Synthesis of the Cognitive Aspects' Science Literacy and Higher Order Thinking Skills (HOTS) in Chapter Momentum and Impulse

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Abstract. This paper is based on the background of the problem in the form of low order thinking skills and science literacy in students. The science literacy that students have has an important role in developing higher-order thinking skills (HOTS) in solving problems in everyday life. The method used in this research is descriptive qualitative research method with literature studies in the form of primary sources (books) and secondary sources (scientific articles). The results of this study obtained a synthesis of cognitive aspects of science literacy and HOTS in momentum and impulses used as a guide in developing overall learning devices combined with physical problems that occur in real life experienced by students in a realistic manner. In addition, the synthesis of the cognitive aspects of science literacy is in the form of several important aspects, such as scientific knowledge and scientific competence. The main aspects in HOTS are discussed in the form of analysis, evaluate, and create. These aspects must be actualized by students in their lives in the present and in the future that are useful for mutual benefit.

1. Introduction
One of the goals achieved in learning activities in schools is to create intelligent and skilled people in various fields. Therefore, students at the secondary school order are directed to achieve maximum educational goals in terms of developing higher-order thinking skills (HOTS) by studying every problem that occurs in everyday life using appropriate physics concepts/science literacy [1]. Meanwhile, the learning objectives can be achieved well, if in carrying out learning activities combined with problems that occur in life that are packaged thoroughly in a learning device [2,3]. Learning tools that combine problems that occur in everyday life must be developed with careful planning so that the implementation of learning runs smoothly and in particular so that aspects of science literacy and HOTS of students can be measured properly [4]. Therefore, with the aim of learning physics and learning devices combined with problems that occur in everyday life, students are expected to be able to optimize science literacy and HOTS. Regarding science literacy and HOTS are two of the most basic things students must have in learning physics. This is because science literacy is the ability of students to solve problems that occur in their lives using appropriate physical concepts [5,6].
If students have understood the concept of physics appropriately, it is possible for students to solve various problems in life from the easiest to the most difficult. After students are able to solve various problems in life using physics concepts from the easiest to the most difficult, they can develop shorter and easier ways to solve problems using HOTS [7,8]. HOTS are basically skills that arise because they often solve problems from the easiest to the most difficult [9]. Therefore, one effort that needs to be done to improve science literacy and HOTS is often practice solving physics problems in everyday life from simple problems to complex problems. Therefore, in general, the achievement of the results of physics learning for Indonesian secondary school students in the international arena in terms of science literacy and HOTS is still low [10]. In general, the achievement of the results of studying physics in Indonesian high school students in the international arena in terms of science literacy and HOTS is still low [10]. Furthermore, based on the achievement of 2012 PISA science literacy from 65 countries, Indonesia is ranked second from the bottom with a science literacy score on average students 382 below the PISA average score, i.e 501 [11].

[12] states that the low reading and writing skills of Indonesian students are influenced by many things, including the education curriculum, the selection of learning methods and models, learning resources, and teaching materials. Furthermore, the achievement of low science literacy can be caused by physics learning activities or inappropriate learning tools [13]. Thus, it needs to be evaluated in learning that prioritizes solving problems in everyday life so that science literacy of students increases. In addition, [14] also states that most middle school students have not been able to find the right solution or find it difficult to solve physics problems correctly, so that their HOTS are still quite low. Therefore, changes in student-centered physics learning activities are needed, so as to improve science literacy and HOTS of students [15]. In addition, the application of learner-centered learning can be done with a variety of innovations, both innovation in learning media, learning devices, or assessment instruments. Meanwhile, the physics chapter used in the synthesis analysis of cognitive aspects of science literacy and HOTS is physics in the scope of mechanics, i.e momentum and impulse. This chapter is adapted to the results of research which states that the momentum and impulse is one of the material in physics subjects that still often occurs in student errors and is one of the physics chapters that are not easy [16]. In this study only limited to the cognitive domain because it is in accordance with [17,18] which states that someone who has good science literacy skills, especially in the aspect of knowledge, will have good HOTS. Therefore, a new author's synthesis or view of cognitive aspects in science literacy and aspects of HOTS in the momentum and impulse can be used as a basis for the development of learning tools or assessment instruments.

2. Methods
The method used in this study is descriptive qualitative method, so that in this paper the data discussed is a synthesis of several primary and secondary sources of scientific books and articles which each of the major publications after 2010 from qualitative data about cognitive aspects of science literacy and HOTS. Qualitative descriptive method itself is a research method that analyzes data in the form of qualitative information which is then connected with other data to obtain clarity about the truth, so that new views or views are obtained by combining existing views [19,20]. In this study, the new points to be discussed are new views on the cognitive aspects of science literacy and HOTS in momentum and impulse. After the data from primary and secondary sources are analyzed, the next step is to conclude the data in general so that new views or new syntheses can be obtained about the cognitive aspects of science literacy and HOTS which can be shown in Figure 1.
3. Results and Discussion

3.1. The Concept of Cognitive Aspect Science Literacy

In accordance with what has been discussed in the background of the problem, taking into account some weaknesses in the abilities possessed by senior high school students in Indonesia, science literacy and HOTS are selected, which are also related to each other. Furthermore, science literacy is one of the important abilities students must have in learning. According to OECD states that the Program for International Student Assessment or PISA defines that science literacy is the ability of students to use scientific knowledge, identify problems and explain scientific facts in order to understand regarding natural phenomena [21]. According to Greenhow, Gibbins, and Menzer that science literacy is an understanding of the concepts and scientific processes needed for making decision [22]. In addition, literacy skills in science are also the ability to understand the nature of science and scientific development; understand and use science intelligently; use scientific processes to solve problems; and understand the relationship between science and technology [23]. The most important thing in developing science literacy of students includes knowledge of science, science processes, development of scientific attitudes, and understanding of students towards science [24].

Someone who has science literacy is someone who uses science concepts and has science process skills to be able to judge in making everyday decisions [25]. Furthermore, students who have science literacy is characterized by the ability to solve problems by using scientific concepts [26]. Science literacy can also be divided into four major dimensions, i.e. the dimensions of the science context, science content, science processes, and the dimensions of scientific attitude [27]. The science context is recognizing everyday life situations involving science and technology, and science content is understanding natural phenomena and changes [28]. Meanwhile, the science process is the ability to use understanding and scientific knowledge to solve various kinds of problems in everyday life, the attitude of science is a marker of interest in science and the motivation to act responsibly [29]. In addition, PISA also suggests that there are three competencies for measuring science literacy skills, i.e identifying scientific issues, explaining scientific phenomena, and using scientific evidence [30]. Identifying scientific issues requires students to recognize scientific problems.
Using scientific evidence requires students to interpret evidence in drawing conclusions and communicating [32]. Meanwhile, in 2006 the aspects measured in PISA included scientific knowledge, scientific competencies, context, and attitudes [33]. In PISA 2015, science literacy is also divided into four aspects of assessment, covering aspects of the context, aspects of scientific knowledge, scientific competencies, and aspects of attitudes [34]. The context aspect focuses on personal, local and global related situations [35].

The scientific aspect of knowledge refers to an understanding of facts, concepts, and theories that form the basis of scientific knowledge [34]. The scientific aspects of knowledge include content knowledge is the knowledge needed to understand natural phenomena; procedural knowledge is the knowledge needed to form various kinds of ideas about science; and epistemic knowledge is knowledge needed to rationally understand the various things that underlie the occurrence of [28]. Furthermore, the scientific aspects of competencies are the ability to apply knowledge in accordance with scientific phenomena [36]. Meanwhile, aspects of attitudes include interest in science and technology [37]. Based on the description of several experts regarding science literacy, it can be concluded that science literacy is the ability to use the knowledge and understanding possessed as a basis for solving problems in daily life scientifically. Science literacy can also be said as the ability of students to understand science as a whole in everyday life. Therefore, students are expected to be able to apply the knowledge gained during classroom learning to be applied in daily life so that students can have sensitivity and concern for their surrounding environment.

3.2 The Concept of Higher Order Thinking Skills (HOTS)

HOTS is the ability to use the mind more broadly to find new challenges [38]. HOTS is also a thought process that involves mental activities that are carried out to gain knowledge which includes thinking of analyzing, evaluating, and creating [39]. HOTS require someone to apply new information or prior knowledge to reach possible answers in new situations [40]. Furthermore, HOTS is a concept of change in the world of education based on Bloom's Taxonomy [41]. Bloom's Taxonomy is a classification of educational goals in behaviors that emphasize intellectual aspects such as knowledge, understanding, and is the order of one's thinking ability [42]. Meanwhile, Anderson and Krathwohl revised Bloom's cognitive taxonomy, from what was originally composed of verbs (knowledge, understanding, application, analysis, synthesis, and evaluation) replaced into verbs (remembering, understanding, applying, analyze, evaluate, and create) [43].

The cognitive domain in the revised Bloom taxonomy is also the basis HOTS with thoughts based on several types of learning that require more cognitive processes than others [44]. Furthermore, in Bloom's taxonomy the ability to analyze, evaluate, and create is considered part of HOTS [45]. Based on Bloom's revised taxonomy, cognitive processes are divided into Lower Order Thinking and Higher Order Thinking [43]. Meanwhile, analyzing is a problem-solving ability by looking for interrelationships from each part [43]. The ability to analyze is a type of ability that is much demanded by students in learning [46]. Demands for students to have the ability to analyze often tend to be more important than other dimensions of cognitive processes [47]. Evaluating includes checking and criticizing activities [43]. Checking leads to testing activities that are inconsistent or failures of an operation or product [48]. When associated with the thought process of planning and implementing, checking will lead to the determination of the extent to which a plan runs well [49]. Meanwhile, criticizing leads to the assessment of a product based on predetermined criteria [50]. Creating includes activities to generalize and produce things [43]. Generalizing is an activity representing problems and finding alternative hypotheses that are needed [47].

Meanwhile, production leads to planning to solve problems [49]. The difference in creating with other dimensions of cognitive thinking is in other dimensions students working with known information, while creating students working and producing something new [51]. Furthermore, details of indicators to measure HOTS such as analyzing, in the form of analyzing information that enters and divides information in smaller
parts [52]. Evaluate, in the form of evaluating solutions and methodologies using appropriate criteria [53]. Meanwhile, creating is in the form of generalizing the perspective on things and organizing things into new structures that have never [54]. Thus, based on some expert opinions on HOTS, it can be concluded that HOTS is thinking at a higher order. However, high-order thinking ability is the ability to connect, manipulate, and transform the knowledge and experience that is already possessed to think critically and creatively in an effort to solve problems in new situations. This is so that students are able to solve various kinds of scientific problems that require a higher cognitive process than scientific problems that they usually solve especially the problems of physics in everyday life.

3.3 Student Problems in the Momentum and Impulse

Momentum and impulse is one of the chapter in physics subjects that still often occurs in students' mistakes and is one of the physics chapter that are not easy [16]. In addition, the concept of momentum and impulse is included in concepts whose phenomena tend to be abstract because this concept cannot be observed with the naked eye. This is in line with the opinion of Sekercioglu and Kocakula which states that the concept of momentum and impulse is considered simple even though it is actually a complex concept [55]. Meanwhile, a study was conducted by Ivowi who examined misconceptions in physics from 128 students from two secondary schools in Nigeria [56]. He asked students to explain clearly about conservation of momentum and about half of the sample gave the wrong answer to the question of momentum conservation [56]. In the study, Ivowi revealed that (although the concept of momentum relates to mass and speed) students associate conservation of momentum erroneously only with the concept of speed.

In another study, Graham and Berry examined students' understanding of momentum, the result is that students' ability to gain momentum can be grouped into four categories, i.e the first they are confused with the concept of momentum. The second is those who do not know the relationship between momentum and impulse and momentum conservation law. The third is those who can understand momentum as a vector quantity. The last group is students who fully understand the concept of momentum [57]. Furthermore, Dalaklıoğlu, Demirci, and Şekercioğlu stated in their research that high school students tend to have many misunderstandings related to momentum, impulses, and energy concepts. For example, students experience difficulties in connecting between momentum and energy conservation in real life [58]. The research conducted by İnceç, Ünlü and Taşar to investigate students' conceptual understanding of momentum, states that the order of understanding students' concepts of momentum is much higher without the need for understanding the concepts of mass and speed [59]. Singh and Rosengrant investigated students' understanding of the concepts of energy and momentum and obtained results that most students had difficulty interpreting conceptually the basic principles relating to energy and momentum [60].

Furthermore, Güneş conducted a study of the order of students' ability to explain the concepts of impulses and momentum that they knew firsthand, the result was that only one-third of students were able to correctly explain the concept of momentum [60]. In addition, some students feel very confused about the concept of momentum and impulse. Students' misconceptions in the impulse and momentum that often occur are that students think that impulse is equal to momentum. Thus, based on some results of research conducted by experts on understanding students' concepts of momentum and impulse, it can be concluded that momentum and impulse is one part of mechanics which is abstract and difficult for students to understand. In addition, students also often experience errors in understanding the concepts of momentum, changes in momentum, and conservation of momentum.

3.4 Results of the Synthesis of Cognitive Aspects’ Science Literacy and HOTS in Chapter Momentum and Impulse

Based on the opinions of several experts on the concept of science literacy, especially the cognitive and HOTS aspects, students need to have the ability to use and understand science, especially in momentum and
impulse as a basis for solving problems in daily life scientifically with HOTS. In addition, the cognitive aspects of science literacy and indicators in HOTS used in this study are science knowledge and science competencies; analysis, evaluate and create. Meanwhile, the opinions of some experts on the concept of science literacy are mainly cognitive aspects and Higher Order Thinking Skills (HOTS), hence the overall synthesis of this research can be shown in table 1.

| Aspect | Reference | Expert | Expert’ Opinion or Research | Synthesis of Cognitive Aspects' Science Literacy |
|--------|-----------|--------|----------------------------|-----------------------------------------------|
| The Concept of Cognitive Aspect' Science Literacy | Book | OECD | The ability of students to use scientific knowledge, identify problems, and explain scientific facts. | The ability to use and understand the science that is owned as a basis for solving problems in daily life scientifically. |
| Spellman and Bayer | | | The most important things in science literacy are knowledge of science, the process of science, the development of scientific attitudes, and students' understanding of science. | |
| Douglas, Klentschy, Worth, and Binder | | | Someone who has science literacy is someone who uses science concepts and has science process skills in making everyday decisions. | |
| OECD | | | Divided into four main dimensions, i.e the dimensions of the science context, science content, science processes, and scientific attitude dimensions. | |
| OECD | | | Three scientific competencies in science literacy, i.e identifying scientific problems, explaining scientific phenomena, and using scientific evidence. | |
| Lau | PISA 2006 | | aspects of science literacy; scientific knowledge, scientific competence, context, and attitude. | |
| OECD | PISA 2015 | | science literacy is divided into four aspects of assessment, i.e, aspects of context, scientific knowledge, scientific competence, and attitude. | |
| Scientific articles | Greenhow, Gibbins, and Menzer | | Understanding of scientific concepts and processes needed for personal decision making. | |
| Zen and Secken | | | The ability to understand the nature of science and scientific development, understand and use science intelligently, and also use scientific processes to solve problems. | |
| Aspect                                      | Reference                | Expert                                      | Expert's Opinion or Research                                                                 |
|--------------------------------------------|--------------------------|---------------------------------------------|------------------------------------------------------------------------------------------------|
| Students who have science literacy         | Olander                  | Students are able to solve problems using  | Students who have science literacy are able to solve problems using scientific concepts, are able to use and maintain technological products, and be creative in making technological innovations. |
| The Concept of Higher Order Thinking Skills (HOTS) | Book                     | Arwood                                      | The process of thinking is carried out to acquire knowledge that includes thinking of analyzing, evaluating, and creating. |
| Conklin and Williams                       |                          | The ability to analyze, evaluate, and create is part of HOTS. |
| Anderson and Krathwohl                     |                          | Capabilities that include HOTS are the ability to analyze, evaluate, and create. |
| Anderson and Krathwohl                     |                          | Bloom's cognitive taxonomy is revised to remember, understand, apply, analyze, evaluate, and create. |
| Scientific articles                        | Budsankom, Sawangboon, Damrongpanit, and Chuenirimongkol | HOTS are carried out by applying new information or prior knowledge by manipulating information to achieve possible answers in new situations. |
| Jensen, McDaniel, Woodard, and Kummer      |                          | The concept of change in the world of education is based on Bloom's taxonomy. |
| Bagarukayo                                 |                          | Bloom's Taxonomy is a classification of educational goals that emphasizes intellectual aspects and is a sequence of one's thinking abilities. |
| Bolotin and Nashon                         |                          | The ability to use the mind more broadly to find new challenges. |
| Vijayaratnam,                             |                          | Cognitive domains in the revised Bloom taxonomy are the basis for HOTS that require more cognitive processes. |
| Student Problems in the Momentum and Impulse Chapters | Scientific articles | McNeill, Lizotte, and Krajcik | Momentum and impulse is a matter of physics that still often misconception in student. |
| Sekercioglu and Kocakula                  |                          | The concept of momentum and impulse is considered simple even though it is actually a complex concept. |
| Ivowi                                      |                          | Students associate the conservation of momentum erroneously, that is, only with the concept of speed. |
| Dalaklioğlu, Demirci, and Şekercioglu      |                          | High school students tend to have many misconceptions related to Momentum and impulse. |
| Synthesis of Student Problems in the Momentum and Impulse Chapters |                          | Momentum and impulse is one part of mechanics that is abstract and difficult for students to understand. In addition, students also often experience errors in Momentum and impulse. |
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Students need to have the ability to use and understand science especially in momentum and impulse as a basis for solving problems in everyday life scientifically with higher order thinking. In addition, cognitive aspects in science literacy and indicators in HOTS used in this study are science and science competencies, respectively; analysis, evaluation and creation.

Furthermore, as for the details of each cognitive aspect of science literacy combined with momentum and impulse chapter, it can be shown in Table 2.

### Table 2. Operational indicators for the cognitive aspects of science literacy

| Cognitive Aspects of Science Literacy | Operational Indicator |
|--------------------------------------|-----------------------|
| **Aspect** | **Sub Aspects** | **Operational Indicator** |
| **Content Knowledge** | | |
| Science Knowledge | | |
| Procedural Knowledge | | |
| Empystemist Knowledge | | |
| Science Competence | | |
| Explain phenomena scientifically | | |
| Interpreting scientific data and evidence | | |
| Evaluating scientific investigations | | |

Furthermore, for details of each indicator of HOTS combined with momentum and impulses, it can be shown in Table 3.
### Table 3. Operational indicators for HOTS

| HOTS Aspect | HOTS SubAspect | Operational Indicator |
|-------------|----------------|-----------------------|
| Analysis    | Distinguish    | Analyze the amount of momentum carried out by an object. |
|             |                | Analyze the amount of impulses on an object. |
|             | Sort           | Analyzing momentum is done by an object based on the law of conservation of momentum. |
|             |                | Analyze amount of impulses on objects associated with changes in momentum. |
|             | Give Special Characteristics | Analyze the momentum of a colliding object. |
|             |                | Analyze the amount of impulses on objects that collide. |
|             |                | Analyze the coefficient of restitution on a colliding object. |
| Evaluate    | Check          | Projecting the relationship between force and time changes in objects moving on the graph. |
|             | Criticize      | Predict an event based on the law of conservation of momentum. |
|             |                | Predict events based on perfect resilience collisions. |
|             |                | Predicting an event based on a collision is not resilient. |
| Create      | Bring up the idea | Form images of phenomena in everyday life that apply the concept of momentum. |
|             |                | Form images of phenomena in everyday life that apply the concept of impulses. |
|             |                | Form images of phenomena in everyday life that apply the concept of collision. |
|             | Planning       | Planning the scheme of a phenomenon in life that applies momentum and impulse. |
|             |                | Planning events in life that apply momentum and impulses by determining their physical quantities. |
|             | producing      | Make imitations of new events that apply momentum and impulse. |

### 3. Conclusions

Based on the expert's view of the basic concepts of science literacy especially in the cognitive and HOTS aspects of momentum and impulses, it can be concluded that students need to have the ability to use and understand science, especially in momentum and impulses as a basis for solving problems everyday life scientifically with HOTS. There are four cognitive aspects in science literacy, i.e. the context, scientific competencies, science knowledge, and attitudes, but in this study only scientific and scientific competencies are used. Meanwhile, there are three aspects in HOTS which are all used in this study, i.e analysis, evaluate, and create.

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