Testing Experimens

1 What are they?

In a testing experiment, students use an explanation or relationship to make a prediction of the outcome of the experiment. They also decide what additional assumptions they are making. Then they perform the experiment, and record the outcome. Based on the (dis)agreement of the prediction and the experimental outcome, and taking into account theoretical assumptions and experimental uncertainties, students have to make a judgment about the explanation or relationship that they are testing.

Students learn that when their prediction agrees with the experimental outcome, it only means that the explanation/relationship cannot be rejected. On the other hand, if their prediction does not agree with the experimental outcome, they have to either reject the explanation/relationship they tested, or reconsider the additional assumptions they made. Thus, the emphasis is on trying to disprove an idea

2 Why do you want to use them?

Testing experiments help provide or develop the following:

- Hypothetico-deductive reasoning
  Students learn to reason using the logic of : if, and, then, but,, therefore
- Epistemology
  Students learn to look for conflicting evidence, not supporting evidence and base their knowledge on evidence not on authority
- Assumptions versus explanations, and predictions
  In everyday language these terms are used interchangeably. Students learn to differentiate among assumptions, explanations, and predictions.
- Epistemic cognition
  Students learn to deal with situations when there is no right answer as the prediction might not work because of poor assumptions, or wrong explanation, or bad experimental techniques.
- Decision making
  Students learn to make decisions about representing data, considering outliers, deciding whether the explanation is rejected.
- Real data
  Students learn to deal with the complexities of real data.

3 How and where do you use them?

Testing experiments can be used in the following contexts:

- In a lecture.
  After developing a new idea, the instructor explains the experimental set-up to test the idea. Students make their prediction based on the idea they just developed. The instructor performs the experiment. Students then decide whether the idea developed is supported, or needs to be revised/rejected.
- In a laboratory.
  Students are given an experimental task in which they have to make a prediction about the result of the experiment using an explanation/relationship, perform the experiment and then make a judgment about the explanation/relationship based on the agreement of their prediction and the experimental outcome.
- As a design task in a laboratory.
  Students design their own experiment to test an explanation or a relationship.

4 What are some types of?

Testing experiments can be qualitative or quantitative. The experimental set-up can be provided to students who then make their prediction, or students can be asked to design their own experiment to test a certain explanation/relationship.

5 How do you score them?

We present an example of a testing experiment, a model solution and an example of student work. After this we present the rubrics we use, the scores on various abilities, and reasons as to why particular scores were given.

Sample design task:

Design an experiment to test the following rule: an object always moves in the direction of the net force exerted on it. You have a dynamics cart, dynamics track, a spring scale, masking tape, a bowling ball, a mallet, a small ball and a cushion to play with. You can also use any other common equipment available in the lab. Feel free to use your lab partner as an object!

Include in your report:

a) State what rule you are going to test.

b) Brainstorm the task and make a list of possible experiments whose outcome you can predict. Decide what experiments are best. Briefly explain why.

c) Write a brief outline of your procedure. Included a labeled sketch.

d) Draw a free body diagram of the object while the force is being applied on it.

e) Make a prediction about the outcome of the experiment. Make sure that the prediction is based on the rule that you are testing.

f) Perform the experiment. Record the outcome.

g) Did the outcome of your experiment match your prediction?

h) Based on your prediction and the outcome of your experiment, can you say that the rule is confirmed or not?

i) Use the hypothetico-deducto reasoning (the if-and-then-and/but-so construction) to summarize your experiment.

j) Decide why this activity was included in the lab. Think of two real life situations [and briefly describe them] in which you need to figure out things similar to this experiment.

Model solution:

We need to test if an object always moves in the direction of the net force exerted on it. The main idea is that one should try to design an experiment which rejects this rule. It is easy to find situations that can support the rule. The key word here is *always*. To be able to reject this statement, it is sufficient to devise one situation where this does not hold.

Possible experiments:

1. I will run towards my lab partner, and he will push me backwards with his arms. Prediction: I will be move backwards.

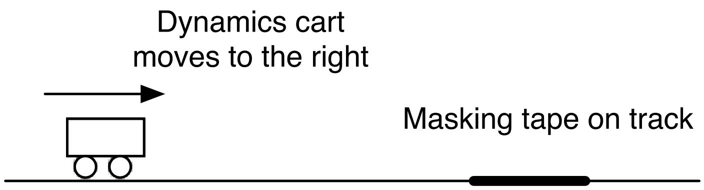
2. We will give the dynamics cart a small push so that it stars moving on the dynamics track to the right. We will also make a part of the track rough. Prediction: The friction force due to the rough track will be to the left, but the cart will start moving to the left.

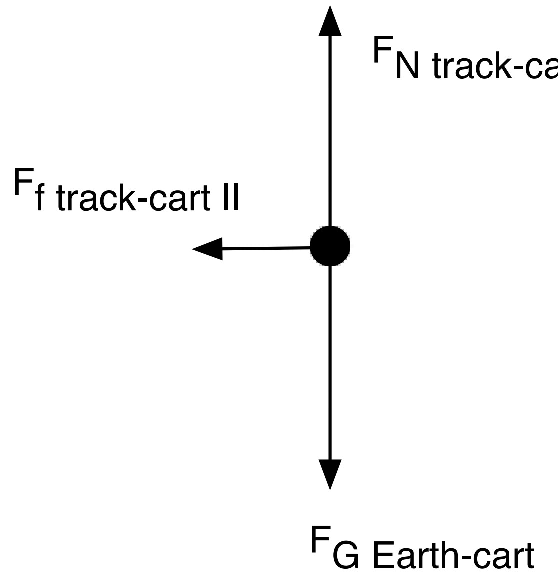
3. Drop a ball on the cushion. Prediction: The ball will start moving upwards.

We chose the second experiment from above. In the first experiment, we cannot exactly predict how my partner will push me. In the third experiment we are not sure how the magnitude of the force the cushion exerts on the ball is compared to the force the earth exerts on the ball.

We will give the dynamics cart a small push so that it stars moving on the dynamics track to the right. We will cover part of the track with masking tape so that it becomes rough. The free body diagram when the cart is on the rough part of the track is shown.

When the cart is on the rough part of the track, the net force is to the left. According to the rule we are testing, the cart should start moving to the left. The cart was initially





moving to the right. When it entered the rough track, it slowed down. It eventually came to a rest.

The outcome did not match our prediction. Since the outcome did not match our prediction , and we did not make any other assumptions, the rule is not supported.

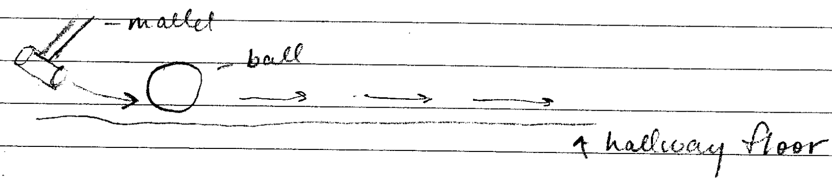
If an object always moves in the direction of the net force exerted on it,
And the dynamics cart moves to the right
Then the cart should move to the left when it rolls on the masking tape (since from my free body diagram, the net force due to the rough tape on the cart is to the left)
But the cart did not move to the left (my prediction was not confirmed)
So the hypothesis that an object always moves in the direction of the force exerted on it is not supported.

II) a) Rule we will test: an object always moves in the direction of the net force exerted on it.

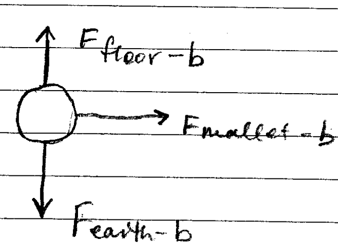
b) Possible Experiments:

1. Hit a bowling ball down a hallway w/ a mallet
2. Push a dynamics cart forward along a dynamics track
3. Push (gently) your lab partner forward

* The first choice would be the best because it would most clearly exhibit the rule we are trying to prove

c) 

d) We will hit the bowling ball (which is sitting at rest) in a forward direction, using a mallet.

e) 

f) The ball will move in the forward direction, the same direction as the net force exerted on it by the mallet, and in no other direction besides that one.

g) The ball moved forward in the exact direction of the net force we applied to it (by hitting it w/ the mallet)

h) YES - prediction was confirmed

i) Based on our prediction and successful outcome, we can say the rule is supported by experimental evidence.

j) If an object is sitting on a surface where friction forces can be assumed to be negligible ... and a net force is exerted in a certain direction ... then the ball will move in the direction of the net force applied to it.

III) a) We paused the video and "clicked" frame by frame to figure out how many frames it took each glider to reach the ending mark of 220 cm. (after starting @ 60 cm - total distance 160 cm).

b) We assumed the starting point would be 60 cm and the end point would be 220 cm. We also assumed friction between the glider and the track to be negligible.

c) On other paper

Scores using rubrics:

Scientific Ability	0	1	2	3
Is able to identify the relationship or explanation to be tested	No mention is made of a relationship or explanation.	An attempt is made to identify the relationship or explanation to be tested but is described in a confusing manner.	The relationship or explanation to be tested is described but there are minor omissions or vague details.	The relationship or explanation is clearly stated.

SCORE: 3

Scientific Ability	0	1	2	3
Is able to design a reliable experiment that tests the relationship or explanation.	The experiment does not test the relationship or explanation.	The experiment tests the relationship or explanation, but due to the nature of the design it is likely the data will lead to an incorrect judgment.	The experiment tests the relationship or explanation, but due to the nature of the design there is a moderate chance the data will lead to an inconclusive judgment.	The experiment tests the relationship or explanation and has a high likelihood of producing data that will lead to a conclusive judgment.

SCORE: 1. The experiment the student has chosen will likely lead to a conclusion that the net force is in the direction of motion. What the student needs to do is design an experiment where the net force and motion are not in the same direction.

Scientific Ability	0	1	2	3
Is able to use available equipment to make measurements	At least one of the chosen measurements cannot be made with the available equipment.	All of the chosen measurements can be made, but no details are given about how it is done.	All chosen measurements can be made, but the details about how it is done are vague or incomplete.	All chosen measurements can be made and all details about how it is done are clearly provided.

SCORE: 3

Scientific Ability	0	1	2	3
Is able to decide whether or not to confirm the prediction based on the results of the experiment	No decision is made to confirm or disconfirm the prediction.	A decision is made but it is not strongly based on the results of the experiment.	A decision is made based on the results of the experiment, but the reasoning is flawed.	A correct decision is made and is based on the results of the experiment.

SCORE: 3 The result of the experiment does confirm the prediction.

Scientific Ability	0	1	2	3
Is able to make a reasonable judgment about the relationship or explanation	No judgment is made about the relationship or explanation, or is not based on the results.	A judgment is made but it is based only on the degree of agreement between the results and the prediction.	A judgment is made based on the reliability of the experiment and the degree of agreement between the results and the prediction, but the reasoning is flawed.	A reasonable judgment is made based on the reliability of the experiment and the degree of agreement between the results and prediction.

SCORE: 1

Scientific Ability	0	1	2	3
Is able to make a reasonable prediction based on a relationship or explanation No attempt to make a prediction is made.	The experiment is not treated as at testing experiment.	A prediction is made but it doesnt follow from the relationship or explanation being tested, or it ignores or contradicts some of the assumptions inherent in the relationship or explanation.	A prediction is made that follows from the relationship or explanation and incorporates the assumptions, but it contains minor errors, inconsistencies, or omissions.	A correct prediction is made that follows from the relationship or explanation and incorporates the assumptions.

SCORE: 1

Scientific Ability	0	1	2	3
Is able to identify the assumptions made in making the prediction	No attempt is made to identify any assumptions.	An attempt is made to identify assumptions, but most are missing, described vaguely, or incorrect.	Most assumptions are correctly identified.	All assumptions are correctly identified.

SCORE: 2

Scientific Ability	0	1	2	3
Is able to communicate the details of an experimental procedure clearly and completely	Diagrams are missing and/or experimental procedure is missing or extremely vague.	Diagrams are present but unclear and/or experimental procedure is present but important details are missing.	Diagrams and/or experimental procedure are present but with minor omissions or vague details.	Diagrams and/or experimental procedure are clear and complete.

SCORE: 2