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DESIGN OF STUDENT WORKSHEETS FOR THE COLLISION MATERIAL TO DEVELOP ANALYTICAL THINKING SKILLS

Husnul Hidayah[1], Nisrina Imtinan[2], Suharto Linuwih[2], Mahardika Prasetya Aji[2]✉

[1]Master's Program in Physics Education, Universitas Negeri Semarang, Indonesia
[2]Department of Physics, Universitas Negeri Semarang, Indonesia

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Abstract

Student worksheets are used as a learning resource that is concise and practical. The design of student worksheets that is concise and practical tends to be low in developing the stages of thinking processes. Physics learning that studies natural behavior always involves analytical thinking. The development of student worksheets based on analytical thinking design is the important goal in this study. Three stages are used to develop student worksheets with an analytical thinking design for momentum material. The differentiating stage includes identifying the quantity of moving object, defining the amount of momentum and estimating the velocity before and after the collision. The organizing stage includes the activities of analyzing and relating the momentum quantity to the collision phenomenon. While the attributing stage includes the activities of deducing the relation between momentum quantity and the collision phenomenon, also evaluating the law of conservation of linear momentum of a collision. The results of student worksheets validation obtained a percentage of 92.9%, so this learning resource is in a highly valid criteria. The design of student worksheets that develop analytical thinking skills can form the basis and support higher thinking skills.

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✉Corresponding author:
Mahardika Prasetya Aji
Department of Physics, Universitas Negeri Semarang, Indonesia
E-mail: mahardika@mail.unnes.ac.id

INTRODUCTION

Student worksheets are classified as very practical learning resources to help and facilitate students in achieving material understanding (Munifah *et al*., 2019). The design of student worksheets that contains material in a complete, coherent, concise, concrete, and evaluation manner makes this learning resouce has an important role in achieving learning objectives (Hanim *et al*., 2017). The scope of learning objectives in the cognitive, affective, and physchomotor aspects can be designed and achieved at the same time in the student worksheets (Nurkanti *et al*., 2019). Thus, student worksheets have a very effective function in the learning process and can change the role of the educator from being a teacher to being a facilitator (Luciano *et al*., 2019).

Nowadays, the variety of student worksheets are developed not only limited to reach the level of understanding. However, the achievement of learning objectives based on the cognitive aspect is developed with more specific goals such as growing or increasing the ability to think critically and creatively (Tsai, 2013; Fatmawati *et al*., 2019). Meanwhile, based on the affective aspect, several student worksheets have been developed for the purpose of developing life skills, and even the variety of characters (Kaleka & Ika, 2018; Fauziah & Nurita, 2019; Windari & Suryadharma, 2019). Psychomotor aspect can be developed by integrating activities such as arranging props and practical work in student worksheets (Anisa *et al*., 2014).

The design of student worksheets that is concise and practical makes the stages of thinking process in learning is very few and even not included. The changes in students understanding and attitudes in learning process using student worksheets tend to go through a low level of analytical thinking process stage. This problem is very important to get a solution. The design of student worksheets that is concise, practical, and has analytical thinking stages is needed. This analytical mindset is an important basis for developing higher order thinking patterns in science learning (Dubas & Toledo, 2016).

The understanding of natural phenomena studied in Physics always involves analytical thinking (Chantaranima & Yuenyong, 2014; Markawi, 2015). The initial stage of analytical thinking in Physics learning can be in the form of logically observing facts which includes identification of concepts and related quantities. Furthermore, the analytical thinking stage includes the ability to relate and even estimate the relation between quantities. The final stage of analytical thinking is to obtain a conclusion or understanding of the concept of the phenomenon that was being reviewed.

Many everyday life events are very closely related to Physics concepts, such as collision phenomenon. The understanding of collision phenomenon is still limited to a low analytical level, which is viewing it as an event of two objects moving in opposite directions and occur a physical contact. The understanding that has been believed is still partial, so it has the potential to produce new misconceptions. This study aims to develop student worksheets based on analytical thinking design. The development of analytical thinking skills is expected to form a coherent and logical understanding of the collision phenomenon.

METHOD

This study was a Research and Development (R&D) using the Gall, Gall & Borg model. Development research was used to produce the design of student worksheets based on analytical thinking product for collision material. The design of student worksheets of collision material is designed to develop analytical thinking stages. The design stages includes differentiating, organizing, and attributing. The aspects in each stage in the development of student worksheets for collision material are shown in Table 1.

Table 1. Design of Student Worksheets Development for Collision Material based on Analytical Thinking Aspects

Stage	Aspects
Differentiating	1. identifying Physics quantities of a moving object 2. describing the momentum concept 3. estimating the velocity before and after collision
Organizing	1. analyzing Physics quantities of a moving object 2. relating the momentum quantitites to the collision phenomenon 3. calculating the velocity before and after collision
Attributing	1. deducing the relation between momentum quantity and the collision phenomenon 2. evaluating the conservation of linear momentum of a collision

Adapted and modificated from BSNP (2014) and Azmi *et al*. (2018), student worksheets

developed based on analytical thinking aspects also consider three aspects of validity for student worksheets, that are didactic, construction, and technical, as shown in Table 2.

Table 2. Student Worksheets Validity Aspects

Components	Aspects
conformance with didactic, content, or material requirements	1. conformity to the material 2. the correctness of concept 3. presentation requires students to learn actively
aspect of construction	1. use of proper languange 2. use of the right sentence 3. questions in student worksheets 4. activites in student worksheets 5. student worksheets provide space for students to write down the results of activities or practical work 6. has clear learning objectives
conformance with technical requirements	1. appereance of student worksheets 2. consistency of writing used 3. use of appropriate figures

Student worksheets validity for the collision material is based on the assessment provided by the material expert. The percentage of score P (%) obtained from the comparison of the score obtained (f) to the total score of the instrument (N) as shown in Equation (1) is used to determine student worksheets validity.

$$P(\%) = \frac{f}{N} x100\% \quad (1)$$

Validity criteria for student worksheets is based on the percentage of P score (%) of Equation (1) with the intervals shown in Table 3.

Table 3. Validity Criteria for Student Worksheets

P (%)	Criteria
$81.25 < P \leq 100$	Highly Valid
$62.5 < P \leq 81.25$	Valid
$43.75 < P \leq 62.5$	Less Valid
$25 < P \leq 43.75$	Invalid

(Sugiyono, 2015)

RESULT AND DISCUSSION

The design of student worksheets based on the development of analytical thinking skills is designed with the main activity of observing collision phenomenon from air track props. The results of student worksheets design based on analytical thinking stages are shown in Table 4.

Table 4. Design of Student Worksheets for Collision Material

Student Worksheets Component	Student Worksheets Contents	Analytical Thinking Stage
Purpose	To understand momentum concept and its application to the collision phenomenon.	-
Content	Material : (i) Momentum concept, (ii) Action-reaction forces of two colliding objects, (iii) The law of conservation of linear momentum of two colliding objects, and (iv) the relation between velocity before and after collision of elastic and inelastic collision.	differentiating
	Activities : arranging props, observing collision phenomenon, calculating and analyzing the velocity of two objects before and after collision.	organizing, attributing
Evaluation	Initial questions (before using air track props).	differentiating, organizing,
	Final questions (after using air track props).	differentiating, organizing, attributing

The students worksheets design based on analytical thinking stages was adapted and modificated from the analytical framework

indicators by Areesophonpichet (2013). Based on the Table 4, the development of analytical thinking skills begins in the content section. The differentiating stage includes identifying motion parameters such as velocity and describing the momentum concept. The object's motion parameter in the form of velocity is needed to define momentum. Identification and understanding of object velocity is not sufficient to explain the collision phenomenon. The organizing stage is designed to relate the momentum quantity to the collision phenomenon.

Observing the collision phenomenon by using air track props is used as a medium to support the organizing and attributing stages. The organizing stage is focused on analyzing the action-reaction forces that work on two colliding objects. The organizing stage is designed in stages with the aim of developing conceptual analysis skills. Whereas, the attributing stage includes relating the velocity relation before and after the collision, deducing the relation between momentum quantity and the collision phenomenon, and evaluating the law of conservation of linear momentum of the collision. Besides in the content component, the development of analytical thinking is designed in the evaluation component. Unlike the content section, the analytical thinking stage in the evaluation section is designed through questions related to the basic concepts in the collision material as shown in the Figure 1.

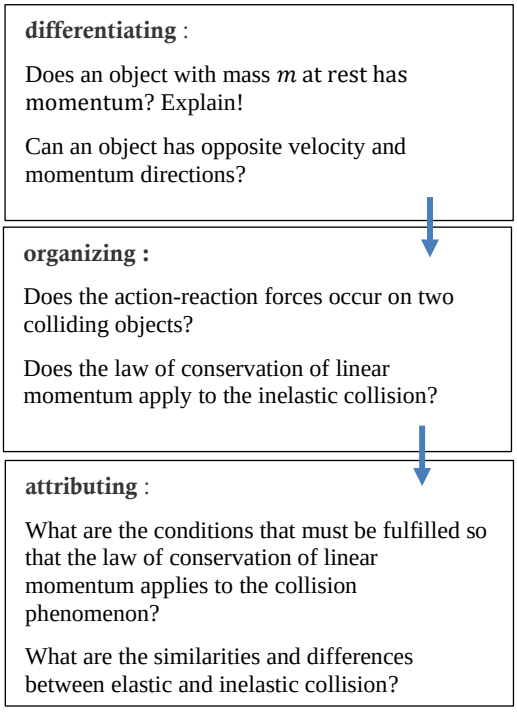

Figure 1. Analytical Thinking Stage in the Evaluation Component

The validity of student worksheets is determined by the validity test based on the assessment of material experts. The result of student worksheets validity test are shown in Table 5.

Table 5. Validity of Student Worksheets for Collision Material

Aspect	Validator score					Criteria
	1	2	3	average	%	
Content (score 40)	36	37	38	37	92.5	Highly Valid
Appearance (score 16)	13	15	16	14.6	91.3	Highly Valid
Language (score 12)	11	12	12	11.6	96.6	Highly Valid
Total (total score 68)				63.2	92.9	Highly Valid

The aspect of validity includes content, appearance, and languange aspects. Each aspect is 92.5%, 91.3%, and 96.6%, and the overall score is 92.9%. Therefore, the student worksheets for collision material based on analytical thinking design is in a highly valid criteria.

The effort to develop analytical thinking through student worksheets based on the design of analytical thinking stages requires students to build a knowledge framework actively and independently. This process provides opportunities for students to develop thinking in accordance with their cognitive abilities (Fitriyana *et al.*, 2019). However, it is possible that the thoughts generated are constructed from a different way. This is because each student brings a different cognitive. Design of student worksheets that has been designed with coherent and structured stages in analytical thinking can reduce thinking by different ways of thinking. The understanding generated from this analytical thinking product will be obtained in accordance in the learning objectives.

The formation of knowledge with analytical thinking is in accordance with the operative thinking aspect. Knowlegde acquired as a result of the transformation of the previous stages (Thaneerananon *et al.*, 2016). This knowldege forms the basis of transformation at a later stage. The transformation of the stages is evident in the design of the momentum material student worksheets which includes the stages: (i) differentiating, (ii) organizing, (iii) attributing. Based on the ability to think analitically, students make it possible to develop their knowledge to higher stages of thinking such as critical and creative thinking (Putri & Aznam, 2019). Thus, student worksheets based on analytical thinking design has the characteristics of three tiered stages for momentum material. This analytical thinking design constructs understanding independently,

activates students, and supports higher levels of thinking.

CONCLUSION

Student worksheets for the collision material with the development of analytical thinking have been designed succesfully. Student worksheets are designed to include three stages of analytical thinking, that are differentiating, organizing, and attributing. Momentum material student worksheets designed based on analytical thinking stages to support the development of higher-order thinking.

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