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STUDENTS' MENTAL MODELS ABOUT THE RELATIONSHIP BETWEEN FORCE AND VELOCITY CONCEPTS

Özgür Özcan, Sevim Bezen

Abstract. *Mental models help us understand the formation of objects, the development of the process and to state an opinion about it. Therefore, in this study, we understand a mental model as 'an internal representation, which acts out as a structural analogue of situations or processes. Although mental models are the representations of knowledge created during a cognitive activity, they are also reflective of personal beliefs. This study intends to exhibit prospective teachers' mental models for the arguments they use in describing the relations between the concepts of force and velocity. In line with this intention, the study employs phenomenographic study method. This study has found that prospective teachers have three different mental models for relating the concepts of force and velocity. One of them is a scientific model called "Newtonian Model". The other two models were determined to be unscientific models and called "Aristotelian Model" and "Impulsive Model" respectively. By bringing these models into light, we were informed of the scientific and unscientific arguments the prospective teachers used in interpreting the relationships between force and velocity. In other words, this study exhibited how prospective teachers organized and structured their knowledge about these concepts.*

Key words: *force and velocity concept, knowledge structure, mental models, prospective teacher.*

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Introduction

Force and velocity are among the concepts individuals encounter frequently in daily life. Individuals have incorrect or inadequate knowledge about these concepts prior to formal education. Despite the fact that studies concerning the concepts of force and velocity within the scope of mechanics course are available in the literature, studies especially on students' inadequate, incorrect or correct knowledge in relation to these concepts have been under focus in recent years (Özdemir, 2007). A review of the literature demonstrates that the studies are more concerned with researching students' learning difficulties and their misconceptions in terms of mechanics, and it was found that students had difficulties in making sense of the concepts in mechanics (Champagne, Klopfer & Anderson, 1980; Clement, 1982; Hapkiewicz, 1999). Students' statements such as "there is a force continuously influencing an object in the direction of the object's movement in horizontal throwing movement" are the examples for students' misconceptions (Sadanand & Kess, 1990) because it is known that the teaching of these concepts forms the basis. Yet, research has shown that students of all levels have difficulty in understanding the concepts of force and velocity (Arons, 1990; Gagliardi, Gallina, Guidino & Piscitelli, 1989; Mcdermott, 1990). It is pointed out that firstly students' mental model should be determined so that meaningful learning can occur in the teaching of such concepts as force and velocity in which difficulty is experienced (Duit & Glynn, 1996). Mental models express the internal representations that students form in order to make sense of concepts (Greca & Moreira, 2000). Beside expressing the representations of concepts and assuring the description of scientific phenomena, mental models also assure that the formations in individuals' minds are uncovered (Coll, 1999; Jansoon & Somsook, 2009). Rebello, Itza-Ortiz and Zollman(2003), for instance, determined students' mental models for Newton's second Law, and they found two different mental models called Newtonian and Aristotelian models.

Mental models help us understand the formation of objects, the development of the process and to state an opinion about it (Harrison, 2001). Models - which arise with the gathering of objects and ideas- can be developed and enriched (Gobert & Buckley, 2000; Ingham & Gilbert, 1991). Although mental models are the representations of knowledge created during a cognitive activity, they are also reflective of personal beliefs (Greca & Moreira, 2000). Besides, since they also contain knowledge obtained through individuals' own experience, they are dependable and are therefore powerful sources of data (Harrison & Treagust, 1996). Only one study was encountered in the literature which determined mental models by associating the concepts of force and velocity. The study conducted by Hrepic, Zollman and Rebello (2010) mentions the concepts within the framework of mechanics and determines students' mental models. Yet this study, as different from the one conducted by Hrepic et al. (2010), analyses the models created from prospective teachers' views in more depth, and makes some additions. It is believed, that associating the concepts of force and velocity -which are difficult to make sense of at any level- and determining prospective teachers' mental models with this study will contribute to the field. Additionally, this study aims to reveal how prospective teachers conceptualise, perceive and understand the phenomena they experience on the basis of phenomenographic study through mental patterns according to qualitative study. Studies conducted on the basis of phenomenographic methods uncover differing experiences individuals have in relation to different phenomena (Marton, 1981). This method of research is used in the field of education in determining what students or prospective teachers understand from the same concept and what they perceive about it (Wihlborg, 2004). Within the scope of this study, the aim is to determine prospective teachers' mental models for associating the concepts of force and velocity because it is thought that they interpret and make sense of the knowledge correctly or incorrectly even if they have completed the Mechanics course successfully (Taber, 1994). Therefore, in this study we focused on students' understanding of the relationship between force and velocity concepts of mechanics using "mental models" as a theoretical framework. Then, our research questions were as follows:

1. What models do prospective teachers have in relation to associating the concepts of force and velocity?
2. How do the models distribute in different contexts?

Methodology of Study

This study intends to exhibit prospective teachers' mental models for the arguments they use in describing the relations between the concepts of force and velocity. In line with this intention, the study employs phenomenographic study method. Individuals' perceptions of and their mental models concerning a certain subject or concept can be determined through phenomenographic study method (Corpuz & Rebello, 2011; Wihlborg, 2004). Moreover, phenomenography aims to determine how individuals perceive and understand the happenings and objects they encounter through mental patterns in a qualitative study (McCosker, Barnard & Gerber, 2003). The study was conducted in the Spring Semester of 2014-2015 academic year with 22 second year prospective teachers, who had taken and achieved the Mechanics I and Mechanics II courses.

Sample of Study

The study group was composed of 22 prospective teachers who have taken and achieved Mechanics I and II courses. The participants were determined through criterion sampling –a method of purposeful sampling (Yıldırım & Şimşek, 2013). The criterion is whether or not prospective teachers have passed Mechanics I and II courses. Prospective teachers' cumulative grade point averages (CGPA) were labelled as high, middle and low. Accordingly, almost equal number of prospective physics teachers of each level of achievement was interviewed. Thus, 8 prospective teachers with academic CGPA of 2.5 and above, 8 prospective teachers with academic CGPA of 2.5-2.0, and 6 prospective teachers with academic CGPA of below 2 were interviewed (Table 1).

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Table 1. Participant selection.

Statements and subscales	Selection criteria	Number of students
Students' physics achievement	CGPA >2,5 [high]	8
	2,5 ≤ CGPA ≤ 2,0 [medium]	8
	CGPA < 2,0 [low]	6

Instrument

Four open-ended questions (paper-and-pencil questionnaire) were used as the instrument of data collection in the study so as to determine prospective teachers' mental models. The questions were prepared by reviewing the literature and relevant course books. The difficulty level of the questions prepared by the researchers and their suitability to the students' level was assured with the analyses performed by two experts who had had studies on physics and physics education. These two experts evaluated several proposed questions for their content validity. So, four open-ended questions were selected for inclusion in the study as a data collection tool via semi-structured interviews. The contexts to be used to determine the mental models in relation to force and velocity are as in the following:

Contexts1a, 1b, 1c: Motion with constant velocity
Contexts 2a, 2b, 2c: Freely falling object
Contexts 3a, 3b: Motion in two dimensions (projectile motion)
Contexts 4a, 4b: Motion with constant acceleration

Data Collection and Analysis

Semi-structured interviews were conducted one-to-one in the classroom setting by one of the researchers. The interviews with prospective teachers lasted 30-35 minutes on average, and were recorded with a voice recorder. The participants were allowed as much time as they demanded to think about the questions, and they were never led by the interviewer. The interviewees were called by their name, but they were coded under different names while analysing the data. Finally, the data obtained from the interviews were transcribed.

Prospective teachers' mental models for relating the concepts of force and velocity were created by following an inductive way. In analysing the data through phenomeographic method, firstly the data were encoded by the researcher and by the experts and were divided into categories. With the categories distinguished, how prospective teachers perceived and described an activity or a concept was found. Besides, care was taken to keep the number of categories as small as possible, and it was considered important for the categories to be reflective of the phenomenon (Didiş, Özcan & Abak, 2008). The model elements arising in consequence of data analyses which were done two times by the researchers at different times were compared and approximately 85% agreement was reached. The cases for which agreement was not reached were re-evaluated. The evaluations continued until full agreement was reached on the model elements. The models and the elements constituting the models are shown in Table 2. The elements of the models shown in the Table 2 are the minimum model elements for the models. For a model to be evaluated as a Newtonian model, for instance, it should contain at least three elements. That is to say, the model can be considered as a Newtonian model when these five elements come together. It is also true for other models. Apart from that, because fragments of knowledge which cannot produce a model cannot create a structure, such cases were coded as "No model".

Table 2. Models and model elements.

Models	Model Elements
Newtonian Model	• When net force is constant, velocity increases • When net force is constant, velocity decreases • $\vec{F}_{net} = m.\vec{a}$ When velocity is constant, force is zero

Models	Model Elements
Aristotelian Model	• If net force increase, speed increases • If net force decreases, speed decreases • If net force is constant, speed is constant • $\vec{F} = m.\vec{v}$
Impulsive Model	• The effects of force is active on an object also in absence of contact • Throwing force represents the direction of movement of an object • Net force is in the direction of throwing

Description of the Course Setting

The participants included in the study were taught the subjects in which the concepts of "force and velocity" were included in the courses Mechanics I and Mechanics II in the first year of university education. Both courses were taught in traditional method. In other words, instructors used teacher-centred methods in teaching the courses. They also made use of such techniques as analogy, asking questions and giving examples from daily life. Additionally, discussions containing quotations from the lives of scientists also enriched the classes. Teachers encouraged students to ask questions, and thus made sure that they participated in classes and raised their motivation. In this way, the teachers facilitated students' learning and focused their attention on the lesson.

Reliability, Validity and Ethical Issues

Special care was taken in this study with ethical issues. For these purposes, it was made sure that all of the participants took part in the study on the basis of willingness. It was pointed out to the participants prior to the interviews that they could quit the interviews whenever they wished. Whereas the interviewers chose the place of interviews, the prospective teachers decided on the time of interviews. It was explained to the prospective teachers that the study results would only be used for scientific purposes and that the participants' names would be kept confidential. At the end of each interview the participants' statements were summarised briefly, and thus participants' approval was obtained.

Validity and reliability analyses were performed for the study. Member checking and experts' opinions were used for internal validity (Yıldırım & Şimşek, 2013). The data collected through interviews were firstly analysed by the researchers separately to attain internal reliability and thus the model elements were determined. The models determined from the researchers based on these model elements were then compared with the results of the analyses performed by an expert out of the study. The agreement between the two evaluations was checked. 85% agreement was reached at the first stage and then full agreement was reached through discussions. Each stage was described in detail in order to increase the external validity. So, the opportunity was provided to perform similar study from other researchers in different settings. Finally, the following points were taken into consideration to increase the external reliability: (1) data collection and analysis, (2) determining the participants, and (3) social setting in which the study was conducted.

Results of Study

It was found that prospective teachers used three different mental models in relating the concepts of force and velocity. Undoubtedly, apart from the models, knowledge fragments which did not construct a model were also used by prospective teachers. Since they did not construct a model, they were encoded as "No Model" in this study.

Newtonian Model

The first model, which is called as "Newtonian Model", is a scientifically accepted model. Thus, it was determined as a model that prospective teachers who made scientific explanations by using such concepts as "when net force is constant, velocity increases"; "when velocity is constant, force is zero", " $\vec{F}_{net} = m.\vec{a}$" had. That is to say, prospective teachers who had this model used these elements coherently while describing the relationships

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between force and velocity. Prospective teachers' conceptual framework was created on the basis of the following operational definitions. The definitions that the prospective teachers available in this model used were as in the following:

- If the net force applied on an object is constant, the object accelerates.
- If the sum of forces acting on an object moving at a constant speed on a frictionless surface is zero, the object continues to move at a constant speed.
- If an object slows down over time, there is net force on the object.

Figure 1 shows prospective teachers' use of Newtonian Model for all contexts. All of the prospective teachers chose Newtonian Model for context 3a, which was followed by context 1a chosen by 18 prospective teachers. Contexts 2b, 2c, and 3b were not however chosen by any participants. On the other hand, because full conceptual frameworks could not be formed by some teachers' statements, they were marked as "No Model".

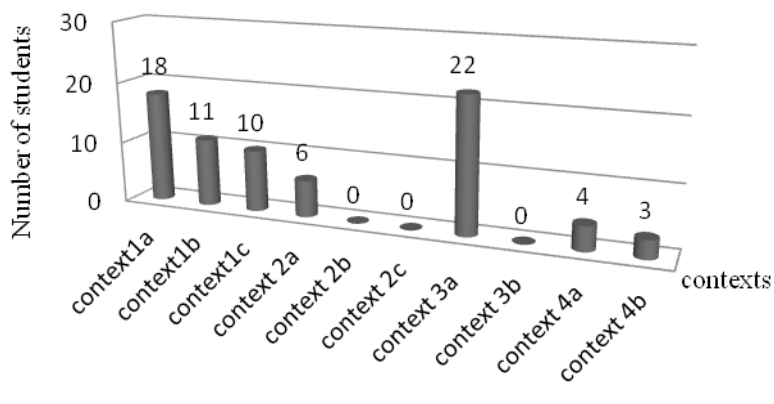

Figure 1: The use of Newtonian model across contexts.

The quotation from an interview with a prospective teacher having a Newtonian model is reported as in the following:

> **Interviewer (I):** A child continues his movement on a plain surface by slowing down without using the pedals and brakes of his bicycle. What can you say about the movement of the bicycle?
> **Student15 (St15):** The bicycle will have a straight and slowing down movement with the effect of frictional force.
> **I:** Do you mean that the speed of the bicycle will decrease?
> **St15:** Yes, I do. It will decrease because of friction.
> **I:** So, what can you say about the forces acting on the bicycle in this process?
> **St15:** The bicycle slows down but the force $\vec{F}\vec{F}$ applied does not change. Because it known from the formula $\vec{F}_{net} = m.\vec{a}$ that acceleration and mass do not change, I can say that force will not change.
> **I:** Can you explain why acceleration and mass do not change?
> **St15:** Acceleration is constant in slowing down motion with constant acceleration. And because the child's weight does not change, the mass is constant.
> **I:** Suppose that the speed of the bicycle was constant. What would you say for the net force applied on the bicycle in this case?
> **St15:** Because acceleration is out of question when speed is constant, [net] force will be zero.

St15 said that a bicycle continuing moving on a plain surface by slowing down will have a smooth slowing down movement under the influence of friction force, and that the bicycle will slow down due to the friction. The students also stated that the friction force between the wheels of the bicycle and the ground would remain constant since the weight of the child on the bike did not change, and thus a constant friction force would act on the bicycle. Thus, it was emphasised that because the acceleration of a smoothly slowing down object was constant, the force applied to the bicycle would not change. Therefore, St15 meant that net force would not change in a smoothly slowing down movement. An explanation similar to St15 was offered by St17, who had a Newtonian model. St17 stated his view as "when speed is constant, the acceleration of the object is zero, and therefore, the net force acting on the object is also zero". An examination of the explanations offered by those prospective teachers, shows that their mental model is Newtonian Model. That is to say, the prospective teachers having this mental model have used the operational definitions related with Newton's second law in a manner that is parallel to scientific knowledge. Besides, these prospective teachers have a conceptual framework triggering their use of scientific models in explaining physical activities. A part of the interview with St8, who had similar thoughts but who stated a different view is as in the following:

I: A ball is thrown upwards in question 2a. Can you show the direction of net force acting on the ball moving upwards in drawing?
St8: Because gravity force is bigger at the time when the ball is thrown upwards, the net force will be downwards.
I: So, what can you say about the speed of the object?
St8: while the ball goes up, its speed decreases.
I: Why?
St8: Because when the ball reaches the peak, its speed should fall to zero. I can make this interpretation since I know that the ball's speed should be zero at the maximum height it can reach.
I: So, what can you say about the force affecting a ball dropped from a certain height?
St8: The object has free fall, and only gravity force is influential.
I: What can you say about the speed of the object?
St8: Because there is a downward net force, I think it will speed up and hit the ground.
I: As is clear from Question 4, the oil leaking from a car at constant intervals leaves a mark on the road. How do you relate the force acting on the car with its speed in relation to the movement of the car from the west to the East?
St8: The car moves by smoothly speeding up. In movement with smooth speed, acceleration is constant, therefore, force is also constant.
I: What about the speed of the car?
St8: Although the force applied to the car is constant, the car is speeding up.
I: What would the speed be if the force applied to the car is doubled?
St8: An increase in speed would be observed but the increase in speed would not be double because acceleration is doubled according to the formula $\vec{F}_{net} = m.\vec{a}$, but when acceleration replaces in the formula $X = \frac{1}{2}at^2$, an increase is observed in speed, but it is not double.

St8 said that the direction of gravity force acting on a ball thrown upward would be downward beginning with the time of throwing. In addition to that, the student said that the speed of the ball would fall as it rose. According to the statement made by the student, in order for its speed to be zero at the maximum height, the speed should decline smoothly while moving up. Additionally, the same prospective teacher continued his comments by saying that only gravity force was influential in a ball having free fall, and that the ball would speed up and hit the ground because the net force acting on the object was downward.

Aristotelian Model

The second model, which we call "Aristotelian Model", is an unscientific model. Basically, the model contains such model elements as "if net force increase, speed increases", "if net force decreases, speed decreases", "if net force is constant, speed is constant" and "$\vec{F} = m.\vec{v}$". The reason for why it is considered to be an unscientific model is that the above mentioned model elements are used in prospective teachers' explanations. Prospective teachers having Aristotelian Model set up direct associations between force and velocity, and they used the elements coherently in all contexts. The conceptual framework of the prospective teachers having Aristotelian Model as their mental model was formed on the basis of the following operational definitions:

- If the speed of an object increases, the force acting on it also increases over time.
- If an object slows down over time, the force acting on it also decreases over time.
- If a constant force is active on an object, the speed of the object is also constant.

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Figure 2 shows prospective teachers' use of Aristotelian Model for all contexts. Accordingly, almost all of the prospective teachers have Aristotelian Model in contexts 4a and 4b. However, none of the teachers have this model in contexts 2a, 2b, 2c, and 3a. The prospective teachers either used two other models in these contexts or they were in the "No Model" situation since they could not form a conceptual framework.

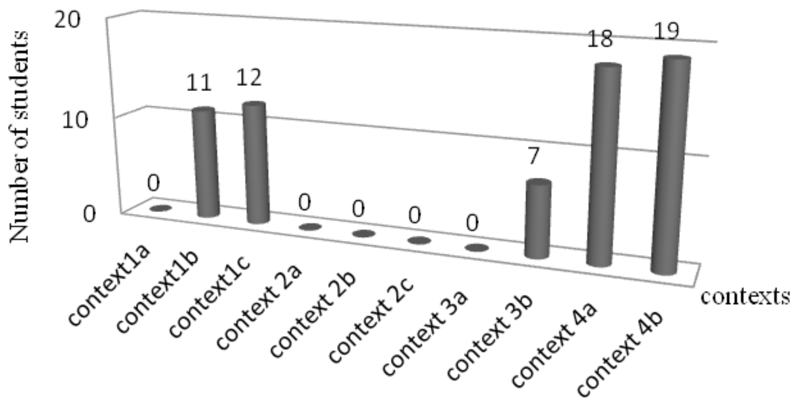

Figure 2: The use of Aristotelian model across contexts.

The quotation from an interview with a prospective teacher having an Aristotelian Model is reported as in the following:

I: A child continues his movement on a plain surface by slowing down without using the pedals and brakes of his bicycle. What can you say about the next movement of the bicycle?
St5: Speed will remain constant since the force will remain constant with the effect of inertial force. The bicycle will have movement with constant speed.
I: How does the force change if the speed is constant?
St5: As is clear from the formula $\vec{F} = m.\vec{v}$, if the speed is constant force does not change, either because they are directly proportional.
I: Do you think that force and velocity are directly proportional?
St5: Yes, I do.
I: If the speed of the bicycle decreased, how would force change?
St5: Since the speed of the bicycle would decline, the force applied would also decline in direct proportion to speed.

By using the formula $\overrightarrow{F} = m.\vec{v}$, St5 stated that force and velocity were directly proportional. Because St5 thought that the force acting on a bicycle continuing its movement on a plain surface by slowing down was constant with the effect of inertial force, he said that speed would remain constant and thus the bicycle would move at a constant speed. St5 concluded that force would be constant if speed was constant and that force would decrease if speed decreased from the formula $\vec{F} = m.\vec{v}$. Some of the prospective teachers having the same conclusions as St5 said that force and velocity were directly proportional on the basis of the formula $\vec{F} = m.\vec{a}$ and $\overrightarrow{V} = \vec{a}.t$. St11, who agreed with St5 and had Aristotelian Model, used similar operational definitions in different statements. A part of the interview with St11 was as in the following:

I: Can you draw the force or forces acting on a ball thrown to the right at speed V in question 3 Figure II?
St11: Throwing force to the right and gravity force downwards are active on the ball.
I: What can you say about the forces acting on a ball which has free fall and on a ball which is thrown to the right at the speed of V by comparing the two forces?
St11: Resultant force acts on the ball thrown to the right at the speed of V. Because forces are divided into its components in resultant force and because there is a sine multiplier, the value of the force decreases. The reason for this is that sine can be 1 at the maximum, and when we multiply a number with a number smaller than one, its value

becomes smaller. Therefore, force acting on a ball that has free fall is bigger.

I: On comparing the speed of the balls, what can you say?

St11: Since only gravity force is active on the ball having free fall, the ball moves faster. Force of throwing to the right acting on the other ball reduces the speed of the ball. Apart from that, since force and velocity are directly proportional, the ball having free fall moves faster.

The model elements "if force increases, speed increases; if force decreases, speed decreases and $\vec{F} = m.\vec{v}$." were confirmed in accordance with the views of St11 and other prospective teachers holding the same views. On comparing the forces acting on a ball thrown to the right and on a ball having free fall, St11 said that the force acting on the ball thrown to the right was smaller. The reason was that resultant force was active on the ball thrown to the right with the effect of throwing force and gravity force and that there was a sine multiplier here during the resultant force. Apart from that, because the force acting on the ball having free fall would be bigger, it was stressed that the speed of the ball would be bigger, and it is also clear here that there is a conceptual framework demonstrating that force and velocity are directly proportional. St11 made the following comments on context 4:

I: As is clear from the question, the oil leaking from a car at constant intervals leaves a mark on the road. Now that we know the car is moving from the West to the East, how can you relate the speed of the car with the force acting on the car?

St11: The car speeds up. That is to say, the car has accelerated. According to $\vec{F} = m.\vec{a}$, acceleration and force are also directly proportional. For the car, to speed up, acceleration should increase according to the formula $\vec{V} = \vec{a}.t$, and thus the force applied to the car should increase according to $\vec{F} = m.\vec{a}$.

I: If the force applied to the car is doubled, what happens to the speed?

St11: According to the formulas $\vec{F} = m.\vec{a}$ and $\vec{V} = \vec{a}.t$, acceleration is doubled if force is doubled. If acceleration is doubled, speed is also doubled. The variable of time is always constant here.

I: Do you mean that force and velocity are directly proportional according to the formula $\vec{F} = m.\vec{v}$?

St11: Yes, I do.

It was found that St11 made incorrect interpretations of the formulas of physics he used in his explanations of acceleration of the car although his approach was correct at the beginning. St11, who associated force and velocity with the formula $\vec{F} = m.\vec{v}$, emphasised that speed stemmed from the gradual increase of the force applied to the car because the distance between oil drops widened more and more. Thus, it was observed that the idea of "force increases in parallel to speed" was dominant in the conceptual frame of St11. The idea underlying the arguments used by prospective teachers having Aristotelian Model is that force and velocity are directly proportional. In other words, the conceptual framework of the prospective teachers having this mental model was shaped around elements reflecting the model.

Impulsive Model

This model, which is called "Impulsive Model", is also an unscientific model. In this model the relationships between force and velocity are expressed through model elements which are coded as "the effect of force is active on an object also in absence of contact", "throwing force represents the direction of movement of an object", and "net force is in the direction of throwing". Prospective teachers' statements show that Impulsive Model is not a scientific model and that the elements they use in explaining the model are coherent with the contexts. The conceptual framework of the prospective teachers having this model as their mental model was formed on the basis of the following operational definitions:

- Force acting on an object is active along its movement.
- Throwing force acting on an object expresses the direction of the movement of the object.
- Net force acting on an object is in the direction of throwing force.

Figure 3 shows prospective teachers' use of Impulsive Model for all contexts. Accordingly, most of the prospective teachers' mental model was Impulsive Model in contexts 2b and 2c. Prospective teachers who did not have this mental model answered the questions by using the other two models in contexts 1a, 1b, 1c, 3a, 4a, and

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4b. Apart from that, "No Model" was encoded for situations in which prospective teachers' answers did not form a conceptual framework.

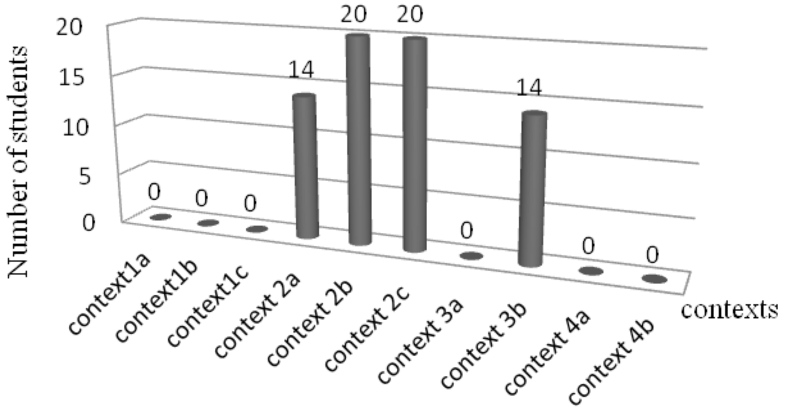

Figure 3: The use of Impulsive Model across contexts

The quotation from an interview with a prospective teacher having an Impulsive Model is reported as in the following:

> **I:** As is clear from Question 2, a ball is thrown upward. Can you represent in drawing the net force acting on the ball while it is moving upwards?
> **St7:** Because throwing force is bigger than gravity force, the object moves upward, and the net force acting on it is also upward.
> **I:** What can you say about the speed of the object?
> **St7:** Because the ball will stop at a point while going up, and then will begin to move downward, I think its speed must be reduced.
> **I:** What is the shape of the net force acting on the ball while it is moving downward?
> **St7:** Because gravity force and throwing force are in the same direction, net force will be the sum of the two forces. Here, throwing force shows the direction of movement of the object. In consequence, net force representation is downwards.
> **I:** What about the speed of the object?
> **St7:** Logically, the object will speed up while moving downward.
> **I:** Can you explain in drawing the net force acting on the object when it is at the climax? And what can you say about the speed of the object at this point?
> **St7:** When the ball is at the peak, throwing force and gravity force are equal because the ball is at the peak. The intersection of these two forces which are equal is zero. And the speed is zero at the maximum point that the object can climb, and it stops at the top.
> **I:** And can you explain in drawing the force acting on the ball dropped from a certain height and on the ball thrown to the right at the speed of V?
> **St7:** Only gravity force is active on the ball having free fall, and throwing force and gravity force are active on the ball thrown to the right at the speed of V. Because there is resultant force on the ball thrown to the right at the speed of V, the ball moves with a bigger force. Because there is more than one force.
> **I:** What can you say about the speed of the balls?
> **St7:** Because two forces are active on the ball thrown at the speed of V, it moves faster.
> **I:** Is throwing force active on the object all through the movement?
> **St7:** Yes, it is. Throwing force acts on the object all through its movement and it is influential in its movement.

During the interviews, St7 stated that throwing force acting on a ball thrown upward was bigger than gravity force and that net force acting on the ball was in the direction of throwing. St7 attributed the decline in the speed of the ball after a while to the gradual reduction of throwing force. St7, having explained that the ball would begin to move downward after it reached a certain height, stressed that net force would be downward since gravity force and throwing force were in the same direction in this case. According to the students' explanations, the effects of throwing force applied to the ball will be active all through its flight. The force will repel the ball during its movement, and thus it will keep moving. St7 also emphasised that because the repelling force and gravity force acting on the ball would be active together on its way back (downward movement of the ball), the speed of the ball would increase during its movement downward. The student also pointed out that throwing force and gravity force would be equal the maximum height it reaches, and thus it would remain suspended in the air for a short while since the resultant force was zero.

No Model

It was found that prospective teachers also had statements that did not belong in any of the three models described. When their answers were inconsistent and did not form a pattern, the answers were not fitted in a model. Such answers were called knowledge fragments and were classified as "No Model".

Discussion

This study has found that prospective teachers have three different mental models for relating the concepts of force and velocity. One of them is a scientific model called "Newtonian Model". By bringing these models into light, we were informed of the scientific and unscientific arguments the prospective teachers used in interpreting the relationships between force and velocity. In other words, this study exhibited how prospective teachers organised and structured their knowledge about these concepts. A scientific model which we call Newtonian Model, for instance, shows that the model emerged with coherent use of the elements composing this model and the ties between them. In Aristotelian Model -another model- however, it was found that prospective teachers used model elements such as "if force increases, speed increases; if force decreases, speed decreases; if force is constant, speed is constant; and $\vec{F} = m.\vec{v}$" coherently. In the "Impulsive Model", prospective teachers used model elements such as "the effect of force is active on an object in the absence of contact, throwing force represents the direction of movement of an object, net force is in the direction of throwing force" in different contexts coherently. In this study, Newtonian and Aristotelian models in addition to the model we called Impulsive Model as different from nomenclature in the literature were also analysed in depth. In this study the students explained scientifically that a bicycle continuing to move on a plain surface by slowing down would smoothly slow down with the effect of friction and that its speed would gradually decline. The mental model of the prospective teachers making this explanation was determined as Newtonian Model. That is to say, it was emphasised in prospective statements that the bicycle would have a slowing down movement with the effect of a net force since constant force would always cause constant acceleration. This result was put forward by prospective teachers with the help of such model elements as "if net force is constant, speed decreases, and $\vec{F}_{net} = m.\vec{a}$" stated by them. The findings obtained in Itza-Ortiz, Rebelo and Zollman (2004) are supportive of this result.

Prospective teachers also stated that force and acceleration would also be zero when speed is constant. A result in parallel to this was obtained in Yıldız, Büyükkasap, Erkol & Dikel (2007). Prospective teachers having Aristotelian Model said that the speed of a bicycle should be constant when the force acting on the bicycle was constant; and that force would decrease if speed decreased. In other words, prospective teachers meant that an object moving with the effect of a constant force would continue moving at a constant speed (Demir, Uzoğlu & Büyükkasap, 2012). It was found that the prospective teachers reached this conclusion with the help of the formula $\vec{F} = m.\vec{v}$. In the Impulsive Model, as opposed to the Newtonian Model, prospective teachers said that throwing force acting on a ball thrown upward would continue existing all through the movement of the ball. That is to say, force would continue to exist on the ball during its flight, and therefore the ball would speed up with the help of gravity force when it began to land. This result obtained is available in the literature as a misconception represented in the statement "a force is always active on a moving object in the direction of its movement (Sequeire & Leite, 1991). Additionally, prospective teachers said in relation to the question about a ball thrown to the right at the velocity of $\vec{V}$ that the speed in the direction of force would be bigger. That is to say, those prospective teachers having the Impulsive Model as their mental model wanted to explain that throwing force would be on the object all through the movement of the ball. Sadanand and Kess (1990, p. 533) also conclude that force in the direction of movement is effective in an object in motion. This conclusion can be said to be similar to the one reached in this study.

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Conclusions

It was found in this study that prospective teachers related the concepts of force and velocity and used their scientific as well as unscientific knowledge in modelling. It was found that prospective teachers offered explanations by predicting their knowledge and thus they exhibited their mental models. Norman (1983) argues that students uncover their mental models through correct, incorrect, incomplete and contradictory knowledge. This study also found that prospective teachers had three different mental models with their correct, incorrect, incomplete and contradictory knowledge. It may be said that the study will contribute to the literature by determining for the first time the mental models for prospective teachers' relating the concepts of force and velocity. The finding that prospective teachers cannot sufficiently explain the relationships between force and velocity with scientific knowledge makes us think that lecturers should lay more emphasis on teaching the basic concepts; because teachers of the future should have mental models in the light of scientific knowledge. In this respect, it may be said that lecturers should make use of such diverse teaching methods as concept maps and analogies while teaching, and that they should encourage students so that meaningful learning occurs. It was also concluded in this study that prospective teachers' mental models could be determined through semi-structured interviews. Although this study was conducted with prospective teachers, it is believed that determining the mental models for these concepts which are among basic concepts by working with primary and secondary education students would also be beneficial to the literature. It is believed that, with the help of mental models, lacking parts in the literature will be compensated and the development of teaching materials will be possible for use in the teaching process (Artun & Özsevgeç, 2014). Finally, it was concluded that it would be important to determine mental models of students of differing levels for other basic concepts in addition to the concepts of force and velocity.

Recommendations

It is extremely important to uncover prospective teachers' ideas, thoughts and views concerning the concepts of force and velocity -which are fundamental concepts- in terms of exhibiting their approach towards the concepts. Besides, determining their mental models for these concepts assures that we become informed of individuals' conceptual framework and their organisation of knowledge. In this way, it is also possible with these cognitive structures to be informed of misconceptions forming in individuals and individuals' understanding difficulty. In addition to that, it would be useful to be informed of the nature of mental models so that knowledge learnt can be meaningfully structured (Duit & Glynn, 1996). It is believed that prospective teachers' alternative thoughts would be transformed into scientific knowledge with such teaching and rich learning environments would be created by using different teaching strategies.

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