	.99	Reliable
Student Teaching Materials	.96	Reliable	.25	Valid	.97	Reliable	.96	Reliable	.25	Valid	.98	Reliable
Critical Thinking Skills Test of Pre-Service Physics Teacher	1.00	Reliable	.26	Valid	.99	Reliable	1.00	Reliable	.26	Valid	.99	Reliable
Teaching Model Implementation Sheet	1.00	Reliable	.26	Valid	.99	Reliable	1.00	Reliable	.26	Valid	.99	Reliable
Student Response Sheet	1.00	Reliable	.26	Valid	.99	Reliable	1.00	Reliable	.26	Valid	.99	Reliable

Notes: r_α = Single measure interrater coefficient correlation; α = Cronbach's alpha; R: Reliability; V: Validity

Table 2. The validity of PBL model instruments.

Components	The Validity of PBL Model Instruments											
	Construct Validity						Content Validity					
	Cohen's kappa	R	r_α	V	α	R	Cohen's kappa	R	r_α	V	α	R
Semester Teaching Plan	1.00	Reliable	.26	Valid	.99	Reliable	.97	Reliable	.26	Valid	.97	Reliable
Lesson Plan	.86	Reliable	.25	Valid	.96	Reliable	.86	Reliable	.25	Valid	.96	Reliable
Student Worksheet	1.00	Reliable	.26	Valid	.99	Reliable	.97	Reliable	.26	Valid	.97	Reliable
Student Teaching Materials	.96	Reliable	.25	Valid	.97	Reliable	.95	Reliable	.25	Valid	.96	Reliable

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Components	The Validity of PBL Model Instruments											
	Construct Validity						Content Validity					
	Cohen's kappa	R	r_α	V	α	R	Cohen's kappa	R	r_α	V	α	R
Critical Thinking Skills Test of Pre-Service Physics Teacher	1.00	Reliable	.26	Valid	.99	Reliable	1.00	Reliable	.26	Valid	.99	Reliable
Teaching Model Implementation Sheet	1.00	Reliable	.26	Valid	.99	Reliable	1.00	Reliable	.26	Valid	.99	Reliable
Student Response Sheet	1.00	Reliable	.26	Valid	.99	Reliable	1.00	Reliable	.26	Valid	.99	Reliable

Notes: r_α = Single measure interrater coefficient correlation; α = Cronbach's alpha; R: Reliability; V: Validity

Table 1 shows that the construct validity of the OR-IPA Model instruments includes: Semester Teaching Plan; Lesson Plan; Students Worksheet; Student Teaching Materials; Critical Thinking Skills Test of pre-service physics teachers, and the research instruments, which includes: Teaching Model Implementation Sheet and Student Response Sheet. All of them have a minimum value of .25 that is greater than r table (.16). All of the components are valid. Otherwise for the reliability are measured by the α value, which are all between the value of .6 and 1, so that all components are reliable. In addition to provide the valid and reliable judgments on the construct validity and the content validity of the OR-IPA Model instruments, the validator also provides several suggestions, namely: (1) Problems should be authentic issues not academic problems; (2) Multi-representation activities shall be designed to train the critical thinking skills; (3) Problems for indicators of evaluation still need to be added one step further; (4) The size of the letters in the Student Teaching Materials should be smaller and not too large; (5) Guidance should be decreased for each student worksheet 1 to student worksheet 4; (6) Consistency of writing scientific terms and symbols of physics; (7) The critical thinking skills need to be provided to the student worksheet for further student training. The suggestion from the validator is used as the reference for revision process of the teaching instruments of the OR-IPA Model in order to be implemented.

Table 2 shows that the construct validity of the PBL Model instruments includes: Semester Teaching Plan; Lesson Plan; Students Activity Sheet; Student Teaching Materials; Student Critical Thinking Skills Test of pre-service physics teacher, and the research instruments, which include: Teaching Model Implementation Sheet and Student Response Sheet. All of them have a minimum value of .25 that is greater than r table (.16). All of the components are valid. Otherwise for the reliability are measured by the α value, which are all between the value of .6 and 1, so that all components are reliable. In addition to provide the valid and reliable judgments on the construct validity and the content validity of the PBL Model instruments, the validator also provides several suggestions, namely: (1) Problems should be authentic issues not academic problems; (2) Multi-representation activities shall be designed to train the critical thinking skills; (3) Problems for indicators of evaluation still need to be added one step further; (4) The size of the letters in the Student Teaching Materials should be smaller and not too large; (5) Guidance should be decreased for each student worksheet 1 to student worksheet 4; (6) Consistency of writing scientific terms and symbols of physics; (7) The critical thinking skills need to be provided to the student worksheet for further student training. The suggestion from the validator is used as the reference for revision process of the teaching instruments of the PBL Model in order to be implemented.

Based on the above description, it can be said that the teaching instruments of OR-IPA Model and PBL Model have fulfilled the content and construct validity requirements to improve the critical thinking of pre-service physics teacher. The teaching instruments of OR-IPA Model and PBL Model can be implemented in the teaching process of basic physics courses.

The Effectiveness of OR-IPA Model, PBL Model and Conventional Model for Critical Thinking Skills of Pre-Service Physics Teachers

The critical thinking skills score and N-gain of pre-service physics teachers were obtained by providing the pre-test and post-test of the critical thinking skills. The detailed score of pre-test, post-test, and N-gain of pre-service physics teachers in the OR-IPA Model, PBL Model, and Conventional Model are shown in Figure 1. While the critical thinking skills indicators of group-1: OR-IPA Model, group-2: PBL Model and group-3: Conventional Model is presented in Table 3. Figure 1 shows that prior to the teaching with OR-IPA Model, PBL Model, and Conventional Model, pre-service physics teachers have low average of critical thinking skills. After the implementation of OR-IPA Model and PBL Model, pre-service physics teachers have an increase in the average of critical thinking skills, but in Conventional Model, all pre-service physics teachers still have average of critical thinking skills in low category. In general, the average of critical thinking skills for pre-service physics teachers in post-test with OR-IPA Model, PBL Model, and Conventional Model is in high category (2.67); Medium (2.14); and low (1.00) and the score ranged from 1 - 4. The average N-gain of critical thinking skills owned by pre-service physics teachers for teaching by using OR-IPA Model, PBL Model, and Conventional Model, is in the category of moderate (.63); moderate (.47); and low (.14), from the score range of 0 - 1.

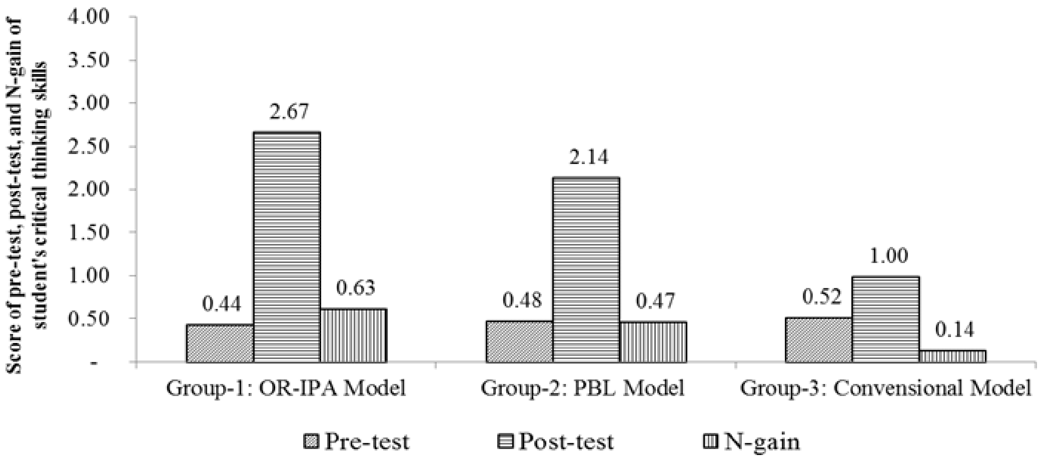

Figure 1: The score of pre-test, post-test, and N-gain of critical thinking skills owned by pre-service physics teachers with OR-IPA model, PBL model, and Conventional Model.

Figure 1 indicates that in order to increase the critical thinking skills of pre-service physics teachers; the OR-IPA Model is better compared to the PBL Model and Conventional Model. While the PBL Model is better when compared to the Conventional Model.

Table 3. The critical thinking skills indicator of group-1: OR-IPA model, group-2: PBL model, and group-3: conventional model.

Group	Score	Indicators of Critical Thinking Skills			
		Analysis	Evaluation	Interpretation	Inference
Group-1: OR-IPA Model	Pre-test	.45	.31	.52	.45
	Post-test	2.91	2.47	3.00	1.96
	N-gain	.69	.59	.71	.43
Group-2: PBL Model	Pre-test	.59	.39	.82	.13
	Post-test	2.36	2.24	2.59	1.39
	N-gain	.52	.51	.56	.33

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Group	Score	Indicators of Critical Thinking Skills			
		Analysis	Evaluation	Interpretation	Inference
Group-3: Conventional Model	Pre-test	.49	.32	.71	.58
	Post-test	1.09	.69	1.29	.93
	N-gain	.17	.10	.18	.10

Table 3 shows that the results of critical thinking skills pre-test of pre-service physics teachers for all critical thinking skills indicators were in the low category, whereas after the implementation of teaching with OR-IPA Model, all the critical thinking skills indicators have increased. In general, the average N-gain for critical thinking skills indicator with OR-IPA Model was in medium and high category, with the value was above .43. The result of critical thinking skills pre-test of pre-service physics teachers for all indicators was in low category, while after implementation of teaching with PBL Model, all critical thinking skills indicators have increased. In general, the average N-gain of critical thinking skills indicator with PBL Model was in medium and high category with the value above .33. The result of critical thinking skills pre-test of the pre-service physics teacher for all critical thinking skills indicators was in low category, while after the implementation of teaching with Conventional Model, all critical thinking skills indicators remain in low category. In general, the average N-gain of critical thinking skills indicators with Conventional Model was in low category with value above .10. Meanwhile, the lowest indicator of critical thinking skills in all groups was inference.

Paired T-test of Critical Thinking Skills Owned by Physics Teachers Candidates with OR-IPA Model, PBL Model, and Conventional Model

The existence of critical thinking skills increase in the pre-service physics teachers is measured by testing the average score of Pre-test and the Post-test score by using Paired t-test. Paired t-test is used (for parametric statistical test) because it has fulfilled the requirements: (1) Pre-test score and Post-test data of critical thinking skills of pre-service physics teacher come from normal distributed population, conducted by normality test (Shapiro-Wilk); and (2) the average of Pre-test and Post-test score data is homogeneous when tested by using the two-variance equality test. Paired t-test for the average score of Pre-test and Post-test of critical thinking skills conducted on Group-1: OR-IPA Model, Group-2: PBL Model, and Group-3: Conventional Model. The result of Paired t-test against Pre-test and Post-test score of critical thinking skills of pre-service physics teachers are presented in Table 4.

Table 4. The results of paired t-test of critical thinking skills owned by pre-service physics teachers in all groups.

Group	N	Paired t-test				
		Mean	Std. error mean	t	df	p
Group-1: OR-IPA Model	31	-2.25	.13	-17.95	30	< .01
Group-2: PBL Model	30	-1.66	.08	-19.83	29	< .01
Group-3: Conventional Model	33	- .48	.05	-9.24	32	< .01

Table 4 shows that the mean scores of critical thinking skills for groups 1, 2 and 3 respectively for: OR-IPA Model, PBL, and Conventional Teaching Model are -2.25; -1.66; and - .48 with degrees of freedom (df) are 30; 29; 32 and giving t value of -17.95; -19.83; and -9.24. The result of Paired t-test for each group is significant, because $p < .05$. Therefore, t counts the negative value, then clearly there is a significant difference at $\alpha = 5\%$ between the pre-test score with the critical thinking skills Post-test in all groups. For teaching with the OR-IPA Model, PBL Model, and Conventional Model, all of them show higher post-test score compared to the pre-test score, or the mean scores of critical thinking skills of pre-service physics teachers after each teaching process with the OR-IPA Model, PBL Model, and Conventional Model are higher than before.

Independent T-test of Critical Thinking Skills Owned by Pre-Service Physics Teachers with OR-IPA Model, PBL, and Conventional Model

In order to analyze which model is more effective in increasing the critical thinking skills of pre-service physics teachers among Group 1: OR-IPA Model, Group-2: PBL Model, and Group-3: Conventional Teaching Model, among others, is done by testing the average N-gain of the critical thinking skills by using Independent t-test. Independent t-test is used (for parametric statistical tests) because it meets the requirements of: (1) the average N-gain of critical thinking skills of pre-service physics teachers (Group 1: OR-IPA Model, Group-2: PBL Model, and Group-3: Conventional Model) are derived from normally distributed populations, performed by normality test (Shapiro-Wilk); and (2) the average N-gain of critical thinking skills of pre-service physics teachers (Group 1: OR-IPA Model, Group-2: PBL Model, and Group-3: Conventional Model) is homogeneous when measured by using multiple-variance test equations. Independent t-test for the average N-gain was performed on Group 1: OR-IPA Model, Group-2: PBL Model, and Group-3: Conventional Model. Independent t-test results on the average N-gain for all groups are presented in Table 5.

Table 5. Independent t-test results on the average N-gain for all groups.

Group	N	Independent t-test				
		Mean Difference	Std. error mean	t	df	p
Group 1: OR-IPA Model Group 2: PBL Model	61	.15	.04	3.58	59	< .01
Group 1: OR-IPA Model Group 3: Conventional Model	64	.49	.04	12.5	62	< .01
Group 2: PBL Model Group 3: Conventional Model	63	.34	.03	12.51	61	< .01

Table 5 shows that the mean difference of N-gain of critical thinking skills for groups: 1-2, 1-3, and 2-3 is .15; .49; .34 and respectively have degrees of freedom (df) = 59; 62; 61, gives a value of t = 3.58; 12.50; and 12.51. The score is significant, because $p < .05$. Therefore, $p < .05$, it is clear that there is significant difference in mean of critical thinking skills N-gain in Group-1 that is the OR-IPA Model with Group-2 that is PBL Model, Group-1 that is the OR-IPA Model with Group-3 that is Conventional Model; Group-2 that is PBL Model with Group-3 that is Conventional Model, for each at $\alpha = 5\%$. The results of the above analysis show that the average N-gain of critical thinking skills of pre-service physics teachers was higher after teaching with the OR-IPA Model when compared to PBL Model and Conventional Model. While teaching with PBL Model gave higher average N-gain when compared to the Conventional Model.

The Pre-Service Physics Teachers Response toward the OR-IPA Model, PBL Model, and Conventional Model

The analysis of student's response toward teaching with implemented model is done by giving the Student Response Sheet for pre-service physics teachers after the physics teaching process. The results of the pre-service physics teachers' responses are presented in Table 6.

Table 6. The pre-service physics teachers' response toward the OR-IPA model, PBL model, and Conventional model.

Group	N	Students' Positive Opinion on the Physics Teaching Process	Category
Group I: OR-IPA Model	31	89 %	Very Positive
Group II: PBL Model	30	89 %	Very Positive
Group III: Conventional Model	33	26 %	Less Positive

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Table 6 shows that in general pre-service physics teacher responded very positively to the teaching instruments of the OR-IPA Model and PBL Model. As for the Conventional Model instruments, student responses show less positive.

Discussion

Validity of OR-IPA Model and PBL Model Instruments

The developed teaching instruments' components include Semester Teaching Plan, Lesson Plan, Student Teaching Materials, Student Worksheet, and Critical Thinking Skills Test of pre-service physics teacher; and the Research Instruments include Teaching Model Implementation Sheet and Student Response Sheet. The assessment of all teaching instruments' components is done by physics education experts in Unesa and has been declared valid as in Table 1 and Table 2. The implication of the instruments has been declared valid and can be used for the implementation of OR-IPA Model and PBL Model in improving the pre-service physics teachers. In addition, Table 1 and Table 2 also show that all components of the teaching instruments are included reliably, shown by the coefficients of Cohen's Kappa. The result of this validity is supported by the opinion of Plomp (2013) which said that a good product (teaching model) must meet the requirements, namely: validity: the validity of the model can be tested by testing the content and construct validity. Content validity is when there is a need for the intervention and its design is based on state-of-the-art (scientific) knowledge; whereas the validity of constructs (construct validity) is the intervention and is 'logically' designed (Nieveen, McKenney, & Akker, 2007). A valid device (content and construct) has an impact on the improvement of the critical thinking skills owned by the pre-service physics teachers on the significant basic physics material as in Table 3 - 5. The statement is reinforced by the results of research stating that PBL can develop critical thinking skills and analysis and exposes students to exercises to solve problems (Klegeris & Hurren, 2011; Şendağ & Odabaşı, 2009). The successful use of this teaching model is determined by the preparation of learning environments and good learning media (Johnson, Rickel, & Lester, 2000) to support each lecturer and student activity (Woolf, 2010) in each stage of the OR-IPA Model and PBL Model syntax. It is a reflection that the developed instruments have been valid and can be implemented to improve the critical thinking skills owned by the pre-service physics teachers.

The Effectiveness of OR-IPA Model, PBL Model, and Conventional Model to Improve the Critical Thinking Skills Owned by the Pre-service Physics Teachers

The individual critical thinking skills score of the pre-service physics teachers is obtained by providing the critical thinking skills test of pre-service physics teachers before the teaching (Pre-test) and after the teaching process is done (Post-test). The data in Figure 1 shows that before the teaching with OR-IPA Model, all students have low critical thinking skills. After the implementation of OR-IPA Model, all students experience increased their critical thinking skills. In general, the critical thinking skills of the pre-service physics teachers in the post-test were in the high category of 2.27 from the range of 1 - 4. The general N-gain scores of pre-service physics teachers with OR-IPA Model were in the medium category of .63. Table 3 shows that all the critical thinking skills indicators in the pre-test are in the low category, whereas after the implementation of teaching with OR-IPA Model, all the critical thinking skills indicators have increased. The general N-gain of critical thinking skills indicators of the OR-IPA Model were in medium and high category with the value was above .43. The results of this research are supported by the work of John Dewey who describes the views of education, with the school as a mirror of the larger society, the class becomes a laboratory for investigation, and solving real-life problems (phase 3). Pedagogy Dewey encourages lecturers to engage students in problem-oriented projects and helps to investigate important social and intellectual issues. Dewey and his followers affirm that teaching in school should be more meaningful, not too abstract (Helterbran, 2010; Loughran, 2013). The vision of purposeful teaching in problem centered is supported by the student's innate desire to explore personal situations for students. The findings of cognitive psychology provide the theoretical foundation for OR-IPA Model. The basic premise in cognitive psychology is that teaching is a process of constructing new knowledge based on current knowledge. Chi, Glaser, & Farr (2014) and Jonassen & Land (2012) assumed that teaching is a constructive process and not an acceptance.

Pre-test, Post-test, and N-gain score of the critical thinking skills owned by pre-service physics teachers in the PBL Model are shown in Figure 1. Based on the data in Figure 1, before the teaching with PBL Model was done, all students have low critical thinking skills. After the implementation of PBL Model, all students' critical thinking skills increase. In general, the pre-service physics teachers gained medium category of 2.14 for their post-test. The general N-gain of pre-service physics teachers by using PBL Model was in the medium category of .47. Table 3 shows that all pre-service physics teachers' pre-test indicators were in the low category, whereas after the implementation of teaching with PBL Model, all the indicators of their critical thinking skills have increased. The general N-gain indicators of critical thinking skills of PBL Model were in medium and high category with value above .33. The results of this research are supported by the characteristics of PBL Model that was designed to assist students in improving the skills of inquiry and problem solving skills, social behavior and skills according to the role of adults, as well as independent learning skills (Arends, 2012: Arizaga, Bahar, Maker, Zimmerman, & Pease , 2016), the PBL Model begins with complex real life (Ledesma, 2016), unstructured, and involves interdisciplinary content (Loucky, 2017), engages in collaborative teaching to manage an increasingly diverse student population (Guilherme, Faria, & Boaventura, 2016; Kang, Kim, & Lee, 2015). PBL is an important practice that provides a student-friendly learning environment (Nuninger & Châtelet, 2017), where they acquire complex problem-solving skills in real life and problem situations, student-centered learning environments, and constructivism approaches (Caesar et al., 2016; Chakravarthi, 2010; Kong, Qin, Zhou, Mou, & Gao, 2014). The results of this research are also reinforced by previous research findings that the PBL Model is very useful to improve motivation, self-confidence, self-study skills, creative thinking skills, critical thinking skills, problem-solving skills, assisting in better retention of knowledge and memory skills, and apply meaningful information with real life situations (Ates & Eryilmaz, 2010; Malan, Ndlovu & & Engelbrecht 2014; Myers, 2017; Nilson, 2016).

The pre-test, Post-test, and N-gain scores of the pre-service physics teachers in the Conventional Model are shown in Figure 1. Based on the data in Figure 1, before the teaching process by using the Conventional Model, all students had critical thinking skills in low category. After the implementation of teaching process by using Conventional Model, all students still had critical thinking skills in low category. In general, critical thinking skills of pre-service physics teacher in Post-test were in the medium category of 1.00. The general N-gain for pre-service physics teacher with Conventional Model was in the medium category of .14. Table 3 shows that all critical thinking skills indicators in the pre-test were in low category, whereas after the implementation of teaching with the Conventional Model all critical thinking skills indicators remained in the low category. The general N-gain of critical thinking skills indicators with a Conventional Model was in the low category with values above .10. The low critical thinking skills of pre-service physics teacher are suspected to have something to do with the teaching process that is implemented. The lesson model that is implemented, the Conventional Model is not able to facilitate in developing the critical thinking skills owned by pre-service physics teacher, resulting in low teaching achievement (Hammond et al., 2015; Mann, & Kaitell, 2001).

The result of Paired t-test presented in Table 4 shows that the mean of critical thinking skills for groups 1, 2, and 3 is -2.25; -1.66; - .48. The whole score is significant, because $p <.05$. Since the result of the calculation was negative, it clearly showed that there was a significant difference between the mean of the pre-test score and the post-test score for the critical thinking skills in all groups, the post-test group was higher than the pre-test group. The low critical thinking skills in theory can be caused by: motivation, lack of responsibility, low analytical skills, and lack of discipline in learning (Adebayo, 2014). This can also be due to a lack of ability to organize time, lazy to learn, and less supportive learning environments (Chakravarthi, 2010; Eaton, 2015). The low critical thinking skills of pre-service physics teacher are suspected to have something to do with the teaching process that is implemented. The OR-IPA Model and PBL Model are able to motivate students to investigate and solve problems in real life situations as well as stimulate students to produce a product in improving the critical thinking skills. Problem-based learning can develop critical thinking skills and analysis and expose students to practice solving problems (Klegeris & Hurren, 2011; Şendağ & Odabaşı, 2009).

The independent t-test for the average N-gain is performed on Group-1: OR-IPA Model, Group-2: PBL Model, and Group-3: Conventional Model. The result of the average t-test of the N-gain by using Independent Samples Test is presented in Table 5, shows that the mean difference of critical thinking skills N-gain for groups 1-2, 1-3 groups, and 2-3 groups is .15; .49; .34 and all are significant, because $p < .05$. This clearly indicates that there is a significant difference between the mean N-gain of critical thinking skills in Group-1: OR-IPA Model with Group-2: PBL Model, Group-1: OR-IPA Model with Group-3 Conventional Model; and Group-2: PBL Model with Group-3: Conventional Model. The results of this analysis indicate that the critical thinking skills N-gain of pre-service physics teachers after the teaching process with OR-IPA Model is higher when compared to PBL Model and Conventional Model. The OR-IPA Model is more effective when compared to the PBL Model in improving the critical thinking skills of pre-service

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physics teachers. The findings are supported by other research that the OR-IPA Model is a multi-representation physics study that can stimulate students in analyzing, synthesis, and evaluation, so that students can build their own understanding (Damon, 2015, Maor, 2001). This is also consistent with Ainsworth's research (2008, 1999); Ciais et al. (2005) which stated that multi-representation learning has three main functions, namely: as a complement, interpretation barrier, and build a more comprehensive understanding. The PBL Model has been proven to improve self-study skills and provides a more realistic picture of higher academic challenges, more confidence, improves problem-solving skills, critical thinking skills, and improved communication skills (Benade, 2017, Leong, 2017; Myers, 2017; Zabit, 2010). However, the weakness of the PBL Model is the lack of initiation and timing, lack of student discipline, and more challenging authentic issues (Ates & Eryilmaz, 2010; Thompson et al., 2012). The findings of this research are supported by questionnaire results of the responses from pre-service physics teachers that are presented in Table 6. The data in Table 6 shows that in general the students of pre-service physics teacher give positive responses to the teaching instruments of the OR-IPA Model. While the result of questionnaire response of pre-service physics teacher toward the teaching instruments and Conventional Model generally shows less positive response. The findings are supported by other research that the Conventional Model is less facilitating students in developing their critical thinking skills, so according to Hammond et al (2015) and Mann & Kaitell (2001) this resulted in low learning achievement. The student response data in Table 6 reinforces that the OR-IPA Model is theoretically and empirically proven to be better than the PBL Model and Conventional Model to increase the critical thinking skills of pre-service physics teacher.

The results of previous studies conducted at the State Junior High School in Jember, Indonesia showed that the OR-IPA Model and PBL Model with implemented teaching instruments can significantly improve teaching outcomes with moderate N-gain (Rosyid, Budi, & Supardi, 2013). The OR-IPA Model is a teaching model that has 5 (five) syntaxes and is designed specifically to improve the weakness of the PBL Model in improving student critical thinking skills. The OR-IPA Model is a problem-based teaching model through a multi-representation approach based on the theory of multiple intelligences, constructivist theory, cognitive theory, and multi-representation theory. Therefore, the OR-IPA Model is theoretically and empirically proven to be better than the PBL Model and Conventional Model in improving the critical thinking skills of pre-service physics teachers.

Conclusions

Based on the results of this research and discussion described above, it can be concluded as follows: (1) The teaching instruments of OR-IPA Model and PBL Model to improve the critical thinking skills of pre-service physics teachers has been prepared, including: Semester Teaching Plan, Lesson Plan, Student Learning Materials, Student Worksheet, and Critical Thinking Skills Tests of pre-service physics teacher. The Critical Thinking Skills Tests of pre-service physics teachers have fulfilled the validity requirements ($r_{\alpha} \sim .26$) and reliability ($\alpha = .96$ - $.99$) the content and construct can be implemented in the teaching process; (2) Teaching process by using OR-IPA Model and PBL Model is effective, as indicated by: (a) there was a significant increase in critical thinking skills of pre-service physics teachers at $\alpha = 5\%$; (b) the average N-gain of physics teaching by using OR-IPA Model and PBL Model are categorized as: moderate (.60) and moderate (.48); and (c) students' responses in each teaching process were categorized as very positive (89%). Meanwhile, physics teaching process by using the Conventional Model was ineffective, as indicated by: (a) there was a significant increase in students' critical thinking skills at $\alpha = 5\%$, (b) low N-gain (.14) and student responses were less positive (26%); and (3) There is significant difference in mean of critical thinking skills N-gain in Group-1 that is the OR-IPA Model with Group-2 that is PBL Model, Group-1 that is the OR-IPA Model with Group-3 that is Conventional Model; Group-2 that is PBL Model with Group-3 that is Conventional Model, for each at $\alpha = 5\%$. Physics teaching process with OR-IPA Model is more effective in improving student critical thinking skills when compared to PBL Model and Conventional Model. The average N-gain of critical thinking skills of pre-service physics teachers was higher after teaching process with the OR-IPA Model when compared to PBL Model and Conventional Model. Implication of this research is that the OR-IPA Model can be an innovative solution to improve critical thinking skills, but there is still a need for repetitive research like this.

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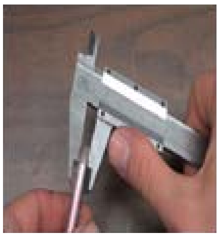
Appendix

CRITICAL THINKING SKILLS TEST
BASIC PHYSICS I

Maximum Time: 3 x 50 minutes.

1. Suppose you are a high school physics teacher should buy just one long measuring instrument to teach your students how to measure book thickness (± 70.0 mm). Meanwhile, there are two options: ruler and sliding term. Based on the advantages and disadvantages of each gauge, which measuring tool would you buy? Give reasons!
2. There are several length measuring instruments as shown in Figure 1, namely: screw micrometer, slider term, and ruler. A student wants to measure the "inner diameter" of a pipe that is approximately 50.0 mm. Which measuring tool is the most accurate for that purpose? Give your arguments!

Screw micrometer



Slider term

Ruler

Figure 1: Length measuring tool

3. Suppose you are a physics teacher who are assigning your three students; each of your students is asked to measure the depth of a ± 80.0 mm pipe with a very small diameter, ± 10.0 mm in a measurement laboratory. Within several minutes later, your students get back and say that they are not successful in measuring the depth of the pipe even though the laboratory has a measuring instrument. What is your conclusion about the length measurement problem? Give your reasons!
4. Two cars move straight in the opposite direction as shown in Figure 2. Car I has a speed of 72.0 km / h to the south. After 4 minutes then car II departs with speed 80.0 km / h to the north. If the distance between the two cars is 20.0 km, what will happen after the car I run for 10.0 minutes? Give your reasons!

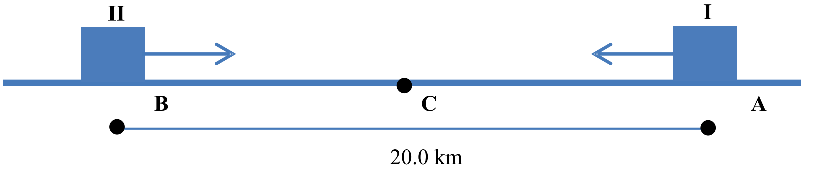


Figure 2: Two cars move straight in the opposite direction

5. An eagle perched on tree limb 19.5 m above the water spots a fish swimming near the surface. The eagle pushed off from the branch and descends toward the water. By adjusting its body in flight, the eagle maintains a constant speed of 3.1 m/s at an angle of 20.0^0 below the horizontal. After 17.0 s flew from the branch into the water, did the eagle catch the fish? Give your arguments!
6. Figure 3 shows position - time graphs for Joszi and Heike paddling canons in a local river; (a) Interpret the position of Joszi against Heike after Heike moves: 0.5 h, 1 h and 1.5 h, (b) What is your conclusion about the rate of the canons.

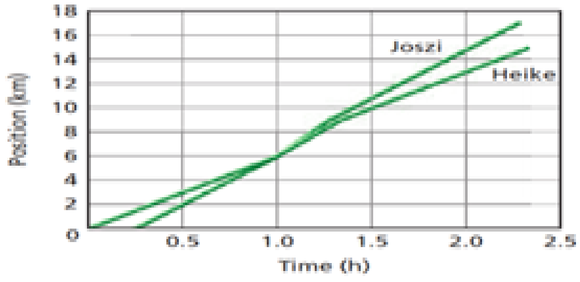


Figure 3: Position - time graphs for Joszi and Heike

(Source: Zitzewitz, et al. 2005)

7. The archerfish hunts by dislodging an unsuspecting insect from its resting place with a stream of water expelled from the fish's mouth (Figure 4). Suppose the archerfish squirts water with an initial speed of 2.3 m/s at an angle of 19.5^0 above the horizontal. When the stream of water reaches a beetle on a leaf at height 30.0 mm above the water's surface will water wet the beetle's body? Give your reasons!

Figure 4: The archerfish hunts by dislodging an unsuspecting insect

(Source: Zitzewitz, et al. 2005)

8. A park ranger driving on a back country road suddenly sees a deer "frozen" in the headlights. The ranger, who is driving at 11.4 m/s, immediately applies the breaks and slows with an acceleration of 3.8 m/s^2. If the dear is 20.0 m from the ranger's vehicle when the breaks are applied, what will happen with the ranger's vehicle? Give your reasons!
9. Observation at the rate of a running car produces graph in Figure 5. Based on the graph, interpret when is the car accelerated and how fast is the car after traveling 30.0 km? Give your reasons!

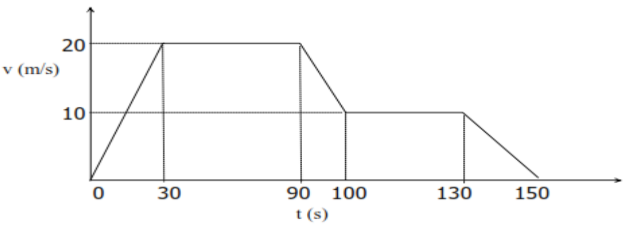


Figure 5: Graph of time - rate for a moving car

(Source: Santoso, 2004)

10. A roadway is banked at proper angle, a car can round a corner without any assistance from friction between the tires and the road. If the angle of the road bend is 26.7°, is the 900-kg car traveling at 20.5 m / s in a turn of the radius of 85.0 m crossing the bend will be safe? Give your reasons!
11. How would you interpret the sprinter's velocity and acceleration as shown in the graph in Figure 6? Give your reasons!

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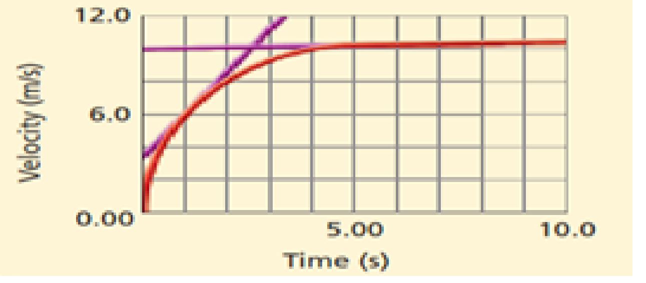

Figure 6: Sprinter's velocity and acceleration

Source: Zitzewitz, et al. 2005

12. A 1200.0 kg car rounds a corner of radius r = 45.0 m. The coefficient of static friction between the tires and the road is 0.8, what can the car run in corner without skidding? Give your reasons!
13. While driving along a country lane with a constant speed of 17.0 m/s, you encounter a dip in the road (Figure 7). The dip can be approximated as a circular arc, with a radius of 65.0 m. If the car seat is only able to withstand 1000.0 N loads, will the car seat be damaged when a mass of 80.0 kg sits in the car seat while the car is at the bottom of the dip as the car's position on the image? Give your reasons!

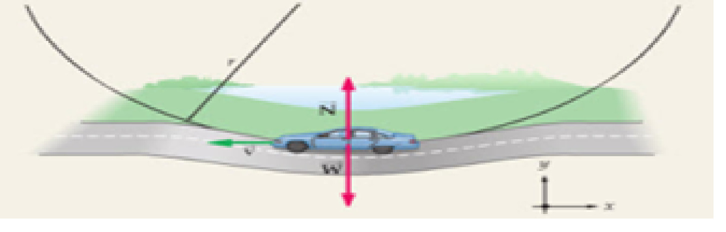

Figure 7: A car crosses the road on a decreasing radius with a radius of 65.0 m depth

(Source: Zitzewitz, et al. 2005)

14. Two youngsters dive off an overhang into a lake. Diver 1 drops straight down, Diver 2 runs off the cliff with an initial horizontal speed v_0. Evaluate the splashdown speed of Diver 2, is **(a)** greater than, **(b)** less than, or **(c)** equal to the splashdown speed of Diver I? Give your arguments!
15. If the height *h* is increased the previous example but the width *w* remains the same, Evaluate the minimum speed needed to cross the crevasse, does it **(a)** increase, **(b)** decrease, **(c)** or stay the same? Give your arguments!
16. From the data indicates that many vehicles are slip when passing a bend in a particular place, what is your conclusion about the path? Give your arguments!

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