ASK08645

Classroom-based interventions to improve students' learning capital

Helen Askell-Williams[1]

Michael J. Lawson[1]

Terry Ellis[2]

1: Flinders University

2: Aberfoyle Park High School

Paper presented at the annual conference of the Australian Association for Research in Education, Brisbane, 2008

Correspondence

Helen Askell-Williams

School of Education, Flinders University

GPO Box 2100, Adelaide, Australia, 5001

helen.askell-williams@flinders.edu.au

Paper Presented at the AARE Annual
Conference, Brisbane 2008
Australian Association
for Research in Education

Classroom-based interventions to improve students' learning capital

Abstract

In this paper we argue that one component of students' intellectual wellbeing is the quality of the students' meta-knowledge about learning, that is, their "learning capital." Learning capital refers to students' knowledge of, and capabilities for, learning. Following Mayer (1998), we see learning capital as extending across the interconnected domains of students' knowledge about motivation, cognition and metacognition, which interact and impact on students' capabilities for problem-solving in learning situations. Pressley (1995) pointed out that poor learners are often deficient in some areas of cognition, metacognition and motivation and "interaction between these component deficiencies compound difficulties" (p5).

We purposefully selected, from the larger sample reported in this symposium, a year 9 science class of 28 students to comprise the intervention group. We worked with the students' class teacher to deliver learning capital improvement modules embedded in regular class lessons, that were delivered as part of regular science lessons. The main focus of the learning capital modules was to prompt students to organise and elaborate the subject-matter information, using diagrams and concept maps, in order to more effectively encode and subsequently retrieve knowledge. The modules included discussions of learning capital and explicit attention to the metalanguage of the psychology of instruction. We collected pre-and post intervention questionnaire data, and students work samples and academic results. We also gathered parallel data about students' life at school and students' mental health status from the class teacher and the students' parents/caregivers.

We provide a micro-level analysis of changes in students' employment of diagrams and concept maps during learning activities. We report summary statistics of students', teacher and parents/caregivers' questionnaire responses and examine changes in students' learning capital across time

Classroom-based interventions to improve students' learning capital

Introduction

One component of students' intellectual wellbeing is the quality of the students' meta-knowledge about learning, that is, their "learning capital." Learning capital refers to students' knowledge of, and capabilities for, learning. Following Mayer (1998), we see learning capital as extending across the interconnected domains of students' knowledge about motivation, cognition and metacognition, which interact and impact on students' capabilities for problem-solving to facilitate effective learning. Pressley (1995) pointed out that poor learners often lack knowledge in some of the areas of cognition, metacognition and motivation, and that "interaction between these component deficiencies compound difficulties" (p5). Early work by Reimann and Chi (1989), and Glasser (1989) argued for recognition of the interaction between subject-matter knowledge and learning strategy knowledge, suggesting that learners need knowledge in the different knowledge domains (content-based and process-based) that contribute to thinking during problem solving for learning. Berthold, Nuckles and Renkl (2007) suggested that more work needs to be done on convincing students of the value of cognitive and metacognitive prompts for learning success.

Our interest has been to design and apply, in authentic classroom settings, instructional interventions to improve students' learning capital. In designing our instructional interventions we were informed by Mayer's (1998) three stages of knowledge acquisition, namely: focussing attention on the key ideas, organisation of key ideas, and elaborative processing of the subject-matter information in order to achieve integration of knowledge. Diagramming and concept mapping are recommended techniques for different stages of the learning process, including knowledge acquisition, knowledge representation for problem solving, and knowledge retrieval (Hilbert & Renkl, 2008; Mintzes & Novak, 2000; White & Gunstone, 1992). Work by Novak and colleagues (Edmondson, 2000; Mintzes & Novak, 2000; J. D. Novak, Mintzes, & Wandersee, 2000) has demonstrated that concept mapping and other visual representations such as Vee-diagrams can facilitate learning due to the need to organise nodes (concepts) hierarchically or heterarchically, and the need to make the links, or interrelationships between the nodes explicit. Hilbert and Renkl (2008) differentiate four main functions of concept mapping that are salient when concept maps are used to learn from text. These four functions are: elaboration; reduction; coherence; and metacognition. Note there is substantial overlap between Hilbert and Renkl's four functions and the categories identified from Mayer's work above. Using concept mapping, or diagramming, as tools to provoke and to support functions for learning is hypothesised to promote substantial gains in students' learning performance (Hilbert & Renkl, 2008; Mintzes & Novak, 2000; J. D. Novak, 1990; J. D. Novak et al., 2000; Pearsall, Skipper, & Mintzes, 1997; White & Gunstone, 1992).

However, although the observed benefits of creating visual representations of material to be learned, or material to be employed when problem solving for learning, has been promoted for some time now, our observations in classrooms suggested that relatively few students appeared to self-generate visual representation strategies during learning. For example, in our survey of 1372 Year 7, 8 and 9 students across four metropolitan schools in Adelaide in 2008, in response to the question:

Mark whether you agree or disagree with the statement, "I draw pictures or diagrams to help me understand [my best] subject." Thirty per cent of students gave a "Strongly disagree" response.

Table 1 displays the total range of students' responses to that question, suggesting that concept mapping and diagramming are not frequently used strategies by this cohort of students.

Table 1: Student response frequencies for drawing pictures or diagrams.

I draw pictures or diagrams to help me understand [my best] subject			
	Score	**Frequency**	**Valid Percent**
Strongly disagree	1	412	30.03
	2	213	15.52
	3	201	14.65
	4	250	18.22
	5	111	8.09
	6	94	6.85
Strongly agree	7	91	6.63
	Total	1372	100.00

* missing=1

Two possible hypotheses suggest why this relatively low use of visual representation strategies might be the case. The first might be that many students do not self-generate visual strategies to support their learning. If this is the case students need explicit teaching and guided practice in such techniques, as well as evidence that such strategies are valuable for learning. A second hypothesis is that teachers either do not feel equipped, or do not value, or feel they do not have space in the curriculum, to teach strategies such as drawing diagrams and concept maps. Thus teachers may also need explicit instruction in strategies for creating visual representations, evidence of the value of such strategies, and ways of embedding into their regular teaching supportive instructional strategies that do not consume (seemingly unavailable) curriculum time.

Thus, in this paper, we focus our attention on explicitly teaching diagramming and concept mapping as tools to promote focussing, organisation and elaborative processing, and metacognitive monitoring, of knowledge, The particular strategy we adopted was to embed into the curriculum of regular class lessons explicit teaching of diagramming and concept mapping without substantially taking time away from the class teacher's typical plans for the science lesson. In addition, we attempted to embed in the regular science lessons, using the set science text and the teacher's usual lesson delivery, opportunities to provide students with guided practice in drawing diagrams and concept maps to represent organise and elaborate knowledge.

In summary, our research questions were:

1. Can we design and embed into regular class lessons instructional interventions that will provoke students to make more use of diagramming and concept mapping as strategies for learning?

2. What changes can be observed in students' use of diagramming and concept mapping as our instructional intervention progresses?

Method

Context

The executive staff of one of our secondary school Australian Research Council Linkage grant partners expressed an interest in incorporating learning strategy instruction into the programmed curriculum for a Year 9 science class. The school is a large public secondary school in South Australia and had over 220 students in year 9 in 2008. The students' families range from lower to upper socio-economic status families, with 12% of students eligible for fee support (school card).

A Year 9 science teacher volunteered to collaborate with the researchers in the design and delivery of an integrated science learning strategy curriculum over three school terms in 2008. Students in the class were 14 or 15 years old, with 11 girls and 16 boys, mostly of Caucasian heritage. One student had a negotiated learning plan to accommodate identified learning difficulties. Thirteen students, (of 28) and their parents/caregivers, from the selected class provided consent for us to report their responses in publications leading from the research.

Instructional Interventions and data collected

Over school terms 2, 3 and 4 of 2008 the researchers attended one or two Year 9 science lessons per week. In some lessons the researchers observed the lesson and assisted students as requested with their class work. In addition, on pre-arranged occasions, but still in regularly scheduled lessons, the researchers explicitly delivered learning strategy instruction to the class of students and collected student work samples to form the data base for this study. The learning strategy instruction delivered during term 2 is the focus of this paper, and was constructed around the instructional aim of: "Building students' learning capital: Using diagrams and concept maps to represent, elaborate, encode and retrieve knowledge".

During term 2, the researchers and the class teacher collaborated to identify the relevant sections of the science text to be delivered as part of the science curriculum. The selected sections of text included words, pictures and diagrams. The teacher's instructional activities required students to view the words and pictures/diagrams, and to construct responses in both word and diagrammatic form. We designed short teaching modules and activities, based upon the subject-matter text, which explicitly addressed the learning strategies of diagramming and concept mapping. We provided different levels of scaffolded instruction, such as varying the amount of prompts, for the drawing of diagrams and concept maps in order to cater for different student ability levels that could be expected to be present in the class (Hilbert & Renkl, 2008). Initially, the researchers delivered the instructional modules to the class. As Term 2 progressed, and into the following Terms 3 and 4, and the class teacher progressively embedded the strategies contained in the instructional modules into his regular science teaching.

Before, during, and after instruction (in school terms 2, 3 and 4) we collected data about students' use of diagrams and concept maps. At the end of each term we provided students with a short presentation of a summary of the work that we had done together in the class that term, a letter to parents containing an overview of the learning strategy interventions during the term, and a small treat to thank the students for their participation.

In addition, as part of the larger Australian Research Linkage Grant project, of which this intervention to improve students' learning capital is part, we gathered broad scale questionnaire from a purpose designed Living and Learning at School Questionnaire.

Table 2 contains information about each of the instructional interventions and data collection events that are the subject of this paper. In total, the researchers worked with the class, either demonstrating or discussing diagramming and concept mapping, on 10 occasions during school term 2. Five of these sessions included researcher-presented, short, in-lesson, explicit instruction and guided practice on diagramming and concept mapping. The other five sessions involved working with the students on their science subject-matter in general, whilst including diagramming and concept mapping in conversations about the lesson content. The class teacher also incorporated small segments about diagramming and concept mapping into his lesson presentations. Data about the students' use of diagrams and concept maps was collected on 13 occasions over Terms 2, 3 and 4 with the aim of constructing profiles of students' use of visual representation strategies.

Table 2: Overview of Lesson Activities: Term 3 2008

Date	In class activities	Data collected
Nov-07	Administer large scale questionnaire about Living and Learning at School (L&LSQ)	L&LSQ
9/05/2008	Distribute information letters and consent forms to students and parents	
14/05/2008	Observe class and talk to students about lesson content (digestive systems)	
16/05/2008	Teacher administers follow-up (L&LSQ) to class	L&LSQ
21/05/2008	Teachers administers pre-test (digestion) including 1) a question inserted that could provoke a diagramming strategy but 2) No prompt to use a diagramming strategy	pre-intervention test responses
26/05/2008	Researchers' first presentation to whole class: “Making connections to promote learning”	
28/05/2008	Observe lesson: talk and work with students on science module: Circulatory systems (dissecting sheep heart)	
30/05/2008	Researchers' second presentation to whole class: "Explicit teaching of diagram strategy: circulatory systems"	
2/06/2008	Teacher administers summative unit test to class (circulation) including 1) a question inserted that could provoke a diagramming strategy but 2) No prompt to use a diagramming strategy)	mid-intervention test responses
4/06/2008	Observe lesson: talk and work with students on science module respiratory systems (measure lung capacity)	
	Audio record student statements to the question "When you did the science test, Did you have in your mind a mental diagram? Did you use the diagram in your test?	
11/06/2008	Researchers' third presentation to whole class: "Explicit teaching of diagram strategy: Respiratory systems "	
13/06/2008	Researchers' fourth presentation to whole class: "practising diagram strategy: respiratory systems"	
18/06/2008	Researchers' fifth presentation to whole class: "applying diagram strategy: digestive, circulatory and respiratory systems"	post-intervention 3-way guided concept maps
25/06/2008	Teacher models concept mapping on white board	
4/07/2008	Teacher works with class on concept maps and diagrams	
4/07/2008	Researcher feedback about progress of research to students and letter to parents	
29/08/2008	Teacher administers summative unit test to class (matter) including 1) a question inserted that could provoke a diagramming strategy but 2) No prompt to use a diagramming strategy	Delayed post-intervention test responses
23/09/2008	Teacher administers summative unit test to class (carbon compounds) including 1) question inserted to provoke a diagramming strategy, and 2) prompt to use a digramming strategy	Delayed post-intervention test responses
29/10/2008	Teacher administers summative unit test to class (acids and bases) including 1) question inserted to provoke a diagramming strategy, and 2) prompt to use a digramming strategy	Delayed post-intervention test responses

Results

Occasion 1: Students' knowledge about learning. (14/05/08)

We asked the students, What do you do to help yourself to learn?

In response to this pre-intervention question, students provided the following responses:

1. *I ask the teacher*
2. *I look on the computer for answers to help me*
3. *By asking other people for answers*
4. *I don't know*
5. *Well I just copy off [my classmates]*
6. *Do the work*
7. *Read the text*
8. *Well, first, I like to read through what we have and then I will memorise it, and try to remember it so next time I need it, I can do it. And if not I will draw pictures or something to remind me what I've learnt from it and everything.*
9. *Read it a couple of times*

Box 1: Interview extracts from, "What do you do to help yourself to learn?

Occasion 2: Pre-intervention summative assessment (21/05/08)

The teacher-selected instructional text on digestive systems included pictures of the human digestive system, and explanatory text of how food enters the mouth, is processed and eliminated. In the pre-instructional intervention test on digestive systems, we included the question:

"What is the role of the stomach in digestion and how does it achieve its role?"

Of the 28 students in attendance for the test, none produced a diagram, concept map, or visual of any sort to answer the question.

Samples of students' answers included

1. *The stomach is a place that temporarily holds food that comes from the oesophogus*
2. *The stomach stores they food for a while after going down the oesophigus & being digested into smaller pieces. It also takes out all the liquid from the food. Then it send the food to the lower half of the digestive system to finish off the process.*
3. *The stomach provides a temporary food area. Muscle movements mix food with gastric juice and that helps to break down proteins. The stomach has acids in it which break down germs.*

Box 2: Text extracts from summative assessment (21/05/08)

Occasion 3: Mid-Intervention summative assessment (2/06/08)

The teacher-selected instructional text on circulatory systems included pictures of the human heart, lungs, and upper and lower body, and explanatory text of how blood is oxygenated and moves around the body. In the mid-instructional intervention test on circulatory systems, we included the question:

"Explain fully the path of blood as it travels through the heart, lungs and body"

Of the 23 students in attendance, 11 students produced a diagram of all or parts of the heart, lungs, and upper and lower body to answer this question. Some diagrams were accompanied by explanations using words. The average score for the non diagram group for this question was 2.29 out of a possible total of 6. The average score for the diagram group for this question was 2.68, a slight score increase.

Sample diagrams included:

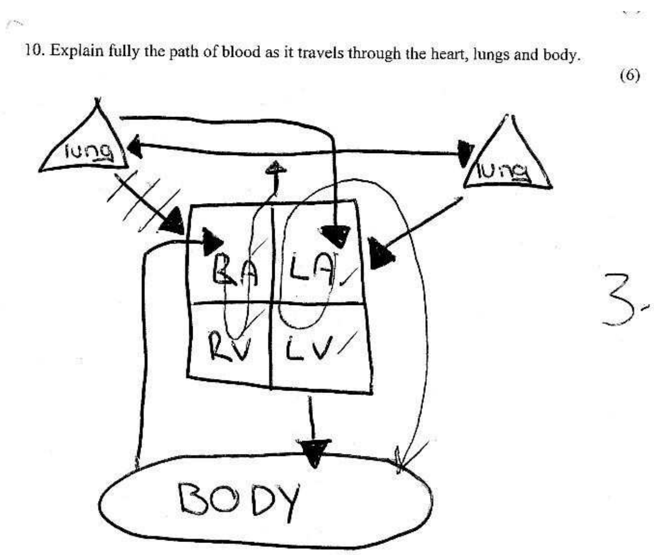


Figure 1: Diagram I from summative assessment 2/06/08

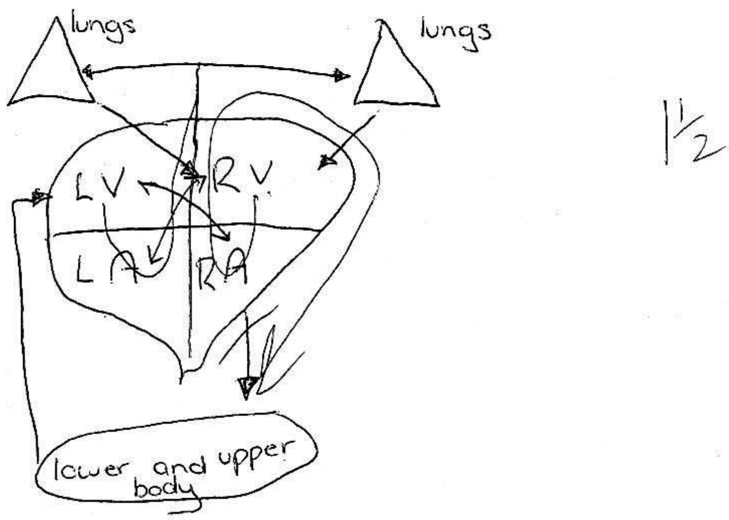


Figure 2: Diagram II from summative assessment 2/06/08

Occasion 4: In class interviews (4/06/08)

Following the Occasion 2 test, we roamed the science class whilst a lesson was in progress, and asked students the following question:

"When you did the science test a couple of days ago, did you have in your mind a mental diagram? Did you use the diagram in your test?

Many students gave limited, or negative, responses to these questions. However, a few responses showed substantial metacognitive insight. For example:

1. *The diagram is there – it's clear whereas the heart it doesn't look the same and it is harder to find everything.*
2. *Just the diagram is easier – it's clearer.*
3. *Yeah, the diagram that he showed us – I put that on the white space there where it said draw the diagram.*
4. *Yep, because I remembered it.*
5. *If you did the diagram like three times it gets stuck in your head, so it helps.*
6. *Yeah, but I think I got it wrong.*
7. *I just drew the diagram.*
8. *On the test we had to answer parts of the body, I remembered from the diagram we did.*
9. *Yeah – I knew like what the heart looked like when he did the diagram and everything, but I didn't know where the arrows went.*

Box 3: Interview responses to "… did you have in your mind a mental diagram? Did you use the diagram in your test?

Occasion 5: Post intervention formative assessment (18/06/08)

At the end of term 2, students were given a guided diagramming /concept mapping task that required them to combine their knowledge from the units of work on digestion, circulatory systems and respiratory systems. The task was stated to the students as follows:

In the past few weeks you have studied three body systems:

Digestive System: Circulatory System: Respiratory System.

Using the large sheet of paper provided, draw a complex diagram that shows how these three body systems fit together. Use the list of key words to help you to draw your diagram. (A list of key words accompanied this task)

The researchers and teacher supported the students in the completion of this task, including answering students' questions and giving prompts about how key concepts, such as diffusion, could apply across the body systems.

Sample diagrams included:

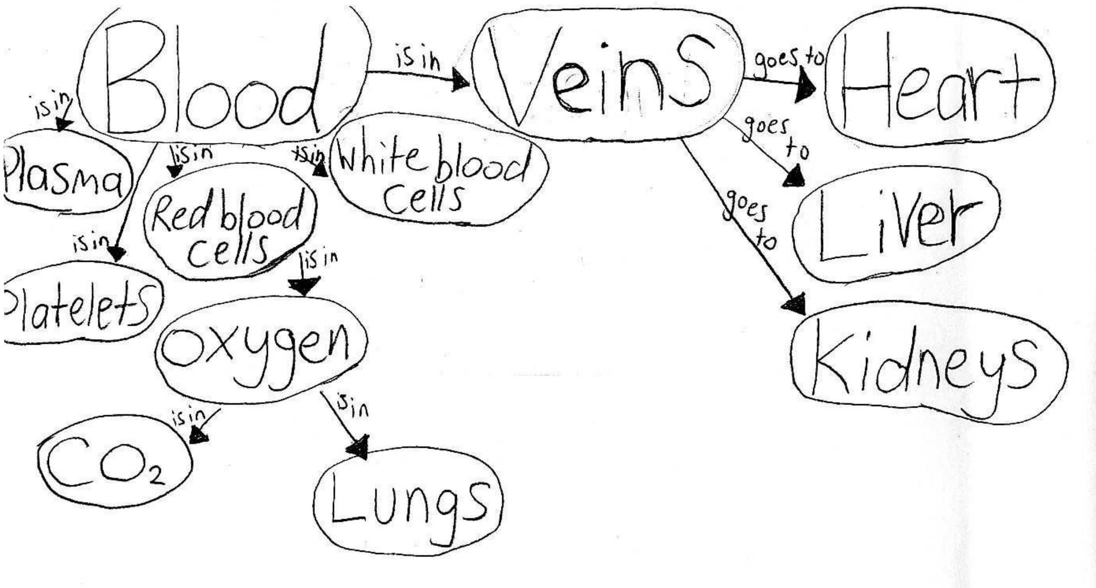


Figure 3: Three-way Concept Map I from formative assessment (18/06/08)

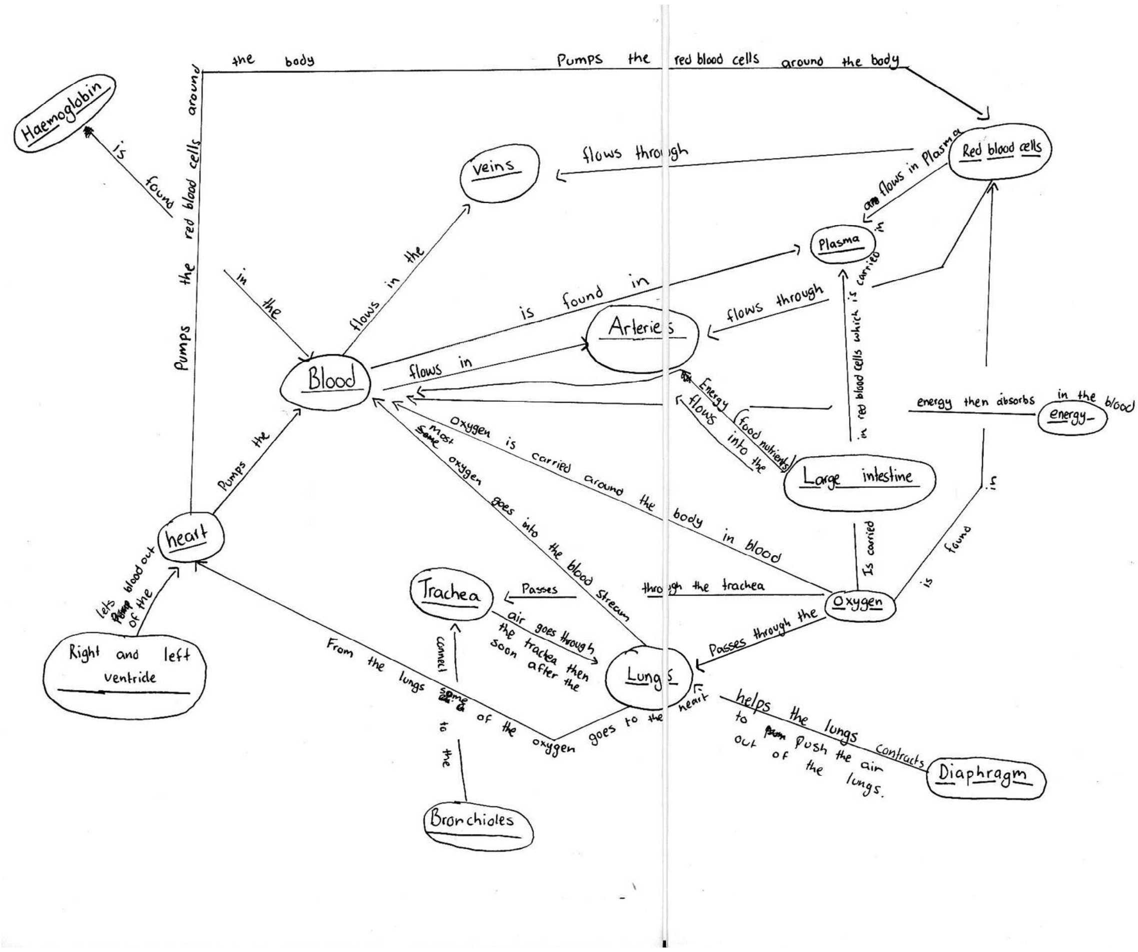


Figure 4: Three-way Concept Map II from formative assessment (18/06/08)

Occasions 6, 7, 8, 9: What will you do to remember this really well?

We asked students to answer a brief feedback sheet in response to the content of specific lessons. Table 3 provides an overview of students' responses to the question,

"What will you do to remember this really well?'

It can be seen that only three students made reference to a diagramming strategy. More common strategies include listen, read, and the generic remember/memorise (but without specific strategies for achieving remembering). In fact, the overall picture of the scope and depth of this class of students' learning capital, as represented by their accounts of learning strategies, is alarming, but not unexpected given other accounts from the literature (e.g.Hattie, Biggs, & Purdie, 1996; Pressley, 1995).

Occasion 10: Delayed post intervention summative assessment (29/08/08)

In the following terms 3 and 4, students studied new units of work (matter and carbon compounds). During term 3 we shifted the focus of our learning capital instructional interventions to another component (focusing on key ideas) however, we continued to collect delayed post-intervention data about students' use of diagrams, concept maps and other relevant visual representations. Importantly, the class teacher made reference to the use of visual representations in his lesson deliveries.

The teacher-selected instructional text included words and visual representations about matter and included key concepts such as metals, non-metals, combustion, conservation, reactions, energy, and photosynthesis.

In the post-instructional intervention test on matter, there was a question with the same question stem "Explain ...." as was included in the summative assessment at Occasion 2. No suggestion about use of diagrams in answering the question was included. The question was:

"Explain the following statements:

a) Fruit ripens more quickly in the sun than it does in the refrigerator

b) Iron fillings will rust quickly if left outside, whereas a sheet of iron will take much longer to rust

c) A piece of paper will burn much better at sea level than it will at an altitude of 10000 metres (slightly higher than Mount Everest)"

All students' responses to these questions were text based. No student used a diagram or visual representation of any kind.

Sample text answers are included in Box 4:

1. *Because the fridge slows down the reaction rate*

2. *Because the surface area. When the iron fillings rust it happens separately but the sheet of iron is one big piece.*

3. *Because it burns better with more oxygen. The higher in the air the less oxygen.*

Box 4: Text responses to summative assessment (29/08/08)

Table 3: What do you do to remember this really well?

RESPONSES TO: What will I do to remember this really well?							
APHS Year 9 Aug 1 08	**response frequency**	**APHs Year 9 Aug 4 08**	**response frequency**	**APHs Year 9 Aug 6 08**	**response frequency**	**APHS Year 9 August 26**	**response frequency**
No response	1	No response	6	No response	4	No response	0
Listen to teacher	5	Listen, listen to teacher	8	listen/listen well/listen to the teacher/listen to instruction	8	Listen	2
Pay attention to teacher	2	Pay attention	1				
Study	2					Study	2
Remember specific feature	2	Remember, memorise	4	remember it/remember the experiment	3		
		Remember different groups and which group elements are in, main elements	2				
Practice , go over them	2	Practice	1	practice/memorise	1	Practice	2
						Practice by connecting to things I need	1
Memorise	2					Memorise, remember	3
use diagrams?	1					Draw diagram	2
Write everything down	1			write in down in our books	2	Write down notes, dot points	2
Write out in way I can remember	1						
Write it lots of times	1						
read and write down	1						
read from book now and then	1	Read	1	read book about what you are doing	1	Read through	5
						Look at, look over	7
						review	2
						Homework	1
						learn	1

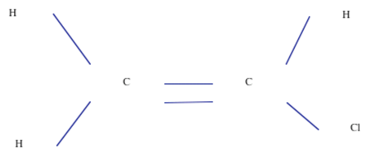
Occasion 11: Delayed post intervention summative assessment (23/9/08)

The teacher-selected instructional text included words and visual representations about carbon compounds and included key concepts such as carbon, hydrocarbon, soap, detergent, PVC.

In the post-instructional intervention test on matter, there was a question with the same question stem "Explain …." as was included in the earlier summative assessments. However, in this case, an additional prompt about diagram use was added to the test question, as follows:

"Long answer question – <u>use diagrams where appropriate</u>

1. Explain how soaps and detergents help to remove grease from dishes, hands, etc.
2. Poly Vinyl chloride (PVC) is a plastic made from the monomer Vinyl chloride, whose structure is shown below: The process of polymerization involves double bonds being replaced by single bonds. Show how PVC can be formed from this monomer. Give one common use of PVC."



Of the 23 students present for the assessment, 15 included a diagrammatic representation in answer to one, or both of the questions at occasion 5. Students who drew diagrams received an average score of 3.03, out of a possible total score of 8, for the two questions. Students who did not draw diagrams received an average score of 1.36 out of 8.

Sample responses included:

Soaps and detergent help to remove grease as they have a grease loving end and a water loving end. Therefore using the water ad grease then cleaning the dishes, etc

Box 5: Text response from Summative Assessment (23/09/08)

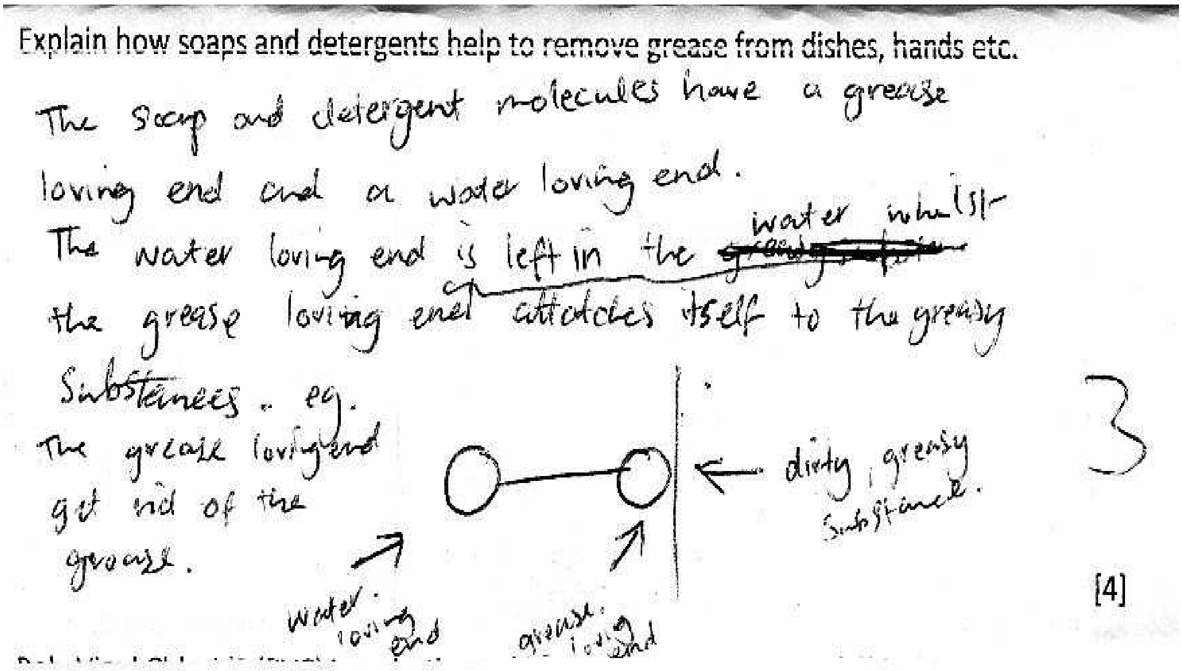


Figure 6: Diagram I from Summative Assessment (23/09/08)

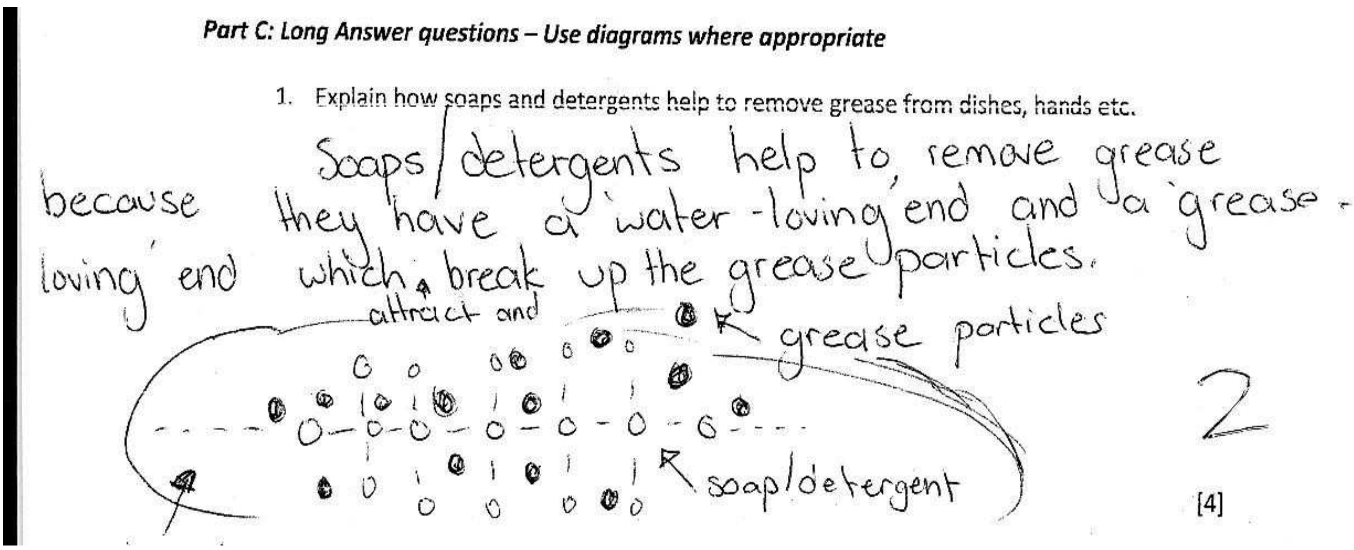


Figure 7: Diagram II from Summative Assessment (23/09/08)

Occasion 12: Delayed post intervention summative assessment (29/10/08)

In the following term 4, students studied new units of work (acids and bases). During term 4 we shifted the focus of our learning capital instructional interventions to another component (end of lesson summaries), however, we continued to collect delayed post-intervention data about students' use of diagrams, concept maps and other relevant visual representations.

The teacher-selected instructional text included words and visual representations about acids and bases, including pictures of common household substances, pH scales, and explanations of the effects, for example, of shampoo with different pH on the smoothness or frizziness of hair..

In the post-instructional intervention test on matter, there was a question with the same question stem as in previous tests, including a prompt to use a diagram. The question was:

"Explain the pH scale for measuring the strength of acids and bases. Refer to the terms strong acid, weak acid, strong base, weak base and neutral. Also, give the approximate pH of at least 4 common substances. Use a diagram if appropriate."

Of the 27 students present for the assessment, 19 included a diagrammatic representation in answer the above questions. Of the eight students who did not draw a diagram, five answered using words only, and three did not answer the question at all.

Sample responses included:

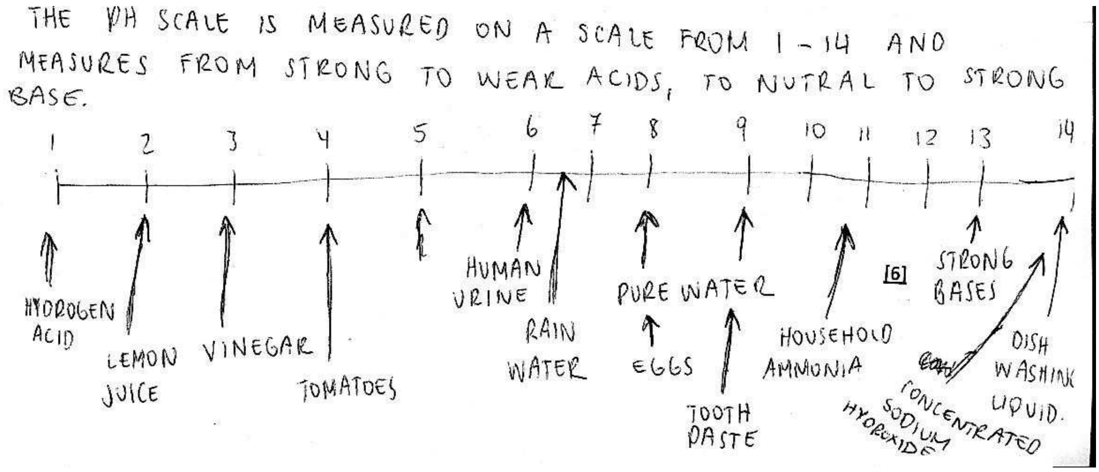
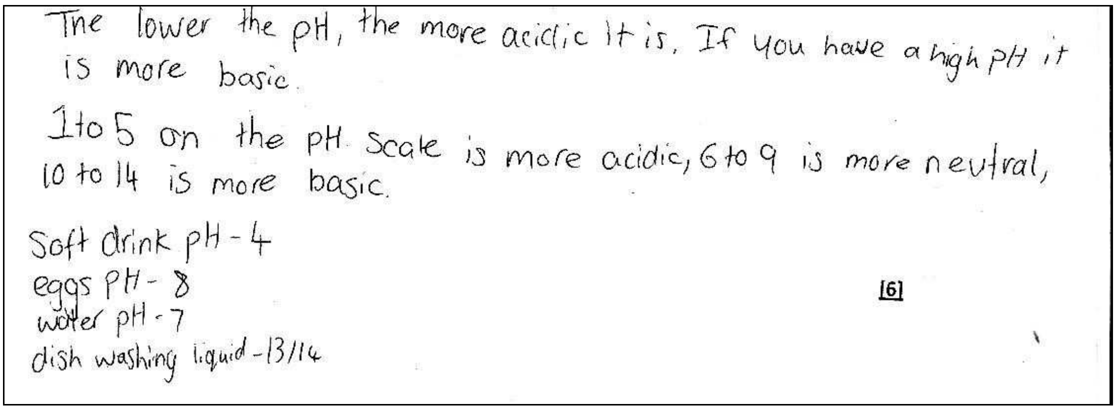


Figure 8: Diagram I from Summative Assessment (29/10/08)


The lower the pH, the more acidic it is. If you have a high pH it is more basic.

1to 5 on the pH scale is more acidic, 6 to 9 is more neutral, 10 to 14 is more basic.

Soft drink pH - 4
eggs PH - 8
water pH - 7
dish washing liquid - 13/14

[6]

Box 6: Text response from Summative Assessment (29/10/08)

Occasion 13: Knowledge about learning

Students were asked to respond in writing to the following two questions:

"What is a thing you learned really well about how to learn?"

Of the 25 students who responded to this task, nine students referred to drawing diagrams or drawing "stuff"

"Is there something about your learning or studying that you would like to know more about?"

In general, students indicated that they did not wish to learn more about learning. Sample responses include

1. *Nothing, I already know how to learn*
2. *Make diagrams???. Take notes when needed*
3. *Nothing, because I already knew all that*
4. *Recording important notes at the time when the teacher is talking about it. Also to draw a diagram*

Student profiles

Table 4 presents the profiles of students' responses to questionnaire items about their initial uses of pictures and diagrams, their self-assessment of coping with school work, their grades, and their uptake of diagramming and concept mapping over the period of our classroom interventions. At baseline, it can be seen that the use of pictures or diagrams was not rated highly by most students. Students indicated that they coped with school work, ranging from a score of 3 (OK/average) to 5 (very well).

The uptake of diagramming and concept mapping by a substantial proportion of students took three school terms, and mostly occurred in situations where the teacher provided clear prompts about the appropriateness of using a visual representation strategy. Students who availed themselves of the diagramming strategy in the prompted tests were represented in the spectrum of grades (A, B, C, D) awarded by the teacher, suggesting that diagrams and concept maps were accessible by students of all ability levels in the intervention class.

Conclusion

The successive interventions and data collection in the Year 9 science class allowed us to observe in fine detail students' behaviour as they engaged in typical classroom-based problem solving tasks, namely, the formative and summative assessments of the regular science test.

The class teacher and the researchers were struck by how many sessions were required for the students to demonstrate uptake of the learning strategy interventions.

One response that emerged from teacher-researcher discussions to this observation about apparently slow uptake is that we were working in a context of "typically" disengaged Year 9 students. Our reaction to that contextual observation is that if we could have an impact on these typical students' learning strategies, then this was a good test of the efficacy of the interventions.

In response to our pre-intervention question in May, What do you do to help yourself to learn? One student nominated creating a visual representation (draw a picture). Prior to our classroom instructional interventions that focused upon the usefulness of diagrams and concept maps for representing, encoding, and retrieving information, at the summative assessment task on Occasion 2, no students invoked diagramming as a problem solving strategy in the test situation (at least not as far as we could tell from the collected student work). Students' use of diagramming/concept mapping increased at the summative assessment at occasion 2, then disappeared at occasion 10, then, with prompting, reappeared at occasions 11 and 12. At occasion 13, in response to the question, "What is a thing you learned really well about how to learn?" nine students referred to a diagramming strategy.

It is not possible to make strong claims for this classroom based research that definitively state that students' increased use of diagrams was solely due to our instructional interventions. However, the pattern of students' responses over time does point to a trend that suggests that explicit instruction about using visual representations such as diagrams has provided students with an additional strategy for learning. The pace of uptake, nevertheless, is slow, occurring in small steps. Learning strategies were not a high priority for some students.

The pattern of students' responses suggests that students' use of diagrams/visuals when prompted indicates that students anticipate what the teacher requires in response to each test question. If the framing of a test question seems to require a text only response, this is what students most will be cued to provide. However, if the framing of the question permits alternative response formats, students can draw upon a broader mental model about the subject matter. We see that the effect of the prompts in the test questions in this study is linked to that observed by Fuchs and colleagues (Fuchs et al., 2003) when they investigated the impact of explicit teaching about transfer. Furthermore, in their study of the use of learning protocols to prompt students to access their metacognitive knowledge, Berthold, Nuckles and Renkl (2007) suggested that more work needs to be done on convincing students of the value of cognitive and metacognitive prompts for learning success. Relating Berthold and colleagues' assessment to the findings in our study, one recommendation for future instructional interventions could be to provide students with more explicit instruction in strategies for interpreting the intent of assessment questions. A second outcome could be to work with teachers to embed intended, and appropriate, cues in assessment questions in order to give students the opportunity to match their own mental models of expectations for correct responses with their teachers' mental models.

The approach of providing the prompt from the teacher seems essential when aligning the assessment concerns of the teacher and student, with the instructional concerns of promoting the use of mental imagery, in the form of flow charts, diagrams, concept maps, for learning. For example, discussions with the class teacher indicated that he felt that the summative "Explain…" test questions at occasion 4 did not lend themselves to a diagramming response. Recall that this is the occasion where no students produced a visual representation as a response. In short, the prompts from the teacher provide cues to the students about the value of encoding and retrieving knowledge using imagery strategies.

Our argument in this paper is that using mental imagery representations such as diagrams and concept maps are valuable strategies for encoding and retrieving knowledge during problem solving for learning. The evidence provided above suggests that students can be explicitly taught such strategies, and that these strategies can be embedded in regular science lessons without unduly adding to the time required to plan or deliver the lesson. However, we have noted that in addition to explicit teaching of mental imagery strategies, it is necessary for the teacher to cue to students that imagery strategies are valued in problem solving situations such as summative assessments. Providing students with explicit instruction, opportunities for practice, and cues to value those strategies, forms part of advancing students' learning capital in order to achieve academic success. This in turn provides a foundation for academic wellbeing. This relationship to wellbeing links this paper to the other papers in this symposium, which deal with dimensions of wellbeing in school communities.

Table 4: Student profiles

ID	use diagrams rating (1 to 7) 16/05/08 *	cope with schoolwork rating (1 to 5) 16/05/08 **	pre-test 21/05/08 (use diagrams?)	non-prompted test 2/06/08	Term 2 grades	strategy feedback 1/08/08	strategy feedback 4/08/08	strategy feedback 6/08/08	strategy feedback 26/08/08	Semester 1 grades	non-prompted test 29/08/08	prompted test 23/09/08	prompted test 29/10/08
1	1	4	no	no	B	no	absent	no	absent	B	no	no	no
2	2	4	no	absent	C	no	no	no	no	C	no	absent	yes
3	1	4	no	yes	C	no	no	no	absent	B	no	yes	yes
4	2	4	no	no	C	no	no	no	no	B	no	yes	yes
5	2	4	no	no	B	no	no	no	no	A	no	absent	yes
6	5	3	no	no	B	no	no	no	no	B	no	yes	yes
7	3	4	no	no	B	no	no	no	no	C	absent	yes	no
8	1	4	no	no	C	no	no	no	absent	C	absent	yes	yes
9	1	3	no	yes	N/A	no	no	no	no	B	no	yes	yes
10	1	4	no	yes	A	no	no	no	no	B	no	yes	yes
11	5	4	no	yes	B	no	no	no	no	B	no	yes	absent
12	1	5	no	yes	B	no	no	no	absent	C	no	no	yes
13	1	3	no	yes	C	transferred	x	x	x	x	x	x	x

*students self- rated their use of pictures or diagrams in the subject they do best at in school on a scale of 1 (strongly disagree) to 7 (strongly agree)

**students self-rated how they cope with schoolwork overall on a scale of 1 (mostly I don't cope) to 5 (very well)

Yes = used or suggested using a concept map or diagram

No = did not use or suggest using a concept map or diagram

Grade range: (highest) A, B, C, D (lowest)

References

Berthold, K., Nückles, M., & Renkl, A. (2007). Do learning protocols support learning strategies and outcomes? The role of cognitive and metacognitive prompts. *Learning and Instruction*.

Butler, D. L., & Winne, P. H. (1995). Feedback and self-regulated learning: A theoretical synthesis. *Review of Educational Research, 65*, 245-281.

Edmondson, K. M. (2000). Assessing science understanding through concept maps. In J. J. Mintzes, J. D. Novak & J. W. Wandersee (Eds.), *Assessing science understanding: A human constructivist view* (pp. 15-40). San Diego, CA: Academic Press.

Fuchs, L. S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C. L., Owen, R., et al. (2003). Explicitly teaching for transfer: Effects on third-grade students' mathematical problem solving. *Journal of Educational Psychology, 95*, 293–304.

Glaser, R., & Bassok, M. (1989). Learning Theory and the Study of Instruction. *Annual Review of Psychology, 40*(1), 631-666.

Hattie, J., Biggs, J. B., & Purdie, N. (1996). Effects of student learning skills interventions on student learning: A meta-analysis. *Review of Educational Research, 66*, 99-136.

Hilbert, T. S., & Renkl, A. (2008). Concept mapping as a follow-up strategy to learning from texts: what characterizes good and poor mappers? *Instructional Science, 36*, 53–73.

Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science, 26*, 49-63.

Mintzes, J. J., & Novak, J. D. (2000). Assessing science understanding: The epistemological vee diagram. In J. J. Mintzes, J. D. Novak & J. W. Wandersee (Eds.), *Assessing science understanding: a human constructivist view* (pp. 41-69). San Diego, CA: Academic Press.

Novak, J. D. (1990). Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional Science, 19*(29-52).

Novak, J. D., Mintzes, J. J., & Wandersee, J. W. (2000). Epilogue: On ways of assessing science understanding. In J. J. Mintzes, J. D. Novak & J. W. Wandersee (Eds.), *Assessing science understanding: A human constructivist view* (pp. 355-374). San Diego, CA: Academic Press.

Pearsall, N. R., Skipper, J. J., & Mintzes, J. J. (1997). Knowledge restructuring in the life sciences: A longitudinal study of conceptual change in biology. *Science Education, 81*, 193-215.

Pressley, M. (1995). Introduction: good thinking, good teaching, and alternative ways of studying good thinking and good teaching. In M. Pressley & C. McCormick (Eds.), *Cognition, teaching, and assessment* (pp. 1-11). New York: Harper Collins College Publishers.

Reimann, P., & Chi, M. T. H. (1989). Human expertise. In K. J. Gilhooly (Ed.), *Human and machine problem solving* (pp. 161-191). New York: Plenum Press.

White, R. T., & Gunstone, R. F. (1992). *Probing understanding*. London: Falmer Press.