Development of concept essential in kinematic topics

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Abstract. Essential concepts were important aspects in physics education, especially in the study of learning development, student evaluation, and curriculum planning. Several types of concept analysis models are commonly applied in the context of physics, i.e. semantic network techniques, concept formation (concept analysis), concept maps, and representing substantive structure. The stages of essential concept development were concept analysis, concept map and essential concept. The research method used development research. The stages of development research included (1) the preliminary study phase, (2) the development study phase, (3) the evaluation phase. The main results of this study were essential concepts on the topic of Kinematics.

1. Introduction

The concept is specific information about one or several objects, events, or processes; the object is a part or group of certain objects or related to another group of objects [1]. Content analyses (concept analyses) are important aspects in physics education, especially in the study of learning development, student evaluation, and curriculum planning [2]. Several types of concept analysis models are commonly applied in the context of physics, i.e. semantic network technique [3], concept formation (concept analysis) [4], concept maps [5-7], and representing substantive structure [8]. The stages of developing essential concepts are concept formation and concept maps.

Analysis of concept is formal strategy for investigating concepts and deciding how the concept was learned. Concept analysis was carried out through seven steps, i.e. (1) determining the name or label of the concept, (2) definitions of concepts, (3) types of concepts, (4) critical attributes, (5) variable attributes, (6) conceptual positions (superordinate, ordinate, subordinate), (7) examples and non-examples [9].

Concept maps are two-dimensional diagrams, hierarchical diagrams of conceptual relationships described important concepts and propositions in the knowledge domain [10]. Concept maps are schematic instrument for representing a set of concept meanings embedded in the form of propositions [6,8]. The main ideas of Ausubel’s cognitive theory are the basis for developing concept maps [11]. Ausubel’s assimilation theory explain learning are the activity of assimilating new concepts and propositions into concepts and proportions in students' cognitive [12-13]. The main components of concept map are hierarchy of concepts, relationships between concepts, cross-links, and examples of concepts [8].

Kinematics is a basic concept in physics as a foundation for students to comprehend the concept of physics comprehensively. Kinematics focuses on the motion of objects assuming the environment has
no effect on the motion system [14-15]. The main concepts of kinematics are translational and rotational motion. The urgency of developing essential concepts on the topic of kinematics is to make it easier for instructors to know the concept hierarchy comprehensively as a base in developing the learning procedures in the class and determining assessment models that are in accordance with the characteristics of the Kinematics concept. The essential concepts for the topic of Kinematics has not been well developed. Thus, the development of essential concept on the topic of kinematics is considered important to develop.

2. Methods
This research was a development research adapted Sugiyono’s development design model [16]. The procedure of development research included (1) the stage of the preliminary study, (2) the stage of development studies, and (3) the evaluation phase. The preliminary study phase was focused on documentation study activities and literature studies. Documentation studies carried out by analysis of physical textbooks used in lectures. The literature studies explored the characteristics and stages of developing concept analysis, concept maps, and essential concepts in articles and textbooks. The development study phase was carried out product design concept analysis, concept maps, and essential concepts. The stages of developing concept analysis were adapted from Herron [9]. The stages of developing concept maps were adapted from Novak and Gowin [6,8]. The evaluation phase was conducted to validate the results of concept analysis, concept maps, and concept essential that have been developed. Validation was carried out by experts in physics and pedagogy in physics.

3. Result and Discussion

3.1. Preliminary Study Stage
The documentation studies of several physic textbooks [14,17] on the Kinematics concept focused on discussing motion without the influence of forces acting on motion. The concept of motion included translational motion, rotational motion, one-dimensional motion, and two-dimensional motion. Some examples of physical quantities in translational motion were distance, displacement, instantaneous speed, average speed, instantaneous acceleration, and average acceleration.

3.2. Development Stage
The stages of developing concept analysis were (1) determining the name or label of the concept, (2) definitions of concepts, (3) types of concepts, (4) critical attributes and variable attributes, (6) concept positions: superordinate, ordinate, subordinate, (7) examples and non-examples. Types of concepts in concept analysis were (1) the concrete concepts i.e. concepts whose examples can be seen; (2) abstract concepts i.e. concepts whose examples cannot be seen; (3) concepts with abstract critical attributes, example can be seen; (4) The concept was based on principle knowledge, i.e. a concept that required knowledge principles to distinguish between examples and non-examples; (5) the concept involved symbol representation. (6) concepts that explained an attribute or atribut. The theoretical attribute stated main characteristics of concept that outlines the concept definition [9]. The concept analysis prototype on the Kinematics topic is shown in Table 1.

| Concept | Attribute | Position | Example | Non-Example |
|---------|-----------|----------|---------|-------------|
| Distance | Concrete | Distance is the length of the passage | Translation of motion | The car moved from city A |
|         |           | Distance, the length of passage | Displacement |                          |
|         |           | Position of particle | Speed |                          |
|         |           | Translational motion | The passage length of a |                          |
The particle passes from A to B to the south of the city of B.

| Displacement | Concrete | Displacement, change of initial position to final position, and the magnitude is the shortest distance between two positions |
|--------------|----------|------------------------------------------------------------------------------------------------------------------|
| Translation  |          | Change in position, i.e. understanding the whole relationship between concepts in a map |
| Distance     |          | The passag length of a particle change from A to B by 5 m to the east |
| Velocity     | A particle change position A to B by 5 m to the east |
|              |          | The concept map prototype on the Kinematics topic is shown in Figure 1. |

The stages of developing a concept map were (1) reviewing the topic or concept domain, i.e. reading books or articles, reflecting on the concepts being mastered; (2) identifying the main concepts, i.e. listing some concepts considered important; (3) determine the hierarchy of concepts, i.e. determine the most inclusive concepts to concepts were less inclusive of the main concepts; (4) linking or labeling relationships between concepts, i.e. adding subordinate concepts to the map as much as possible to deepen and broaden knowledge on the concept; (5) deepening or broadening concept maps, i.e. trying to connect and label the relationship between the concepts that already exist on the map [10,11].
The last stages of development were essential concepts as derivatives from the stages of concept analysis and concept maps. An example of an essential concept prototype on the topic of Kinematics is shown in Table 2.

Table 2. The prototypes of essential concepts on the topic of Kinematics

| Codes | Essential Concepts |
|-------|--------------------|
| K1    | Distance is the length of the passage through which the particle passes |
| K2    | Displacement is a vector quantity stated the change in initial to final position, and the magnitude is the shortest distance between two positions |
| K3    | Average velocity is the particle displacement divided by the time interval of displacement |
| K4    | Average speed is the total distance divided by time |
| K5    | Instantaneous velocity is the limit of the particle displacement ratio divided by the time interval, with an interval close to zero |
| K6    | Instantaneous speed is the magnitude of instantaneous velocity |
| K7    | Average acceleration is a change in particle velocity per unit time |
| K8    | Average speeding up is the magnitude of the average acceleration |
| K9    | Instantaneous acceleration is the velocity change limit ratio divided by time interval, with interval of close to zero |
| K10   | Instantaneous speeding up is the magnitude of the instantaneous acceleration |
| K11   | Regular straight motion is a motion with a straight track and constant speed |
| K12   | Regular changed straight motion is a straight motion with a constant change in velocity with time (constant acceleration) |
| K13   | Angular displacement is change in the position of the angular (against the reference line) certain time interval in the rotational motion |
Angular distance is the magnitude of angular displacement
Average angular velocity is the ratio of angular displacement with certain time intervals
Average angular speed is the magnitude of the average angular velocity
Instantaneous angular velocity is the limit ratio of particle displacement divided by time interval, with time interval close to zero
Instantaneous angular velocity is the magnitude of the instantaneous angular velocity
Average angular acceleration is the ratio of the change in angular velocity ($\Delta \omega$) during certain time interval ($\Delta t$)
Average angular velocity is the magnitude of the average acceleration, which is a scalar quantity
Instantaneous angular acceleration is the limit of comparison of changes in angular velocity and time interval, the time interval is close to zero
Instantaneous angular speeding up is the magnitude of the instantaneous angular acceleration
Parabolic motion is motion with curved path influenced by constant gravitational acceleration towards the center of the earth
Circular motion is motion with circular path with a fixed axis center
Tangential velocity is the velocity component of the tangential direction of a circle path
Centripetal velocity is component of velocity in the direction towards the center of the circle
Tangential acceleration is acceleration component the direction in a circular motion tangential
Centripetal acceleration is acceleration component of the circular motion in the direction towards the center of the circle
Regular circular motion is circular motion with tangential velocity constant and the tangential velocity direction varies, centripetal acceleration toward the center of the earth
Regular changed circular motion is a circular motion with tangential velocities varying (direction and magnitude), centripetal acceleration towards the center of the earth
Rotational motion is the motion of rigid body on fixed axis with path in the circle form

3.3. Evaluation Stage
The results of the development of concept analysis, concept maps, and essential concepts were validated by two experts in the field of physics education. In general, there were some expert suggestions on concept analysis products, concept maps, and essential concepts developed were shown in Table 3. Suggestions from the validator as basis for improving the instruments developed.

Table 3. Suggestions for improving concept analysis.

| Assessment criteria     | Recommendation for improvement                                      |
|------------------------|---------------------------------------------------------------------|
| Concept label          | Distinguish understanding of concepts and learning material          |
| Concept type           | Change the type of concept because it is not appropriate with characteristics of the concept type |
| Concept definition     | Change redaction the definition of the concept because concept explanation created misconception meaning |
4. Conclusion
The product of this research is essential concepts on the Kinematics topic. The stages of developing essential concept include the preliminary study stage, the development stage, and the evaluation stage. The main function of essential concepts is to make it easier for teachers to comprehensively understand the hierarchy and characteristics of the concept as foundation in developing the learning process in the classroom and determine assessment models that are appropriate with the characteristics of the Kinematics concept.

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