Open ended problem solving and the influence of cognitive factors on student success

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Aims

- To investigate the factors that affect student success in solving open-ended problems

- To investigate the effect of context on students engagement with open-ended problems

- To investigate how students might become more effective problem solvers

Employability of Graduates

- Increasing demand for 'transferable' skills
  - > Team work, communication, IT, time management, career planning, numeracy, etc

- Intellectual skills - Higher order cognitive skills (HOCS)
  - > Problem solving
  - > Critical reading
  - > Critical thinking
  - > Decision making
  - > Understanding argument
  - > Constructing argument

What affects the development of Higher Order Cognitive Skills?

- Previous knowledge (Ausubel et al, 1978)

- Type of learning undertaken.
    - > Content heavy
    - > Memory and recall - tests only lower order cognitive skills (LOCS)
    - > Problem based learning (Savin-Baden, 2000)
    - > Problem solving
    - > Meaningful context (Mandl, Gruber and Renkl, 1993)

- Student's cognitive style
    - > Working memory capacity
    - > M-Capacity
    - > Degree of field dependence or disembedding ability
    - > Attitude/Motivation

Problem Solving

- What is a problem?

"Whenever there is a gap between where you are now and where you want to be and you don't know how to find a way to cross that gap, you have a problem."
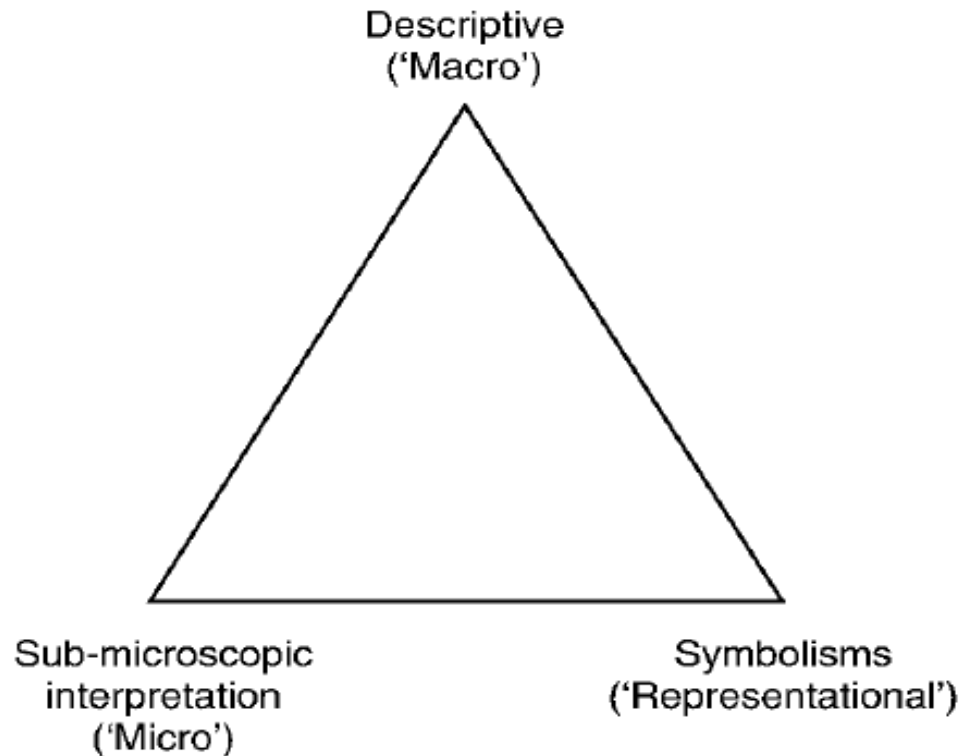(J Hayes, 1980)

Problem Types

Classification of Problems (Johnstone, 1993)

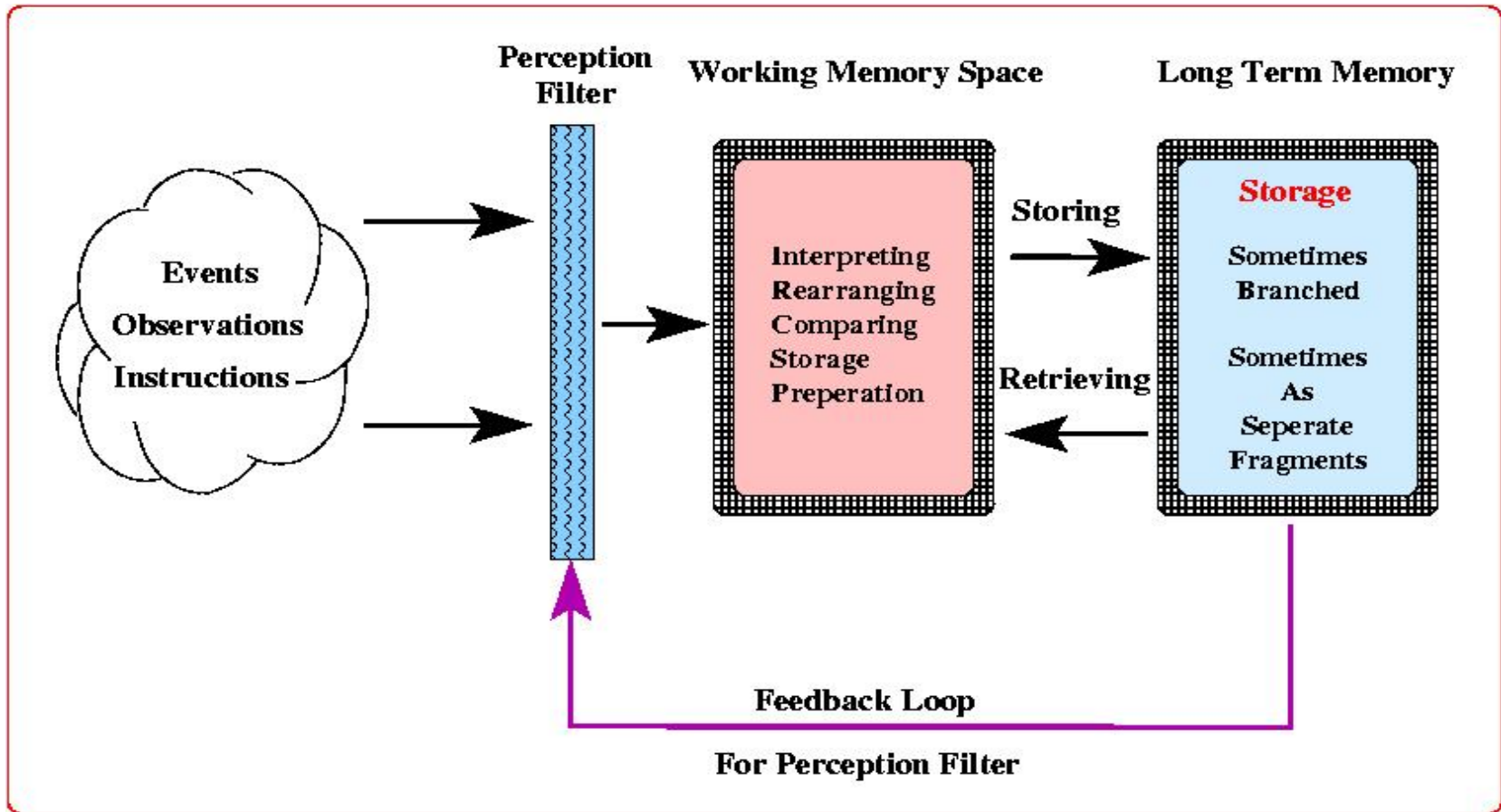| Type	Data	Methods	Outcomes/Goals	Skills Bonus
1	Given	Familiar	Given	Recall of algorithms.
2	Given	Unfamiliar	Given	Looking for parallels to known methods.
3	Incomplete	Familiar	Given	Analysis of problem to decide what further data are required.
4	Incomplete	Unfamiliar	Given	Weighing up possible methods and then deciding on data required.
5	Given	Familiar	Open	Decision making about appropriate goals. Exploration of knowledge networks.
6	Given	Unfamiliar	Open	Decisions about goals and choices of appropriate methods. Exploration of knowledge and technique networks.
7	Incomplete	Familiar	Open	Once goals have been specified by the student, these data are seen to be incomplete.
8	Incomplete	Unfamiliar	Open	Suggestion of goals and methods to get there; consequent need for additional data. All of the above skills.

Use of context

Johnstone 1991

Descriptive ('Macro')

Sub-microscopic interpretation ('Micro')

Symbolisms ('Representational')

Cognitive style

- Information Processing Model (Johnstone and El-Banna, 1986)
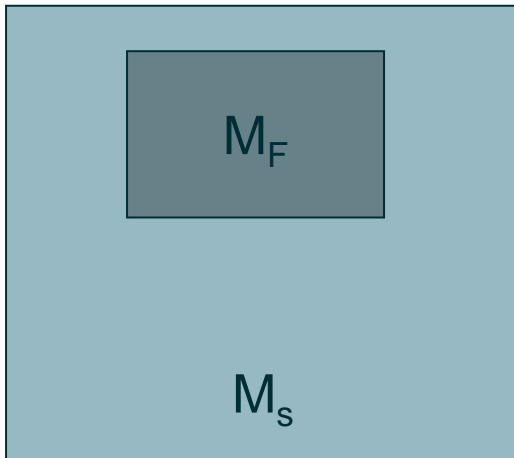
Cognitive style tests

- Working memory capacity

Digit Span Test

5	8	2						
6	9	4						
6	4	3	9					
7	2	8	6					
4	2	7	3	1				
7	5	8	3	6				
6	1	9	4	7	3			
3	9	2	4	8	7			
5	9	1	7	4	2	8		
4	1	7	9	3	8	6		
5	9	1	9	2	6	4	7	
3	8	2	9	5	1	7	4	
2	7	5	8	6	2	5	8	4
7	1	3	9	4	2	5	6	8

Cognitive style

- M-capacity
  - > Pascual-Leone et al (1978)
  - > Number of pieces of information that can be processed at once.
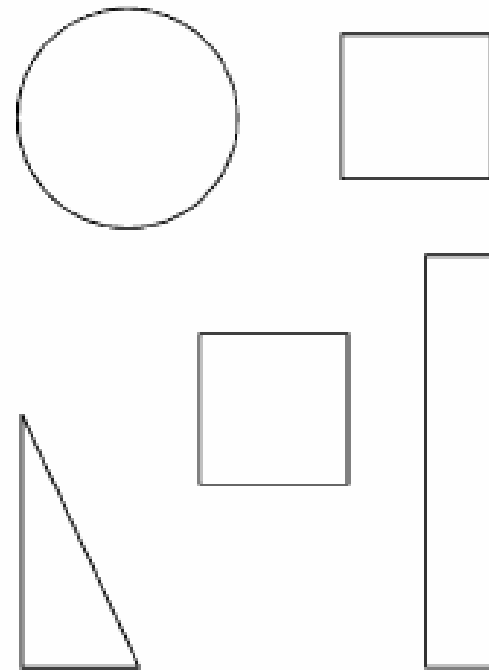
M_F

M_S

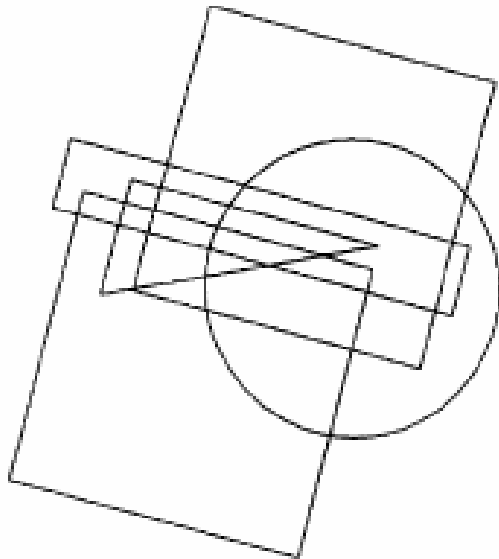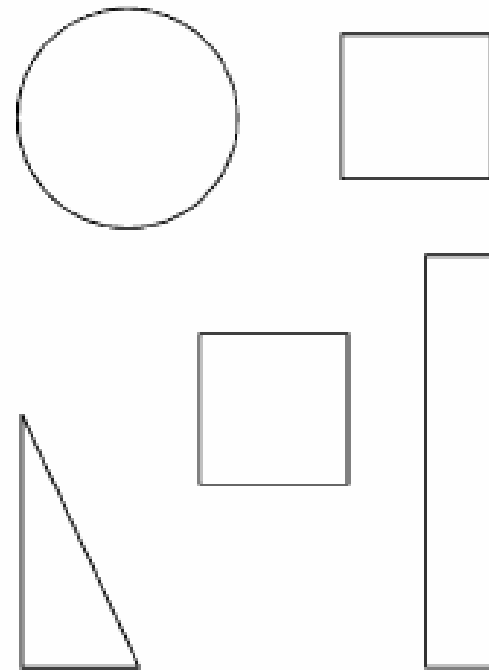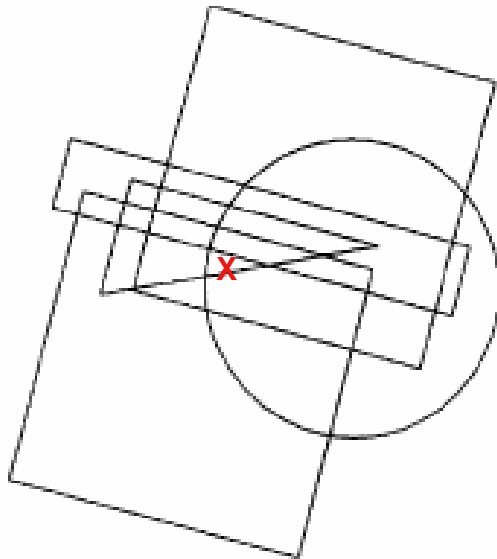Low Processors

M_F

M_S
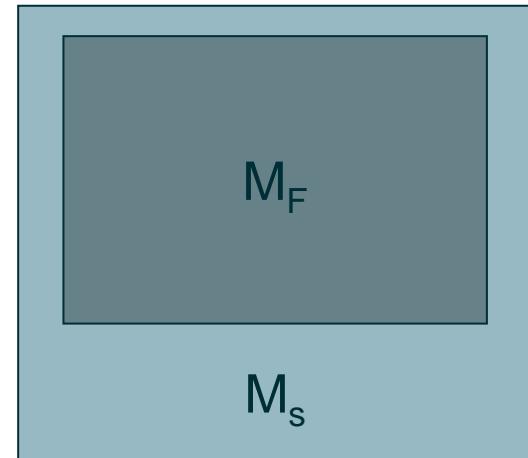
High Processors

Cognitive style tests

- M-capacity
  - > Figural Intersection Test

Cognitive style tests
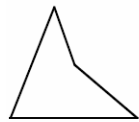
- M-capacity
    - > Figural Intersection Test

Cognitive style

- Field dependence/independence (Witkin et al, 1971)

    > Disembedding ability

    > Ability to separate relevant from irrelevant information.
    - "signal from noise"

    > Field dependent
    - Lower achiever

    > Field independent
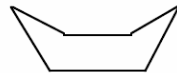   - Higher achiever

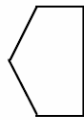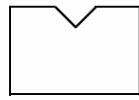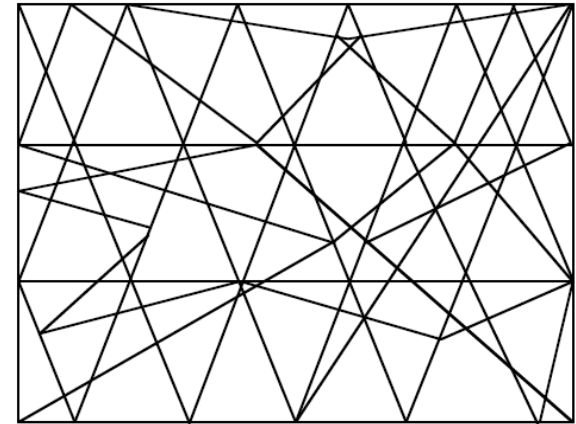# Cognitive style tests
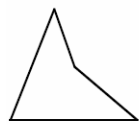
> Group Embedded Figures test

A   B   C

D   E   F

Find shape A

Cognitive style tests

> Group Embedded Figures test
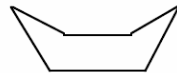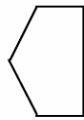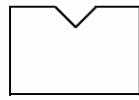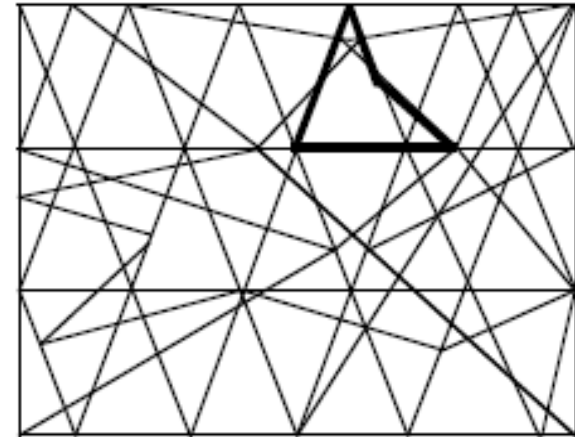

Find shape A

Attitude

"Our attitudes control our lives. Attitudes are a secret power working twenty-four hours a day, for good or bad. It is of paramount importance that we know how to harness and control this great force." - Tom Blandi.

"A positive attitude may not solve all your problems, but it will annoy enough people to make it worth the effort." - Herm Albright

Attitude questionnaire

Strongly Agree, Agree, Neutral, Agree, Strongly Agree.

	Questions 1-5 begin with, I find chemistry:						
1	Challenging	SA	A	N	A	SA	Easy
2	Varied	SA	A	N	A	SA	Repetitive
3	Interesting	SA	A	N	A	SA	Boring
4	Satisfying	SA	A	N	A	SA	Unsatisfying
5	Exciting	SA	A	N	A	SA	Tedious
	Questions 6-16 about problem solving in chemistry:						
6	I am good at problem solving.	SA	A	N	A	SA	I am poor at problem solving.
7	I usually have enough time to complete a set problem.	SA	A	N	A	SA	I usually struggle to complete a set problem in time.
8	I have an effective strategy for tackling unfamiliar problems.	SA	A	N	A	SA	I have not found an effective strategy for tackling unfamiliar problems.
9	Open ended problems enhance my understanding of the subject.	SA	A	N	A	SA	Open ended problems don't affect my understanding of the subject.
10	Problem solving is a useful skill to acquire.	SA	A	N	A	SA	Acquiring the skill of problem solving is a waste of time.

The problems

- Andrew "Freddie" Flintoff loves cricket, he also loves curry and once again he will be able to indulge both passions on his return to the subcontinent for England's tour of India. Use the following data to calculate how much curry Freddie will need to eat to provide with him the energy he needs to get through a test match and a one day game.

- You've been on Who Wants To Be a Millionaire and won £64,000. You decide to treat yourself and some mates to a holiday in America. The flight from Heathrow to New York is 7 hours. To provide breathable air on an aircraft recirculation cells containing KO_2 are used. Potassium dioxide reacts with the exhaled carbon dioxide as follows:

  $4KO_2 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$
  $K_2CO_3 + CO_2 + H_2O \rightarrow 2KHCO_3$
  What mass of KO_2 would be needed on a Boeing 747 for this flight?

The problems

- Research chemists want to produce nanoparticles on an oxide surface for catalysis. Their landlady gave the research team her Krugerrand. How many nanoparticles can the team produce from the Krugerrand?

- Taxol is used as a treatment for cancer. It can be extracted from Yew tree clippings. A dose of 1mg of taxol when given to a rat is an effective dose and is cleared from the blood in 3 hours. How many daily oral doses for a human can be extracted from the clippings of one yew tree?

- The rivers and oceans contain levels of dissolved gold of between 5 and 50 ppt. Extraction of gold from seawater has been seriously considered many times. Approximately how many kg of gold are present in the world oceans.

- How many oxygen atoms are there in the room?

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Industrial problems

- Some unscrupulous food producers often adulterate products or claim certain products are from a different region than they actually are. High quality Californian orange juice is often mixed with an inferior orange juice or beet sugar to increase volume. It is however sold as authentic Californian orange juice. Greater profits are made by adulterating the juice. How would you go about detecting this adulteration?

- Mechanics for a rally car team are experiencing frequent gearbox failures of oil filled gearboxes during track testing. There appears to be no evidence of gross mechanical failure and they have asked you to investigate. How do you go about finding the cause of failure?


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Results

- Generally
  - > Correlation between A level scores and problem solving ability
  - > Increased positive attitude towards problems with real life or work related context
  - > All found problem more enjoyable than conventional ones
  - > All found them more challenging than conventional ones
  - > P/T students performed much better on problem solving tasks
  - > Problem solving sessions engage students
- Year 2
  - > Group and individual, n=60
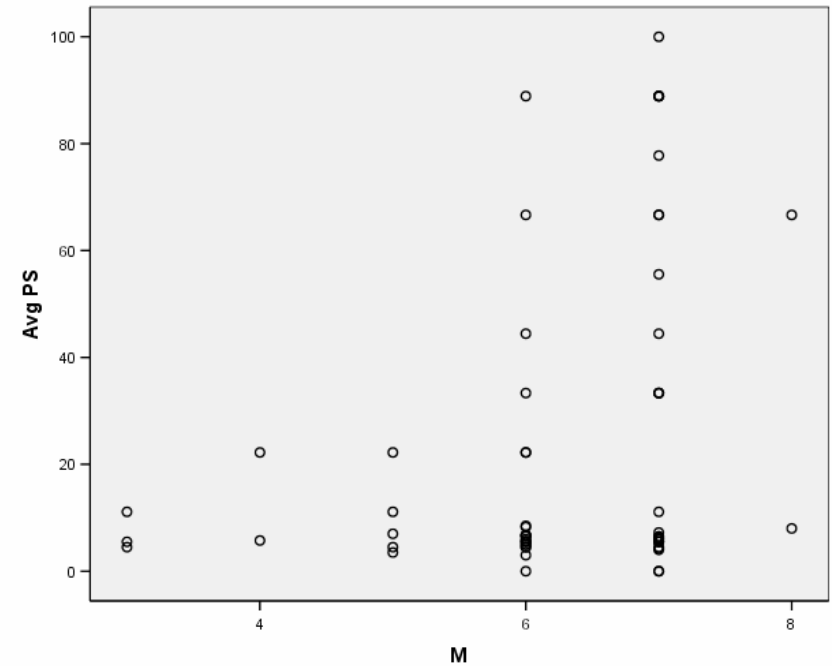 - > Correlation between Field Independence and problem solving ability

Results

- Year 3 05/06 + 06/07
    - > Individual & groups n = 60
    - > Indication of correlation between M-Capacity and Field Dependence and M-Capacity and problem solving ability

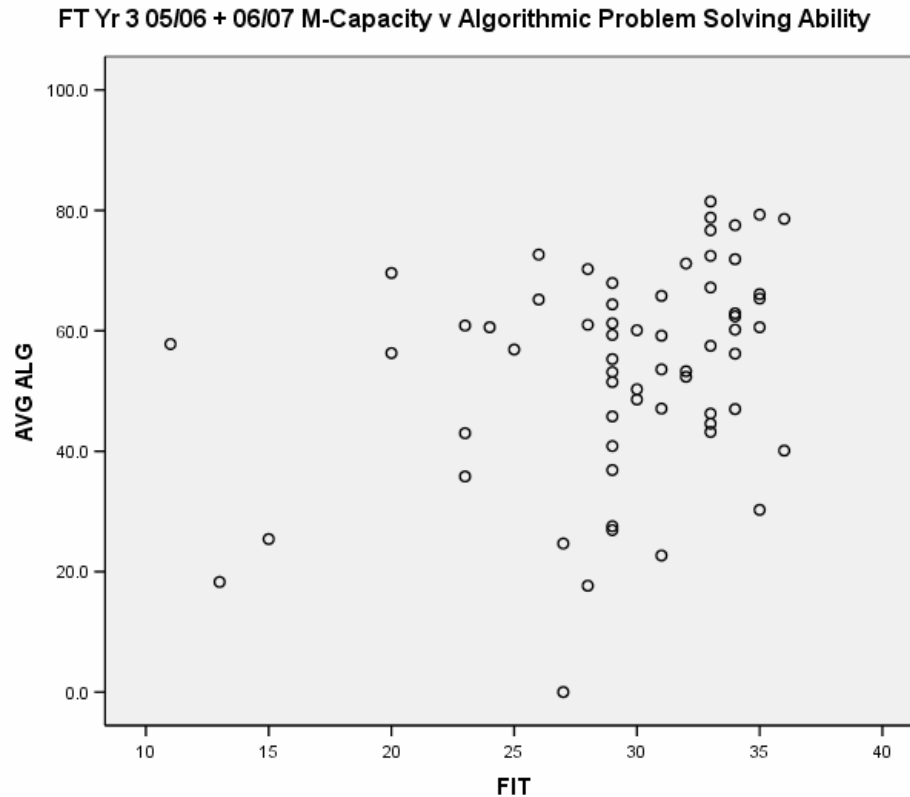FT Yr 3 05/06 + 06/07 M-Capacity v Field Dependence/Independence

R Sq Linear = 0.188
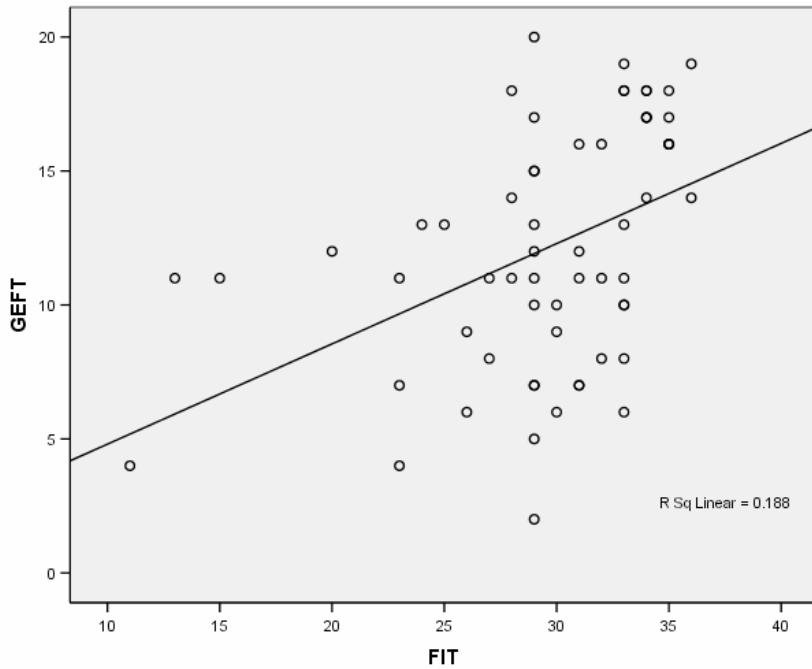
FT Yr3 05/06 + 06/07 M-Capacity v Problem Solving Ability

Results

- Year 3 05/06 + 06/07
  - > Indication of correlation between M-Capacity and Algorithmic problem solving ability

FT Yr 3 05/06 + 06/07 M-Capacity v Algorithmic Problem Solving Ability

What next?

- Evaluate Interviews and case studies data
  - > Evaluate effect of context based learning
- Repeat to improve sample size
- Investigate the impact of industrial experience
- Industrial problems with year 4 students
  - > Collaborations?

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Thanks to our undergraduates

- *"fun, got to discuss and decide which route to take to solve problem"*
- *"explore range of answers and knowledge of chemistry"*
- *"better to have questions in context!"*
- *"everyone threw in own ideas and discussed"*
- *"had to use brain in a better way"*
- *"enjoyed whole experience, exercised mind"*