Maths Skills in Science: Promoting representational fluency amongst undergraduate physics students through weekly online learning modules

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Multiple Representations

Multiple Representations in Mathematics and Science

- Communication
  (Learning and Sharing)

- Solving problems

Multi-representational reasoning

› Metavisualization

› Representational Competence

› Metarepresentational Competence
Multi-representational reasoning

› Metavisualization
› Representational Competence
› Metarepresentational Competence

› Making meaning out of different modes of representation (concrete, verbal, symbolic, visual and gestural) (Gilbert, 2004)
› Understanding why particular representations are helpful, and the ability to choose appropriate representations (Durfresne, 2004)
› Learning new representations quickly (diSessa, 2004)
› Using representations “authentically” (as experts do) in a particular domain (Kohl, 2005; Roth & Bowen, 1999)
› Using the combinations of representations unique to a discipline (Airey & Linder, 2009)
A “Critical Constellation” of Representational Modes

“Fluency in a critical constellation of modes of disciplinary discourse may be a necessary (though not always sufficient) condition for gaining meaningful holistic access to disciplinary ways of knowing”

(Airey & Linder, 2009)

The Representational Fluency Survey (RFS)

**Created:** 2011 (Hill, 2014)

**Structure:** 6 items (multiple choice questions) with space provided for reasoning/working.

**Questions:** Chosen from other sources (5) and created (1) to be at a conceptual level beneath 1st year physics students such that the difficulty in answering the question relates to the representations used.

RFS Q1

Acceleration versus time graphs for five objects are shown below. Acceleration is a measure of how velocity changes with time. All axes in the graphs have the same scale. Which object has the greatest change in velocity during the interval?

(A)  
(B)  
(C)  
(D)  
(E)  

Answer: ____

Provide information supporting your answer or why you chose your answer:

RFS Q1
Tier 1: Correct answer?

Tier 2: Correct/congruent information imbedded in representation?

Tier 3: Information imbedded in representation consistent with chosen answer?

Acceleration versus time graphs for five objects are shown below. Acceleration is a measure of how velocity changes with time. All axes in the graphs have the same scale. Which object has the greatest change in velocity during the interval?

(A)  
(B)  
(C)  
(D)  
(E)

Answer: YS

Provide information supporting your answer or why you chose your answer:

\[ a = \frac{dv}{dt}, \quad v = \int a \, dt \]

= Area under graph,

Student A: Correct answer, scientifically congruent reasoning, consistent reasoning and answer - 3 marks
Tier 1: Correct answer?

Tier 2: Correct/congruent information imbedded in representation?

Tier 3: Information imbedded in representation consistent with chosen answer?

“I probably couldn’t put them (graphs and words) together and synthesise that information so therefore answering the question became difficult as I didn’t have the stimulus fully understood.”
The Representational Fluency Survey (RFS)

2012 RFS Mean Marks

Level of Physics Learning Experience

The Intervention: Online Learning Modules

**Summary:** 688 students, weekly, pre-lecture, online with two streams *representations* and *concepts* = 24 modules + one reflection module

**Design:**
- *Representations (Experimental)* cued in a representation and linked multiple representations
- *Concepts (Control)* modules introduced content (Seery & Donnelly, 2012)
- Three sections followed by a common question

**Delivery:** Available 5pm Thursday until 10am Monday of the week of lectures. Delivered using eLearning site Blackboard.

Example of a free body diagram:

There are two free body diagrams in the picture below the text, one for each basketball player.

The man on the right is standing on the ground and therefore there is a ‘normal’ force (‘n’) from the ground on the man pointing upwards. The two forces balance out so he will experience no acceleration at this point.

The man on the left has jumped in the air. The only force applying to him is the weight force downwards. Therefore we can calculate his acceleration using Newton’s 2nd Law (F=ma)

Structure:
(Using elements of Jackson, 2013)
1 – Information
2 – Questions/Problem Solving
3 – Reflection

Purpose:
Priming the perception filter
Reducing cognitive load

To what extent do you agree with the statement: "I understand the above information well"?

- a. Strongly Agree
- b. Agree
- c. Neither Agree nor Disagree
- d. Disagree
- e. Strongly Disagree
The Intervention: Online Learning Modules

Control group 2: Not completing OLM
Measuring impact of Online Learning Modules

Two pre-tests and two post-tests were completed either side of the intervention

1) The Force & Motion Concept Evaluation (FMCE) as a test of Conceptual ability (Thornton, 1997)
2) The Representational Fluency Survey (RRS) as a test of Representational Ability

This was supplemented by data from interviews and end of semester exam results

Effect of OLM on conceptual ability

**FMCE Gains**

<table>
<thead>
<tr>
<th>Representations OLM</th>
<th>Concepts OLM</th>
<th>Non-participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-FMCE</td>
<td>Post-FMCE</td>
<td></td>
</tr>
<tr>
<td>&lt;g&gt; = .20</td>
<td>&lt;g&gt; = .22</td>
<td>&lt;g&gt; = .15</td>
</tr>
</tbody>
</table>

(n=137) (n=124) (n=53)
Effect of OLM on Representational Fluency

RFS Gains

- Pre-RFS: <g> = .33
- Post-RFS: <g> = .26

(n=151) Representations OLM
(n=134) Concepts OLM
(n=58) Non-participants
Interpreting Learning Gains

(a) FMCE, Hake (1998)

(b) FMCE, Sharma et. al. (2010)

(c) FMCE

(d) RFS
The student voice: How did the Online Learning Modules relate to your learning in lectures?

Representations Stream
› at a subconscious level it is working so you could maybe look at the lecture in new ways
› (The modules) told me about the graph and how it works… when they started talking about how it is to be applied and what it means, as opposed to being stuck with how it works and being behind, I already knew.

Concepts Stream
› Initially for the first two or three weeks I thought they were pointless… but by doing the modules we do have a rough idea of what we are going to learn so when it ends up in lectures we know what the lecturer is telling us so we don’t have to stop or pause it and ask him for every single time rather we can just move on with the class.
› Obviously you can’t show up to a lecture and understand 100% what they are saying without some prior knowledge, so I feel that the online stuff did give me that prior knowledge that you needed
Both sets of online learning modules (representations and concepts) produce conceptual learning gains
- greater than not completing the online learning modules in 2013
- greater than historical data over multiple years at the University of Sydney

Cuing in representations (priming the perception filter) is effective in supporting conceptual learning in lectures

The same is also true for representational learning gains.
Does completing OLM correlate with physics success?
Does completing OLM correlate with physics success?

Average number of OLM completed vs Physics Grade

Number of OLM

Fail | Pass | Credit Grade | DI | HD

0 | 0 | 0 | 0 | 0

Grade


