Students' SCIENTIFIC MODELS OF Momentum

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Abstract. A group of 7 grade ten students of The Demonstration School of Ramkhamhaeng University (Secondary Level) had been taught by modeling-centered instruction sequence (MCIS) on the topic of momentum for 2 hours. The students participated in nine learning steps of MCIS; (1) anchoring phenomena and central question, (2) construct an initial model, (3) empirical investigations, (4) evaluate and revise the initial model, (5) introduce scientific ideal and simulations, (6) evaluate and revise the model, (7) peer evaluation, (8) construct a consensus model, and (9) use the model to predict or explain. Then, we focused on evaluating their ability to create scientific model during the steps 6, 7, 8, and 9. The students' ability to create scientific model was analyzed by separate evaluation criteria (Analytic Rubrics).

Keywords: Model-Centered Instruction Sequence, scientific model, momentum

1. Introduction

For science curriculum, the aim is to provide students with knowledge they need to know. Especially, physics, which many students think it is difficult to understand, invisible and sometimes learn to memorize. It is necessary to enhance them learn with correct understanding. In 2009, Model-Centered Instruction Sequence (MCIS) [1] was developed under a project called model project for learning science at Michigan State University. The MCIS has several features that are likely to be important in bringing scientific modeling practices and lets students learn with deep understanding. There are nine steps of MCIS; (1) anchoring phenomena and central question: the unit begins by introducing an engaging phenomena and a central question, (2) construct an initial model: individual students construct an initial model that encompasses their ideas or hypotheses for answering the central questions, (3) empirical investigations: students in groups conduct a set of empirical investigations about the phenomena, (4) evaluate and revise the initial model: students evaluate their initial model with empirical findings and revise their model, (5) introduce scientific ideal and simulations: fundamental scientific concepts, ideas and theories related to the general phenomena or model are introduced, (6) evaluate and revise the model: students evaluate and revise their model using the scientific ideas and simulations to which they have been introduced, (7) peer evaluation: each student presents his or her model to peers who provide feedback on it, (8) construct a consensus model: students compare various models and construct a consensus model either within a small group or as a whole class, and (9) use the model to predict or explain: students use the consensus model to predict or explain other related phenomena.

In this study, nine learning steps of MCIS on the topic of momentum was tried out with 7 grade ten students, collected data during the instruction and evaluated to see their scientific model.

2. Methodology

Two groups of 7 grade ten students of The Demonstration School of Ramkhamhaeng University (Secondary Level) participated in MCIS lesson on the topic of momentum. (1) An instructor showed students a demonstration. Released 2 bottles with different amount of water from the same height. Student's suspicion and question what the magnitude of the force has been applied to stop the bottles. (2) Students constructed their initial model to demonstrate their understanding of the situation. (3) Students brainstormed in group to create a model that offers a research plan or experimental work. They carried out inspections, collect data and evidence. (4) Students used evidence collected from empirical investigations to evaluate and revise their model of momentum. (5) The instructor introduces scientific ideas and let students watch a video clip about what momentum is. (6) Students used ideas collected from peer evaluation, mini-lecture, and simulations to evaluate and revise their own model of momentum again. (7) Students shared their second model of momentum in a group to obtain feedback from their peers. (8) All students compared diverse models of momentum and collectively constructed a consensus model. (9) The instructor asked students to explain new situations; (a) dropped a sand bag from different height and (b) dropped one and two sand bags (bound together) at the same height. We spent 2 hours in April, 2018 during the school off period. Document review were used as qualitative data collection methods during steps 6, 7, 8, and 9. We, then, evaluated the document to see the students' scientific model. There are five model types. Pictorial Representation, a model that expresses knowledge in the manner of painting symbol, diagram or image. Experimental Representation, a model that illustrates the process of experimentation with drawing materials, equipment, symbols and text. Graphical Representation, a model that expresses knowledge, understand or relationships between variables in a table, bar chart and graph function. Mathematical Representation, the model shows knowledge of equations. It consists of variables and mathematical constants, and Conceptual Representation, a model that expresses knowledge in terms of writing, lecturing, or speaking.

3. Research Findings

3.1 Step 6 Evaluate and Revise the Model

Revision is a way for students to bring their scientific ideas from the peer evaluation, mini-lecture, and simulations to assess and improve their own models. Student nos. 2 and 4-7 provided Pictorial Representation as they all demonstrated concept of science and displayed dropping objects with different mass from the same height. In table 2, students revised their models based on the evidence from self-study. It was found that most of them had clear understanding that momentum is the product of mass and velocity of an object. It is a vector quantity and varies with mass if speed is the same. If m is an object's mass and v is the velocity (also a vector), then the momentum is $p = mv$ in *SI* units, it is measured in kilogram meters per second (kg.m/s).

Table 2. Students' scientific model during step 6

Student nos.	Student scientific model
1	**Mathematical Representation:** Based on the scientific concept, students wrote mathematical equations. P = mv, P = momentum, m = mass (kg), v = speed (m/s) **Conceptual Representation:** Greater mass and greater speed cause larger momentum. Smaller mass and lower speed cause smaller momentum.
2	**Mathematical Representation :** P = m×v **Conceptual Representation:** Greater mass cause larger momentum if the speed of the object is the same. So, mass varies with momentum.
3	**Mathematical Representation:** P = mv , P = momentum , m = mass , v = speed **Conceptual Representation:** Momentum is the amount that affects motion of an object.
4	**Experimental Representation:** Students demonstrated process of releasing sandbags in one direction by painting. **Mathematical Representation:** P = mv , P = momentum (kg·m/s) , m = mass (kg) , v = speed (m/s)
5	**Conceptual Representation:** Mass varies with momentum if speed is the same.
6	**Mathematical Representation:** P = m×v
7	**Mathematical Representation:** P = m×v **Conceptual Representation:** Mass varies with momentum if speed is the same.

3.2 Step 7 Peer Evaluation

Peer evaluation is the student presenting their second model individually and discussing together within the group to obtain feedback. Student nos. 1, 3 and 7, evaluated and improved their models by identifying vector marks. The others provided symbolic representation and clearer writing. Their modified model was concluded as presented in table 3.

Table 3. Students' scientific models during step 7

Student nos.	Student scientific model
1	**Conceptual Representation:** Students provided clear writing: greater mass and greater speed cause larger momentum. Smaller mass and lower speed cause smaller momentum.
2	**Pictorial Representation:** Students demonstrated concept of science and displayed dropping objects with different mass from the same height clearly. **Mathematical Representation:** $\vec{p} = m\vec{v}$; The mathematical equation is completely correct. **Conceptual Representation:** Students provided clear writing: greater mass cause larger momentum if the speed of the object is the same. So, mass varies with momentum.
3	**Conceptual Representation:** Provide a clear understanding of the writing; Momentum is the amount that affects the motion of an object.

Student nos.	Student scientific model
4	**Pictorial Representation**: Students demonstrated concept of science and displayed dropping objects with different mass from the same height but it is not clear. **Experimental Representation**: Students demonstrated the process of releasing sandbags in one direction by painting is clear. **Mathematical Representation**: $\vec{p}$= m$\vec{v}$; The mathematical equation is completely correct.
5	**Pictorial Representation:** Students demonstrated concept of science and displayed dropping objects with different mass from the same height. **Conceptual Representation:** Mass varies with momentum if speed is the same.
6	**Pictorial Representation**: The symbolic representation ($\vec{v}$, m) must be clearly defined and should be $m_1\vec{v}_1$ and $m_2\vec{v}_2$. **Mathematical Representation**: P = m$\vec{v}$; Not specified vector marker.
7	**Pictorial Representation**:Students demonstrated concept of science and displayed dropping objects with different mass from the same height. Mass images are not clear. The mass should be clearly defined (m_1, m_2).

3.3 Step 8 Construct a Consensus Model

Construction is to allow students of each group to present a class page model and compare the models of each group. Together, they created a modified model that was a joint resolution in the classroom. In table 4, they were able to identify variables related to the phenomenon and show relationship between variables accurately and clearly. There was a clear drawing as they put objects with different mass with different size and put clearly visualized symbols. The students could define that mass varies with momentum if speed is the same

Table 4. Students' scientific models during step 8

	Student scientific model
Student nos. 1-7	**Pictorial Representation**: Students provided descriptions of conditions or something to study: releasing objects at the same height. There is a clear height drawing. Students put objects with different mass with different size and put clearly visualized symbols ($\vec{v}$, m) and $m_1\vec{v}_1$ and $m_2\vec{v}_2$. **Experimental Representation**: Students could visualize an experiments by releasing different sandbags in the same direction and identify the variables that have been studied correctly and clearly. **Mathematical Representation** : $\vec{p}$ = m$\vec{v}$, $\vec{p}$ = momentum (kg·m/s), m = mass (kg), $\vec{v}$ = speed (m/s) **Conceptual Representation**: Mass varies with momentum if speed is the same.

3.4 Step 9 Use the Model to Predict or Explain

Students used the created model to describe or predict new given situations correctly. They could explain situations (a) dropped a bag of sand from different height and (b) dropped one bag and two sand bags (bound together) at the same height. They predicted that the sand bag which dropped from higher level should exert more force because the speed is higher. Momentum is also greater because the speed affects momentum. Students could also predict that two sand bags should exert more force. Momentum is also greater because the mass affects momentum. It indicated that students understand that momentum depends on mass and speed of the object.

4. Conclusion

Learning by MCIS, students can create four model types to explain momentum except Graphical Representation. (1) Pictorial Representation, student drew and provided symbols ($\vec{p}$, m,$\vec{v}$) and images related to momentum. (2) Experimental Representation, they showed scientific concept during the experimental stage by painting and providing symbols and messages related to momentum. (3) Mathematical Representation, they presented some understand of relationship between mathematical variables such as $\vec{p} = m\vec{v}$, $\vec{p}$ = momentum (kg·m/s), m = mass (kg), $\vec{v}$ = speed (m/s). (4) Conceptual Representation, students concluded that amount of momentum depend on how much stuff is moving and how fast the stuff is moving.

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