Utilizing a Laboratory Practical To Clear Up Urban High School Students' Misconceptions of Newton's Second Law: An Experimental, Action Base Research

Dennis Wairia

&

Patrice Juliet Pinder

Paper Presented at the 31st Regional Eastern Educational Research Association Conference, Hilton Head Island, SC, Feb. 20 -23, 2008

February 29, 2008

Utilizing a laboratory practical to clear up urban high school students' misconceptions of Newton's second law: An experimental, action base research

ABSTRACT

This activity discusses a unit exercise in which a physics practical was implemented during a laboratory session. The lab practical design was centered on Newton's Second Law. The practical was implemented in a high school setting. Further, through the administration of both a pre and post test we were able to assess the effectiveness of the lab practical treatment exercise. Essentially, students' performances before implementation of the physics practical (i.e. initial pre-test results) were compared to students' performances after successful implementation of the lab practical (i.e. post test results). Students performances before and after implementation of the lab practical gave some insight into the effectiveness of our implemented instructional unit (which was the physics laboratory practical). Moreover, results on the post test indicated the effectiveness of our instructional unit for high school students.

Key Words: force, velocity, Newton's Law

{Conference research paper, 3 references}

© Pinder & Wairia

Introduction & Theoretical Basis for Study

This paper discusses the implementation process of an instructional instrument in the form of a laboratory practical that was design to teach the concept of force acting on a body in motion and its velocity. The instructional instrument was based on Newton’s second law and was designed to assist students to understand the relationship between the force acting on a body in motion and its velocity. According to Newton’s second law, if a force acts on a body, it will accelerate, that is, change its velocity in the direction of the force. This force is directly proportional to the acceleration and it explains how a body will change its velocity if it is pushed or pulled.

In designing and implementing the instructional instrument the conceptual change viewpoints were held that students’ prior knowledge about phenomena often differs significantly from the knowledge to be learned (Dekkers and Thijs 1997). This view was evident in the pre-test results which indicated that students always think of force as an innate or acquired property of objects, which implies that forces are not seen as arising from an interaction between objects (Savinainen, Scott, and Viiri 2004). The students’ prior knowledge about a certain concept plays a major role in determining their learning outcomes. Similarly, research has shown that conceptual change teaching challenges students to modify or change their alternative conceptions for better scientific ideas (Hausfather 1992). Post-test results indicated that there was a substantial gain in the students’ knowledge about the relationship between force acting on a body in motion and its velocity. The study was carried out in three stages which were: pre-test administration, implementation of the instructional instrument, and the post-test administration.

Methodology and Materials

Sample size

The study involved a Physics teacher and eight 11th grade students. All eight students took the pre-test. During the implementation of the instructional instrument however, only six students showed up for the laboratory practical. The author was also present on the day of the lab practical, but the physics classroom teacher was more actively involved in the data collection process.

Pre-test Instrument

The pre-test was administered on February 24th 2006, and consisted of two tasks of five points each. In the first task, there was a brief statement which explained the relationship between force acting on a body in motion and its velocity. In this task, however, students were required to state whether the given statement was either true or false. Then they were required to support their position with an explanation as to why they chose either of the two choices.

The second task consisted of an extended response question. In this task, students were required to draw a motion diagram of a body being pulled by a string on a flat surface. They were then required to label the forces acting on the body while indicating the direction of acceleration and the net force.

Post-test Instrument

The post-test was administered on March 16 2006, a week after the implementation of the practical. The post-test consisted of five test items which were based on the relationship between the force acting on a body in motion and its velocity. The five items were similar to those that were in the pre-test. The maximum score for each item was five points. Below is a sample item from the post-test.

If you push a book in the forward direction, does that mean its velocity has to be forward? Explain.

Implementation of Laboratory Practical (the treatment which was given before the post test, but after the pre test administration)

Two groups each of three students participated in the implementation of the instructional instrument. In the two groups, each of the students played a different role. The first student attached one side of the string to the CD case and the other side to a cup that hung from the side of the table. On one side of the table a line was drawn to mark the start point; while on the other end, another line was drawn at a distance of 50 cm to mark the end point.

Next, one student placed the CD case at the start point and held it firmly while another student placed a marble inside the cup. As the student holding the CD case released it to move forward, another student recorded in the data table the time of travel from the start point to the end point. This step was repeated six times. After the practical, the students calculated the speed of the CD case between the two points and then recorded the speed in their data table. The step by step procedure for implementing the instructional instrument is outlined in the laboratory practical procedure below.

Laboratory Practical

***Objective**:* Student will understand that the force acting on a body in motion is always in the same direction as the velocity of that body.

Materials

- Graph paper
- A pencil or a marker pen
- CD case
- Cup or Pan for holding marbles
- Marbles or some weights
- Meter rule
- Thin string
- Timer or a stop watch

Procedure

1. Place the CD case on top of the table. Knot one side of the string and shut it inside the CD case. Tie the other end of the string to the cup, such that it hangs from the table as shown in the figure below.
2. Mark a start point on one side of the table with a marker. Mark an end point at a distance of 50 cm from the start point.
3. Place the CD case at the start point and hold it firmly. Another student is to place a marble on the surface of the cup.
4. The student holding the CD case will let it go, allowing it to move forward.
5. Another student is to record the time of travel on the data table from the start point to the end point.
6. Repeat steps 3-5 times with two marbles in the cup. Record the time. Repeat this step with additional marbles and record the result in the data table.
7. Calculate the speed in m/s.

8. Plot the data on a graph paper. Label y-axis “Speed” in m/s. Label the x-axis “Force” with the unit being the number of marbles.

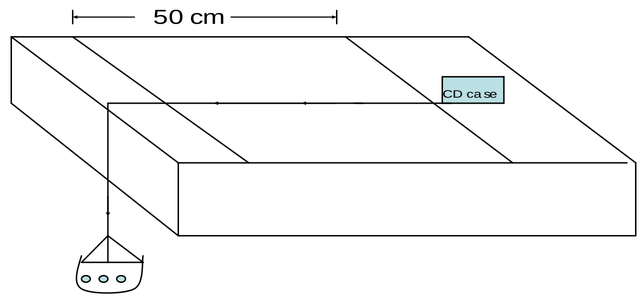
Table 1. Data table

Number of Marbles	**Time (sec)**	**Speed (m/sec)**
1		
2		
3		
4		
5		
6		

Questions:

1. What happens to the speed of the CD case when an additional marble is placed in the cup?
2. How would you describe the motion of the CD case from the start point to the end point?
3. Explain how the velocity of the CD case and the weight of the marble relate to Newton’s second law.

Practical: Diagram



Results

Practical

The table below shows results obtained after the laboratory practical from one of the two groups.

Table 2. Data from the Practical

Number of marbles	Time (sec)	Speed (m/sec)
10	1.56	0.32
11	1.00	0.50
12	0.90	0.55
13	0.84	0.59
14	0.79	0.63
15	0.78	0.64

After collecting the experimental data, the two groups drew a graph of the "number of marbles" on the x-axis and the "speed of the CD case" on the y-axis. A linear graph was obtained showing that there was a linear relationship between the number of marbles and the speed of the CD case. The frictional force was assumed to be negligible throughout the experiment.

After the practical, each of the group gathered together and responded to the three questions in the practical. For the first question which asked students to describe what happened to the CD case when an additional marble was put inside the cup, the two groups gave similar answers. They indicated that the speed of the CD case increased as the number of marbles placed inside the cup also increased. For the second question which required the students to describe the motion of the CD case after it was released, the first group stated that the CD case started sliding slowly and then the speed increased more until it reached the end point. The second group stated that the CD case had a constant motion throughout the entire distance.

For the third question which asked about the relationship between the weight of the marble and Newton's second law, the first group stated that as the number of marbles increased, the faster the CD case moved. This implied that the CD case accelerated when the weight was increased. Similar response was given by the second group. They stated that as the force was increased, the velocity of the CD case also increased.

Pre-test Results

Pre-test results indicated that only two students out of the eight students had prior knowledge of the relationship between the force acting on a body in motion and its velocity. The first student identified that if you pull an object, it moves forward and the velocity of that object will be in the same direction as the direction it is pulled. But for the second question, it was difficult for him to illustrate the forces that acted on the body in motion. This student had a score of eight out of the maximum ten points. The second student recognized that the force acting on a body in motion is the one that causes the body to move in the same direction at a certain speed, which is the velocity of that body.

The third student had mixed feeling about the relationship, because in one instance, he stated that the forces acting on a body can come from the same direction making the velocity of the body to be in the direction of those forces. But because sometimes these forces can come from different directions, the velocity of the body can also change the direction depending on the direction of each of the force acting on it. Similarly, four other students seemed not to understand the relationship between the force acting on a body in motion and its velocity. They argued that the velocity is always in a different direction from the force acting on a body. The reasons they gave were that when the body is moving, the wind blows it from different directions, and therefore, the velocity must also be in a different direction. The last student, however, seemed to have no idea about the relationship. He left a blank space for the first item and for the second item, he had a diagram that was very sketchy and one could not tell whether it represented forces or not. The teacher, however, gave him a score of one out of the maximum ten points. Table 3 below shows a comparison of the pre-test scores and the post-test scores in percentages for each of the physics students.

Table 3. Pre-test and Post-test scores for each of the Physics students

Student	Pre-test (%)	Post-test (%)
1	10	15
2	65	85
3	45	50
4	55	50
5	60	75
6	80	90
7	80	95
8	40	65

Post-test Results

Results from the post-test indicated that most of the students were able to understand the concept of Newton's second law better after performing the laboratory practical. For instance, one of the students stated that the velocity of a body and the force acting on it must always be in the same direction. For the question that required them to describe what happened to the CD case when it was being pulled, most of the students indicated that since the CD case was moving in the forward direction it was being pulled by the weight of the marble, therefore, they assumed that the force and the velocity must also be in the same direction. On the other hand, one of the students argued that the velocity of the CD case was in the same direction as the direction of the force because the string was attached to the CD case. Otherwise, the force and the velocity could have been moving in different directions.

Table 2 below shows the comparison of the mean and the standard deviation of the pre-test, the post-test and the practical. From the table, the mean score for the post-test was higher than that of the pre-test, an indication that most of the students were able to give a correct relationship between the force acting on a body in motion and its velocity.

Table 4. Mean Scores for the Pre-test, Post-test and the Laboratory Practical for each of the Physics Students

Pre-test	**Post-test**	**Lab**
Mean (SD)	Mean(SD)	Mean(SD)
54.36(23.06)	72.86(26.65)	74.33(18.4)

The mean score from the practical was also higher than that of the pre-test which indicated that the practical helped most of the students to give correct responses regarding the relationship between the force acting on a body in motion and its velocity. These results therefore showed that students' alternative conceptions were rooted in knowledge that was productive and effective, even if this was the case only in limited contexts (Dekkers, et al.1997).

Figure I: Comparison of the overall distributions of Students' Pre-test and Post-test Scores

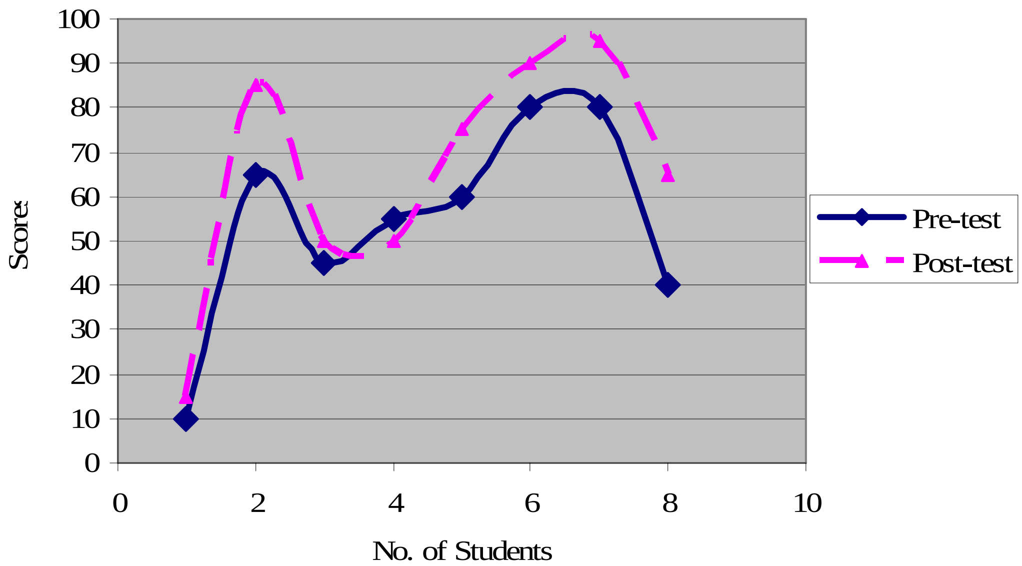


Figure 1 shows a comparison of the pre-test scores and post-test scores for each individual student. Results showed that the post-test scores were higher than the pre-test scores except for one student. This score is for one of the student who was missing during the laboratory practical. The second student who also missed the laboratory practical scored a little higher in the post-test than in the pre-test. Moreover, the higher post test scores were attributed to gains in students' knowledge of the physics concept taught by way of the laboratory practical.

Discussion, Limitations, and Conclusion

During the practical, some small adjustments were made due to the available materials within the school. For instance, the distance between the start point and the end point was reduced to 50 cm because of the size of the tables that were available in the laboratory. This affected the results of the practical; in that, it was difficult to measure the time of travel between the two points. Although the two groups obtained some results, they indicated that they had to either round up or round off some values to come up with the true measurements.

Additionally, the number of marbles was increased from 5 to 15 as initially indicated. This increase was due to the fact that the marbles that were available were of small sizes and a minimum of 10 marbles were required to make the CD case slide. There were only two groups of three students. This was due to the fact that only six students were present on the day of the laboratory practical. However, the two students who missed the laboratory practical were present on the day of the post-test. As a result, therefore, the post-test scores reliability was affected because the two students' scores from the pre-test and the post-test were identical. The laboratory practical was administered to help students to understand the relationship between the force acting on a body in motion and its velocity and the two students never gained that knowledge because they were absent from the laboratory practical.

For the other six students, results showed that there was a substantial gain after the laboratory practical, an indication that the laboratory practical helped in their understanding of the relationship between the force acting on a body in motion and its velocity. Further, students were able to realize that the force acting on an object is always in the same direction as the velocity of that object. Results also indicated that conceptual change teaching challenged students to modify or change their alternative conceptions for better scientific ideas (Hausfather 1992).

References

Dekkers, P. J. J. M., and Thijs, G. D. (1997). Making productive use of students' initial conceptions in developing the concept of force. *Science Education* 82(1), 31-50.

Hausfather, S. J. (1992). It is time for a conceptual change. A flexible approach leads to understanding. *Science and Children* 30(3), 22-23.

Savinainen, A., P. Scott, and Viiri, J. (2004). Using a bridging representation and social interactions to foster conceptual change: Designing and evaluating an instructional sequence for Newton's Third Law. *Science Education* 89(2), 175-195.