# Teaching, Learning and Conceptual Development of Force and Motion in Third - Year Preservice Physics Teachers

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**Keyword:** force and motion concept, alternative concept, preservice physics teacher, PCK modeling

**Abstract**

Four third-year preservice physics teachers from Rajabhat University in the middle part of Thailand were interviewed individually in relation to teaching and learning about force and motion in secondary school, university and the period of pedagogical content knowledge (PCK) modeling in the physics methods course. In addition, to explore the conceptual development of force and motion, they were interviewed in-depth in relation to force and motion before and after participated in the period of PCK modeling by using the interview-about-instance (IAI) technique. The results revealed that the teaching and learning about force and motion in secondary and university levels were usually driven by lecture and strongly emphasized memorizing force and motion equations rather than understanding key ideas of force and motion and their applications in daily life. Additionally, the participants lacked understanding of force and motion and had negative attitudes toward learning force and motion. The activities during the period of PCK modeling potentially enhanced the participants' understanding and reasoning of force and motion and positive attitudes toward learning force and motion. The participants' ideas of force and motion in case of accelerated, at rest and vertical motion were respectively enhanced. However, the human-centred viewpoint and the impetus concept are regarded as the stumbling block for learning force and motion.

## Introduction

Force and motion concepts are the key physics concepts situated in physics teacher preparation curriculum because these concepts are explicitly mentioned in Thai Science Curriculum in the 4$^{th}$ Substance: Force and Motion, which aims to promote students' understanding the nature of force and a variety types of motion in the nature (Institute for the Promotion of Science and Technology Teaching, 2545: 11). Furthermore, force and motion is the basic concepts for learning Mechanics in the higher education in particular to Newton's laws of motion (Hellingman, 1989: 36). If students lack the understanding of force and motion, they may face problems in learning Mechanics that make Mechanics meaningless (Hestenes et al., 1992: 150).

However, the literature indicated that, mostly, students and preservice teachers hold alternative concepts of force and motion in particular to impetus concept and human-centred viewpoint. Those alternative concepts appear as the stumbling block for learning physics because learners may distort content in the lesson and/or results and their interpretations from learning activities to fit with their alternative conceptual framework (Champagne et al., 1983).

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**Research objectives**

- To explore the teaching and learning of force and motion in secondary schools, university, and the period of pedagogical content knowledge (PCK) modeling of third-year preservice physics teachers.
- To explore the conceptual development of force and motion in third-year preservice physics teachers during the period of PCK modeling in the physics methods course.

**Methodology**

This study is the survey research, which was conducted in the 16-week physics methods course in the second semester of 2004 academic year. There were four preservice physics teachers (2 male, 2 female) from one Rajabhat University in the middle part of Thailand participated in this study. The research instruments included:

**1. Individual interview:** Each participant was interview individually in relation to teaching and learning, teaching materials, assessment and problems in learning force and motion in secondary school, university and the period of PCK modeling

**2. Interview-About-Instance (IAI)** (Osborne & Gilbert, 1980): Each participant was interview to reveal his/her concepts of force and motion. He/She was shown the simple drawing of object in various situations: at rest, moving with constant velocity, moving with acceleration and moving downward, then he/she was asked to explain force exerting on, and motion of, the object in those situations. There were eight questions used in the IAI.

**3. Activities during the period of PCK modeling:** The period of PCK modeling was conducted during $7^{th}$-$11^{th}$ week of the physics methods course in one Rajabhat University. In this period, the first author as the methods course instructor took a role as the physics teacher and the preservice physics teachers took a role as secondary students. Activities in this period were based on the constructivist theory. According to this theory, the learner is not a blank slate or *tabula rasa* waiting for knowledge from the teacher. Instead, he/she comes to the class with a variety of prior knowledge and experience. The learner takes a role as an active learner (Oxford, 1997), who him/herself constructs knowledge by linking prior knowledge and experience with knowledge and experience acquired from interactions within learning environments occurring inside and outside the class (Colburn, 2000). The teacher takes a role as a facilitator, who encourages, supports and guides ways to construct knowledge to learners, by setting suitable learning environments for them (Tobin & Tippins, 1993: 10). The content during the period of PCK modeling included: force and net force, Newton's laws of motion and the change of momentum and force. The rough details of activities in each week can be depicted as Table 1.

Table 1 Activities during the period of PCK modeling

| Week | Activity |
|---|---|
| $7^{th}$ Force and net force | • Generative learning model of teaching (Osborne & Wittrock, 1985) was used to introduce lesson with activities: "shooting a goal" game; pictures of car accidents; and dropping clays from different height<br>• Students and teacher discussed with respect to force and change of velocity of objects<br>• Students conducted experiment on "force and motion", presented results, discussed and completed worksheet on "net force" |
| $8^{th}$ Newton's first law of motion | • Predict-Observation-Explanation (POE) technique was used by requiring students to predict, observe and explain coin in two situations: placing coin on paper on glass and pulling paper rapidly; and placing coin on ruler on table and pushing ruler rapidly<br>• Students and teacher discussed with respect to net force and change of velocity of object |

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|---|---|
| | • Students conducted experiment on "motion of object in case of zero net force", presented results, discussed and completed worksheet on "Newton's first law of motion" |
| 9th Newton's second law of motion | • Constructivist teaching sequence (Driver & Oldham, 1980) was used to introduce lesson: teacher demonstrated dropping ball, pushing objects on table<br>• Students and teacher discussed with respect to net force exerting on objects: at rest and moving condition<br>• Students conducted experiment on "motion of object in case of non-zero net force", presented results, discussed and completed worksheet on "Newton's second law of motion" |
| 10th Newton's third law of motion | • Constructivist teaching sequence was used to introduce lesson: "tug-of-war" activity, rope tied with the table and dropping table-tennis ball<br>• Students and teacher discussed with respect to action-reaction force<br>• Students conducted experiment on "action-reaction force", presented results, discussed and completed worksheet on "Newton's third law of motion" |
| 11th Change of momentum and force | • Generative learning model of teaching was used to introduce lesson: passing basketball; and receiving table-tennis ball, tennis ball, football and metal ball from same height<br>• Students and teacher discussed about net force exerting on objects: at rest and moving condition<br>• Students conducted experiment on "stopping an moving object", presented results, discussed and completed worksheet on "momentum and net force" |

The researcher analyzed the data by verbatim transcribing audiotapes of interview. To capture the conceptual development of force and motion, the researcher interpreted and compared the participants' concepts of force and motion before and after participated in the period of PCK modeling. In this case, their ideas of force and motion were interpreted into three categories: scientific concept, partial scientific concept and alternative concept.

**Results and discussions**

Teaching And Learning About Force And Motion:

The participants reflected problems of the teaching and learning force and motion in secondary schools and university, that is, physics teachers strongly emphasized on lecture and seldom used teaching materials and experiments in teaching. They emphasized students to remember equations related to force and motion rather than understanding of key concepts and its application in daily lives. Consequently, the participants lacked understanding of key ideas of force and motion, felt boring and did not aware the value of learning force and motion. These appear as the obstacles for learning force and motion in the higher level. According to constructivism, when students lack prior knowledge needed for linking with knowledge acquired in the lesson, it is difficult for them to construct new knowledge and succeed in learning that lesson (Alesandrini & Larson, 2002). Accordingly, it is the responsibility of the teacher in preparing students to be ready for learning new concepts. In addition, the teacher should encourage students to evaluate their constructed knowledge by applying it in various daily-life situations to make them aware the value of their constructed knowledge (Driver & Oldham, 1986).

During the period of PCK modeling, the participants initially felt uncomfortable with constructivist activities employed in this period because they had to practice and do various activities and experiments by themselves instead of only listening and jotting down the lecture as they were familiar. However, within the support from the course instructor, they gradually adapted with constructivist activities and had more positive attitude toward learning in this period. Because they could understand more key concepts of force and motion, not just memorized many equations, and could apply their understanding in explaining daily-lives events. These benefits will probably enhance their attention to use constructivist activities in the future teaching because preservice teachers tend to teach as the ways they were taught (Duit & Treagust, 1995). Consequently, the PCK modeling of constructivist teaching should be considered as the potential way to encourage preservice teachers to implement the constructivist teaching activities in classrooms.

Conceptual Development Of Force And Motion:

In the case of force and motion at rest condition, the participant, who previously had scientific concepts, improved their reasoning by giving more details. The participant, who previously had alternative concepts, developed understanding into scientific concepts and improved their reasoning. However, one participant still used the conflict metaphor to describe action-reaction force (Hestenes et al., 1992: 144-145. In addition, most of participants (3 from 4) neglected some forces, i.e. gravitational force, frictional force and/or reaction force, because they hold the human-centred viewpoint (Gilbert et al., 1982).

In the case of force and motion at constant velocity, all participants had partial scientific concept because they hold the human-centred viewpoint (Gilbert et al., 1982). In addition, they had alternative concept called "impetus concept" – there is a force[impetus] from an active agent (e.g. human) embeds in the moving object, even it was released (Kruger et al., 1990: 92).

In the case of force and motion at accelerated and vertical motion, all participants had partial scientific concept because they hold the human-centred viewpoint (Gilbert et al., 1982) and had alternative concept – impetus concept. In this case they stated that impetus is decreased because of resistance e.g. frictional force, gravitational force, etc. (Shelley & Marjan, 2000).

**Implications**

This study revealed that alternative concepts resist for change, maybe, because they can give learners more appreciation in interpreting, predicting and explaining events in daily lives than scientific concepts (Champagne et al., 1983: 177; Hestenes et al., 1992: 142; Jimoyiannis & Komis, 2003). Alternative concepts are the thing to remind teachers, administrators and involved personnel to be aware of the quality of content preparation for preservice teachers and prevent them to transfer alternative concepts to students (Pardhan & Bano, 2001). The suggestions from this study are as follows.

1. The teacher should investigate students' prior knowledge and experience and use them as guidelines for preparing the lesson to help them change alternative concept into scientific one.

2. The teacher should employ constructivist activities to encourage students to construct their knowledge by themselves and have more positive attitudes toward learning force and motion.

3. To change the human-centred veiwpoint, the teacher should encourage students' practice in various activities and experiments to perceive or feel the existence of some abstract forces e.g. gravitational force, frictional force and reaction force, etc.

4. To change the impetus concept, the teacher should help students keep clear that force exerted from the interaction between objects – if there is no interaction, there is no force – and explain that the physics property embeds in the moving object is momentum, not force.

5. Teacher preparation programs should improve content preparation for preservice physics teachers and test their content knowledge before they perform the teaching practice in schools or graduate.

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