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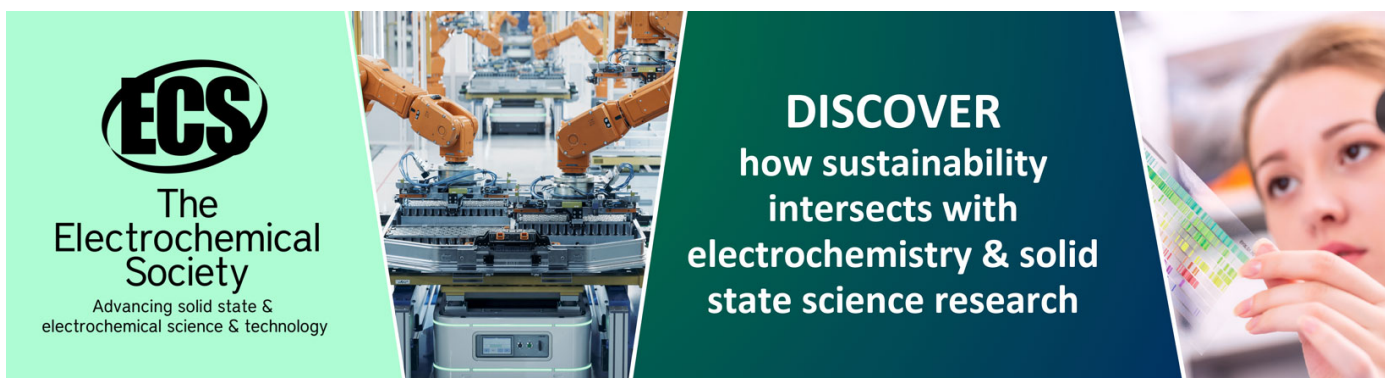
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How student worksheet oriented of content complexity and cognitive processes can improve conceptual understanding and critical thinking skill of student in physics learning in high school

A Putra^{*1}, Lufri², Festiyed¹ and Ellizar³

¹Physics Department, Faculty of Mathematics and Science, Universitas Negeri Padang, Indonesia

²Biology Department, Faculty of Mathematics and Science, Universitas Negeri Padang, Indonesia

³Chemistry Department, Faculty of Mathematics and Science, Universitas Negeri Padang, Indonesia

*amali.unp@gmail.com

Abstract. The use of instructional materials oriented to the fulfilment of 4 dimensions of knowledge and 6 stages of cognitive processes is necessity in high school learning, overall on the standard content curriculum of 2013. This study aims to develop, apply, and evaluate the study materials based on researches in the form of Student Worksheet oriented to content complexity and cognitive processes. This article is intended to share the experiences with teachers in physics of high school who used the student worksheet. This research was conducted in 2017-2018 at high school in Padang city. The activity begins by problem identification of student physics learning. Low conceptual understanding and critical thinking of students are two substantial issues that identified. For these two problems, the Student Worksheet was developed with metacognitive strategies on the concept of Circular Motion and Force on Objects. Eligibility of the Student Worksheet was obtained from suggestion and validation of 5 experts judgment, and 3 practitioners of physics in high school. The Effectiveness test was conducted through an experimental study involving two classes of students in the design of "pre-test and post-test control group design". The results of triangulation data obtained from expert judgment, practitioners, and students was concluded that the developed Student Worksheets are in valid, practical and effective categories to improve the conceptual understanding and critical thinking of students in physics learning in high school.

1. Introduction

In the practice of human life, it shows that different individuals make various conveniences in their surroundings [1]. Those who have high-level thinking ability, is considered able to solve the various problems faced in life to face the changes in the 21st century [2]. Complex knowledge, can only be obtained through learning that contains the various content of knowledge necessary for life [3]. In learning in school, the ability to think critically can be achieved, if students are trained to analyze and evaluate the various objects of learning so that obtained the knowledge it understands [4]. With such



knowledge is expected to students' thinking ability will increase and creativity of students will grow in solving various relevant problems faced. With the learning experience, students are expected to be creative in accordance with the level of education that lived.

To accommodate the need for knowledge complexity, as well as high-level thinking ability, the Government of the Republic of Indonesia through the Ministry of Education and Culture of the Republic of Indonesia to improve school curriculum. If in the past curriculum, the knowledge discussed in the lesson focuses on conceptual knowledge of the nature of understanding, then in the current curriculum, the competence of knowledge to be achieved consists of four dimensions, namely the factual, conceptual, procedural, and metacognitive dimensions. These four dimensions apply to every level of education, the difference is the level of complexity.

At the time of the current start of the current 2013 curriculum in design, the demands of the cognitive process fulfillment that the student wishes to achieve, are limited by decoding the cognitive process taxonomy between levels, as stated in the basic competencies for each subject, are different. For elementary levels focused on the level of remembering and understanding, SMP at the level of applying and analyzing, while high school to the level of evaluating and creating. The limitation of basic competencies has an impact on the learning process, as if elementary students are quite up to low-level thinking, whereas high-level thinking just begins at the high school level. In the last 3 years the 2013 curriculum has been implemented (2014-2017), has undergone various revisions, with the emission of education and culture ministries number 20, 21, 22, 23 and 24 in 2016, in this revised curriculum, the cognitive level of students for all levels, freed from the ability to remember as the lowest level, to the highest level that is the ability to create. The intensity of the ability to create a diligent tailored to the level of student age [5].

Completion of the 2013 curriculum, referring to the Bloom Bloom's revised taxonomy by Anderson and Krathwohl (2001). The new taxonomy, combining the four dimensions of knowledge (factual, conceptual, procedural, and metacognitive), with 6 levels of cognitive processes (remembering, understanding, applying, analyzing, evaluating and creating) [6]. The result of this combination is contained in the Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 21 of 2016 on Curriculum Content Standards. The government's expectations, the adoption of optimum content standards, will meet the complexity of the content and process of learning cognition in high school. The levels of cognitive processes to be achieved in high school physics learning are primarily concerned with abilities: analyzing, evaluating, and creating (creating). These three levels are known by the term "*Higher Order Thinking Skills (HOTS)*" [7]. Experts agree that through training these abilities will awaken the ability to think critically to students.

If observed, the main difference between the curriculum 2013 compared to the old curriculum (Education Unit Level Curriculum = KTSP / 2006 curriculum) is the content and cognitive processes have included the element of metacognitive knowledge on learning content and the ability to create at the level of cognitive processes. Experimental analysis results through various studies, suggesting that metacognitive knowledge can foster students' critical and creative thinking skills to produce active, productive individuals with a variety of novative works. With metacognitive knowledge, the concepts of the studied science are not only limited to memory, but also can be comprehensively holistic with attributes attached to the concept, and the benefits it can produce. A holistic understanding of physics involves a variety of knowledge related to the concept, complete with the understanding, related facts, and scientific work procedures involved in developing the concept. If the students understand a concept, it is expected to explain the concept correctly, either orally or in writing, be able to apply it, analyze and evaluate related facts, and creativity can be improved.

Understanding the concept and principles of physics will be built on students themselves if the students are actively involved in building the concept through the activities created by teachers. Student activity in classroom learning is usually poured through various teacher instruction in teaching materials such as student worksheets, modules, textbooks and so on. The availability of teaching materials is a must in every learning, if teachers want to apply learning based on understanding centered on student activities [8]. Without teaching materials, teachers will tend to inculcate a concept

dominated by lecture methods and tend to be rote. Teaching materials designed and used by teachers should include activities that can produce Higher Order Thinking Skills (HOTS) through analyzing, evaluating and creating exercises, so that the ability of these abilities is attached to the students themselves.

Moving on with the need for student achievement in current high school physics, questions are asked: a) What are the characteristics of student worksheets that can improve conceptual understanding and students' critical thinking skills in high school physics? and b) Are student worksheets oriented to the complexity of the content and the complexity of the process can cognitive improve conceptual understanding and critical thinking ability of students in high school physics learning?

2. Literature Review

2.1. *The Nature of Visibility of Content and Cognitive Processes in Physics Learning*

The term content in learning, often used to express the essential subject matter of a subject, or the answer to the question of "what students learn" for the achievement of the learning objectives poured into the curriculum [9]. The main task of educators is to choose content and activities that are relevant to the needs of students in order to optimize student learning [10]. According to Ansyar [11], content includes 4 components, namely: learning activities, knowledge, experience, and competence. It is expected that a learning approach designed in the curriculum can be viewed as an instrument that educators use to transform content into student knowledge, experience, and competence.

Content by Dewey [12] is *record of knowledge* in the form of data, information, symbols, concepts, theoretical principles and others; while knowledge according to Zais [13] interpreted as a result of individual understanding of the content through interaction and individual experience. After the students have successfully transformed the content into knowledge, the next process is the educator must provide more intensive and intensive learning activities from previous learning activities, so that the students transform knowledge into experience. Knowledge that students gain through experience in learning activities by Shambaugh and Magliaro [14] holistic, because it is formed from a combination of knowledge, skills and attitudes, which are transformed cumulatively into competence. Through teacher-designed learning experiences, these three domains are integrated into the student's cognitive structure, which accumulatively shapes students' competencies. This means experience, an important part of the formation of student competence.

Content in physics, containing knowledge compiled based on observations of facts in nature. Observational data, processed by following the steps of scientific method. Anderson and Krathwohl [15], through Bloom's taxonomic revision, proposed 4 complete dimensions of knowledge, comprising factual, conceptual, procedural, and metacognitive knowledge. When linked to content and knowledge of physics, these four dimensions of knowledge fit perfectly into activities in understanding the concept of principles and the laws of law in physics. Factual knowledge in physics learning can be a statement, whereas conceptual, procedural and metacognitive knowledge is formed on the basis of factual knowledge, each constructed knowledge is built on the answer to the question posed.

Factual knowledge is the knowledge that contains the basic elements that must be known before studying a discipline or solving a problem in the discipline that is generally located at a low level of abstraction. Included in factual knowledge such as: symbols, words, numbers, signs, images, events, and so on. In physics learning, factual knowledge is often expressed in the form of events / phenomena. Example of factual knowledge of electric current: "if both poles of the battery, connected by a wire with a light bulb to form a closed circuit, there will be an electric current and the bulb will light".

Conceptual knowledge, is knowledge in the form of classification, categories, concepts, principles, and generalizations. For example: the principal amount, the magnitude of the derivative, the concept of heat, the principle of free fall motion, the law of conservation of momentum, and so on. In learning

conceptual knowledge is composed based on answers to questions about factual knowledge and is contained in instructional activities designed by teachers. Sample question:

1. What is an electric current?
2. From where are the poles where the electric current occurs?
3. What factors affect the amount of electric current?
4. How is the relationship between electric current strength with battery voltage and the constraint of conductor in a closed circuit?

The answers to these questions can be grouped into the conceptual knowledge of electrical current. Procedural knowledge, is knowledge of various processes, ways of doing things, tips, how to derive the physics formulas, algorithms and so on. In learning procedural knowledge can be built on students through instructional teachers in the form of orders or instructions. Example instructions: Write down the steps of the activity to find out the relationship between the electric current strength and the battery voltage and the constraint of the conductor in a closed circuit based on the experience obtained in the electrical practice that has been done. The sequence of steps the student draws on his experience is a procedural knowledge. Metacognitive knowledge, is knowledge of cognition / in general, and awareness of self-cognition. With metacognitive knowledge students will be able to manage their thinking in solving a problem, based on the factual, conceptual, and procedural knowledge that is controlled and which is not mastered, with the right strategy. Of course, students will not choose a strategy that is not mastered. In learning physics this knowledge can grow and develop if students are often given an analytical workout. With sufficient metacognitive knowledge students' critical and creative thinking skills will be formed.

These four dimensions of knowledge should be planned by the teacher and are present in each learning content as the complexity of knowledge that students must master. Thus, the complexity of content in physics learning is defined as the fulfilment of the four dimensions of knowledge through student learning. All dimensions of knowledge are hierarchically an algorithm of the process of conceptualization of the concept of a holistic involving the ability of high-level thinking and steps of scientific methods, as presented by the diagram in Figure 1.

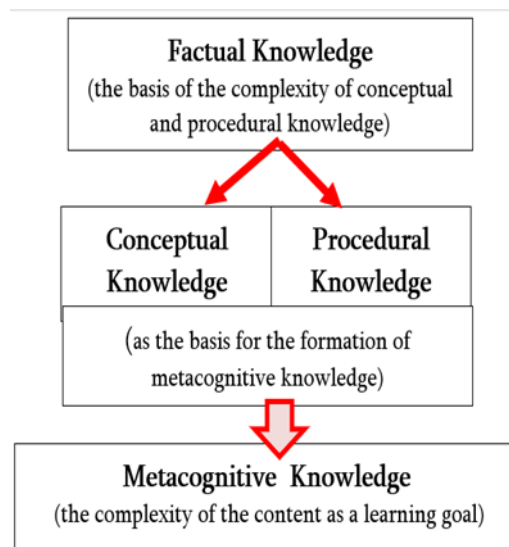


Figure 1. The four dimensions of knowledge as the algorithm the formation of the complexity of content in students' thinking

2.2. Conceptual Understanding in Physics Learning

Contextually, physics is knowledge built on facts. It is the true reality of everything that happens in nature. For example, a ball thrown into an angle $0 < \alpha < 90^\circ$ will form a curved track and eventually fall

on the ground. If the ball is thrown vertically upward, it gradually stops, and eventually also falls back to the ground, and so on. Various facts in nature are the foundation of developing Natural Science, including physics.

Facts that are experienced, observe and feel in Bloom's revised taxonomy, including factual knowledge, as the basis for the formation of concepts, legal principles, theories and models are grouped into conceptual knowledge. Examples of conceptual knowledge such as: the concept of force, the principle of free fall, Newton's law, field theory, Rutherford's atomic model and so on. Conceptual knowledge is factual. The concept of force, defined as *"a form of attraction or impulse acting on an object and may cause a change in the object it touches. In principle form, for example the principle of free fall motion when air friction is ignored, an object dropped without initial velocity, takes time to reach the ground"*. The principle of free fall motion satisfies the equation $t = \sqrt{2h/g}$ with h is altitude fall, and g is acceleration of gravity. Based on these examples, concepts and principles in physics are abstractions of various events, objects, phenomena and facts. The concept has certain properties and attributes. A concept has at least five important elements or elements of name, definition, attribute, value (value), and example. The concept of force that has been defined above, its attributes are caused by the letter F (force), its value is expressed with newton unit (N) in international units, the example of force is friction force, gravity force and so on.

The term principle is often also defined as a rule or law. Everything is also shaped based on relevant facts and concepts that explain facts in nature. Theories and laws of physics are explaining the macroscopic aspects (directly observable) and also for something microscopic (not directly observable), such as atomic theory, gas kinetic theory, the theory of relativity. Theory is tentative because it has not been based on the strong facts as the law, so it still needs proof. A model is a form of representation that is visualized for something that is not invisible or microscopic. The presence of models is to help understand a theory or a natural phenomenon.

Understanding, defined as a person's ability to interpret, interpret, translate, or express something in his own way about the knowledge he has received. Conceptually, interpreted as matters relating to the concept. Thus, the definition of conceptual understanding is the ability to interpret the concepts studied independently. Understanding the concepts of physics, is one of the main goals in learning. In fact, the meaning of conceptual understanding is used in a definite way. Understanding, closely related to learning. With different learning practices, it is possible to have different conceptual understandings.

In the context of learning, one is said to understand the concepts learned if he is able to link the concept into the scheme it possesses. On the other hand, understanding is seen as the knowledge that has been formed in the mental image of a person derived from his learning experience. Anderson et al. stated *"understand is defined as constructing the meaning of instructional messages, including oral, written, and graphic communication"*. The level of one's conceptual understanding can be seen from the types of understanding it has. Understanding is divided into seven kinds, namely: *exemplifying, classifying, summarizing, inferring, comparing, explaining dan interpreting*.

Exemplifying, in the form of specific examples which illustrate the characteristics of a concept or principle such as, characteristic of free falling motion, parabolic motion, and use of such characteristics to select or construct more specific examples, for example why the ball is thrown to form a parabolic motion. *Classifying* occurs when the student recognizes that an event belongs to a particular category based on relevant traits or patterns, so that it fits into specific examples of concepts or principles, such as, motion groupings based on the shape of their paths differentiated by straight motion and curved motion. *Summarizing* occurs when the student is able to propose a single statement representing the presentation of information or a summary of a common theme that includes the construction of an information representation, making a summary that can form a theme, for example, the acceleration is directly proportional to the force acting on it and inversely proportional to the inert mass of the summing object this forms the theme of learning: "The relationship of acceleration with force and mass of things". *Inferring* encompasses the discovery of patterns and sequences of instances or events that occur when students are able to summarize the concepts or principles under discussion

eg after experiments on electrical circuits students conclude that the conditions for the occurrence of an electric current are the presence of a voltage source, equipment using electric current, and form a closed circuit *Comparing* occurs when students find similarities and differences between two or more objects, events, problems, or situations, for example after learning the constraint arrangement, students can compare the different functions of the use of series and parallel series arrays. *Explaining* occurs when students are able to construct and use the causal model of a system derived from formal theory, based on research or experience. For example, after studying various atomic theories, students are able to construct and use various atomic models to explain the characteristics of an arrangement of atoms that construct matter. *Interpreting* occurs when students are able to represent a concept into an image and explanation. For example, after studying the shunt and multiplier constraints in the circuit, students can represent an explanation of the principle of series and parallel array arrangements on both such obstacles in manipulating the measurement limits of the electric current and voltage. The seven forms of understanding, in classroom learning, serve as an indicator of the achievement of knowledge competence on aspects of understanding. Thus, conceptual understanding is the basis of the ability to apply various concept in solving various relevant physical problems.

The lowest level of cognitive processes that students do in developing their knowledge is the ability to remember (C1), that is, the ability to resurrect what was once in its nature in the past, when it comes to situations related to that experience which are not followed by an interpretation of the experience. The second level is the ability to understand (C2), namely the ability to interpret, interpret experiences that have been passed, and able to express the similarities and differences of objects that the object he studied. The third level of cognitive processes, is the ability to apply (C3), namely the ability to implement the knowledge and experience that has been passed in various relevant situations. Ability to remember (C1) understand (C2) dan apply (C3) grouped into *Lower Order Thinking Skills* (LOTS) (Figure 2).

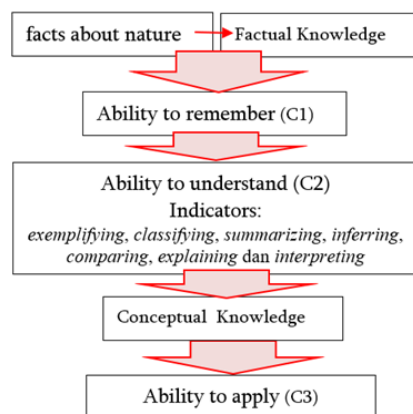


Figure 2. Schematic formation of Lower Order Thinking Skills in learning physics

In practice education in Indonesia, currently LOTS, is a minimal ability that must be mastered at the middle level of education. The current curriculum expects the students' achievable abilities to Higher Order Thinking Skills (HOTS) to include the analytical (C4) evaluating (C5) and creative (C6) abilities. In the HOTS there is the ability to think critically, and the ability to think creatively, as the goal to be achieved by the current curriculum. The six levels of cognitive processes are the optimal capabilities (complexity of cognitive processes) that must be achieved in high school learning (Figure 3).

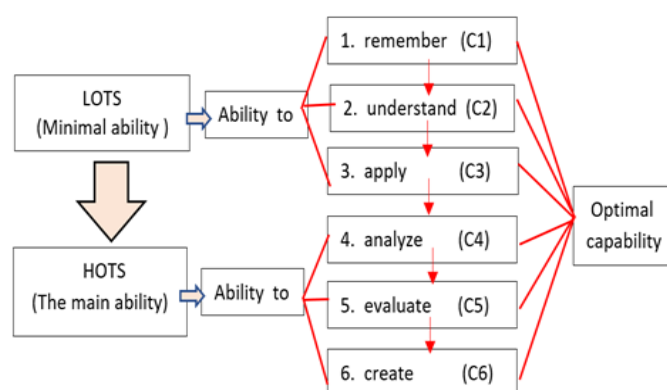


Figure 3. Schematic complexity of cognitive processes in learning

2.3. The Ability of Critical Thinking and Indicators of Achievement

Thinking is a part of reasoning activity that is defined as the process of determining relationships meaningfully between aspects of a knowledge piece following steps; formation of understanding, opinion formation and decision-making. Thinking activity is more than just remembering and understanding. By thinking someone moves out of the information he or she remembers and understands. Every individual can update his knowledge through his thinking activities. One of them is critical thinking activity.

In school learning, teachers should facilitate students to think critically in acquiring new knowledge through collaborative problem solving. The intended thinking activity is facilitated by involving students to discover how to research, conclude, make decisions, and create and apply new knowledge to real-world situations. Orlich et al. [16] states that effective critical thinking will emerge by associating abilities: (1) observing; (2) identify patterns, relationships, causal relationships, reason-logic, logical and bias errors; (3) establish criteria and classify; (4) compare and differentiate, (5) interpret; (6) summarizing; (7) analyze, synthesize and generalize; put forward hypothesis; (8) distinguish relevant data from irrelevant, verifiable and non-verifiable data, distinguishing the problem from irrelevant statements.

Kneedler and Costa [17], suggests 3 steps of critical thinking that is: 1) the introduction of problem problems; 2) assess relevant information; and 3) solve problems or draw conclusions. The first step requires 4 abilities: abilities: a) identifying problems; b) compare similarities and differences in observed aspects, c) select relevant information and d) formulate problems. The second step requires 5 skills: 2) selecting facts, opinions, results of judgment; b) check consistency; c) identify assumptions; d) recognize possible stereotypical factors; e) recognize possible biases, emotions, propaganda, misinterpretations, and; f) recognize the possibility of different values and ideology orientations. Step 3 requires 2 abilities: abilities: a) recognize the data needed and whether or not enough data; and b) Predict the possible consequences of the decision / problem solving / conclusion drawn. Correspondingly, Ennis [18] also suggests 6 Indicators of critical thinking ability, namely: 1) formulating the problem, 2) giving arguments, 3) deducting, 4) induction, 5) evaluating, and 6) making decisions.

The ability to think is not automatically owned by students. Because it is not a direct result of learning, but the student who performs his own transfer of thinking skills, through training with the teacher's intensive guidance. With a routine exercise done by students, will have an impact on the efficiency and automation of thinking that students have.

Various research results show that critical thinking skills can be improved through various approaches, models, and learning strategies. such as cooperative learning, problem-based learning, discovery-based learning, project-based learning and so on, which are generally based on a scientific approach (at least 5M implementing, ie, pretending, asking, trying, reasoning and communicating).

2.4. Learning Thinking Flow to Increase Conceptual Understanding and Critical Thinking Ability of Student

There are two main aspects of learning goals in school, namely to increase knowledge and to improve the ability to think. These two aspects are a provision for the life of students so that later easily adapt to their environment and able to solve various problems encountered in his life. On the basis of that, the content in learning in the planning of the teacher should contain a variety of knowledge that is useful for the life of students later and contains exercises to think and reason for the level of cognitive ability of students increased. Referring to Bloom's taxonomic revision, the intended learning content contains 4 knowledge dimensions and 6 levels of cognitive processes. The combination of these two aspects, if implemented with a scientific approach, will be trained critical thinking skills, through observing activities, asking, trying, reasoning and communicating. The exercise of such activities will enhance the conceptual understanding of the content learned in line with the growth of students' thinking ability. It is expected that the improvement of these two aspects of learning will result in individuals whose attitudes and skills improve as the knowledge increases (Figure 4).

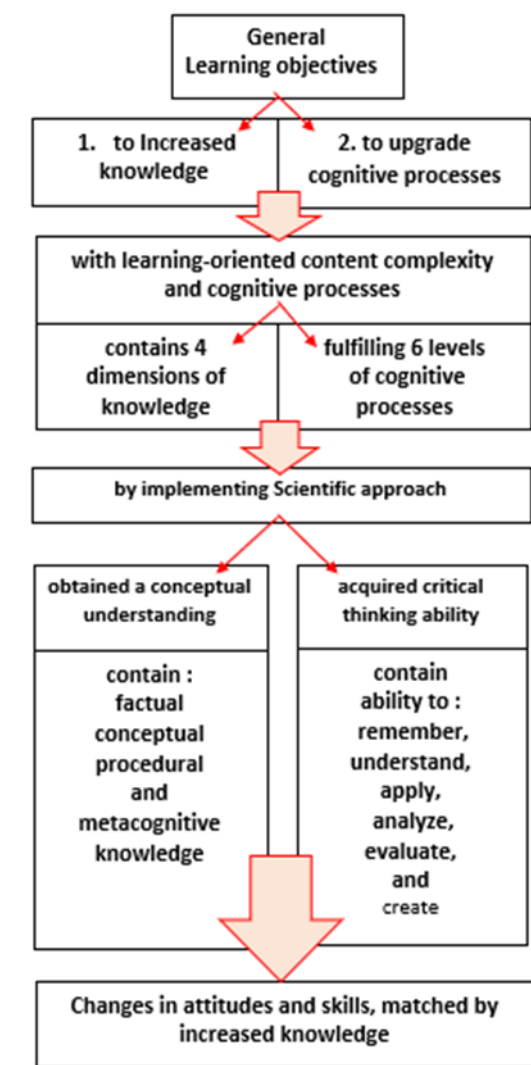


Figure 4. Learning flow to improve conceptual understanding and creative thinking ability.

One of the important learning planning components is teaching materials. Without teaching learning materials tend to be dominated by teacher activity with meticulous method. With the right

teaching materials, learning activities will be centered on students that involve their thinking ability. The instructional materials are all materials used to assist teachers or instructors in a systematic set of materials, both written and unwritten, to create an environment or atmosphere that enables students to learn. A teaching material contains instructional and learning content that must be mastered by students learning process done by students through the instruction contained in teaching materials. One form of teaching material is in student worksheets. That is a sheet that contains guidelines for students to carry out programmed activities that contain instructions, guidance questions and understanding so that students can expand and deepen their understanding of the material being studied. A student worksheet usually contains material briefly, learning objectives, manual work on questions and a number of questions that students must answer.

3. Research Method and Finding

3.1. Research Methods

The research method applied to get to this research goal is Research and Development (R & D), using model of ADDIE (Acronym from Analyze, Design, Develop, Implementation, and Evaluate) This research is conducted from 2015 to 2017 by following Step ADDIE [19] as follows:

Needs Analysis (2015). Conducted field studies in 4 high schools in the city of Padang that has run the 2013 curriculum in the city as much as 2 activities, namely:

First, using the instrument in the form of test with 24 items result of combination of 4 dimension of knowledge and 6 level of cognitive process to know conceptual understanding of class X student toward physics material. The results of the analysis show that, mastery of student knowledge is mostly at the level of remembering, understanding and applying. And only a small part is at the level of analyzing. While the ability at the level of evaluate and be creative tend not to appear.

Secondly, observation of the implementation of learning in the classroom using the instrument of questionnaire, observation format and interview question of observation result indicate that: a) The scope of knowledge conveyed by teacher is dominated by factual knowledge in the form of concept of law and theory principle, followed by factual knowledge, and procedural knowledge with relatively fewer proportions than conceptual imagery. While the implementation of metacognitive knowledge tends not to appear. b) student work sheet tends to discuss knowledge at the remembering level. and c) the scientific approach has not been well implemented. The results of the analysis at these two stages, recommended the development of student worksheets-oriented content complexity and cognitive processes.

Design Model (2015). At this stage in the design of student worksheets oriented content complexity consisting of several activities, namely:

- First, the literature study required and used for modelling, includes theories on: model development, teaching materials and student worksheets, Bloom Bloom's Taxonomy, conceptual concepts and understandings, as well as critical thinking skills.
- Second, analyzing the learning objectives in the mathematics physics of class X of SMA for the concept of force on Objects (Newton's Law 1, 2, and 3) so that the competence achievement indicator is obtained to describe the student worksheets to be designed, the learning process to be performed and the evaluation instrument.
- Third, design student worksheets according to the flow diagrams presented in Figures 4 and 5, complete with related tools (Snapshot syllabus, Learning Plan, media and evaluation instruments)
- Fourth, the design of student worksheets validation instrument based on indicators of student's worksheets eligibility indicators, content complexity, the complexity of cognitive processes, conceptual understanding, and critical thinking skills.

- Fifth, ask for feedback on the student worksheets that have been designed and validation tools from 4 expert cleaning experts as validator and learning practitioner.
- Sixth, Improve the resulting product based on feedback received from the auxiliary expert judgment, and produce it for the activity at the development stage. The resulting product design is the result obtained at the design stage.

Development (2016). At this stage the development activities of 4 student worksheets products that have been in the design follow the steps as follows:

- First, ask 5 experts judgment experts to provide input to the student worksheets produced.
- Second, make improvements of student worksheets products based on input from 5 people such expert judgment.
- Third, ask 5 experts judgment who have been appointed to assess the product of student worksheets that have been refined in terms of validity.
- Fourth, ask 3 teaching practitioners to provide input regarding the precision of the resulting student worksheets product.
- Fifth, improving the practicability aspects of student worksheets products based on input from 3 practitioners.
- Sixth, asks 3 appointed practitioners to assess the product of student worksheets that have been improved in terms of their theoreticality in theory

Expert judgment and practitioners' assessment data is summarized, in the process, and summarized as the result of activities at the development stage. Research at this stage has resulted in student worksheets oriented on the content complexity and cognitive processes that are valid and theoretically practical in the form of hypothetical models to be applied in the real class in physics learning on materials on force in class X semester 2.

Implementation (2017). At this stage carried out effectiveness test through the study of pseudo experiments with the design “*One group pre-test and post-test design*” which involves 3 classes as a sample class. The effectiveness test was performed on the 5 student worksheets produced (still in the form of hypothetical model) to be tested in real class. The research was conducted for 2 months in 3 classes, each one from 3 SMA in Padang city which has implemented the 2013 curriculum, namely SMA 3, SMA 4, and SMA 7 Padang. The material that is related to this research is related to the force on the Object that runs in the second semester of the academic year 2016/2017. At this stage, there are two activities:

- First, conduct an experimental study to find out the effectiveness of student worksheets based on pre- test and post-test difference, and the difference of learning outcomes in experimental class and control class.
- Second, to test the practicality, based on students' responses using questionnaires of practicality after students follow the lesson using the product of student worksheets produced.
- The effectiveness test results, and the practicality based on the student's response is the result of the implementation of the implementation stage research in the limited class.

3.2. Results

Characteristics of student worksheets produced. Develop student worksheets, identical to developing teaching materials. Referring to the fulfilment of the complexity of the content, in the preparation of student worksheets with the steps as presented in Figure 5.

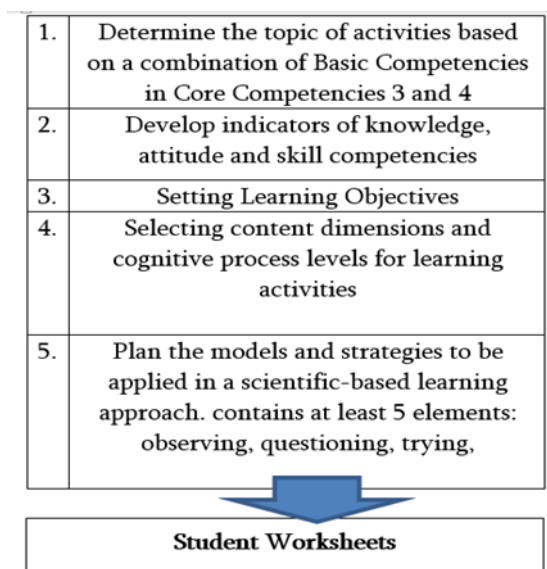


Figure 5. Flow Analysis of the Preparation of Student Worksheet

Student worksheets, consists of 6 components namely: 1) Title/Activity Topics; 2) Basic competencies; 3) Learning Objectives; 4) Student Study Guide; 5) Reference Learning, and 6) Student Activities.

- 1) *Title/Activity Topics*, prepared based on the linearization of Basic Competencies contained in Core Competencies 3 and 4. In this study developed 5 student worksheets associated with Newton's Laws of Motion for learning in class X SMA in semester 2. The topics of student worksheets are:
 - a. Force concept
 - b. Inertia properties
 - c. Relationship between acceleration with force dan object mass
 - d. Relationship between Action and Reaction
 - e. Solving problem about force on objects
- 2) *Basic Competencies*, written according to Core Competencies 3 and 4
- 3) *Learning Objectives*, adjusted to indicators and topics of *student worksheets*, which is constructive.
- 4) *Student Study Guide*, based on student needs, is useful to further clarify the focus of student activities.
- 5) *Reference Learning*, containing materials that are learning reference such as terms, quantities, units and conversions. Besides it also contains the state of a material, and the phenomenon that becomes the basis of learning
- 6) *Student Activities*, is a sequence of student activities in following learning which involves observing, asking, trying, reasoning and communicating activities.

The complexity of content and cognitive processes applied to student worksheets, referring to Minister of Education and Culture of the Republic of Indonesia Regulation No. 21 of 2016 and Bloom's Blooming Taxonomy (Anderson and Krathwohl, 2002). The reference of the student worksheets in question is presented by the diagram in Figure 6.

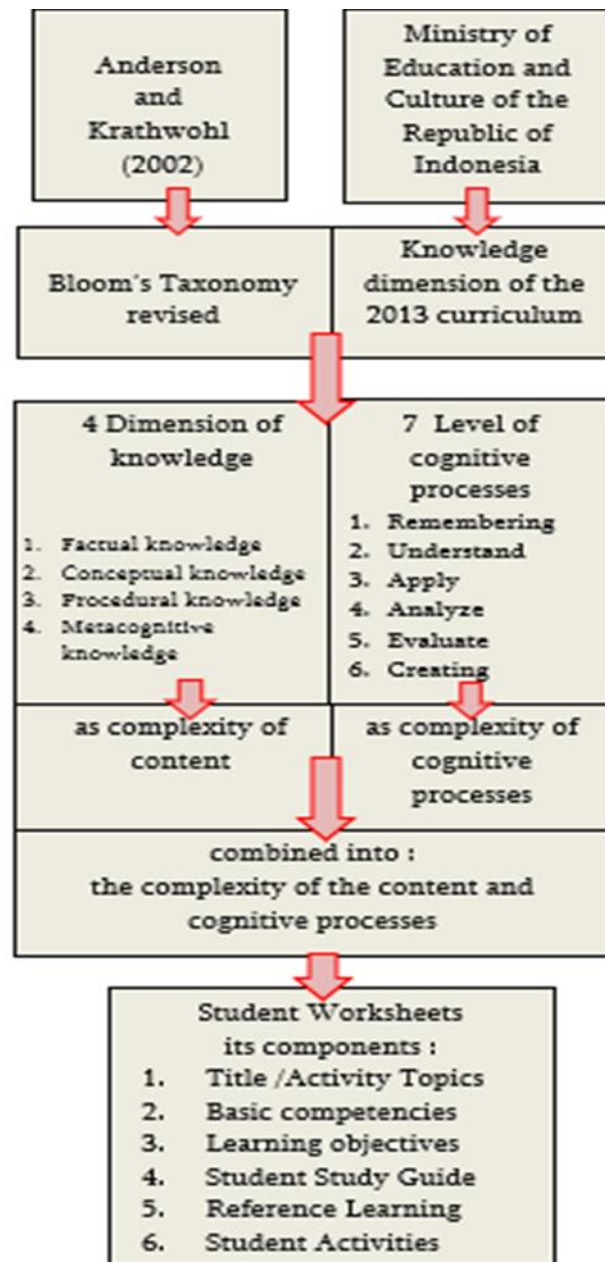


Figure 6. Rationale of student worksheet oriented to the complexity of content and cognitive processes

An overview of changes in conceptual understanding and students' critical thinking skills during the study. Assessment of conceptual understanding of the application of the five student worksheet topics, conducted using a test instrument designed with indicators involving 4 dimensions of knowledge and 6 levels of cognitive processes refers to Bloom's revised (Bloomberg) texts (2001). The number of questions is designed as much as 30 pieces for 5 worksheets topics with scoring rubrics each question can be scored 1, 2, 3, or 4 for criteria (ugly, ample, good and excellent). Score obtained is converted to a value with maximum value = 100. Instrument feasibility is done by guiding the question grid, validator input and validity test and obtained. its reliability with $r_{xy} = 0,68$. The value obtained by each student in the order and obtained the minimum value, maximum, mean, and standard deviation. Furthermore, this data is tested for normality using Liliform test techniques as analytical requirements

to calculate the normalized gain average N-Gain $\langle g \rangle$, which is defined as the actual average increase ratio $\langle G \rangle$ for maximum average gain with upgrade criteria: "High-g" if $\langle g \rangle > 0,7$; "Medium-g" if $0,7 > \langle g \rangle > 0,3$; and "low" if $\langle g \rangle < 0,3$. (Hake, 1999) [20]. The data in Table 1 shows an improvement in the conceptual understanding of students for each of the 5 learning subjects.

Table 1. Average initial, final, and N-Gain values from Student Conceptual Understanding of each Sample Class.

The Order of Learning Topics	Topics of Learning Activities on Student Worksheets	The average value of conceptual understanding and N-Gain students of each sample class (maximum value : 100)								
		Sample Class 1			Sample Class 2			Sample Class 3		
		Initial	Final	N-Gain	Initial	Final	N-Gain	Initial	Final	N-Gain
1	Characteristics of Force	41.67	54.17	0.21	37.50	45.83	0.13	41.67	54.17	0.21
2	Nature of Inertia	54.17	58.33	0.09	45.83	54.17	0.15	54.17	62.50	0.18
3	Relationship Acceleration, Force and Mass	58.33	66.67	0.20	54.17	62.50	0.18	62.50	66.67	0.11
4	Relationship of action and reaction force	66.67	70.83	0.12	62.50	70.83	0.22	66.67	70.83	0.12
5	Solving problems about force on objects	70.83	79.17	0.29	70.83	79.17	0.29	70.83	75.00	0.14
Initial situation compared to the final state		41.67	79.17	0.64	37.50	79.17	0.67	41.67	75.00	0.57

The data in Table 1. shows that the use of worksheets oriented to the complexity of content and cognitive processes for each activity from 1 to 5 always shows an increase in the average of N-gain $\langle g \rangle$ between $0,09 \leq 0,29$ index, 0,18 averages in low category. When compared to the initial state and the final state there is an increase in the average $\langle g \rangle$ in $0,57 \leq 0,67$ index with 0,63 averages in medium category. This data shows that by using student worksheets oriented to the complexity of content and cognitive processes there is an increased conceptual understanding of the average student in the medium category.

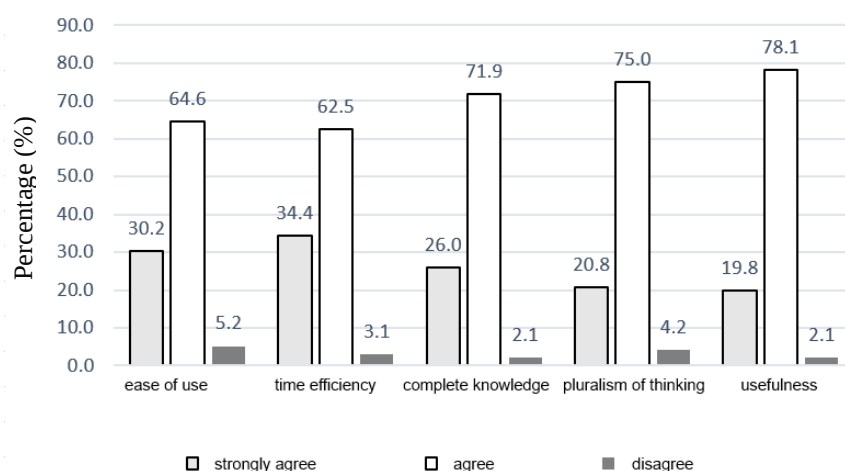
Assessment The critical thinking ability of applying the 5 topics of student worksheets, designed as a format of critical thinking ability contained in the student activity section in student worksheets involving 6 indicators are: 1) formulating the problem, 2) giving argumentation, 3) doing deductions, 4) doing induction, 5) evaluate, and 6) make decisions. These six indicators are from the 5 M element in the applied scientific approach. Each of these indicators is also assessed with a scoring rubric of 1, 2, 3, or 4 for criteria (bad, sufficient, good and excellent). The scores obtained are converted to values with a maximum value of 100. The feasibility of this instrument, carried out by guiding the indicator of critical thinking ability, and input validator. The value obtained by each student in the order and obtained the minimum value, maximum, mean, and standard deviation. Furthermore, this value data is tested for normality using the Liliform test technique as the analytical requirement to calculate the normalized gain average of N-Gain $\langle g \rangle$. The data in Table 2 shows the improvement of students' critical thinking skills for each topic of learning.

The data in Table 2 show that the use of worksheets oriented to the complexity of the content and cognitive processes for each activity from 1 to 5 always shows an increase in the average N-gain $\langle g \rangle$ between the indexes of $0,10 \leq 0,29$ with an average of 0,19 is in the low category. If compared to the initial and final states there is an average increase of $\langle g \rangle$ with an index $0,65 \leq 0,72$ with an average of 0,67 in the medium category. This data indicates that by using student worksheets-oriented content complexity and cognitive process there is improvement of students' critical thinking ability in medium category.

Table 2. Average initial, final, and N-Gain values of students' Critical Thinking Skills of each Sample Class

The Order of Learning Topics	Topics of Learning Activities on Student Worksheets	The average value of critical thinking ability and N-Gain students of each sample class (maximum value : 100)								
		Sample Class 1			Sample Class 2			Sample Class 3		
		Initial	Final	N-Gain	Initial	Final	N-Gain	Initial	Final	N-Gain
1	Characteristics of Force	29.17	45.83	0.24	25.00	41.67	0.22	29.17	45.83	0.24
2	Nature of Inertia	45.83	54.17	0.15	41.67	50.00	0.14	45.83	54.17	0.15
3	Relationship Acceleration, Force and Mass	54.17	62.50	0.18	50.00	58.33	0.17	54.17	62.50	0.18
4	Relationship of action and reaction force	62.50	66.67	0.11	58.33	62.50	0.10	62.50	70.83	0.22
5	Solving problems about force on objects	66.67	75.00	0.25	70.83	79.17	0.29	70.83	75.00	0.14
Initial situation compared to the final state		29.17	75.00	0.65	25.00	79.17	0.72	29.17	75.00	0.65

Effectiveness of student worksheets generated to improve conceptual understanding and critical thinking skills of students in high school physics learning. Quantitative data from the results of the study showed that by using the Student Worksheet oriented content complexity and cognitive processes can improve conceptual understanding and critical thinking skills are in the medium category, t test results from the data obtained showed that the improvement of both aspects of learning is significant at the level of confidence 95%. Furthermore, by using questionnaires to capture students' opinions about the quality of student worksheets for aspects: ease of use, time efficiency, completeness of knowledge, plurality of thinking, and usefulness, obtained data as shown graph in Figure 7.

**Figure 7.** Graph of percentage of student responses to student worksheets used

The results of the graph analysis concluded that to all students who are the subject of research as many as 3 classes which amounted to 96 students, showed that on average as many as 26.3% of respondents stated strongly agree, 70.4% agreed, 3.3% said less agree, and none of the respondents expressed disagreement. This study concludes that student worksheets-oriented content complexity and cognitive processes are effective in improving conceptual understanding and students' critical thinking skills in high school physics learning.

4. Discussion

There are four factors that become the reason why student worksheets are oriented to the complexity content and cognitive processes can improve the conceptual understanding of students in physics learning, which is implemented in this research, namely: 1) the existence of factual knowledge as the

learning reference and the students' basic thinking to build the concept based on their learning experience, so that the concepts studied are well controlled. It is filled with learning that contains the complexity of the content embodied by the four dimensions of knowledge discussed in the lesson [21] [22, 23, 24] ; 2) the involvement of students in building the concept scientifically, in this case the application of scientific approach is the right learning approach that trains students find scientific concepts physics; [25, 26]; 3) the use of reason and students' thinking ability in building and understanding the concept of physics concept. In this case the learning by trained with 6 levels of cognitive processes are complete in the student's natural learning [27, 28]; 4) the existence of a container that can train to learn. In this case student worksheets are one form of teaching materials that accommodate student-centered learning.

One of the factors that also affects the improvement of critical thinking ability, in the applied learning, is the existence of 5 M element in learning with scientific approach, which in container especially observation activity. Through observation will build students' critical thinking skills through identification of problems discussed in the learning, so that students are able to formulate problems, formulate hypotheses, try, reasoning to communicate.

5. Conclusions

Student worksheets developed oriented towards the complexity of content and cognitive processes and applied with a scientific approach in physics learning on the concept of force on objects resulted in improved conceptual understanding and critical thinking skills in the three study sample classes. Furthermore, the results of qualitative analysis also support quantitative data and show that students recognize that the worksheets applied are very useful for embedding the concept of holistically, and developing critical thinking skills, so that students are expected to solve various relevant physical problems.

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