# A Learning Study science case in H.K.
# "*Action and Reaction*"

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# Outline

- Science (S.1-3) Curriculum
- The research team
- The learning difficulties of the students
- The teaching strategies and the pattern of variation
- Evaluation of the learning outcomes
- What does the research team learn ? What will be done ?



# Science (S1-3) Curriculum

*Thematic / STS approaches*

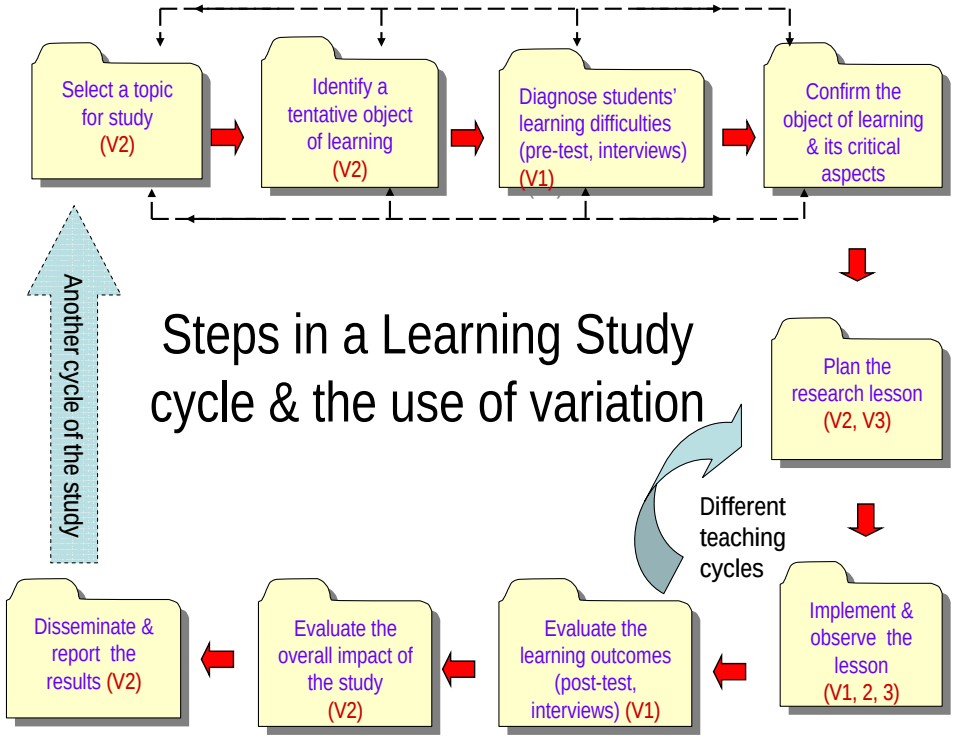
- Unit 9 – Space Travel
  - Force, friction, gravity, **launching of a rocket**, life of an astronaut in space and space exploration.
- Unit 11 – Sensing the Environment
  - How we see: functions of main parts of the eye, limitations of our eyes, eye defects
  - How we hear: the production and transmission of sound: functions of main parts of the ear, audible range and sound level, effects of noise pollution: protection of our ears
  - The brain and our senses: interpretation of sense signals
  - Effects of drugs and solvents on our senses

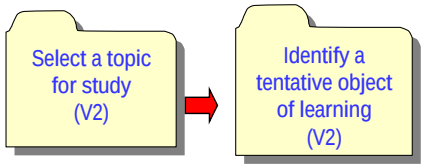
**http://resources.edb.gov.hk/cd/science/en/syllabuses/science_s1-3/synopses/is_syll_e.zip**



# The Research Team

- Two researchers from the Hong Kong Institute of Education
- Five teachers from the school
  - the science panel chairman
  - an I.T. teacher
  - a physics teacher
  - a chemistry teacher
  - the chemistry panel chairman



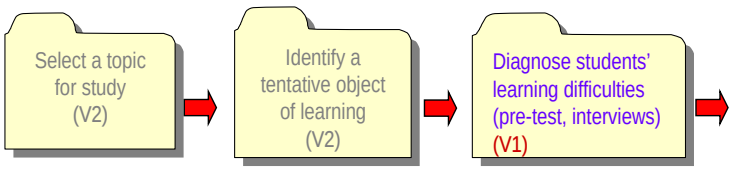




V2: Variation in teachers' understanding of what the most worthwhile object of learning is & ways of handling it

"Action & Reaction" was proposed by the teachers as the object of learning

- difficult to teach
- misconceptions
- one of the fundamental concepts for the learning of other mechanics topics






V1: Variation in students' understanding about the topic

- What do the students know already?
- What is/are difficult for them to learn about the topic?

**Pilot test and Pilot Interview:**

- **Two Secondary 2 students**
- **Five Secondary 3 students**
- Students were asked to answer a pilot test paper.
- In the interview, the researchers from HKIEd asked students to explain their answers.



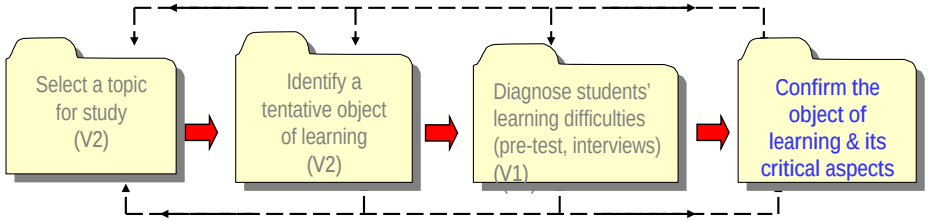
# Findings from Sec. 2 students

- A common misconception:
  - There must be a force acting on a moving object in the direction of motion
- Had no idea what the action and the reaction were.

# Findings from Sec 3 students

- Did not know the action and the reaction
  - **must be** equal in magnitude
  - **must be** opposite in direction
- There could be an action but no reaction.
- They were confused by the weight, the friction and the reaction force.
- They seldom had chance to make scientific reasoning in science lessons.






## The Object of Learning

**To infer the relationship between action and reaction based on the observations from some linear motion experiments**

## The Critical Features

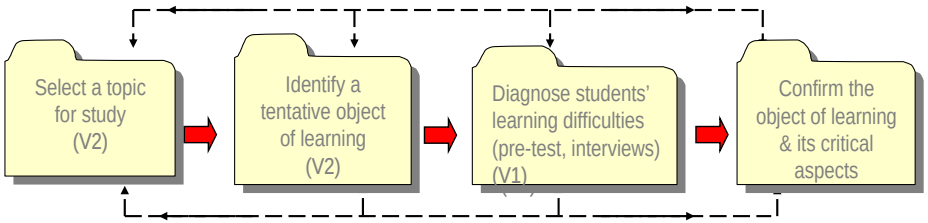
**CF1 :** **If there is a change in the state of motion of the object, there must be a force acting on that object. (the pre-lesson knowledge)**

~~**CF2: The students have the awareness to use scientific principles, and not by intuition, to make scientific reasoning.**~~

**CF3:** **When A acts a force on B, at the same time there *must be* a force acting on A by B, and, these two forces**

- ***must be* opposite in direction, and**
- ***must be* equal in magnitude**






- How to teach the research lesson?

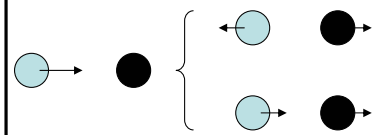
V2: Variation in teachers' understanding of what the most worthwhile object of learning is & ways of handling it

V3: Using "Pattern of Variation" as a guiding principle of pedagogical design

Plan the research lesson (V2, V3)



# Lesson Design / Pattern of Variation (1)

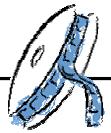
| Activity | Discernment | Varied | Invariant |
|---|---|---|---|
| Revision:<br>• The relationship between the force and the change of state of motion<br>• To determine the direction of the force from observing the change of the state of motion. | | | |
| Experiment:<br>• a marble colliding with an iron sphere<br>• an iron sphere colliding with another iron sphere<br>  | Action and reaction are opposite in direction | The states of motion after the collision. | The states of motion before the collision.<br>  |

# Lesson Design / Pattern of Variation (2)

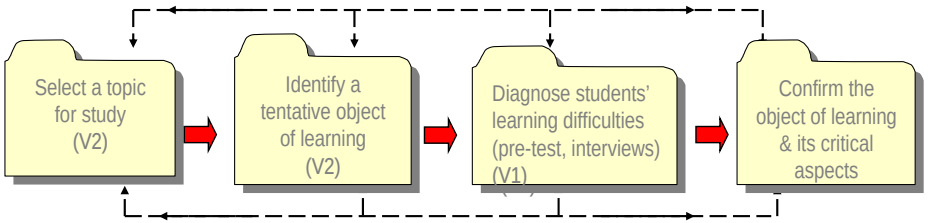
| Activity | Discernment | Varied | Invariant |
|---|---|---|---|
| Experiment:<br>• student A pulling student B<br>• student A pushing student B | Action and reaction are opposite in direction | Direction of the "active" force | A acts a force on B |
| Analyzing some common phenomena or experiences | Action and reaction are opposite in direction | The contexts to be analyzed (e.g. walking, jumping, swimming, rowing etc.) | When someone applies a force in certain direction, his/her change of state of motion will be in the opposite direction |



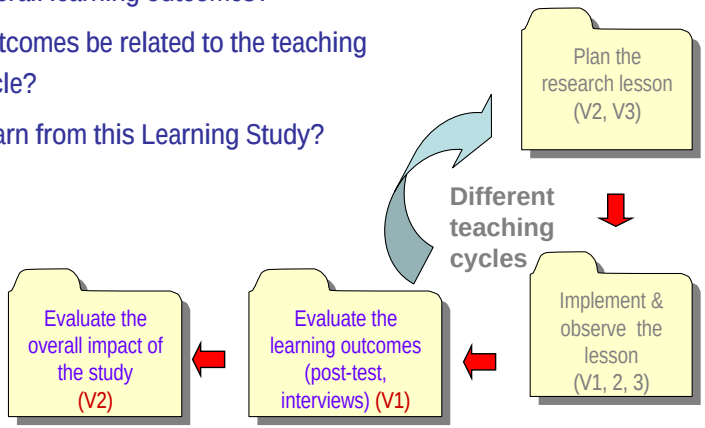
# Lesson Design / Pattern of Variation (3)

| Activity | Discernment | Varied | Invariant |
|---|---|---|---|
| A spring balance pulls another spring balance | Action and reaction are equal in magnitude | The pulling force | The readings of both spring balance are the same. |
| A force sensor "collides" with another force sensor.  | Action and reaction are equal in magnitude | Different colliding conditions | The readings of both force sensors are the same. |



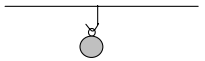



- What is the overall learning outcomes?
- How do the outcomes be related to the teaching act in each cycle?
- What do we learn from this Learning Study?

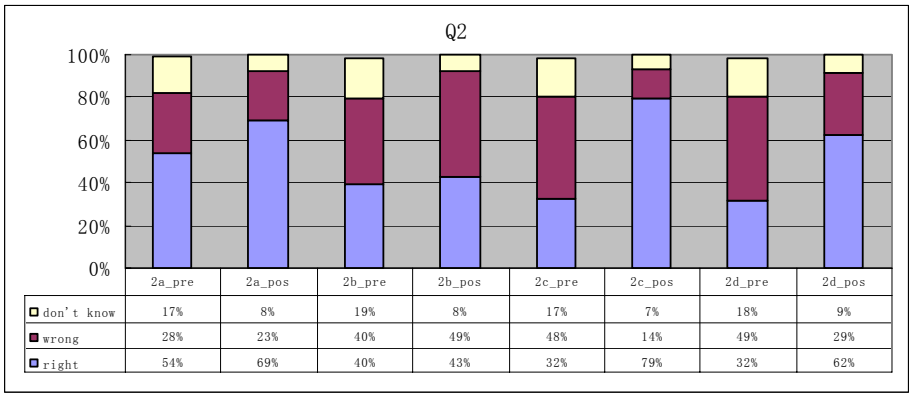


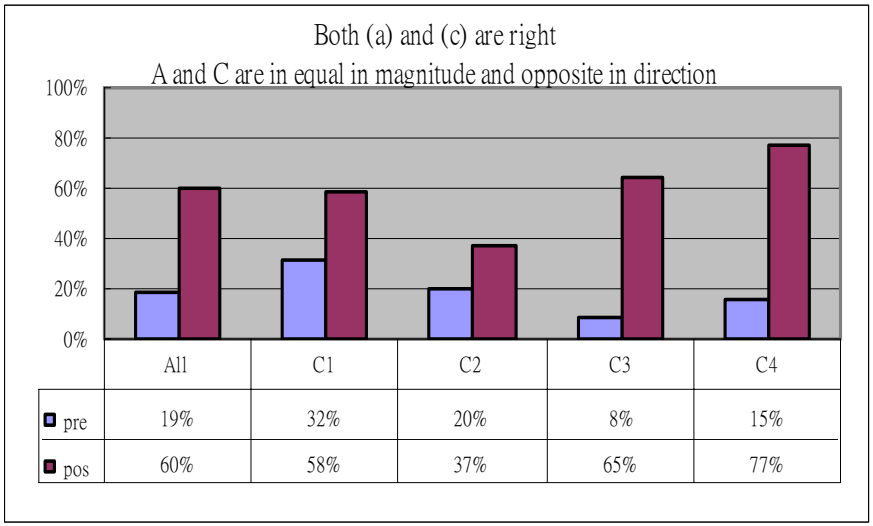

(2)

A：the force exerted by the sphere on the hook
B：the gravitational force acting on the sphere
C：the force exerted by the hook on the sphere



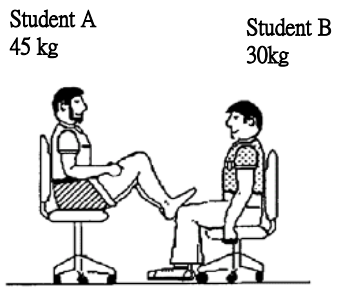
| | | | | |
|---|---|---|---|---|
| (a) | A and C is a pair of action and reaction | ☐correct | ☐incorrect | ☐don't know |
| (b) | B and C is a pair of action and reaction | ☐correct | ☐incorrect | ☐don't know |
| (c) | If A is 10 N, then C must be 10 N | ☐correct | ☐incorrect | ☐don't know |
| (d) | Given that A is 10 N, we are not sure whether C must be 10 N | ☐correct | ☐incorrect | ☐don't know |








| 2. | Student A places his bare feet on student B's knees. Student A then suddenly pushes outward with his feet, causing both chairs to move. | | | |
|---|---|---|---|---|
| (a) | A exerts a force on B, but B doesn't exert any force on A | ☐correct | ☐incorrect | ☐don't know |
| (b) | Each student exerts a force on the other but A exerts the larger force | ☐correct | ☐incorrect | ☐don't know |
| (c) | Each student exerts the same amount of force on the other | ☐correct | ☐incorrect | ☐don't know |




(a) Misconception: only active agents exert forces.

(b) Misconception: greater mass implies greater force.

(c) Correct answer.

Hestenes, Wells & Swackhamer (1992)



| 2. | Student A places his bare feet on student B's knees. Student A then suddenly pushes outward with his feet, causing both chairs to move. | | | |
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| (a) | A exerts a force on B, but B doesn't exert any force on A | ☐correct | ☐incorrect | ☐don't know |
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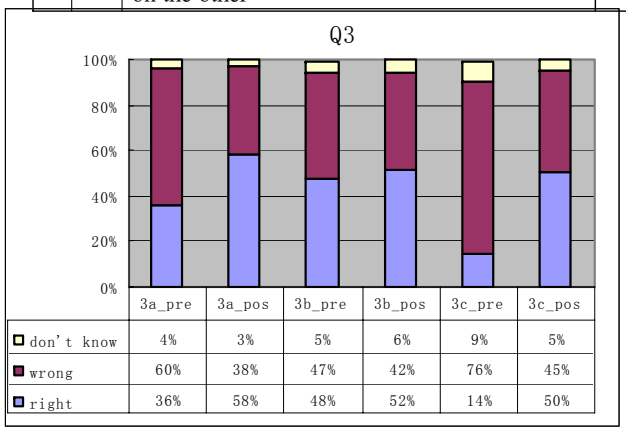


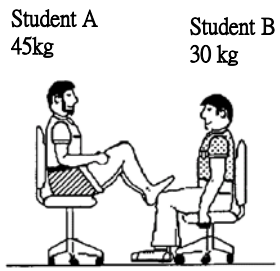




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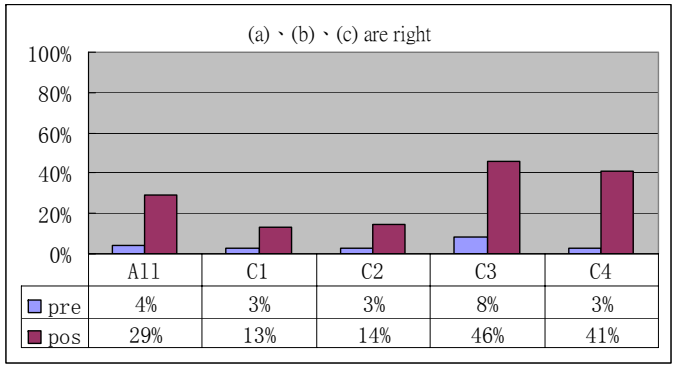


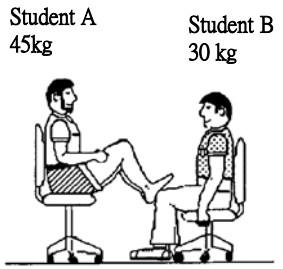

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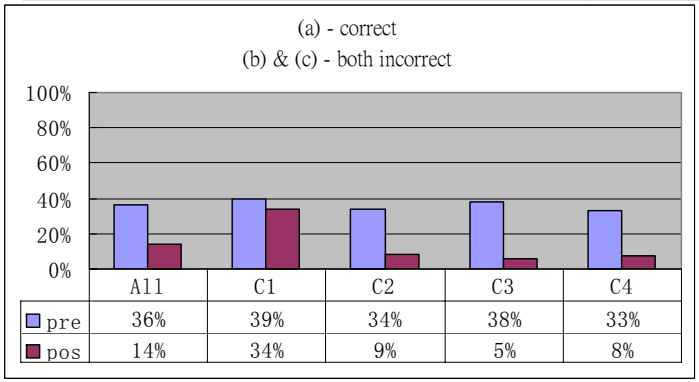
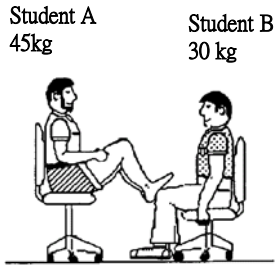


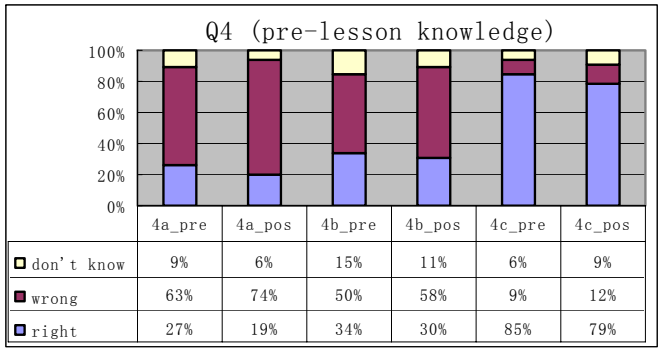

| | All | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|
| pre | 36% | 39% | 34% | 38% | 33% |
| pos | 14% | 34% | 9% | 5% | 8% |




**Before the research lesson, around 40 % of the students thought that only the active agent could exert forces**

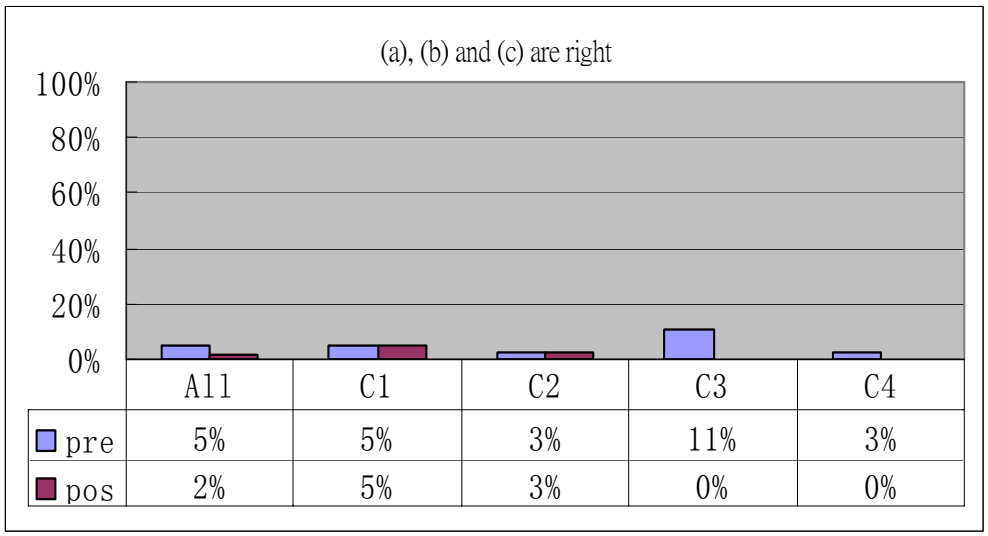


| 4. | The photo shows a man throwing a ball upwards. The speed of the ball decreases as it rises. After rising to a certain maximum height, it then falls. As it falls, its speed increases. | | | |
|---|---|---|---|---|
| (a) | When the ball is rising, the speed decreases because it is affected by the throwing force. | ☐correct | ☐incorrect | ☐don't know |
| (b) | When the ball is at the maximum height, the throwing force is exactly cancelled by the gravity. | ☐correct | ☐incorrect | ☐don't know |
| (c) | When the ball is falling, its speed increases because it is affected by the gravity | ☐correct | ☐incorrect | ☐don't know |




| | 4a_pre | 4a_pos | 4b_pre | 4b_pos | 4c_pre | 4c_pos |
|---|---|---|---|---|---|---|
| don't know | 9% | 6% | 15% | 11% | 6% | 9% |
| wrong | 63% | 74% | 50% | 58% | 9% | 12% |
| right | 27% | 19% | 34% | 30% | 85% | 79% |



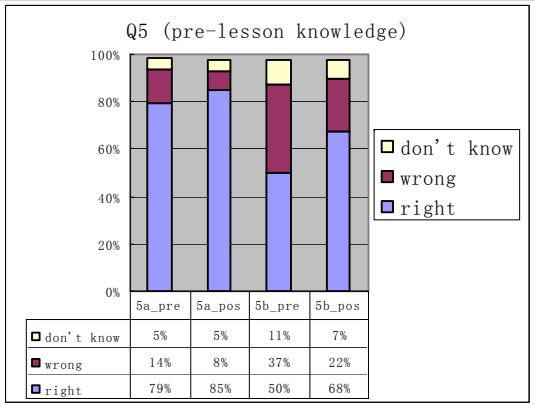



| | All | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|
| pre | 5% | 5% | 3% | 11% | 3% |
| pos | 2% | 5% | 3% | 0% | 0% |

Most students were still not inferring the direction of the force from the change of speed.



| 5. | (a) | When a force is acing on a moving object, its speed or direction change. | ☐correct | ☐incorrect | ☐don't know |
|---|---|---|---|---|---|
| | (b) | If an object is moving to the left with an increasing speed, it must be experienced a force towards the left. | ☐correct | ☐incorrect | ☐don't know |

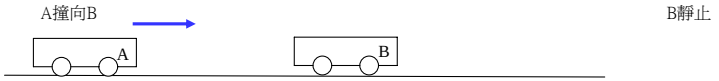



| | 5a_pre | 5a_pos | 5b_pre | 5b_pos |
|---|---|---|---|---|
| don't know | 5% | 5% | 11% | 7% |
| wrong | 14% | 8% | 37% | 22% |
| right | 79% | 85% | 50% | 68% |

- Most student knew when an object experienced a force, its speed or the direction of motion will change
- Some students could not infer the direction of the force from observation.

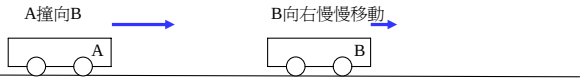
6. 請**圈出**正確的答案。

(a) 圖一顯示小車A撞向同一質量但靜止的小車B，碰撞時，A產生一個作用力4N於B，該力的方向是向 ( 左 / 右 / 上 / 下 )，其反作用力 ( 大於 / 等於 / 小於 ) 4N，方向是向 ( 左 / 右 / 上 / 下 )。



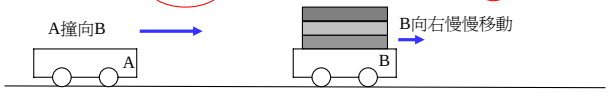

圖一

(b) **如果小車B在開始時並不是靜止，而是慢慢向右移動** (如圖二)，當A碰撞B時，假設作用力是3N，那麼該力的方向是向 ( 左 / 右 / 上 / 下 )，其反作用力是 ( 大於 / 等於 / 小於 ) 3N，方向是向 ( 左 / 右 / 上 / 下 )。



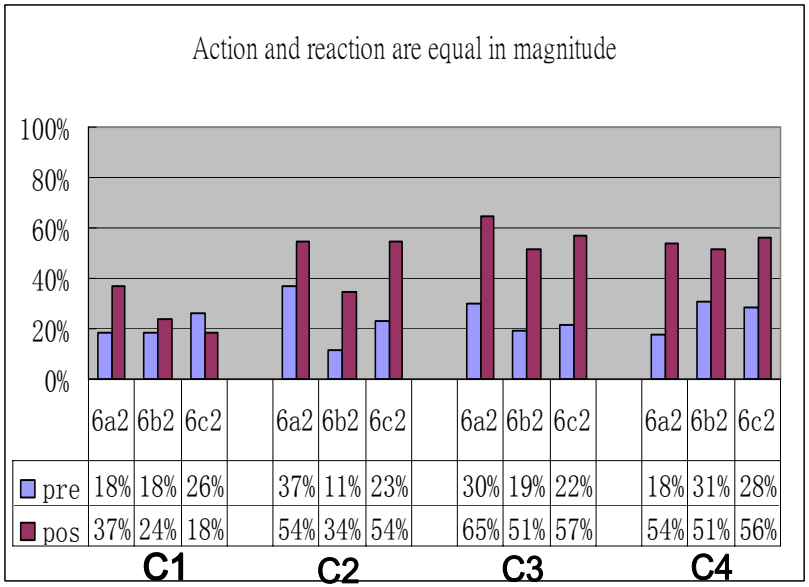

圖二

(c) **如果小車B在開始時除了向右慢慢移動外，它還比A重很多** (如圖三)，當A碰撞B時，假設作用力還是3N，那麼該力的方向是向 ( 左 / 右 / 上 / 下 )，其反作用力是 ( 大於 / 等於 / 小於 ) 3N，方向是向 ( 左 / 右 / 上 / 下 )。



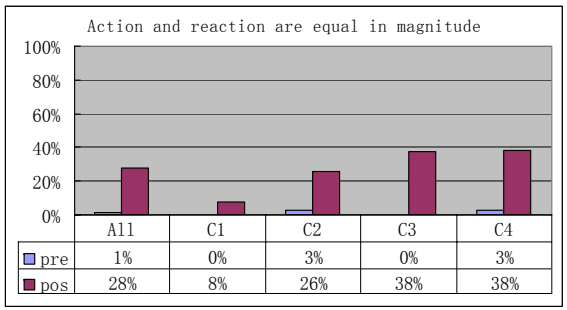

圖三



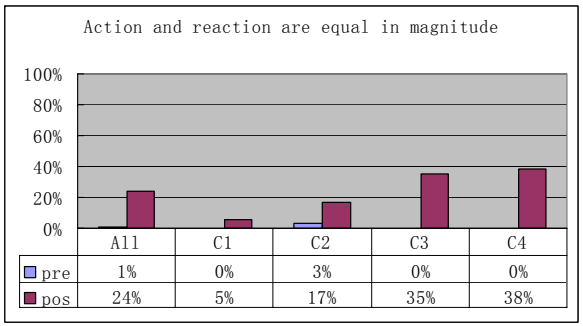




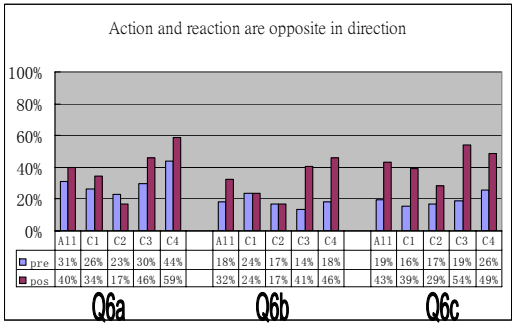

## (a), (b) and (c) of Qu 6 are all correct

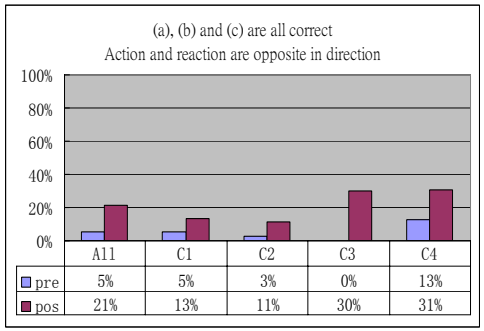



## Correct in both Qu 6 and Qu 3





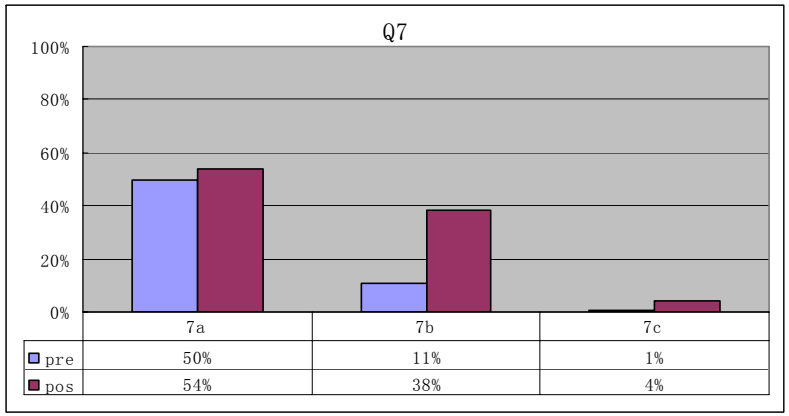



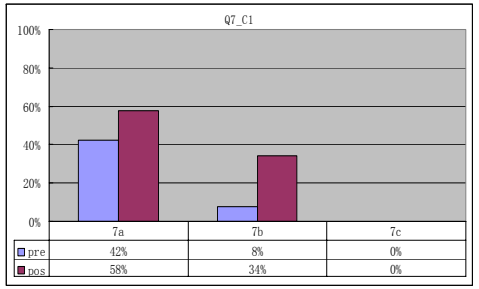
7.

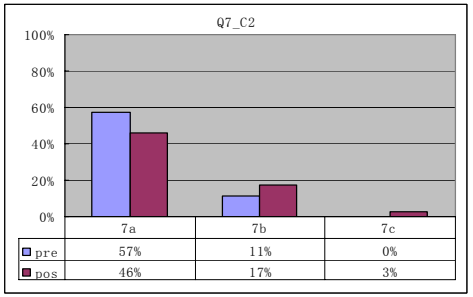

In which direction should the man row in order to moving to the left. Why ?

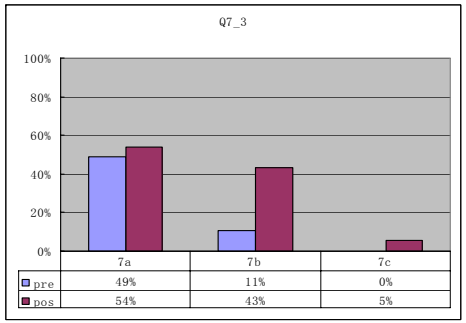
**a = direction correct**
**b = relate to reaction**
**c = explain correctly how the reaction is produced**

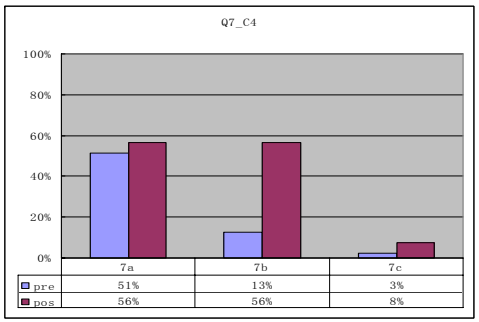




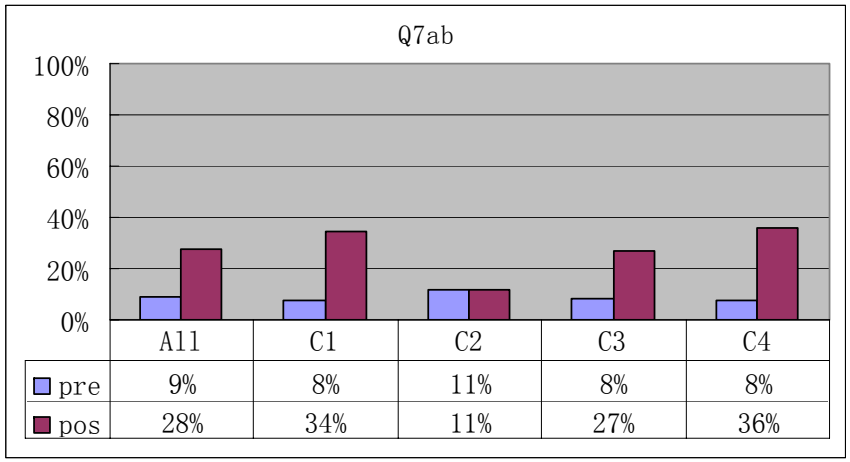






The direction is correct and explain in terms of reaction force



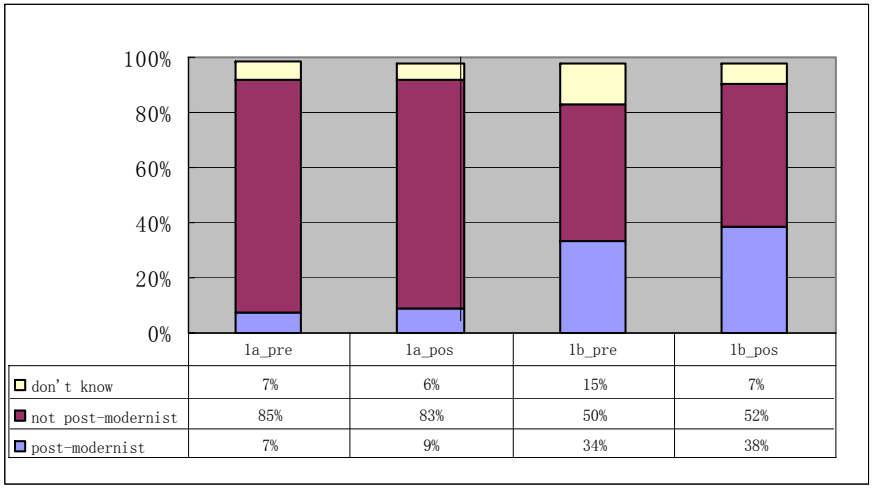



# Discussion (1)

- Problems with the “wordings” in discourse.
- Too much contents in 60 minutes
- Students queried whether the concepts could be generalized to all situations

| | | | | |
|---|---|---|---|---|
| 1. | A science theory is accepted because | | | |
| | (a) scientists can prove it to be correct in all situations | ☐correct | ☐incorrect | ☐don’t know |
| | (b) scientists cannot find a situation in which it is incorrect | ☐correct | ☐incorrect | ☐don’t know |

A post-modernist view




| | 1a_pre | 1a_pos | 1b_pre | 1b_pos |
|---|---|---|---|---|
| don't know | 7% | 6% | 15% | 7% |
| not post-modernist | 85% | 83% | 50% | 52% |
| post-modernist | 7% | 9% | 34% | 38% |

More *Nature of Science* elements should be included in the science curriculum



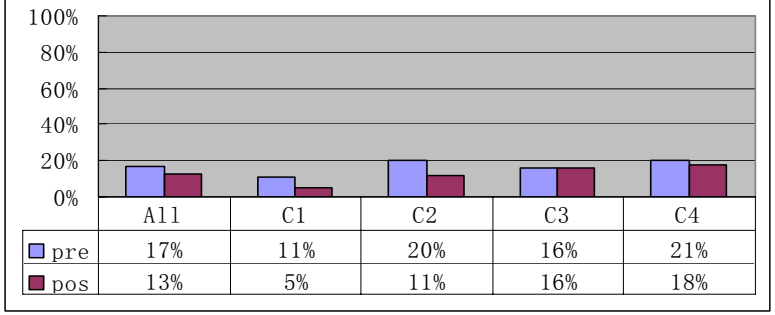
# Discussion (2)

**Most students still made judgment by intuition**

**5(b) If an object is moving to the left with an increasing speed, it must be experienced a force towards the left.**

**4(a) When the ball is rising, the speed decreases because it is affected by the throwing force.**

Students thought that 5(b) is correct and 4(a) is incorrect




| | All | C1 | C2 | C3 | C4 |
|---|---|---|---|---|---|
| pre | 17% | 11% | 20% | 16% | 21% |
| pos | 13% | 5% | 11% | 16% | 18% |