Structuring Reasoning Process in a Science Explanation through the use of Multiple Representations

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Introduction

- Students are often required to address **how** and **why** a phenomenon happens
- Students lack the **reasoning skills** required to construct scientific explanation[1]
- Role of **multiple representations** in reasoning process is often not clearly known
- Constructing scientific explanation is a **disciplinary specific skill**

1. Sandoval, W. A., & Millwood, K. A. (2010). The Quality of Students ' Use of Evidence in Written Scientific Explanations, (July 2014), 37–41.

Disciplinary Literacy

- Ability to participate using the tools of the discipline
  1. Specialized language
  2. Multimodal representations of the discipline
- Disciplinary literacy involves[1]:
  1. Fundamental sense of literacy
     - Read, Write, Communicate with Science text
  2. Derived sense of literacy
     - Idea of Scientific Knowledge, Core Science Concepts, Key Science Relationship
- Importance of both content knowledge and disciplinary habits of mind[2]

1. Fang, Z. (2014). Disciplinary Literacy in Science: Developing Science Literacy Through Trade Books. *Journal of Adolescent & Adult Literacy*, *57*(4), 274–278.
2. Fang, Z. (2013). Disciplinary literacy: What you want to know about it. *Journal of Adolescent & Adult Literacy*, *56*(May), 627–632.

Scientific Explanation

- Importance of content knowledge and scientific reasoning skills[1] (Kuhn, Schauble, & Garcia-Mila, 1992)
- Content and context are also necessary[2]

Two stages of Causal Explanation [3]	Evidence-based Scientific Explanation[2]	Scaffold used to structure explanation
Known facts	Evidence	Principle/ Premise
Temporal or causal sequences which leads to phenomenon	Reasoning	Reason
	Claim	Outcome

1. Kuhn, D., Schauble, L., & Garcia-Mila, M. (1992). Cross-domain development of scientific reasoning. *Cognition and Instruction*, *9*(4), 285–327.
2. McNeill, K., & Lizotte, D. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences* (October 2013), 37–41.
3. Veel, R. (1997). Learning how to mean-scientifically speaking: Apprenticeship into scientific discourse in the secondary school. *Genre and Institutions: Social Processes in the Workplace and School*, 161–195.

What is Reasoning?

- Reasoning is the **logic** for why the **evidence** supports the **claim**, which can often include **scientific principles**.[1]
- Indication of logical relation through conjunctions between clauses[2]

Type of logico-semantic relations[3]	Examples
Additive	And
Comparative	Likewise, but
Temporal	While, as
Consequential	Because, due to, since, results in, causes

Reason

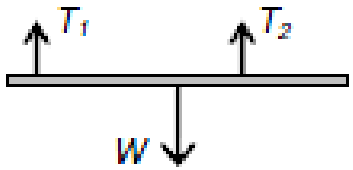
- Reasoning process: Steps taken to guide students in considering **scientific knowledge** and **contextual information** in various aspects to construct a scientific explanation.

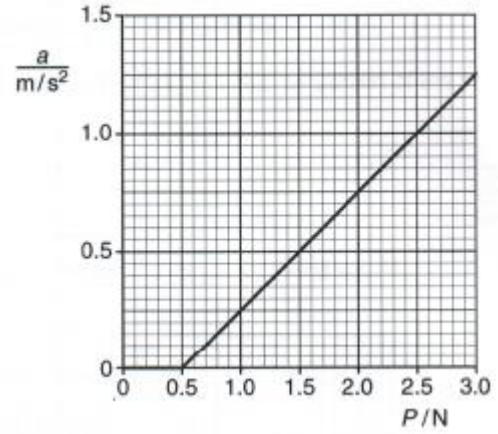
1. McNeill, K., & Lizotte, D. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the …*, (October 2013), 37–41.
2. Martin, J. R. (1992) *English Text: System and Structure* (Amsterdam: Benjamins).

Modes of Representations

- What are common modes of representations in physics?

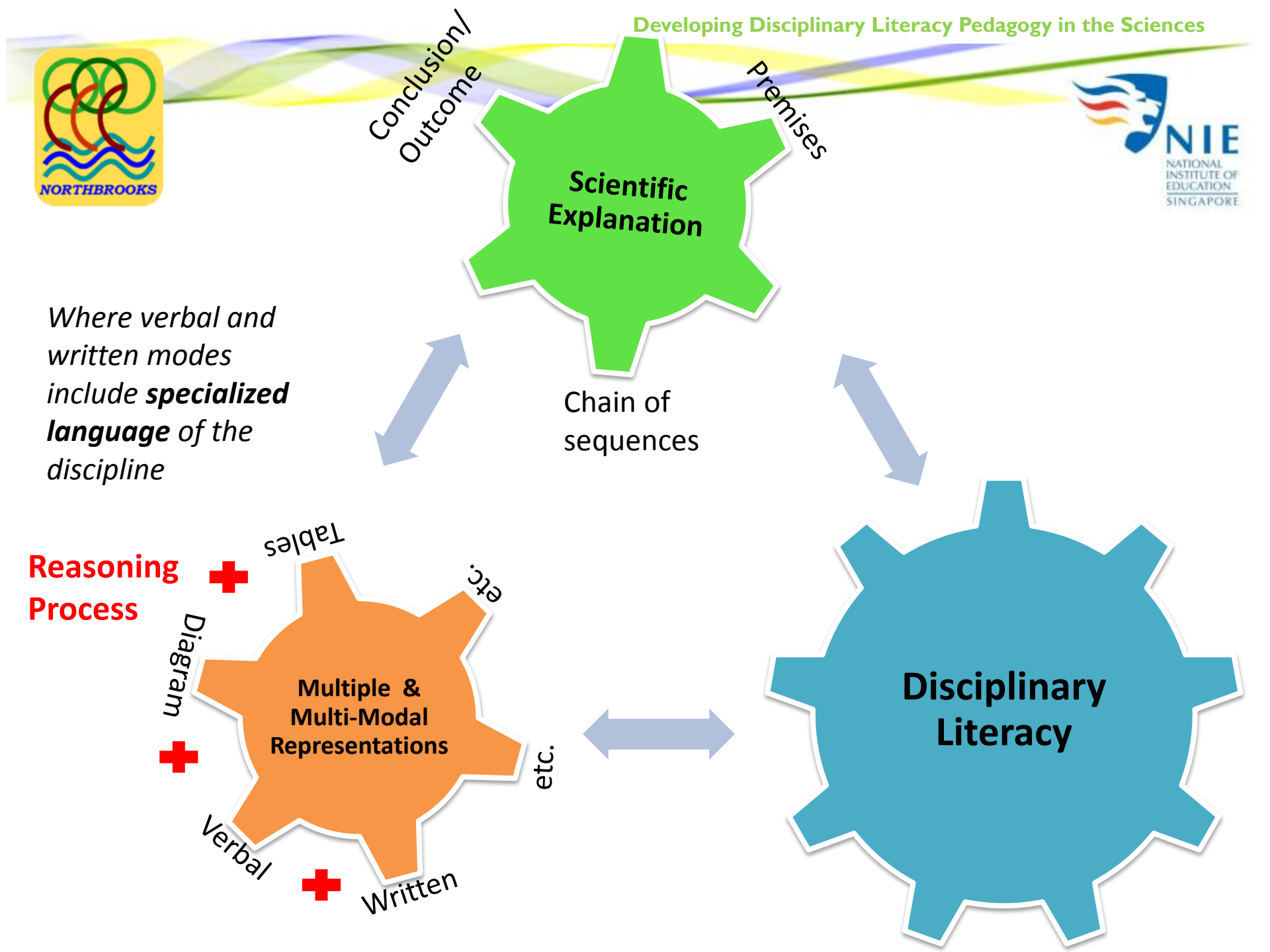
$$F = ma$$





- Students do not know how to make meaningful connections across multiple modes of representations[1]

1. Roth, W. M., & Tobin, K. (1997). Cascades of inscriptions and the re-presentation of nature: how numbers, tables, graphs, and money come to re-present a rolling ball. *International Journal of Science Education*, *19*(9), 1075-1091.


Conclusion/
Outcome
Premises
Scientific Explanation
Where verbal and written modes include specialized language of the discipline
Chain of sequences
Reasoning Process
Tables
etc.
Diagram
Multiple & Multi-Modal Representations
etc.
Verbal
Written
Disciplinary Literacy

Research Context

- 2 year design research project
- Two Phases:
  1. Baseline observation
  2. Intervention study
- Secondary 3 Pure Physics Class
- 32 students

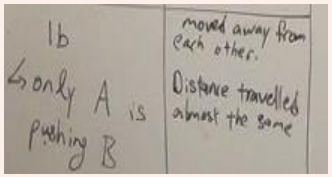
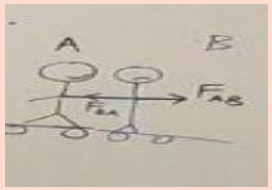
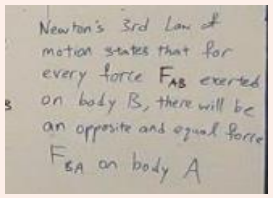
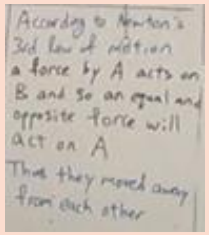
Lesson Design

Task	Activities
Task 1: Observation (Engage)	Video, demonstration or in-class experiment **Demonstration / Hands-on-activity [5min]**
Task 2: Students' discussion (Explore)	Group/ Pair discussion with writings **Discussion, Writing: Prediction with initial Explanation; Observations; Post-observation Explanation [40 min]**
Task 3: Introduction of Concepts: (Explain)	Introduction of terminologies; Teacher modelling process of problem solving /crafting explanation **Newton's third law; T's modelling [12min]**
Task 4: Writing Scaffolds (Explain)	Flowchart, tables, jumbled-up sequences, sentence starters, sub-heading **PRO & Sentence starter [Homework]**
Task 5: Consolidation/Extension (Elaborate)	Slightly modified question with scaffolds removed **Pop Quiz [5 min]**
Task 6: Peer and teacher assessment (Evaluate)	Reading and evaluating peer's writing; Student presenting answer **Teacher assessment**

Lesson Design

Task 1- Observations

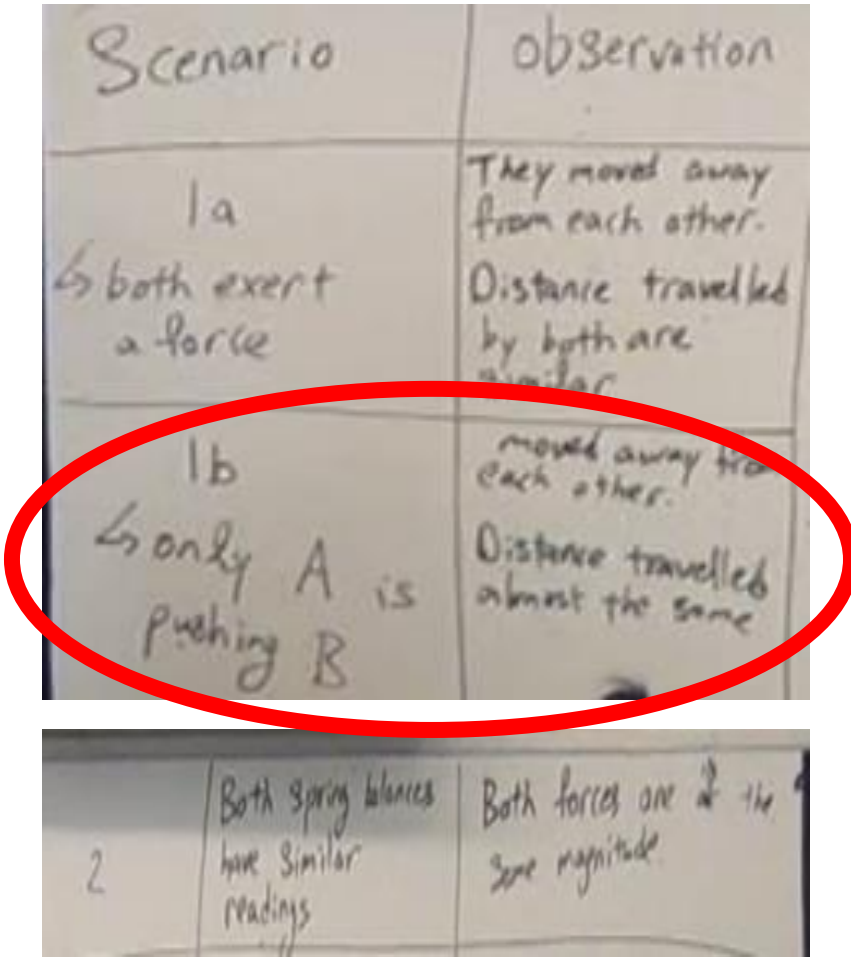
Scenario	Observation
Scenario 1a [2 skaters pushing each other]	
Scenario 1b [1 skater pushes the other]	
Scenario 2 [Pulling of one end of the spring balances]	

Video Time/Episode	Photo	Mode of Representation	Move pertaining to Reasoning Process	Structure of Explanation (P, R, O)
[2 min] **Episode 1**		Body Gesture		
[1:29:16 – 1:30:38] **Episode 2**		Everyday Language		
[1:32:36 – 1:35:19] **Episode 3**		Visual Free Body Diagram		
[1:35:20 – 1:38:03] **Episode 4**		Written Scientific Language		
[1:38:04 – 1:39:40] **Episode 5**		Written Scientific Language		

Episode 1- Observations

Scenario	Observation
Scenario 1a [2 skaters pushing each other]	
Scenario 1b [1 skater pushes the other]	
Scenario 2 [Pulling of one end of the spring balances]	

Episode 2 : Recall Observation



Episode 2: Elicit Recall Observation

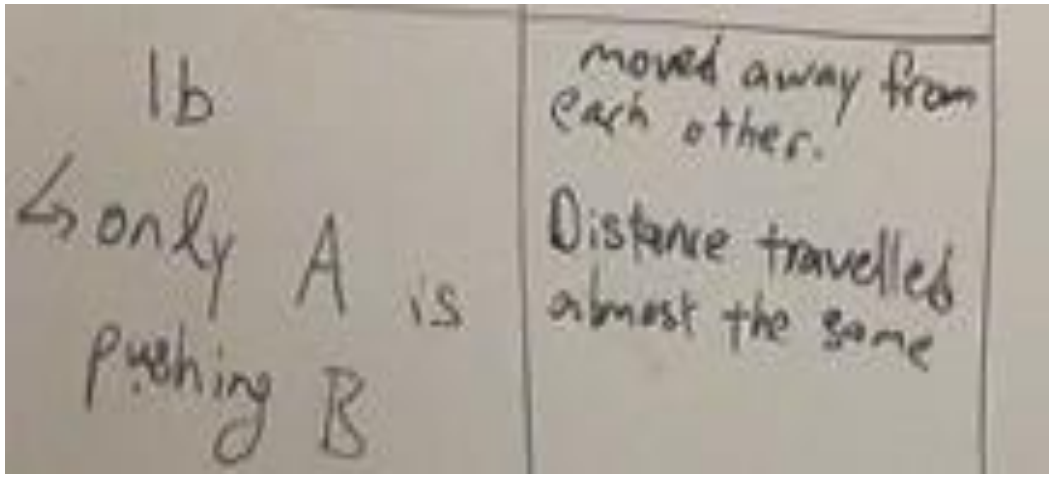
T *And then* when we move on to 1b, where only Shawn is **pushing** Zac.

T Sorry Yvonne?

T When Shawn is **pushing** Zac right, what is the **observation**?

S Both of them **move** back

T Again they **move away** from each other.



Explanation Structure: Premise, Reason, **Outcome**

Episode 3

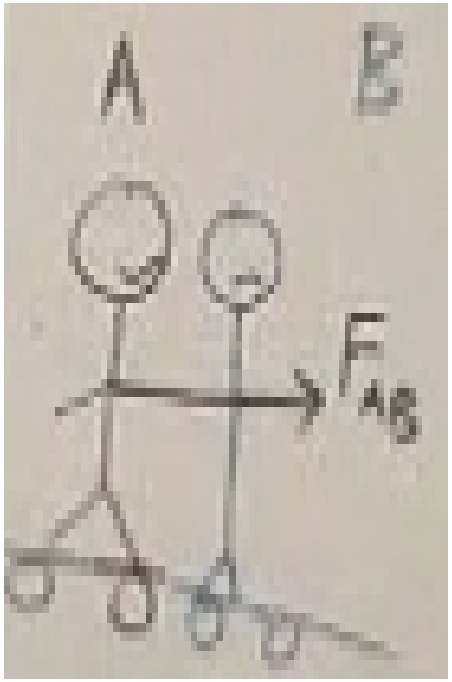
- [Video]

Episode 3: Re-represent/ Recall Observation

T I have Shawn here, always with a weird smile.
T He **exerts** a **force** on Zac...
T *So*, A, let's call it A , A easier…and B
T A pushes B, *so* where did the **force** come from?
S A
T Come from A.
T *But* it's **acting** on?
S B
T B
T *So* basically we say that he **exerts** a **force** on him
[Draw arrow and labels F_{AB}]

Explanation Structure: **Premise**, Reason, Outcome

Shawn **Zac** **Stickman**

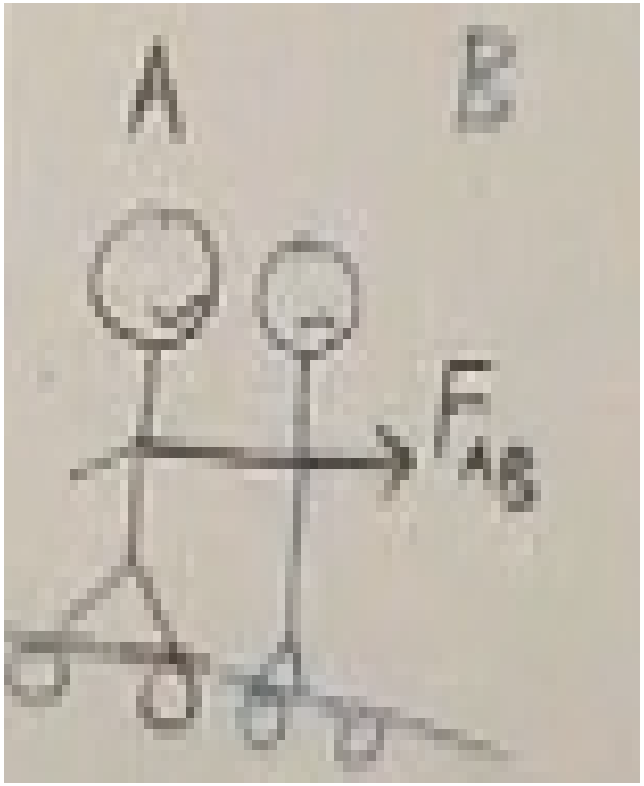


Episode 3: Making Hypothesis

T I am using black color *because* this represent the force from Shawn.

T Okay, this make sense. *So* the force is acting on B. *That's why* B move forward.

T *Then* ***why did A move backward*** according to you all?



Explanation Structure:
Premise, **Reason**, Outcome

Episode 4

- [Video]

Episode 4 (I) : Making Connection

T When the blue color guy exert this black color force on him, what will the blue color's back (**pointing to his own back**) do onto him?

T He will **exert** an?

S Blue color force

T Opposite, yah, blue color **force** acting backwards like this.

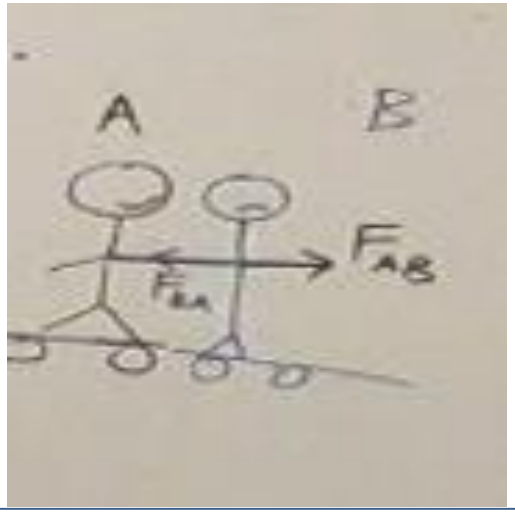
T Eh, so I write this AB **because** the **force** comes from A acting on B.

T And from this one, **because** the moment they have contact like what you have observed or you have say there will **an equal and opposite reaction force** that is from B onto?

S A

T A

T **So** they are **acting** on different body. One force is on B, one force is on A.



Explanation Structure:
Premise, **Reason**, Outcome

Episode 4 (II): Establish Newton's 3rd Law

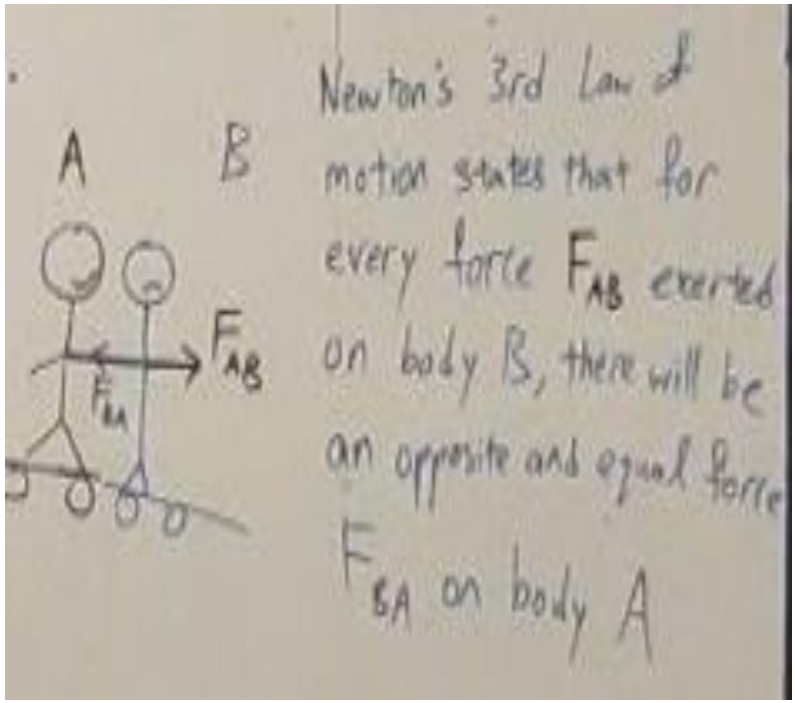
T What you have observed here - is actually….this law called?

S Newton's third law

T Newton's third law of motion. Some of you have already read the textbook. So **Newton's third law of motion** states this.

T Newton's third law of motion states that for every **force exerted** by…

T Sorry, every **force exerted** on body B, there will be an **opposite and equal force** F-B-A on body A. This is essentially **Newton's third law of motion**.



Explanation Structure:
Premise, Reason, Outcome

Episode 5: Crafting Explanation

T ***<u>So how do you craft the answer</u>*** for exam?

T We have to follow our **P R O**.

S Pro

T Yah, a pro.

T Like principle, ***<u>so</u>*** that first thing that we write is....***<u>according to</u>*** ***newton's third law of motion***.

T I completed my **P, principle**.

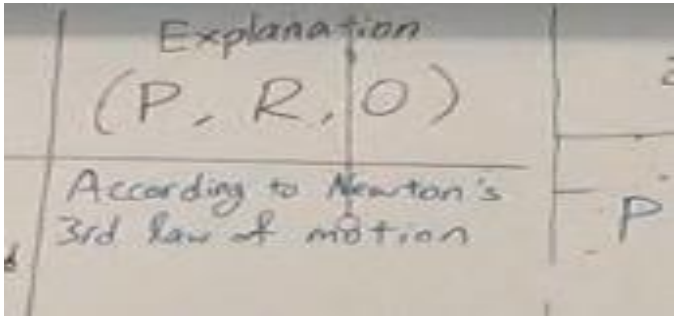
T I am explaining the first scenario, *a* ***force*** *by A acts on B, and* ***<u>so</u>*** *an* ***equal and opposite force*** *will act on A.*

T This is my **reason**.

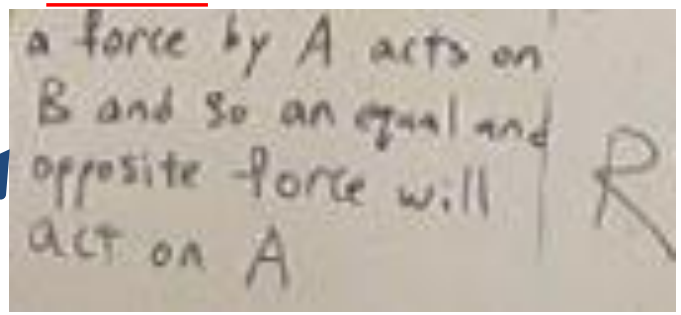
T And finally, ***<u>thus</u>*** *they move away from each other*.

T This is my **outcome** or my observation, **P R O**.

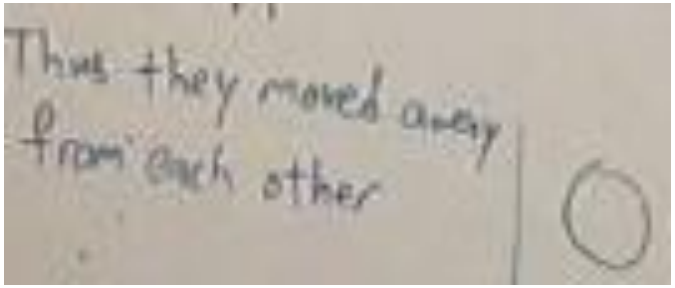
<u>Premise</u>



<u>Reason</u>

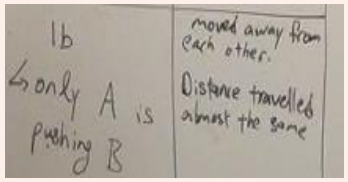
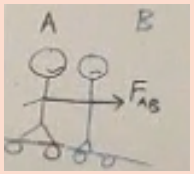
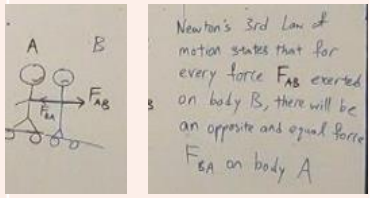
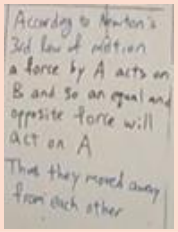


<u>Outcome</u>



Crafting of Explanation

Scenario	observation	Explanation (P, R, O)	2	Both spring balances have similar readings	Both forces are of the same magnitude
1a ↳ both exert a force	They moved away from each other. Distance travelled by both are similar	According to Newton's 3rd law of motion a force by A acts on B and so an equal and opposite force will act on A Thus they moved away from each other	P R O	A B F_{AB} F_{BA}	Newton's 3rd Law of motion states that for every force F_{AB} exerted on body B, there will be an opposite and equal force F_{BA} on body A
1b ↳ only A is pushing B	moved away from each other. Distance travelled almost the same				

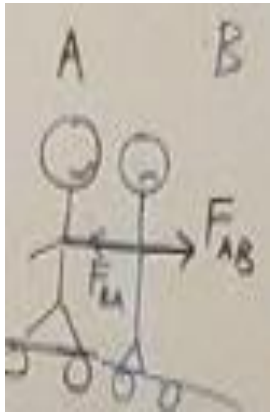
Video Time/Episode	Photo	Mode of Representation	Moves pertaining to Reasoning Process	Structure of Explanation (P, R, O)
[2 min] **Episode 1**		Body Gesture	Observation	Outcome (O)
[1:29:16 – 1:30:38] **Episode 2**		Everyday Language	Recall Observation	Outcome (O)
[1:32:36 – 1:35:19] **Episode 3**		Visual Free Body Diagram (FBD)	Consider observation; Making hypothesis	Premise (P) Reason (R)
[1:35:20 – 1:38:03] **Episode 4**		(I) Visual FBD + (II) Written Scientific Language	Making Connection Science Principle	Reason (R) Premise (P)
[1:38:04 – 1:39:40] **Episode 5**		Written Scientific Language	Crafting Explanation	Premise (P) Reason (R) Outcome (O)

Physical Object/ Experience

Meaning making

Representation

Pair of action and reaction force in opposite direction



Modes of Representation	Reasoning Process
Concrete Physical	Observation
Translation of representations ↓	↔ Reasoning Process ↓
Abstract with Language	Scientific Explanation

Findings

- Modelling of reasoning process could be embedded in two common practices:
  1. Sequential translation of multiple representations
  2. Discursive techniques to link up the rhetorical parts of the explanation

Discussion

- Multi-modal (graphic, verbal) aspect to make thinking explicit
- Three characteristic of effective classroom talk[1]:
  1. Use of question-and-answer sequences to guide development of understanding and reasoning
  2. Use students' contributions as a resource for building shared knowledge
  3. Teach not just content, but also procedures for problem-solving and making sense of experience

1. Mercer, N. (2000). *Words and minds: How we use language to think together*. Psychology Press.

Reasoning Process

Moves pertaining to Scientific Reasoning	Components of Scientific Reasoning (i.e. type of information)
Recall Observation; Interpreting Question	**Contextual Information:** which contextual information is considered
Recall Scientific Knowledge; Consider scientific information; Stating Scientific Principle	**Scientific Information:** which relevant scientific principle is considered
Identify Casual Factor/ Key Idea; Predict; Hypothesize	**Hypothesis:** which hypothesis of a particular factor (e.g. causal factor or key factor) is made based on some information
Construct Chain of Causal Sequences; Apply Scientific information in the Context	**Connection:** which connection between the scientific principle and contextual information is made
Stating Outcome; Evaluate sufficiency of Reason to support Outcome	**Evaluation:** which evaluation is made

How representations can be used to facilitate connection making?

Implications

- Representations as tools which could be used to scaffold scientific reasoning
- Greater awareness of the unique role each representation plays in scaffolding and modelling of scientific reasoning
- Making procedures pertaining to reasoning more explicit
- Future research on the impact of more explicit structuring of reasoning process

Thank you!

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