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CONTENT COMPLEXITY DESIGN AND COGNITIVE PROCESS LEVEL ON DYNAMIC FLUID CONCEPTS FOR HIGH SCHOOL PHYSICS LEARNING

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ABSTRACT

In physics learning tools, it is necessary to develop increasingly complex knowledge dimensions and higher level thinking skills for each student according to the revised Bloom's Taxonomy by Anderson and Krathwohl. The situation encountered in the field, the availability of content complexity contains dimensions of knowledge and cognitive processes in teacher learning tools that have not been developed properly. This research was conducted to provide a solution, namely by designing the complexity of the content and levels of cognitive processes as outlined in learning tools in the form of lesson plans, teaching materials and evaluation instruments on Dynamic Fluids concept to be used as references for teachers in developing content and levels of cognitive processes in other concepts. This type of research is Research and Development (R&D) using the Plomp development model. The research instrument used consisted of an interview sheet instrument, an assessment instrument and a validation instrument. The data from this study were processed using the Aiken V statistical formula. The results of the validation of learning tools by a team of experts (lecturers) were 0.84 in lesson plans, 0.76 teaching concepts, and 0.79 evaluation instruments while the practitioner team (teachers) was 0.91 on lesson plan, 0.85 teaching concepts, and 0.94 evaluation instruments. Thus, it is concluded that the design of content complexity and cognitive process levels in the Dynamic Fluid Physics learning device meets the very valid criteria and is suitable for use in high school physics learning.

Keywords : Design; content complexity; cognitive processes; Dynamic Fluids; Learning Tools.

I. INTRODUCTION

The development of Science and Technology in the 21st century is increasingly rapidly known as the industrial revolution era 4.0. Revolution, can be interpreted as changes that occur quickly regarding the joints of life [1]. This is marked by the shortening of the lifespan of a technology product, which then quickly switches to more sophisticated and modern technology based on automation, digital systems and uses a lot of machine power and intelligent robots. Thus, jobs that are dominated by the ability to work muscles are getting eliminated. As a result, the unemployment rate will increase if the competence of each individual is not updated in accordance with the demands of the job market and the times. Meanwhile, industry is defined as an activity to produce something that has added value or a finished product that is useful for life [1]. This means that the estuary of competence from every educational activity is after attending an education, what creations can be produced by each individual.

The more difficult jobs are based on muscle work, the orientation of education must be oriented to the work of the brain. This can be done through optimizing the training of thinking (cognitive) and reasoning skills which must be increased in intensity, so that cognitive abilities are increasing from level 1 (remembering and understanding), to level 2 (applying), and level 3 (analyzing, evaluating, and creating). One of the advantages of the 2013 revised 2017 curriculum is that it has facilitated students to be able to develop these six abilities from elementary school to university, according to their age level and the development of their thinking skills.

Physics is one of the compulsory subjects in the revised 2017 edition of the 2013 Curriculum taught in high school. Physics is a natural science that comes from natural phenomena [2]. Physics lessons are lessons that focus more on problems related to material aspects, the nature of nature and examine various physical symptoms that can be found in the human environment [3]. Problem solving is an important goal in studying physics because it

is a students cognitive processes activity to building physics knowledge [2]. The author's experience during the implementation of educational field practice, found problems in learning fluid physics, namely the mastery of students' concept, especially with regard to the basic concepts and principles that build laws on Dynamic Fluid content. The indication is that when the teacher throws questions or problems that ask for arguments, explanations and descriptions from students after learning is done, students rarely can answer them, especially to questions that begin with the question words why, why, and how. This condition indicates that in learning, teachers only develop factual knowledge and conceptual knowledge through emphasis on memory skills training, while problem solving exercises that can develop procedural knowledge and metacognitive knowledge are not applied by teachers.

Content in English means content, while in the Big Indonesian Dictionary online content means information or material available through speech, writing, media or electronic products. Content in learning can be interpreted as subject matter. Thus, the complexity of the content can be interpreted as the completeness of the subject matter contained in a subject to be taught to students. As for how to integrate content in learning, namely planning competency-based learning through mapping of Core Competencies, Basic Competencies, Indicators and Learning Objectives. Then compose the learning content that will be presented referring to the competencies to be achieved by providing media or learning resources that are equipped with evaluation instruments to achieve the competencies that students must possess [4]. In the selection, development and determination of learning content, it is necessary to develop increasingly complex knowledge dimensions and higher-level thinking skills for each student as a provision for his life. The knowledge dimension in Revised Bloom's Taxonomy consists of Factual, Conceptual, Procedural, and Metacognitive knowledge. Factual Knowledge, contains the basic elements that students must know if they are going to study a discipline or solve problems in that discipline. Conceptual knowledge, includes knowledge of categories, classifications, and relationships between two or more categories of knowledge that are more complex and organized. Procedural knowledge, which is knowledge of how to do things and metacognitive knowledge, emphasizes methods to make students more aware and responsible for their own knowledge and thoughts [5].

The four knowledges are complementary (complementary). Factual knowledge is the basis for building conceptual knowledge and procedural knowledge. These three knowledges are a source of inspiration for each student to build metacognitive knowledge based on self-knowledge, about the advantages and disadvantages of each in dealing with and solving the problems they face. While thinking skills include six levels of cognitive processes in the revised Bloom's Taxonomy consisting of remembering (C1), understanding (C2), applying (C3), analyzing (C4), evaluating (C5), and creating (C6). Remembering means an effort to regain knowledge from past memories or memories, both those that have just been obtained and those that have been obtained for a long time. Understanding means building meaning or understanding based on previous prior knowledge, linking new information with previously owned knowledge, or integrating new knowledge into pre-existing schemas in thinking. To apply means to utilize or use a method or procedure to carry out an experiment or solve a problem. Analyzing means solving a problem by separating each part of the problem, then looking for the interrelationships of each of these parts and finding out how these interrelationships can cause problems. evaluating means making a judgment or assessment based on existing criteria and standards where the criteria that are often used are quality, effectiveness, efficiency and consistency and creating means producing a new product by organizing several elements into a different form or structure from the previous one [6]. This taxonomy is used as the basis for the 2013 curriculum by the Ministry of Education and Culture. Through the application of this Revised Bloom's taxonomy, it is hoped that the quality of learning will be better, and the learning outcomes achieved by students will increase, so that educational goals can be achieved as they should. In addition, in strengthening the learning process, the 2013 Curriculum demands that physics learning in high school be carried out using a scientific approach which consists of five steps, namely observing, asking questions, trying/gathering information, reasoning/associating and communicating [7].

The real conditions encountered in the field regarding physics learning based on the initial investigation phase or field needs analysis through interview sheets and observations of physics subject teachers regarding dynamic fluid material, in high school in the Mentawai Islands Regency are: 1) the results analysis of lesson plans and teacher teaching concepts regarding physics learning approaches from the three schools that were sampled, the availability of aspects of the scientific approach has not been accommodated properly; 2) the results of the analysis of the lesson plans owned by the teacher, show that the lesson plans has not been developed properly, tends to copy and paste from the existing lesson plans so that it cannot be used as a guide for the direction of teacher learning activities and is only needed as a teacher administration requirement. Other indications of lesson plans are: a) Operational verbs used tend to measure low-level thinking skills regarding the ability to remember, understand and apply, while higher-order thinking skills related to the ability to analyze, evaluate and create are very few, and tend to be invisible. b) The knowledge aspect that follows Operational Verbs in lesson plans is still general in nature and tends to the dimensions of factual and conceptual knowledge, while procedural knowledge and metacognitive knowledge have not been developed much; 3) the results of the analysis of the availability of four dimensions of knowledge as teacher learning content in teaching concepts, show that the proportions are not

evenly distributed for each dimension of knowledge; 4) the results of the analysis of cognitive ability exercises contained in the learning tools of teaching concepts and evaluation instruments based on the results of the analysis of the availability of cognitive processes in the learning tools of Physics teachers from the three schools showed that the average number was dominated by the ability to remember, the ability to understand and the ability to apply, while the ability to analyze , the ability to evaluate, and the ability to create is also not seen; 5) the results of discussions and interviews with physics teachers who became respondents, information was obtained that teachers need to design the complexity of content and levels of cognitive processes as outlined in learning tools in the form of lesson plans, teaching concepts and evaluation instruments on Dynamic Fluids material to be used as references for teachers in developing content and levels of cognitive processes in other concepts.

II. METHOD

The research conducted is Research and Development/R&D. R&D is one of the research methods that can be used to research, design, produce, and test the validity of the products that have been produced [8]. The development procedure in this study based on the Plomp development model consists of five phases, namely the preliminary investigation phase, which is an activity to analyze the needs to find out the problems encountered in the field that require solutions, the design phase is a problem solving activity, the realization/construction phase is a problem-solving activity realized, the test, evaluation and revision phase is an activity to test the feasibility of the product produced and the Implementation Phase is a product implementation activity for a wider area [9], but the development of the Plomp model is only applied to the test, evaluation and revision phase. Data analysis techniques are carried out to process data into information that is easy to understand and useful as a solution to problems. The data were analyzed using the Aiken V statistical formula:

$$V = \frac{\sum s}{[n\,(c-1)]} \qquad (1)$$

Description:
V = Aiken Validity
S = r-I_0
c = The highest validity rating score
I_0 = The lowest validity rating score
r = Number given by validator
n = Many validators

Aiken's validity index can be seen in Table 1:

Table 1. Aiken's validity index

Validity Index	Evaluation
V < 0,4	Not Valid
0,4 < V < 0,8	Valid
V > 0,8	Very Valid

(Source: Ref [10])

The validation instruments and learning tools developed are said to be valid if based on the interpretation criteria the scores obtained are in the valid or very valid category.

III. RESULTS AND DISCUSSION

Based on the research objectives and needs analysis in the initial investigation phase, it was shown that the learning tools for high school physics teachers in the Mentawai Islands Regency did not contain the complexity of content and levels of cognitive processes optimally and proportionally. The availability of four dimensions of knowledge as teacher learning content in teaching materials shows that the proportions are not evenly distributed for each dimension of knowledge. The results of the analysis of the availability of content complexity on teacher learning tools can be seen in Figure 1.

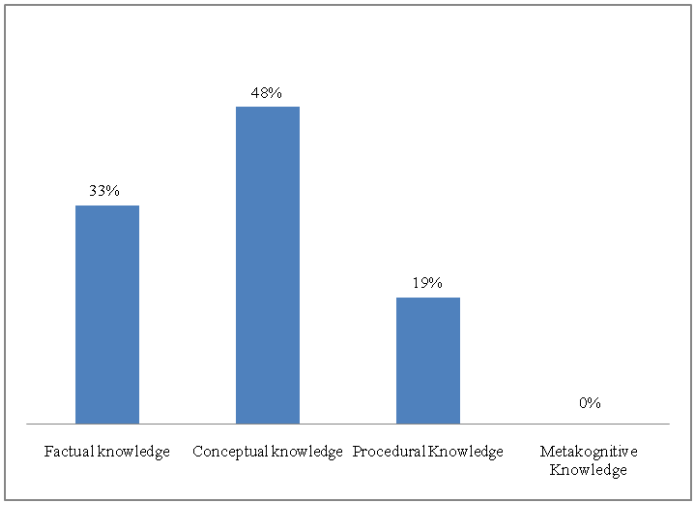

Fig. 1. Availability of Knowledge Dimension

Based on the graph in Figure 1, it can be seen that the availability of content complexity in teacher learning tools with the highest intensity is in conceptual knowledge and factual knowledge while the other two knowledges are still low and tend to be invisible, while the availability of cognitive abilities contained in learning tools in teaching materials and evaluation instruments teachers have not been accommodated properly, the results of which can be seen in Figure 2.

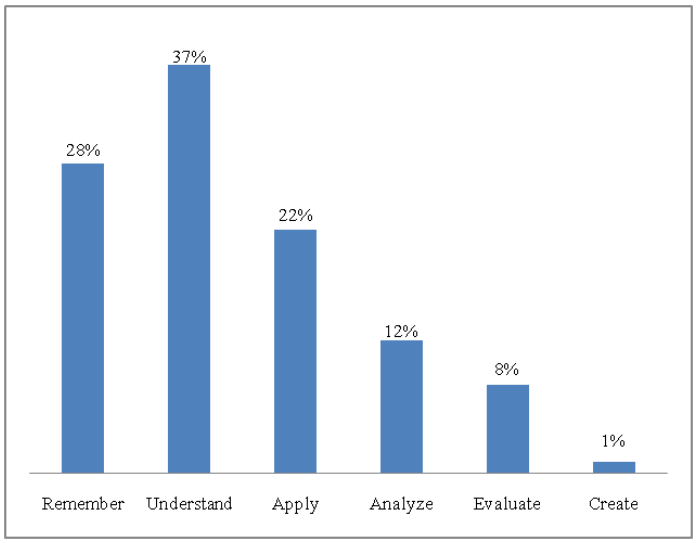

Fig. 2. Cognitive process availability

Based on the graph in Figure 2, the availability of cognitive processes in the Physics teacher's learning tools has the highest intensity in the ability to understand, remember and apply, while the other three abilities are low and tend to be invisible. The results of this study are almost in line with Amali Putra's 2015 research at Padang City Public Senior High School, which concluded that the quality of student competency achievement in physics learning at Padang City High Schools was still low, in terms of the complexity of the content and the level of cognitive processes in Physics learning content because some Most of them are still at levels C1, C2, C3, while for levels C4, C5, C6 are still very few and tend not to appear [4]. In addition, the availability of a scientific approach has not been properly accommodated in the lesson plans used by teachers. In practice, students are not used to actively asking or answering questions, especially questions that use the question words why, why, and how. The results of the analysis of the availability of the scientific approach on teacher learning tools can be seen in Figure 3.

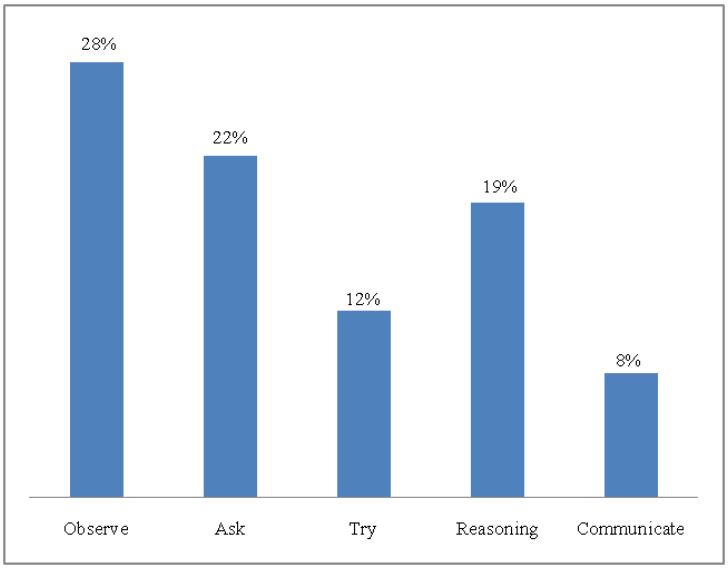

Fig. 3. Availability of scientific approach

Based on the graph in Figure 3, it can be seen that the availability of the scientific approach in the teaching tools of the Physics teacher with the highest intensity is dominated by observing and asking questions, while the other three activities are still low. This condition indicates that the results of the analysis show that the teacher does not really understand integrating the dimensions of knowledge and the level of cognitive processes in the content of Physics lessons, especially Dynamic Fluids. To create quality learning, of course, it takes a good design from the teacher so that the thinking skills of students develop well and the knowledge of students increases.

One form of design in the Design Phase is to design steps for the complexity of content and cognitive process levels in Dynamic Fluids, consisting of: First, analysis of Basic Competencies in Core Competencies which produces learning topics and sub-topics; Second, the Basic Competency analysis produces Competency Achievement Indicators. The indicator consists of two indicators, namely the Competency Achievement Indicator which is known as the learning indicator and the Assessment Indicator which is used in compiling the grid and writing questions known as the question indicator which is formulated using Operational Verbs. Operational verbs are selected based on changes in behavior or skills to achieve minimal basic competence [11]. Operational Verbs are verbs whose achievement can be measured, changes in behavior or actions can be observed, can be tested and used to formulate indicators and learning objectives. Examples of the application of Operational Verbs in designing evaluation questions based on the knowledge dimension are:

a. Factual Knowledge: ***Sequence*** the activity steps to determine the relationship between the diameter of the leak hole and the fluid velocity (analyze (C4)).
b. Conceptual Knowledge: ***Examine*** why airplanes and helicopters are designed differently, even though they are both used as air transportation (evaluate (C5)).
c. Procedural Knowledge: ***Calculate*** the furthest horizontal distance from the perforated tank using tools and materials available in the Laboratory (apply (C3)).
d. Metacognitive Knowledge: ***Realize*** a simple tool by applying Bernoulli's principle (creating (C6)).

Third, analysis of Competency Achievement Indicators (CAI) to produce Learning Objectives (LO). Learning objectives are formulated using the principles of A(Audience), B(Behavior), C(Condition), and D(Degree) + K (Knowledge). Audience is a learning target, namely students, Behavior is a cognitive process or student activity in learning, Condition is a condition created by educators for students in the learning process, Degree is a comparison of conditions before and after learning and Knowledge is knowledge about the competencies to be achieved . These five components must be in the formulation of learning objectives for each Basic Competency in order to create a quality learning process and make learning more meaningful [12]. Examples of the application of the ABCD+K principle in formulating learning objectives are:

a. Given the concept of SI and the cgs system, students are able to recognize quantities related to dynamic fluids (symbols, units and dimensions) correctly.
b. Given a problem regarding a perforated tank, students are able to use the Torricelli Theorem equation in solving problems with a perforated water tank correctly.

c. Given learning resources, students are able to describe the working principle of a carburetor and perfume sprayer well.
d. Given an example of the application of the Bernoulli principle, students are able to make imitation products from the application of the Bernoulli principle well.

Fourth, the analysis of Learning Objectives to generate content complexity includes the dimensions of factual, conceptual, procedural and metacognitive knowledge. An example of dynamic fluid content can be seen in Table 2:

Table 2. Examples of knowledge dimensions in dynamic fluid concepts

Knowledge Dimensions	Example
Factual Knowledge	- The flow of river water when passing through a wide river gap its speed is slow but after passing through a narrow river gap its speed becomes fast. - The water coming out of the mouth of the hose the speed of the water is slow but after the mouth of the hose is pressed with your fingers the speed of the water becomes faster.
Conceptual knowledge	- Discharge is a physical quantity that expresses the volume of fluid flowing through a certain cross section every second - Laminar flow or streamline is a steady flow in which each fluid particle follows a certain path without crossing each other with the paths of other fluid particles.
Procedural knowledge	- The experimental work step determines the relationship between the height of the tank leak hole and the distance the fluid falls from the leak hole - The experimental work steps determine the relationship between pressure and fluid density in two streams that have different heights
Metacognitive Knowledge	- Strategies to solve problems using the Bernoulli's equation - Strategy for drawing flow lines for fluid flow in pipes

Fifth, the analysis of Learning Objectives to produce evaluation instruments includes the cognitive process level. Examples of dynamic fluid evaluation questions are:

Question indicator : Information and pictures of the Torricelli Theorem experimental procedures and graphs of the results are presented, students can evaluate conclusions from pictures and graphs.
Cognitive Level : L3 (evaluating).

The following experiment is one way to strengthen the understanding of Bernoulli's principle on tank leakage. The tool used is a tank design made of hollowed out paralon, equipped with a meter scale on the paralon wall and on the floor as shown in Figure 1. The experiment was carried out by filling it with water. When allowed to leak, students take pictures of the scale of the water drop (a) and other students take pictures of the horizontal direction of water jets (s) simultaneously, with the same signal seven times. The data is processed and graphed with (a) as the X axis and (s) as the Y axis as shown in Figure 2.

Fig. 1

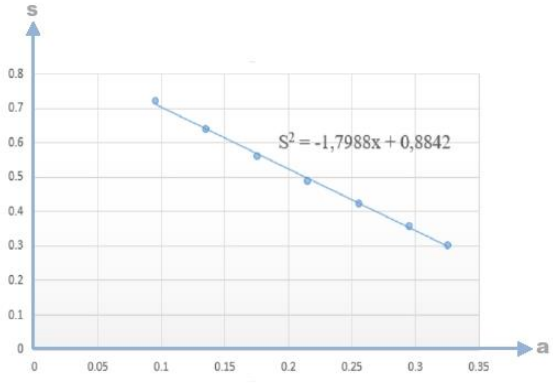

Fig. 2

The conclusion of the experiment is....
1. The water level affects the horizontal water jet distance
2. The decrease in water is inversely proportional to the emission distance
3. The greater the drop in water, the shorter the distance the water flows
4. The higher the water drop, the farther the distance from which the water flows
Do you agree with each of these conclusions? Give reasons for each!

The questions above are included in Level 3 on the Cognitive evaluation dimension, because to answer these questions, students must be able to understand the experimental procedure, compare the data obtained from the graph of the experimental results, analyze the graph, and evaluate the four conclusions.

Furthermore, the steps of content complexity and levels of cognitive processing can be seen in Figure 4.

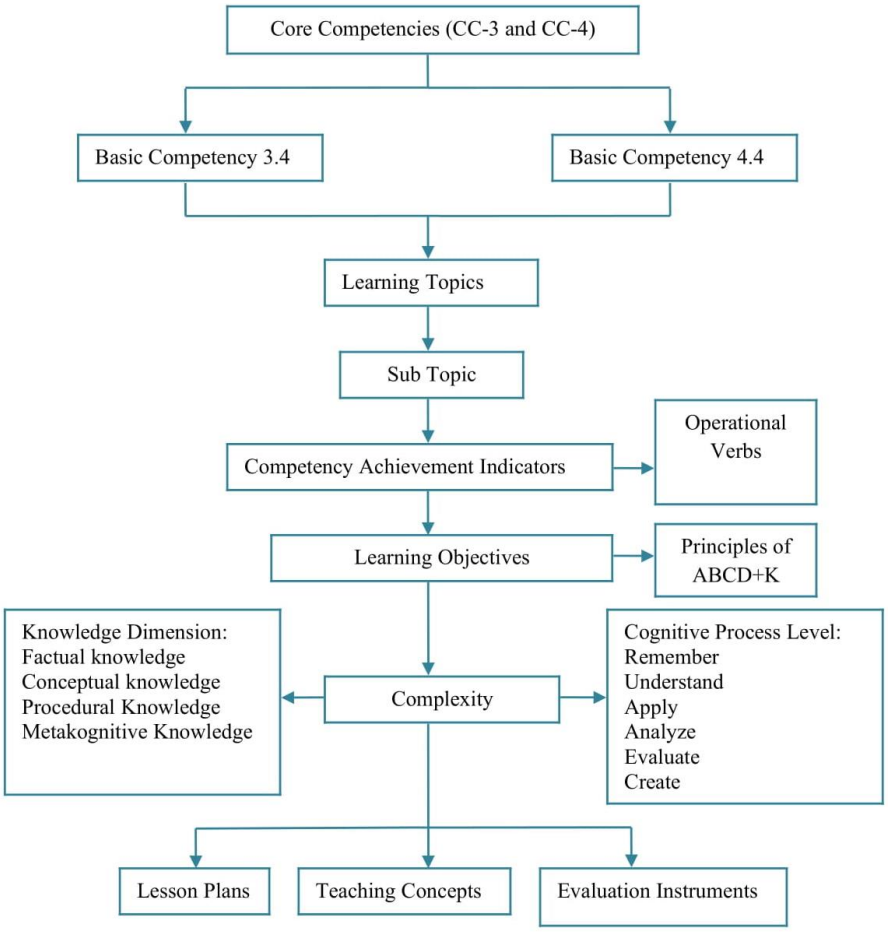

Fig. 4. Need analysis steps

In the realization/construction phase, the design of the complexity of the content and the level of cognitive processes is outlined in the learning tools. Learning devices are tools and materials used by educators in learning activities. Learning devices are tools and materials used by educators in learning activities. Learning tools are important for a teacher because they are a guide for teachers in carrying out their duties in the classroom and as a benchmark for teachers to analyze students' abilities to the subject matter that has been taught so that teachers can see the extent to which the material is mastered by students [13]. The learning device developed consists of several components, namely: 1) Competency Achievement Indicators; 2) Learning Objectives; 3) Lesson Plan; 4) Teaching Concepts; 5) Evaluation Instrument.

Lesson Plan, is a plan that describes procedures and learning management to achieve one or more basic competencies specified in the content standards and explained in the syllabus [14]. according to the Regulation of the Minister of Education and Culture No. 22 of 2016 Learning Implementation Plan is a learning activity plan that is prepared for one or more meetings. In the development process, there are two functions of the Learning Implementation Plan, namely the planning function and the implementation function. The planning function, namely the Learning Implementation Plan, can encourage teachers to be more prepared in carrying out learning

activities, so that each time they will carry out learning activities the teacher must have both written and unwritten preparations. While the implementation function intends to make the process of learning activities effective as planned.

The steps for preparing the Lesson Plan according to the 2016 Minister of Education and Culture Regulation are: (1) reviewing the syllabus; (2) analyze the relevance of Graduate Competency Standards, Core Competencies, Basic Competencies in order to formulate Competency Achievement Indicators, learning materials, learning activities, and assessment plans according to the contents of the Basic Competencies; (3) determine the time allocation for each meeting based on the results of the analysis of the time required for the achievement of each Competency Achievement Indicator and adjusted to the characteristics of students in the education unit; (4) formulating learning objectives based on Basic Competencies using Operational Verbs that can be observed and measured including attitudes, knowledge, and skills; (5) compiling learning materials (6) determining appropriate learning approaches/models/methods; (7) determine the media, tools, and materials used in the learning process; (8) ensure the learning resources that will be used in the elaboration step of the learning process; (9) describes the steps of learning into a more operational form (prioritizing active learning; and (10) developing an assessment of learning processes and outcomes.

Teaching Concepts, are a concepts, information, tools/media used by lecturers to carry out learning includes creating an atmosphere that encourages students to learn [15]. In the Ministry of National Education in 2008 regarding guidelines for the development of teaching materials, the format of the developed teaching materials consists of: 1) title/identity, 2) study instructions, 3) competencies to be achieved, 4) supporting information/material summary, 5) work instructions /Student Worksheet, evaluation, and feedback.

Evaluation Instrument, is the process of collecting and processing information to measure the process and results of achieving student competence in the form of a combination of mastery of cognitive processes [12]. In preparing the learning evaluation instrument to be used, the teacher must pay attention to the level of cognitive processes that will be used based on the revised Bloom's taxonomy by Anderson and Krathwohl 2001 including: remembering, understanding, applying, analyzing, evaluating, and creating. These six cognitive level processes are arranged according to the level of difficulty of an activity in learning starting from small things such as remembering to big things, namely creating. The application of the levels of cognitive processes used in compiling learning evaluation instruments can be started from compiling a grid of questions, questions, and answer keys. Items can be varied with types ranging from LOTS (remembering, understanding, and applying) to HOTS (analyzing, evaluating, and creating) so that the evaluation instrument compiled becomes complete and becomes a good evaluation instrument.

The learning tools were developed based on the analysis of Regulation of the Minister of Education and Culture No. 22 of 2016, Ministry of Education and Culture 2017 and Ministry of National Education in 2008. Then proceed with the test, evaluation and revision phase where the learning tools are assessed first by expert lecturers with the results of the instrument validation assessment being 0.84 with a decision on the overall components of the validation instrument, each device is considered very valid and according to the assessment is declared suitable for use for testing after revision. Then, it was followed by validation of learning tools by a team of experts (Physics Lecturers) and a team of practitioners (Physics teachers) covering several aspects, namely aspects of content feasibility, linguistic aspects, graphic aspects and presentation aspects. The results of the validation of learning tools by a team of experts were 0.84 on lesson plans, 0.76 of teaching concepts, and 0.79 of evaluation instruments while the results of the validation of learning tools by a team of practitioners were 0.91 on Rpp, 0.85 of teaching concepts, and 0, 94 evaluation instruments with a decision on the overall components of the learning device validation instrument were considered very valid and declared eligible to be used for trials.

IV. CONCLUSION

Design validation of content complexity and cognitive process level on learning devices by a team of experts (Physics Lecturer) and a team of practitioners (Physics teacher) consists of aspects of content feasibility, linguistic aspects, graphic aspects and presentation aspects. Based on data analysis, the final validation result was obtained 0.87 on the lesson plan with very valid criteria, while on teaching concepts 0.80 with valid criteria and 0.85 on the evaluation instrument with very valid criteria. Thus, it is concluded that the design of content complexity and cognitive process levels in the Dynamic Fluid Physics learning device meets the very valid criteria and is suitable for use in high school physics learning.

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