The Monash Critical Thinking Study

Many people reason poorly, by almost any measure of reasoning. Although there is evidence that people can be taught to think critically, educators don't really know how. They don't know what works, what doesn't, or why. This report describes the Monash Critical Thinking Study – a three year project to investigate the effectiveness of a number of teaching methods for improving critical thinking. Monash University students enrolled in a first-year critical thinking course are pre- and post-tested using the California Critical Thinking Skills Test (CCTST) and the critical thinking section of the Graduate Skills Assessment (GSA).The course is taught in both semesters and the teaching methodology varied each time, so that the effectiveness of different methods can be compared. In these pages, we give brief descriptions of the teaching methods investigated and report some preliminary results.

CONTENTS

Background

What is Critical Thinking?

Critical thinking is a set of skills and dispositions, essentially involving the ability to analyse and evaluate real arguments in natural language. More specifically, we define critical thinking to include the following set of skills and related dispositions:

1. Argument analysis

Clarify the meaning of claims

Identify arguments

Identify premises and conclusions in arguments

Identify implicit premises

Identify the structure of arguments

2. Argument evaluation

Assess the plausibility of statements

Assess explanations

Evaluate arguments

Draw correct conclusions from data

Other terms that are often used for critical thinking in this sense are: *informal reasoning*, *informal logic* and *critical reasoning*.

How good are people at critical thinking?

Evidence from a number of different sources suggests that the answer is: not very good.

1. **Studies showing that many people find it difficult to provide reasons or arguments to support their beliefs**

There is evidence that many people have great difficulty in understanding the concept of an argument – the process of giving *reasons* for a belief that they hold. (Kuhn 1991). Subjects in Kuhn's study were asked for their opinions on the underlying causes of various social problems, such as:

What causes prisoners to return to crime after they're released?

Why do children fail in school?

What causes unemployment?

Subjects had no difficult in offering opinions on these subjects. However, when asked to give *reasons* or *evidence* to support their views, most were unable to do so. Typically, they were able to do little more than simply restate their opinion in different words.

2. Studies that reveal the existence of systematic biases in reasoning

There is a great deal of empirical evidence for systematic errors and biases in human reasoning. (Kahneman et. al. 1982, Baron 1994). These biases include:

1. Insensitivity to base-rates and sample size

People appear to assess probabilities in terms of conformity to stereotypes, ignoring base rate information, even when it is available.

2. Belief in the 'law of small numbers'

Overestimation of the representativeness of small samples.

3. Confirmation or myside bias

The tendency to weigh arguments in support of an accepted belief more strongly than arguments against.

4. Outcome/hindsight bias

> The tendency to evaluate decisions and predictions in terms of their outcomes, rather than in terms of the evidence available at the time.

These biases are robust and widespread and even experts are prone to them.

Can critical thinking be improved through teaching?

Given that people typically are not very good at informal reasoning, the question arise whether there is anything that can be done about it. Can reasoning be improved through teaching? The evidence here is mixed. Since our focus is on university level teaching, we review here some of the data on the how university affects critical thinking skills.

1. A university education is associated with better critical thinking

Kuhn (1991) found that people with a university education were better at informal reasoning. In particular, philosophy graduate students interviewed in her study performed much better than the average, as one might expect. By itself, this is very weak evidence of the effect of university of course, since philosophy graduate schools *select* for high level skills in reasoning and argument.

However, a more detailed analysis of the available evidence does support the view that a university education has an effect on critical thinking skills over and above that which can be accounted for by maturation and selection or attrition effects. In their review of studies, Pascarella and Terenzini (2005) estimated that the first three years of university provide an improvement of about **0.55** standard deviations, or 20 percentile points in critical thinking, most of the improvement occurring in the first year.

Other studies have shown that university level teaching can lead to improvements in specific reasoning skills, though the effects are not uniform across disciplines. For example, one longitudinal study of U.S college students (Lehman & Nisbett, 1990) found that four years of undergraduate training in social science subjects lead to large improvements in statistical and methodological reasoning (70%) compared to natural science and humanities subjects (25%). (Figure 1).

The same study found that four years of undergraduate training in natural science or humanities subjects leads to improvement in conditional deductive reasoning (60%) compared to social sciences or psychology (0%). (Figure 2).

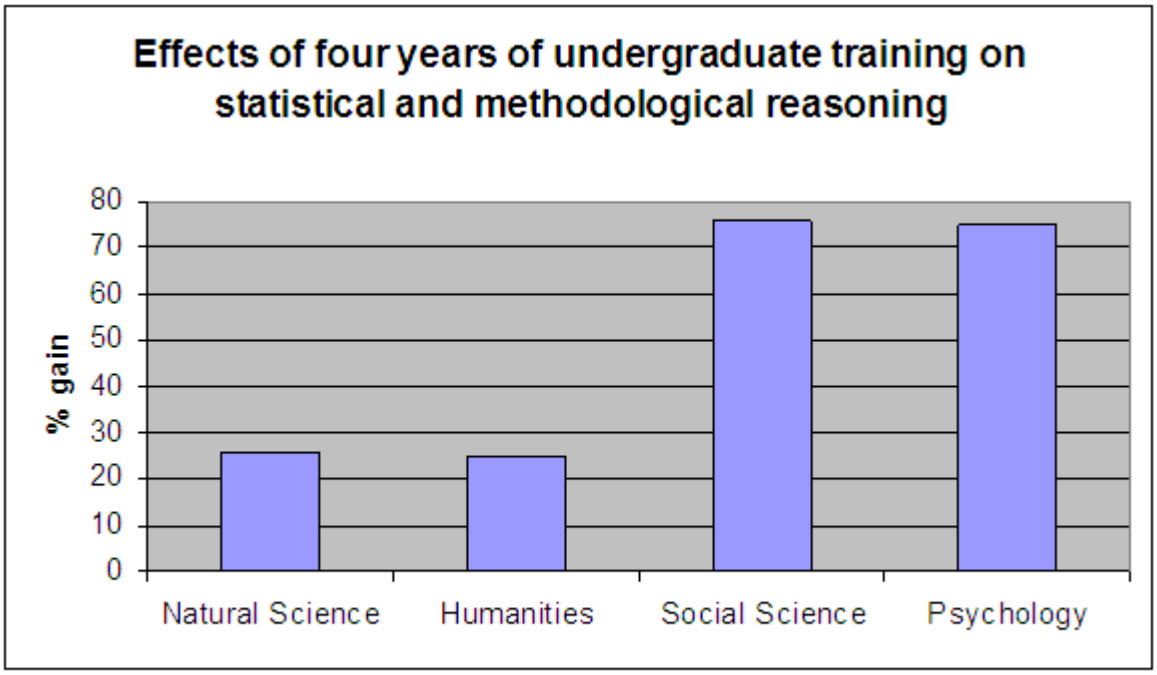


Figure I

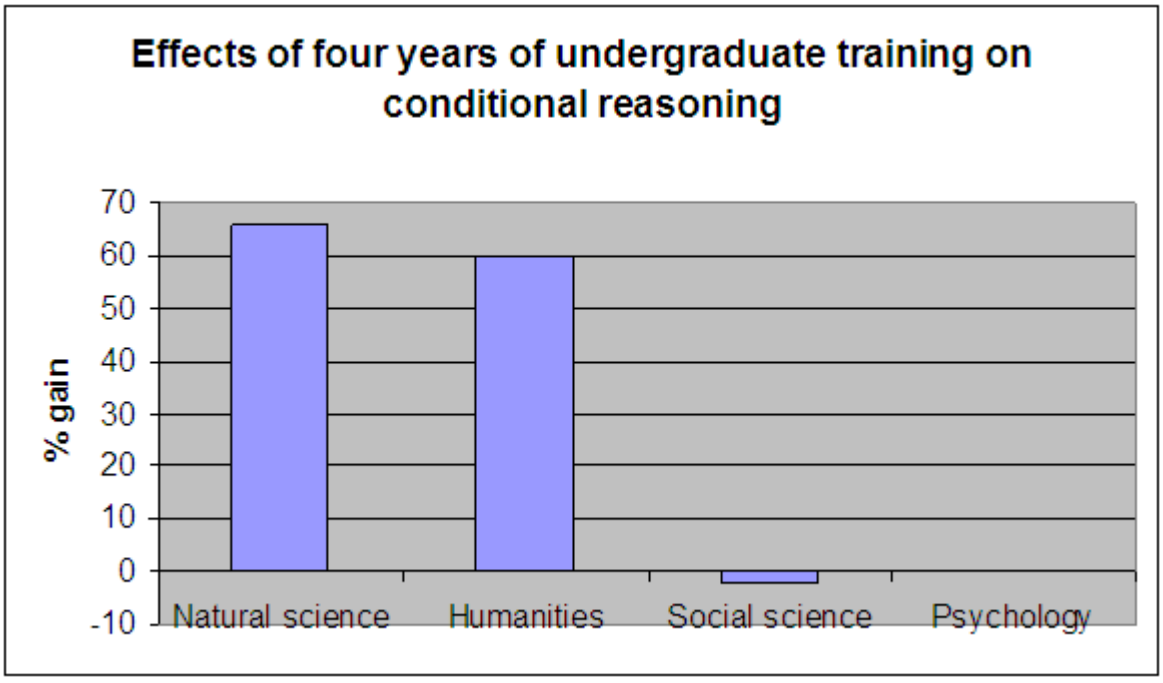


Figure 2

2. **Dedicated instruction can improve critical thinking**

What about courses that are specifically aimed at improving informal reasoning? Again, the evidence is mixed. A review of 27 studies of college courses designed to enhance informal reasoning found *no evidence* that specific courses or instructional techniques lead to any improvement. (McMillan 1987, see also Pascarella and Teremzini 1991, McKeachie et. al 1986.) However, more recent studies suggest that some critical thinking courses *do* work. Figure 3 shows data from a number of university courses aimed at improving critical thinking. Students in all these studies were pre- and post-tested using the a standardized test of critical thinking, the California Critical Thinking Skills Tests (CCTST, Facione 1991, 2002). Effect sizes for gain scores range from 0.32 to 0.89 standard deviations, corresponding to average gains from pre- to post- test of 4.1 to 11.8 percentage points on the CCTST.

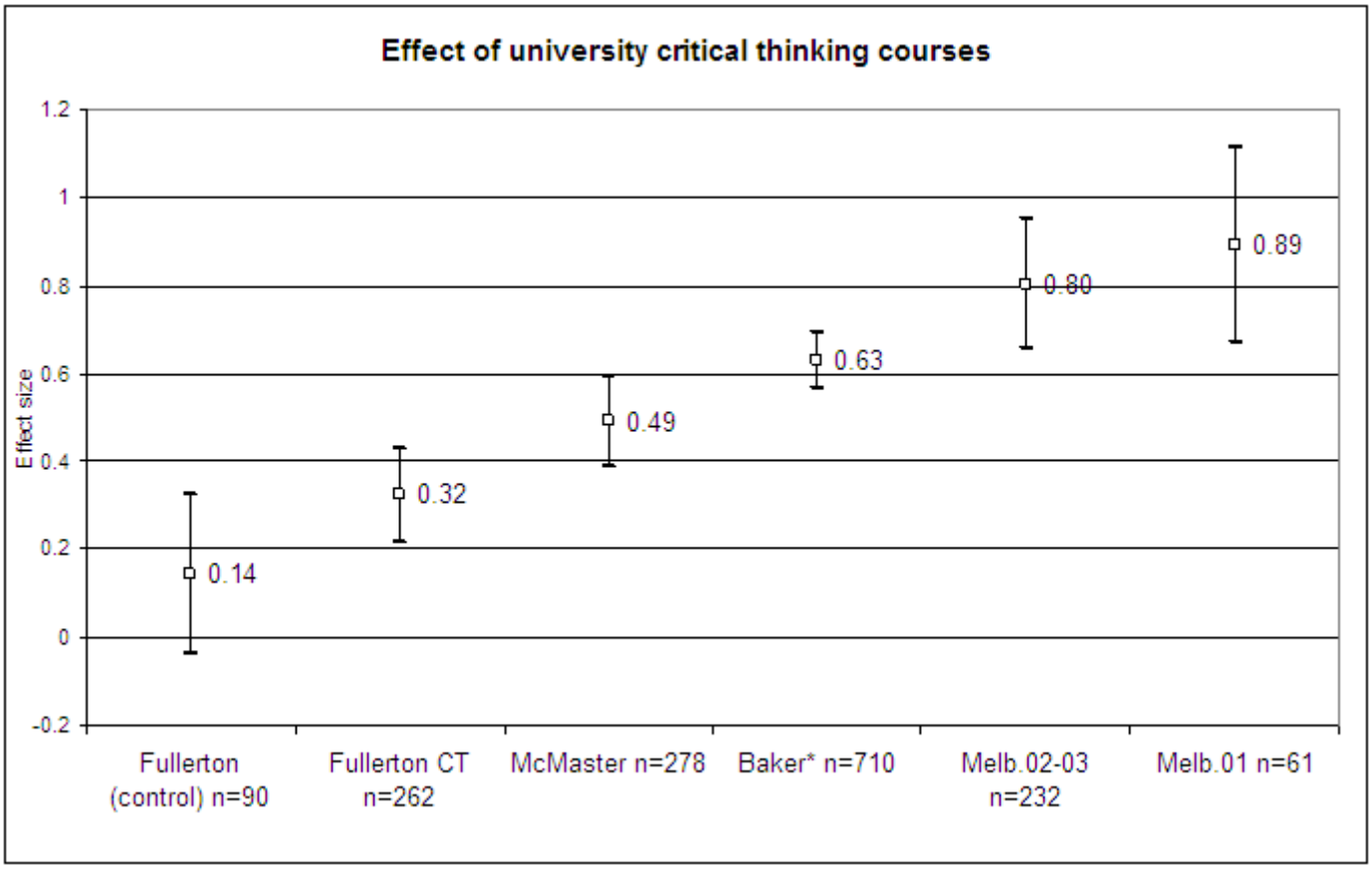


Figure 3

Bars show 95% confidence intervals for gain in standard deviations.

*Two semester course.

Sources: Fullerton (Facione 1990), Baker (Hatcher 1999, 2001), McMaster (Hitchcock 2003),

Melbourne (van Gelder 2001, 2004).

These effect sizes are comparable to the estimated for the improvement due to a full three years of university education (0.55 standard deviations). Still, even the best courses lead to gains that are not the best one might hope for. Figure 4 shows the improvement of the students in each of the above studies as a percentage of how much the class could have improved, given the average pre-test score for the class. Even the biggest effect (0.89 standard deviations) obtained at Melbourne university, corresponds to an class average improvement of just 25%.

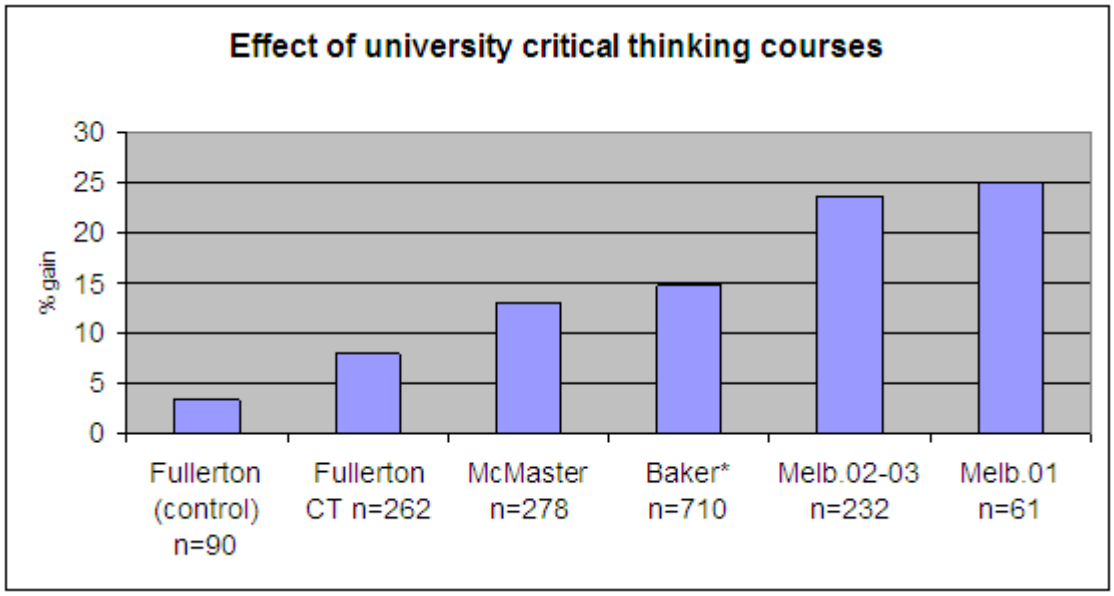


Figure 4

The Monash Critical Thinking Study

The fact that many attempts to teach critical thinking fail, while a few are successful raises an obvious question; what teaching methods work and which do not? What are the successful course doing right and what are the unsuccessful courses doing wrong? The Monash Critical Thinking Study was set up with the aim of answering these questions. After a pilot study in 2003, work began in semester 1, 2004. The final study will be completed in semester 1, 2006.

Aims

1. To investigate the factors that effect students' critical thinking and reasoning skills.

2. To cross-validate an Australian test of reasoning (the GSA) with an international standard.

3. To compare the effectiveness of a number of teaching methods for improving students' critical thinking and reasoning skills:

- Computer-assisted argument mapping
- Actively Open-Minded Thinking (AOMT)
- Peer-instruction

Methodology

Participants

Participants are Monash University students enrolled in a single semester first-year critical thinking course (PHL 1030: *Thinking: Analysing Arguments)* taught by the Monash School of Philosophy and Bioethics. All students taking the course are required to complete the pre- and post-test. They are informed about the study and asked to sign a consent form giving permission for the test scores to be used. A grade incentive is also offered – the highest pre- or post-test score replaces the students lowest graded piece of assessed work.

Test instruments

Students are pre-tested and post-tested using two different measures; the California Critical Thinking Skills Test (CCTST) and the critical thinking section of the Graduate Skills Assessment (GSA). Both are timed (45 minute) multiple-choice tests. Each test comes in two equivalent forms, A and B.

Procedures

Students complete the CCTST and GSA tests during the scheduled 2-hour tutorials for the course. Both pre-tests are completed in the first tutorial (usually week 2 of the course) and the post-tests are completed in the final tutorial (week 13 of the course). A small number of students who are unable to attend these tutorials complete the tests in separate sessions. The tests are completed under examination conditions, as outlined in the test manuals. Students are not informed of their test scores until after the end of the course.

In the first three studies, Form A was used for the pre-test and Form B was used for the post-test for both the CCTST and GSA. For the last two studies, Forms A and B of each test were randomly distributed for the pre-test and students were given the opposite test form for the post-test.

Comparison group

Each semester, an attempt is made to recruit students enrolled in a concurrent first-year philosophy course (PHL 1010/1020) a comparison group. These students volunteer to take the GSA test (only) as a pre- and post- test. These volunteers typically take the tests at one of a number of separately scheduled sessions, outside their normal class time. These sessions take place during the same week that the PHL 1030 students are taking their tests. The test sessions are conducted under the same conditions, as specified in the test manuals. Informed consent procedures are identical: students are informed of the study and asked to sign a consent form giving permission for their scores to be used. They are also offered the same grade incentive as students' enrolled in PHL 1030. Students are not informed of their test scores until after the end of the course.

Variation in teaching methods

The course runs in both semesters (twice a year) and the teaching methodology varied each time. The course syllabus and lectures stay more or less the same each semester. Variations in teaching methods are implemented in the tutorials.

Course structure

1. Overview of the course

Single semester course, 12 weeks of instruction.

- One hour lecture per week.
- One 2-hour tutorial per week.
- 4-6 homework assignments.
- Tutorials and homework practice consists of:

    1. Exercises constructed using LSAT logical reasoning questions

    2. Analysis and evaluation, through class discussion and written work of example arguments. Various sources: philosophy, science, law, politics. Since semester 2, 2004 examples have been extracted from Peter Singer's book *The President of Good and Evil.* (Singer 2004).

2. Course structure

1. Argument analysis (identifying conclusions and premises, argument structure) 30%

2. Argument evaluation (truth, relevance, strength) 20%

3. Criticism (criticising arguments, repairing arguments) 20%

4. Fallacies 30%

Teaching Methods

2003, Semester 2 Pilot study

2004, Semester 1 Web-based argument mapping with automated feedback

2004, Semester 2 Standard course (no special method)

2005, Semester 1 Reason!able

2005, Semester 2 Actively Open-Minded Thinking (AOMT)

2006, Semester 1 Peer instruction

1. Web-based Argument Mapping

Description

One view about how critical thinking can best be taught is represented by the Quality Practice Hypothesis (van Gelder 2001). According to this theory, acquiring expertise in critical thinking, as in other areas, requires large amounts of *deliberate practice*.

Deliberate practice must be:

1. Motivated: the student should be deliberately practicing in order to improve skills

2. Guided: the student should have some way of knowing what to do next

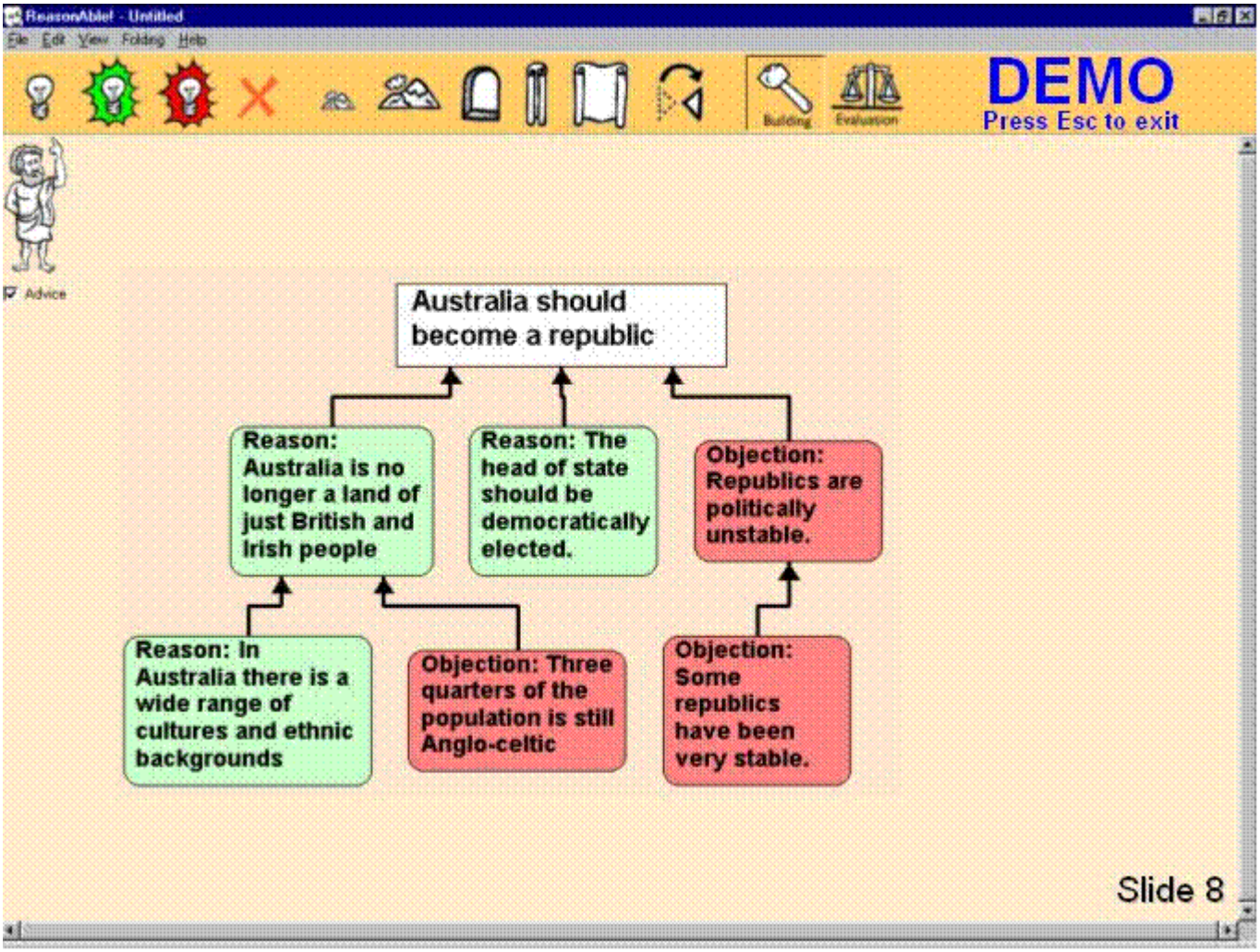
3. Scaffolded: in the early stages, there should be structures preventing mistakes

4. Graduated: tasks should gradually increase in complexity

5. Feedback provided: the student should have some way of knowing whether they are doing the right thing or not.

The use of computer assisted exercises can help to achieve these goals, without expensive one-on-one tutoring.

This is the fundamental idea behind the use of argument-mapping software such as Reason!able for improving critical thinking skills. Students are given many natural language arguments to analyse and must create an argument map to represent the structure of the argument.



An argument map constructed using the Reason!Able software

The software itself supports the creation of these argument maps in a way that is both guided and scaffolded (gradually increasing difficulty and complexity is arranged for by the creator of the exercises). A significant problem remains however – that of providing appropriate *feedback* to the student. Typically, tutors will provide feedback to students on whether their argument maps are correct or not. With large classes of course, this can be difficult; there may not be enough time to give every student the feedback they need. One solution is to provide model answers, so that students can assess themselves. However, students might not be able to work out why their answer is wrong and the model answer correct. Furthermore, they may not be able to tell when a difference between their map and the model answer is an *important* difference.

With this in mind, we investigated computer assisted argument mapping exercises where the computer is able to automatically provide instant feedback to the student as they construct a map of a given argument.

Figure 1 shows a simple example. The window in the top left hand corner contains the text of a simple argument. The student's task is to construct a map of the argument, using the mouse to select the appropriate segment of text and then clicking on the buttons below. The argument map gradually appears in the larger pane to the right.

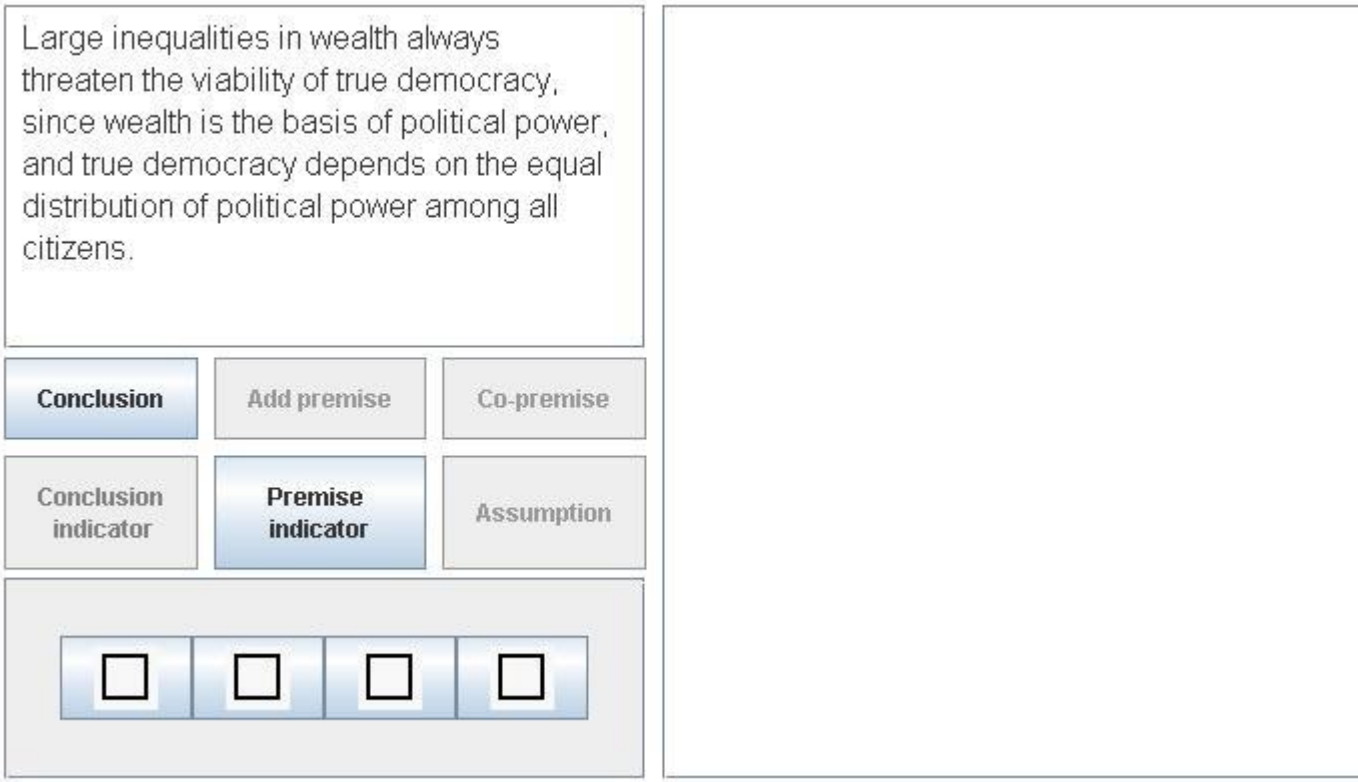


Figure 1

In figure 2, the student has selected the segment of text that they take to represent the conclusion of the argument. The student then clicks on the button labelled 'Conclusion' to indicate their choice. In this case, the student's identification of the conclusion was incorrect, so a small red cross appears in the boxes underneath the buttons. The student knows they must think again. After re-reading the argument, the student selects the correct conclusion in figure 3. This time a green tick replaces the cross, so that the student knows they have

correctly identified the conclusion. A box representing the conclusion now appears in the right hand pane.

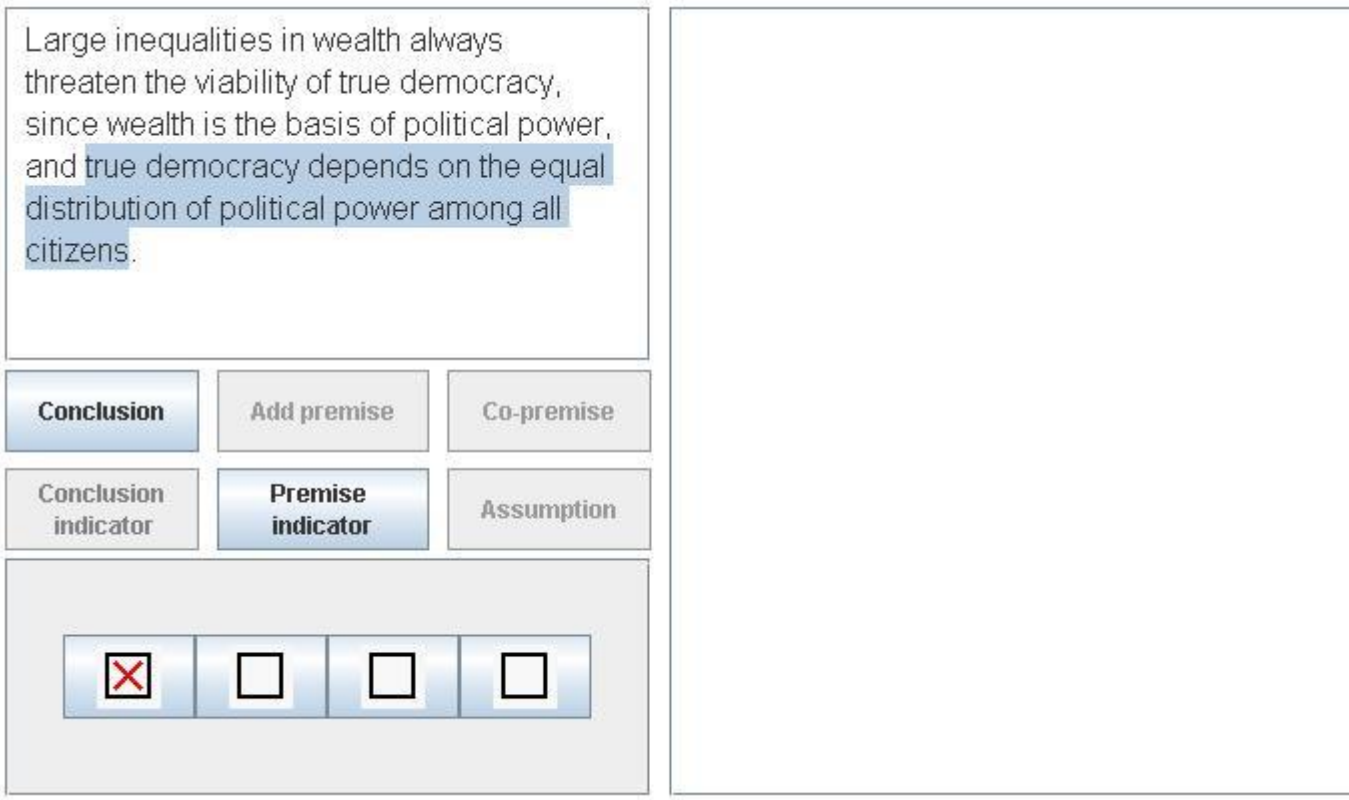


Figure 2

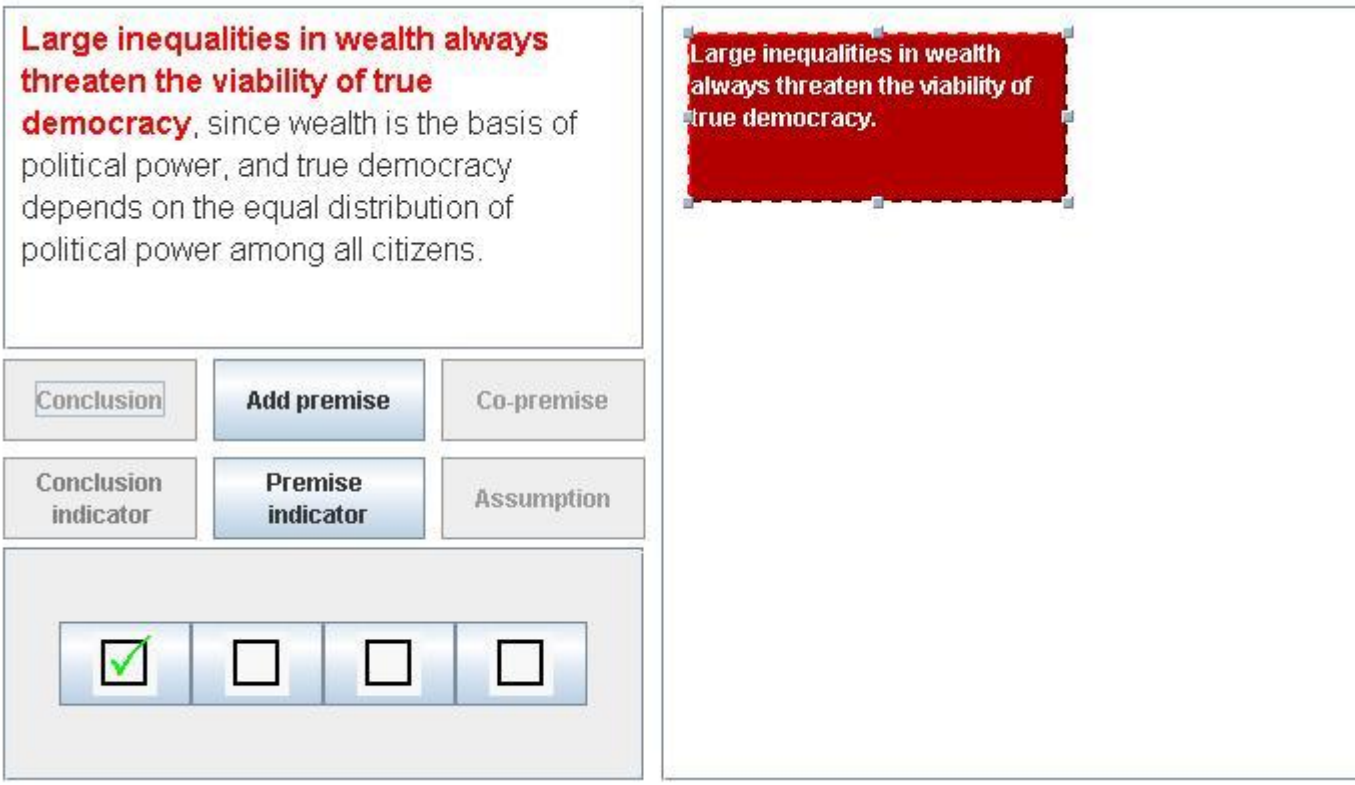


Figure 3

The next step is to identify the premises supporting this conclusion. In figure 4, the student has correctly identified the word ‘since’ as a premise indicator. Again, a green tick has appeared in the box to the right of the first tick, to indicate that this identification is correct (the word is then also underlined). The identification of the premise indicator provides a clue that that the text immediately following is a premise. In figure 4 the student has selected all of the text following the word ‘since’ and clicked on the ‘Add premise’ button. This is not correct however – there are actually two separate premises in this example. A red cross appears to indicate that the student has not correctly identified a premise of the argument.

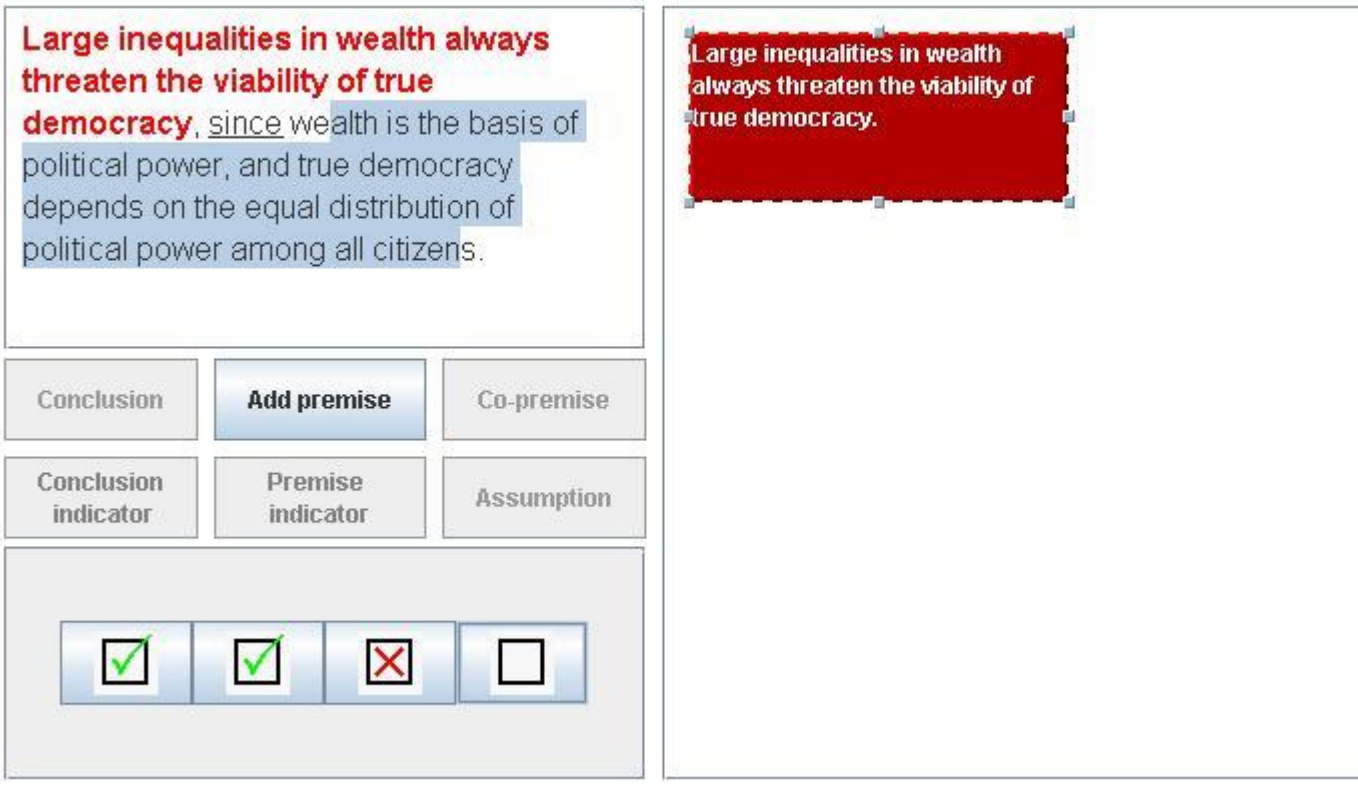


Figure 4

In figure 5, the student has correctly identified one of the premises, by selecting the appropriate text and clicking on the ‘Add premise’ button (This adds a supporting premise underneath the currently selected box in the right hand argument map pane). A tick appears to indicate that this is correct and a box representing that premise is added to the argument map pane.

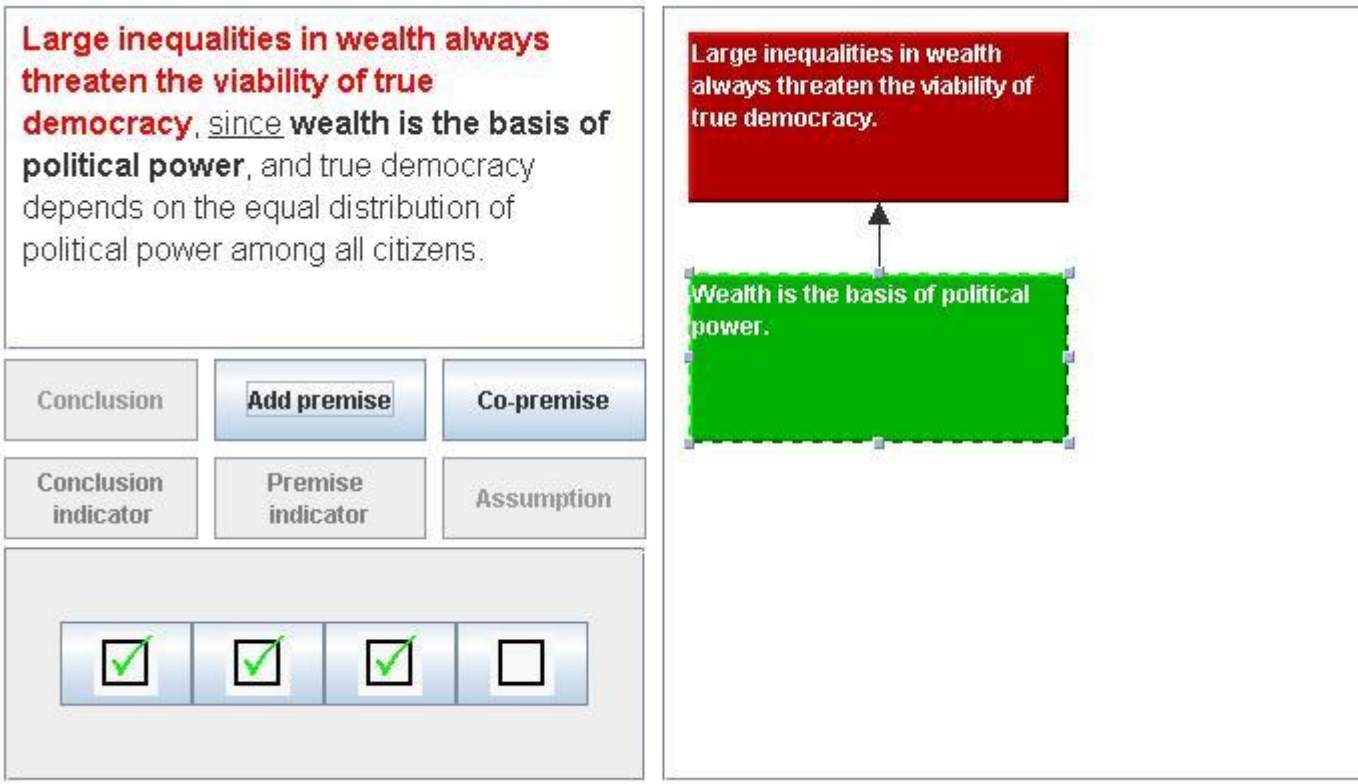


Figure 5

The fact that only one box has yet to be ticked tells the student that they have only more component of this argument to identify. In addition, some of the buttons have now been disabled, so the student knows that the remaining item is either a co-premise or a supporting premise. This is the main way in which the software provides guidance and scaffolding.

In figure 6, the student has selected the appropriate segment of text and clicked on the 'Add premise' button. This adds the selected text as a supporting premise below the currently selected box in the argument map pane (in this case, the premise 'Wealth is the basis of political power'). This choice is incorrect however; the selected text does not support that premise, but rather acts as a co-premise supporting the main conclusion. So a red cross has appeared in the final box, to indicate that the student has made a mistake.

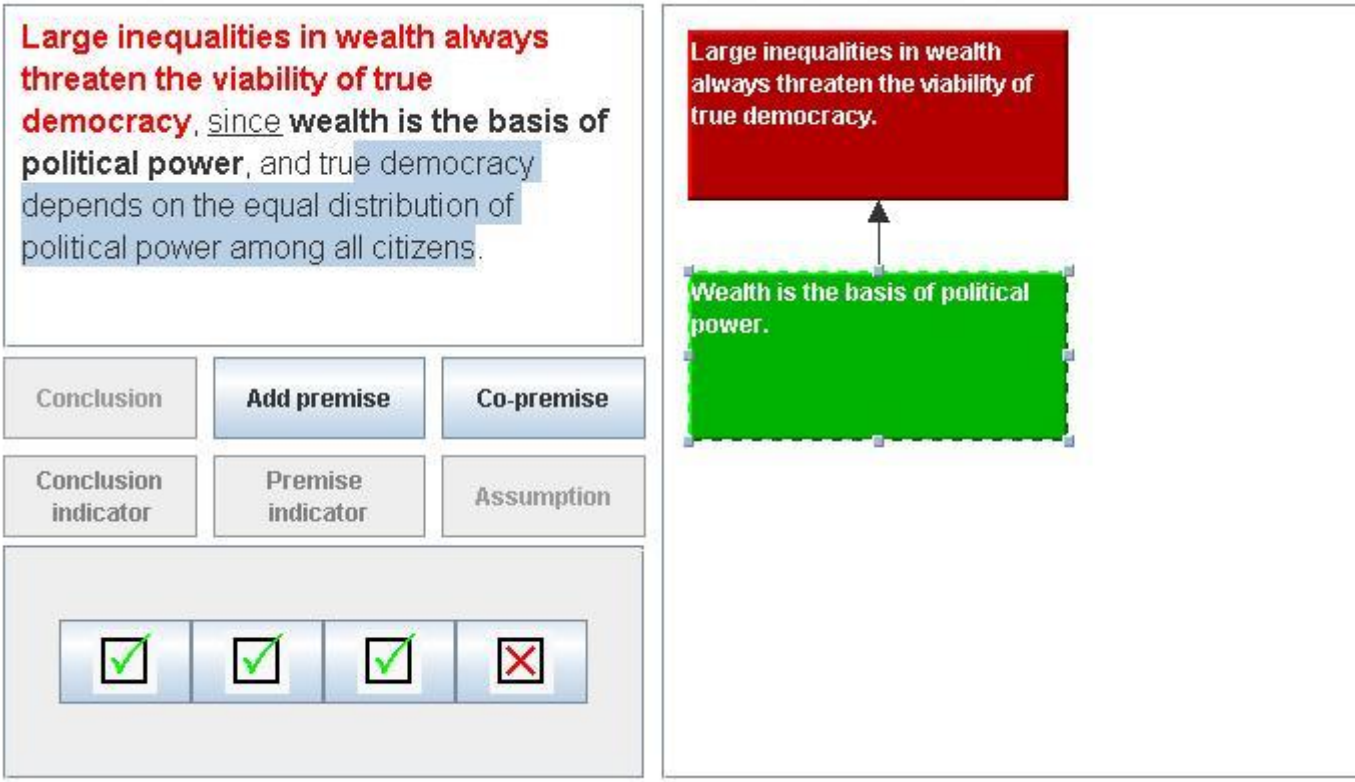


Figure 6

Finally, in figure 7, the student has correctly identified the selected text as a co-premise. The co-premise is added to the argument map and a green tick appears in the final box, informing the student that they have completed this exercise and can go on to the next one.

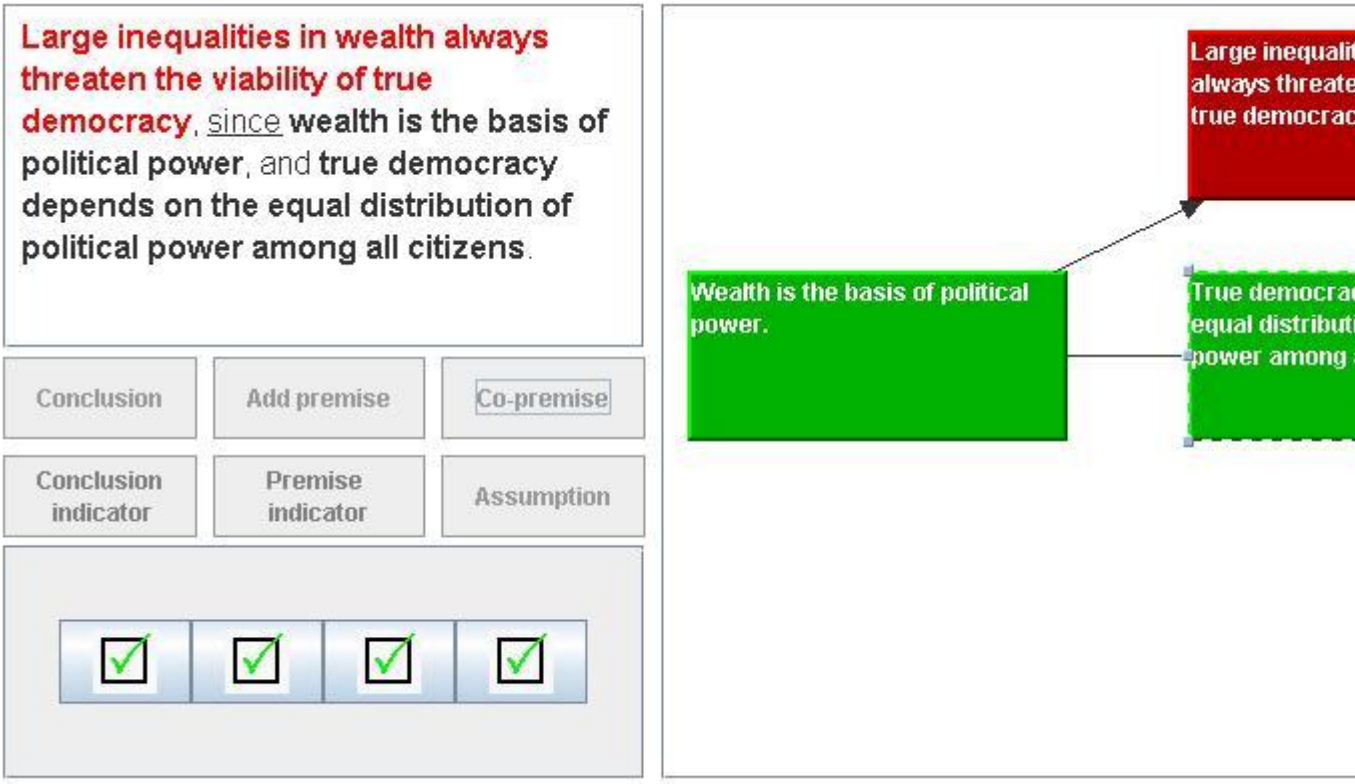


Figure 7

The exercises gradually become more complex as the student progresses through the course. An argument with a more complex structure is shown in figure 8.

An additional feature is the ability to incorporate unstated premises ('assumptions') into the argument maps. This is done by clicking on the 'Assumption' button and selecting the assumption from a list (see figure 9). Some exercises also incorporated a multiple-choice question, which asked for an evaluation of the argument.

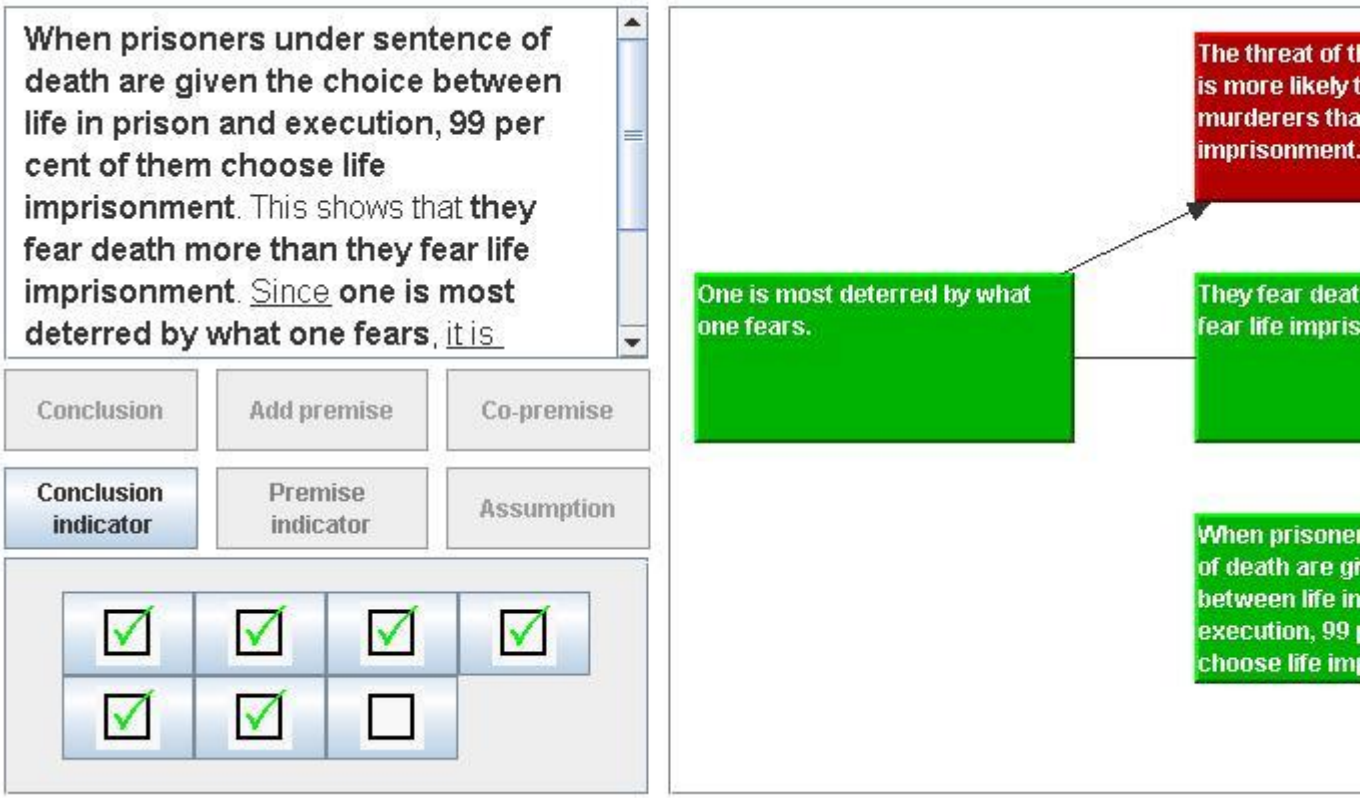

When prisoners under sentence of death are given the choice between life in prison and execution, 99 per cent of them choose life imprisonment. This shows that they fear death more than they fear life imprisonment. Since one is most deterred by what one fears, it is
Conclusion
Add premise
Co-premise
Conclusion indicator
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Figure 8

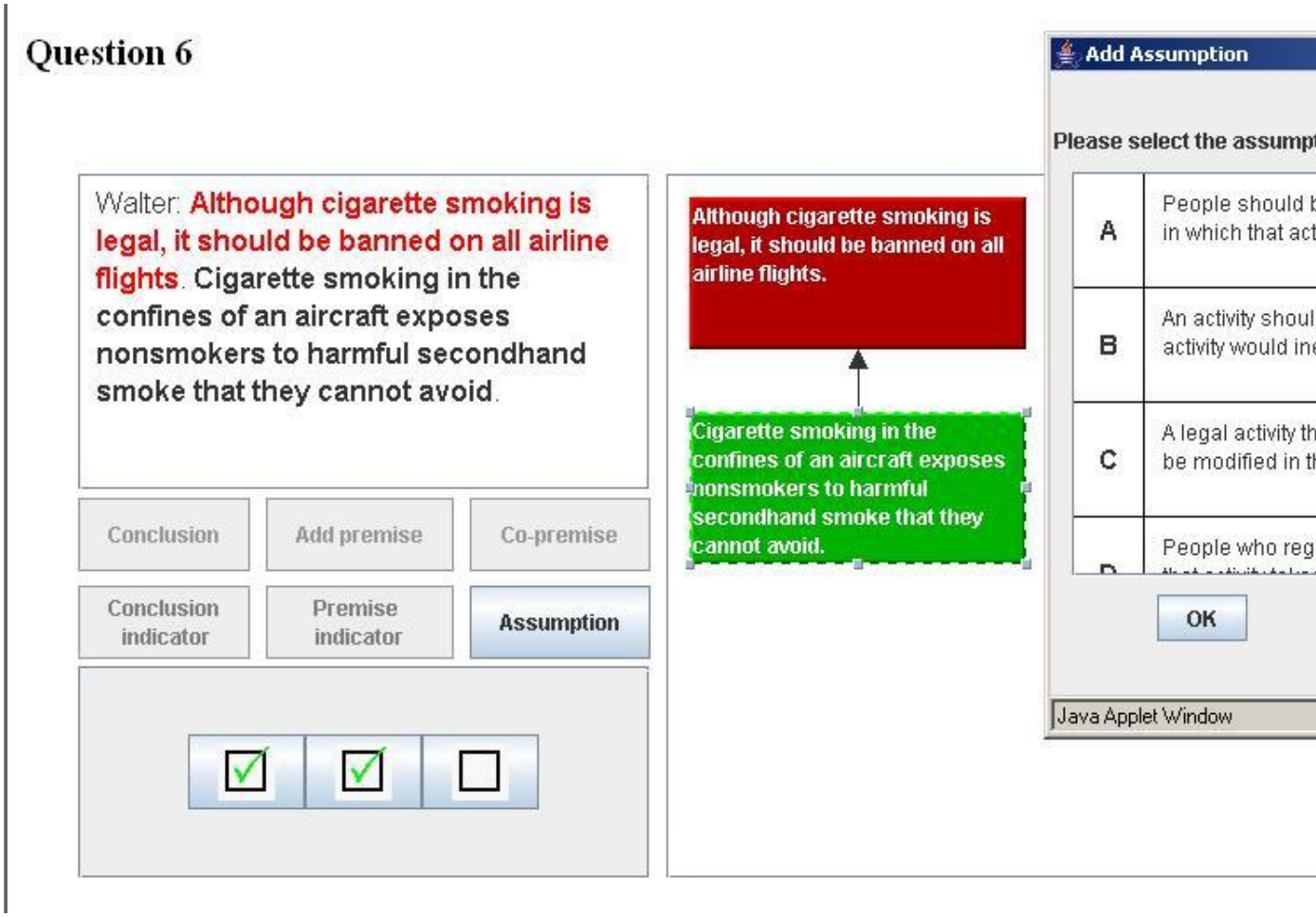


Figure 9

Click here to try out some sample exercises for yourself (Java browser plug-in required).

Procedure

Ten sets of exercises, consisting of 5-10 arguments for analysis were provided. These were made available on the WebCT site for the course. Students worked on these exercises in their scheduled tutorials, which took place in computer labs. Students worked at their own pace. On average, approximately 30-40 minutes each week were spent working on these exercises. The tutor was present to offer help if required. The exercises were made available on the WebCT website for the course. This allowed students to complete the exercises at home if they did not finish them in class. Several students took advantage of this opportunity, although the exercises were not graded.

Results

Students showed a statistically significant improvement in critical thinking scores on the CCTST.

Average improvement: 14%. Effect size: **0.45** standard deviations. (*n* = 43)

GSA data for this semester is not available.

Sample characteristics

Semester 1, 2004 sample	
Sample size	43
Sex	
Age	
Year level	
Faculty	

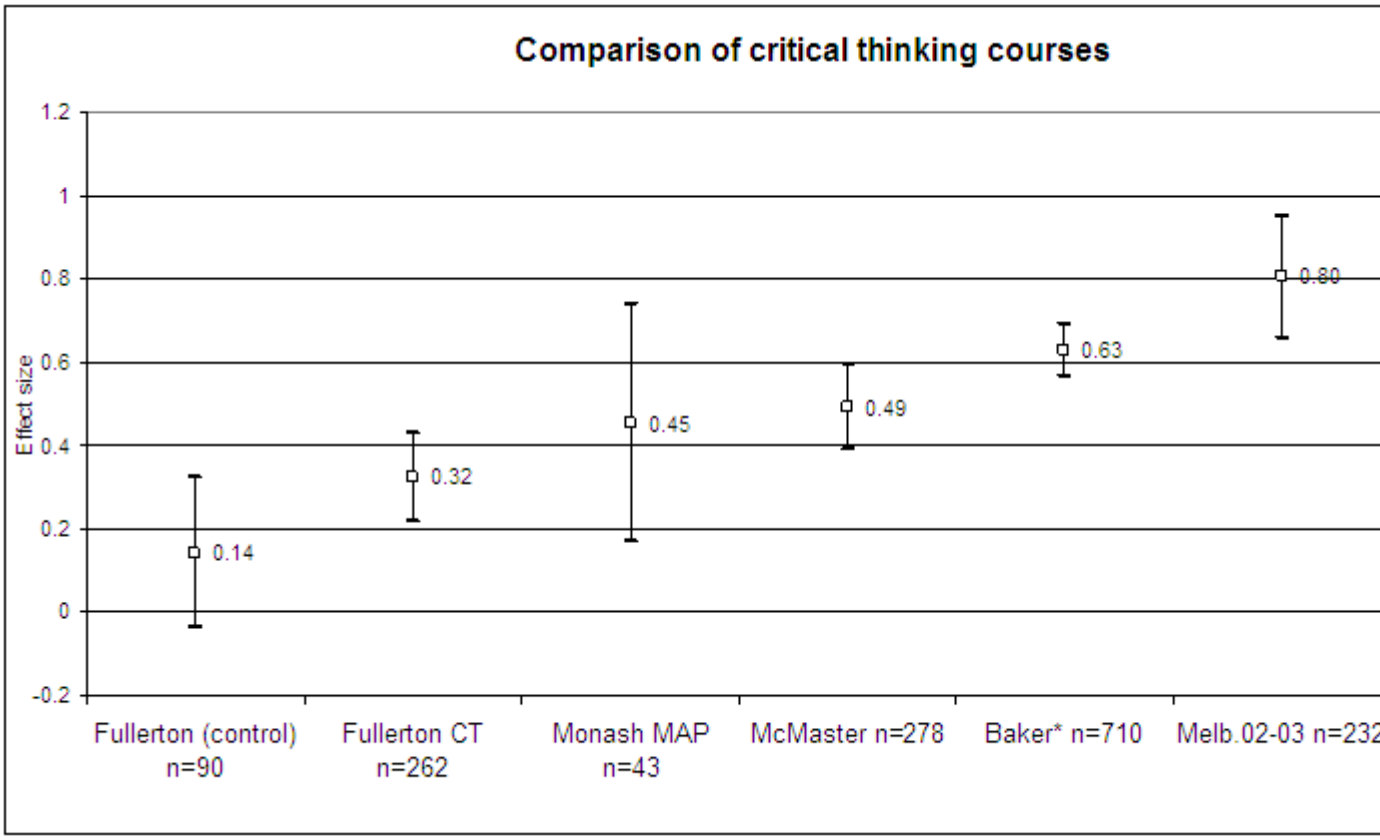
Gains on critical thinking tests

CCTST (Max. score = 34)			
	Mean	**95% confidence interval**	**Standard deviation**
Pre-test	18.209 (53.5%)	[16.73, 19.69]	4.8
Post-test	20.233 (59.5%)	[18.6, 21.87]	5.32
Gain	2.02	[0.74, 3.29]	4.1432
Effect size	**0.45**	[0.17, 0.74]	
Percentage gain			

Effect sizes calculated using pre-test standard deviation estimates of 4.45 CCTST points.

Form distribution.

Comparison with other studies



Gains for all studies measured using the CCTST.

* Two semester course.

2. Standard version

Description

This was a standard version of the course, following the same syllabus as other semesters, but without any special pedagogical technique.

Peter Singer's book *The President of Good and Evil* (Singer 2004) was used as a text for the course. Students were required to read a chapter each week. The arguments from each chapter were then discussed and analysed in tutorials. Homework exercises consisted of LSAT questions and further passages from Singer's text for analysis and evaluation.

Click here for a sample of tutorial materials.

Results

Students showed a statistically significant improvement on critical thinking scores on the GSA.

Effect size: **0.27** standard deviations (n=65). Significant at the 0.05 level.

Students showed a slight improvement on critical thinking scores on the CCTST.

Effect size: **0.19** standard deviations (n=65). Significant at the 0.1 level.

Sample characteristics

Semester 2, 2004 sample (Standard)	
Sample size	65
Sex	
Age	

Year level	
Faculty	

Gains on critical thinking tests

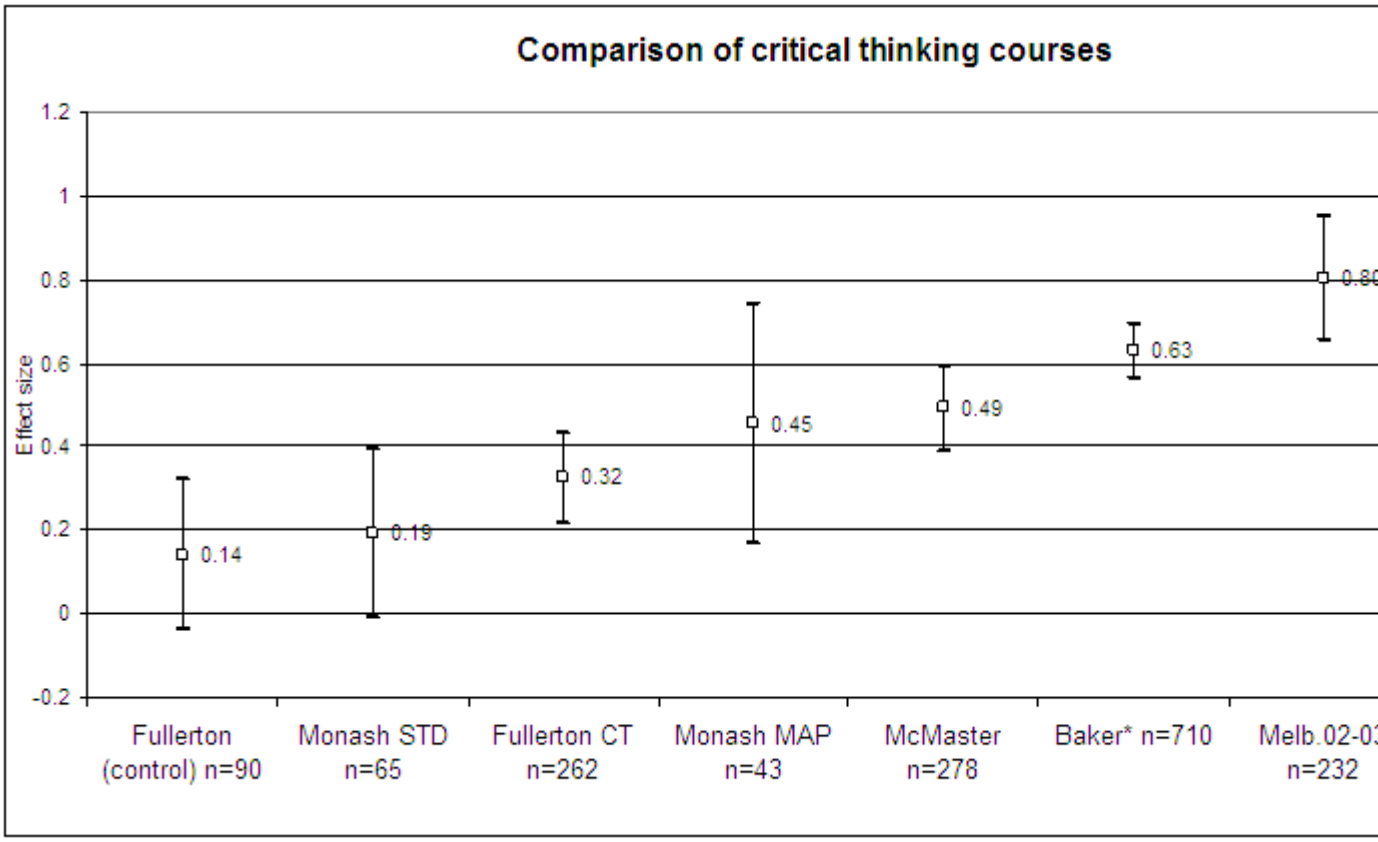
CCTST (Max. score = 34)			
N = 65	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	19.769 (58%)	[18.75, 20.79]	4.13
Post-test	20.615 (60.6%)	[19.29, 21.94]	5.35
Gain	0.846	[-0.04, 1.74]	3.61
Effect size	**0.19**	[-0.01, 0.39]	
Percentage gain			

GSA (Scaled scores)			
N = 65	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	425.48	[400.92, 450.04]	99.11
Post-test	453.46	[428.98, 477.94]	98.78
Gain	27.98	[9.47, 46.4]	74.5873
Effect size	**0.27**	[0.09, 0.45]	
Percentage gain			

Effect sizes calculated using pre-test standard deviation estimates of 4.45 CCTST points and 102.76 GSA (scaled) points.

Form distribution.

Comparison with other studies



Gains for all studies measured using the CCTST.

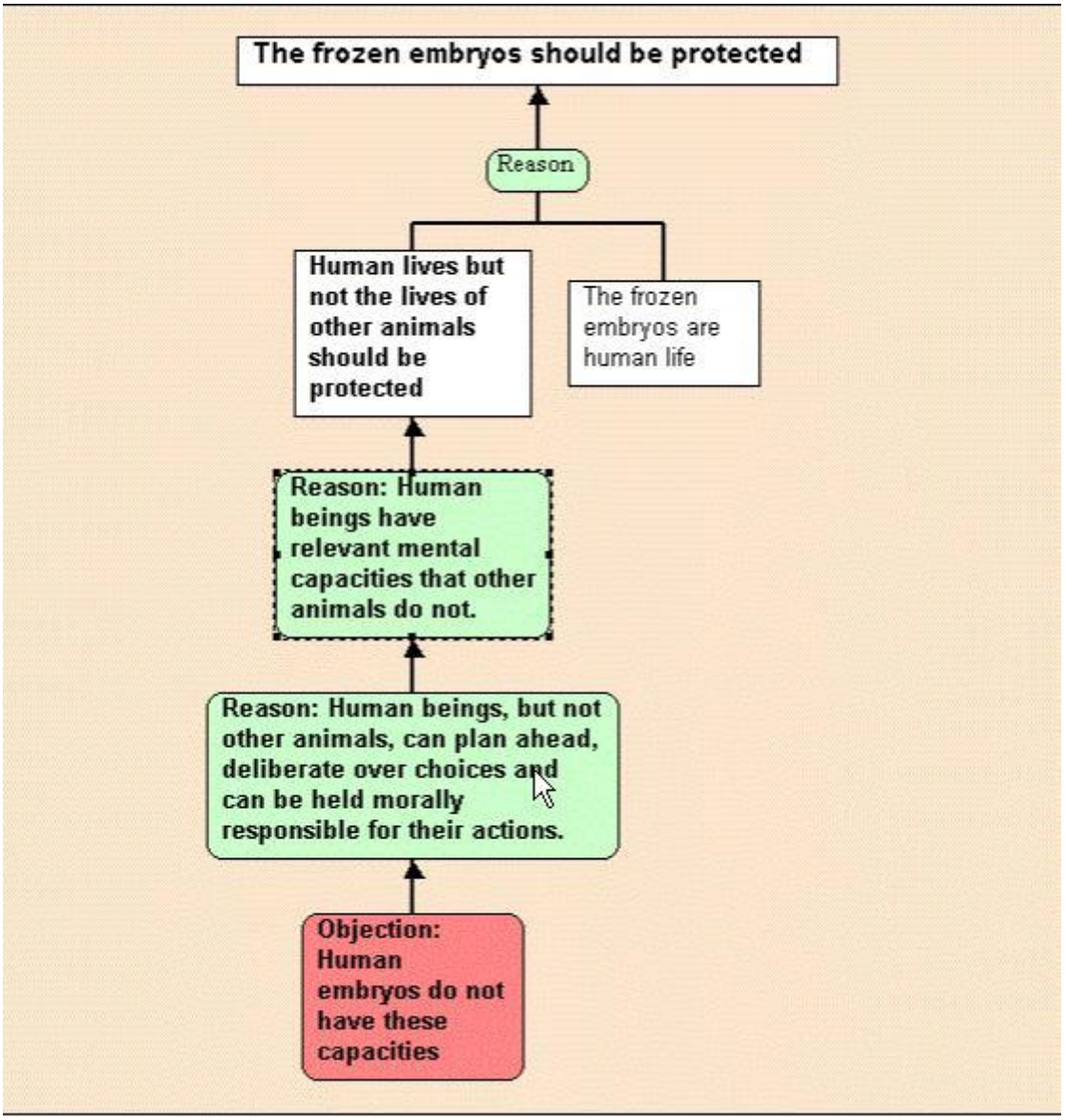
* Two semester course.

3. Reason!able argument mapping

Description

The second hour of each tutorial was spent in a computer lab, working on argument mapping exercises using the Reason!able software.

As in semester 2, 2004 Singer's book *The President of Good and Evil* (Singer 2004) was used as a text for the course. Students were required to read a chapter each week. Arguments from each chapter were discussed in class, then the students moved to a computer lab, to work on constructing *Reason!able* argument maps of the arguments. Homework consisted of LSAT questions and further passages from Singer's text for analysis and evaluation using *Reason!able*.



An example Reason!able map of an argument from Singer 2001

Click here for a sample of the exercises.

Results

Students showed a slight improvement on critical thinking scores on the CCTST.

Effect size: **0.22** standard deviations (n=65). Significant at the 0.1 level.

Students showed no improvement on critical thinking scores on the GSA.

Sample characteristics

Semester 1, 2005 sample (Reason!able)	
Sample size	41
Sex	
Age	
Year level	
Faculty	

Gains on critical thinking tests

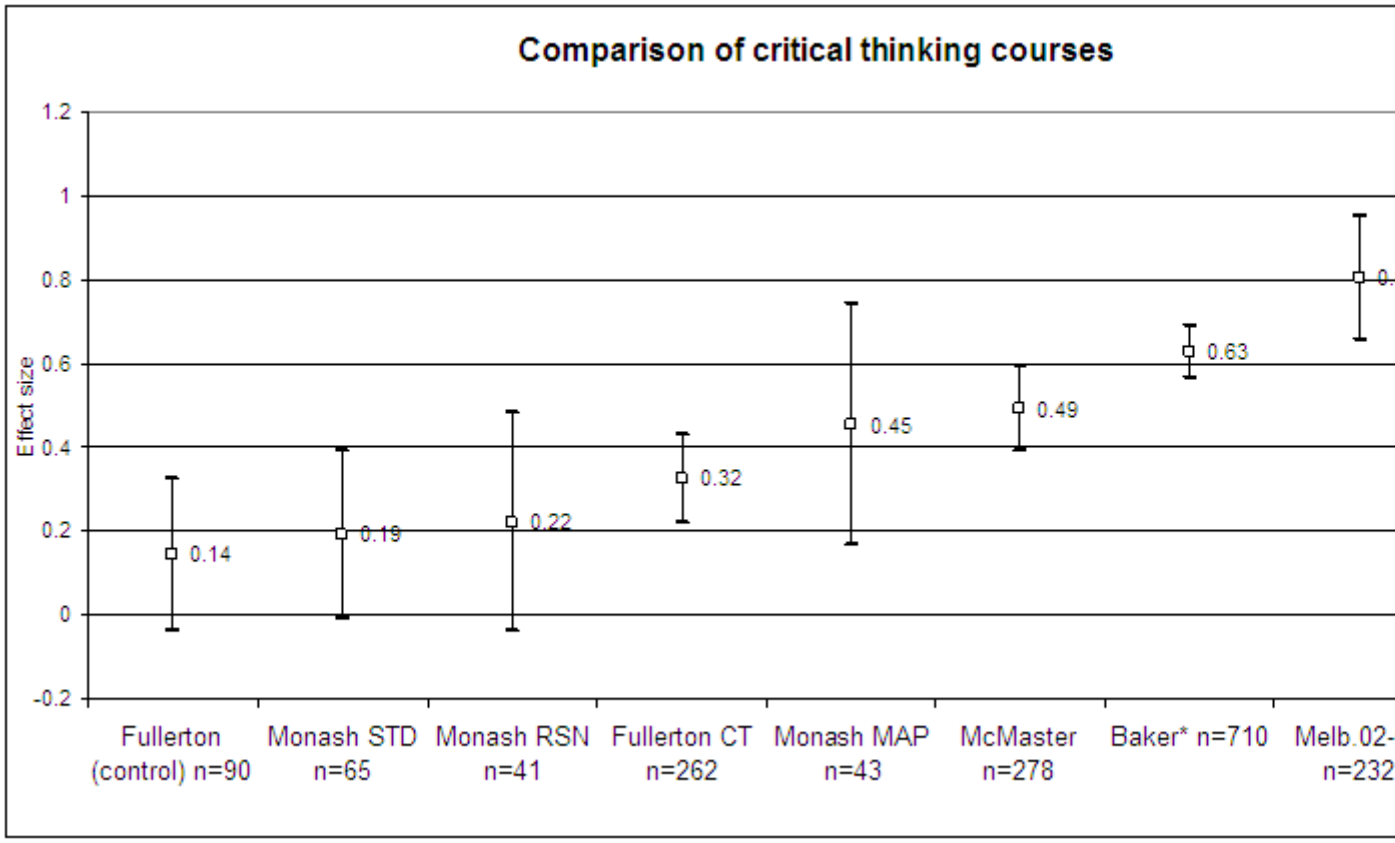
CCTST (Max. score = 34)			
N = 41	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	19.146 (56.3%)	[17.48, 20.82]	5.29
Post-test	20.122 (59.18%)	[18.57, 21.67]	4.92
Gain	0.98	[-0.17, 2.14]	3.67
Effect size	**0.22**	[-0.04, 0.48]	
Percentage gain			

GSA (Scaled scores)			
N = 40	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	437.3	[407.14, 467.46]	94.31
Post-test	441.53	[416.44, 466.61]	78.44
Gain	4.225	[-15.29, 23.74]	61.08
Effect size	**0.04**	[-0.15, 0.23]	
Percentage gain			

Effect sizes calculated using pre-test standard deviation estimates of 4.45 CCTST points and 102.76 GSA (scaled) points.

Form distribution.

Comparison with other studies



Gains for all studies measured using the CCTST.

* Two semester course.

4. Actively-Open Minded Thinking (AOMT)

Description

Actively Open-Minded Thinking (AOMT) is “the willingness to search actively for evidence against one’s favoured beliefs, plans or goals and to weigh such evidence fairly when it is available” (Baron 2002). There is a great deal of evidence that AOMT is not widespread in the general population. In particular, people are susceptible to confirmation bias or “myside” bias: people tend to overestimate arguments for claims they already accept and underestimate arguments against claims they accept. (Baron 1994, Nickerson 1998). This cognitive bias is very robust and widespread, even experts are susceptible to it. AOMT is simply the disposition and ability to avoid “myside bias”.

What factors affect individual differences in AOMT?

1. There is some evidence that cognitive ability (general intelligence) is positively correlated with AOMT. (refs).

2. There is also evidence that certain *attitudes* to thinking or *thinking dispositions* are also positively correlated with AOMT (Stanovich and West, 1997, 1998).

Thinking Dispositions Questionnaire

Consider the following statements:

1. There is nothing wrong with being undecided about many issues.

2. Difficulties can usually be overcome by thinking about a problem, rather than waiting for good fortune.

3. Changing your mind is a sign of weakness.

4. Intuition is the best guide to making many decisions.

Studies have shown that people who agree with statements like 1-2 and disagree with statements like 3-4 perform much better on a wide variety of reasoning tasks (even statistical reasoning tasks) and are less prone to myside and other biases. (Stanovich and West, 1997, 1998)

Perhaps then, people do not reason well because they are not disposed to do so. Perhaps people are capable of reasoning well, but do not see the value in doing so. If so, then instruction aimed at changing attitudes might lead to improvements in critical thinking ability. This is *Baron's Hypothesis*.

To investigate this, we attempted to incorporate some AOMT teaching strategies into the course.

AOMT teaching strategies

1. Students were taught about some of the empirical evidence for myside bias and the evidence that AOMT reduces bias and improves thinking.

2. Exercises that focus on the ability of students to find alternative explanations or counter-evidence for a given claim.

3. Students taught that good arguments must take into account all the relevant evidence and counter-arguments or possible objections to the reasoning or premises.

4. Exercises in which students must criticise arguments in support of their own position on the topic under discussion and suggest evidence or arguments against their position.

5. Exercises in which students are instructed not just to pick the answer, but to actively look for evidence against their choice, by carefully considering the alternatives.

As in previous semesters, Peter Singer's *The President of Good and Evil* (2004) was used as a text for the course. Students were required to read a chapter each week. The arguments from each chapter were then discussed and analysed in tutorials and the above AOMT strategies were incorporated into the exercises. Homework exercises consisted of LSAT questions and further passages from Singer's text for analysis and evaluation.

Click here for a sample of exercises.

Procedure

Students were pre- and post-tested using the CCSTS and GSA. Test forms were distributed randomly at the pre test and students were given the opposite form for the post-test. Students were also pre- and post- tested using the Stanovich and West *Thinking Dispositions Questionnaire* (TDQ) as a measure of open-minded attitudes. (Stanovich and West, 2003).

Results

Students showed no significant improvement on critical thinking tests scores on either the GSA or CCTST.

Students showed a statistically significant improvement in open-minded attitudes, as measured by the TDQ.

Effect size: **0.32** (N=28). Significant at the 0.05 level.

Statistically significant correlations were found between critical thinking scores and open-minded attitudes.

Sample characteristics

Semester 2, 2005 sample (AOMT)	
Sample size	49
Sex	
Age	
Year level	
Faculty	

Gains on critical thinking tests

CCTST (Max. score = 34)

N = 49	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	18.86 (55.47%)	[17.45, 20.26]	4.89
Post-test	19.47 (57.26%)	[17.89, 21.05]	5.49
Gain	0.612	[-0.47, 1.70]	3.78
Effect size	**0.14**	[-1.1, 0.38]	
Percentage gain			

GSA (Scaled scores)			
N = 48	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	415.79	[390.54, 441.04]	86.96
Post-test	421.48	[391.16, 451.80]	104.43
Gain	5.69	[-14.68, 26.06]	70.25
Effect size	**0.06**	[-0.14, 0.25]	
Percentage gain			

Gains on open-minded attitude scale

Thinking dispositions questionnaire			
N = 28	**Mean**	**95% confidence interval**	**Standard deviation**
Pre-test	174.4	[165.4, 183.4]	23.2
Post-test	182.0	[173.6, 190.3]	21.5
Gain	7.5	[1.1, 3.8]	16.3
Effect size	**0.32**	[0.05, 0.59]	
Percentage gain			

Effect sizes calculated using pre-test standard deviation estimates of 4.45 CCTST points and 102.76 GSA (scaled) points.

Form distribution.

Correlations

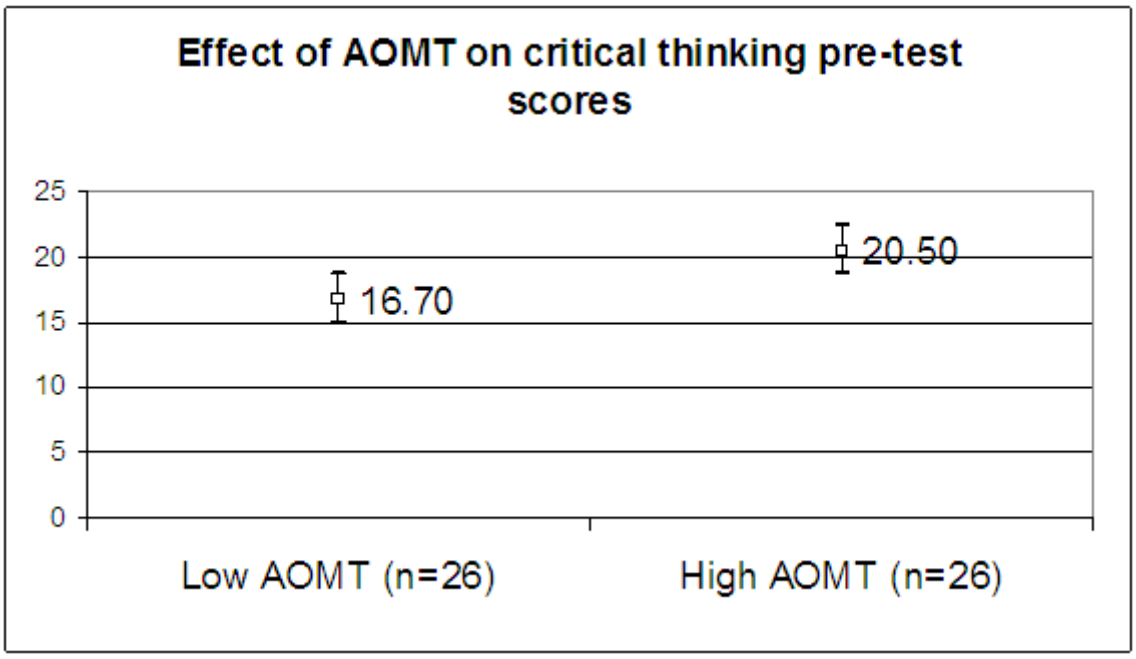
1. There was a significant correlation between pre-instruction open-minded attitudes and critical thinking test scores.

Pre-test CCTST-TDQ correlation : r = **0.32**, n = 52. Significant at 0.05 level.

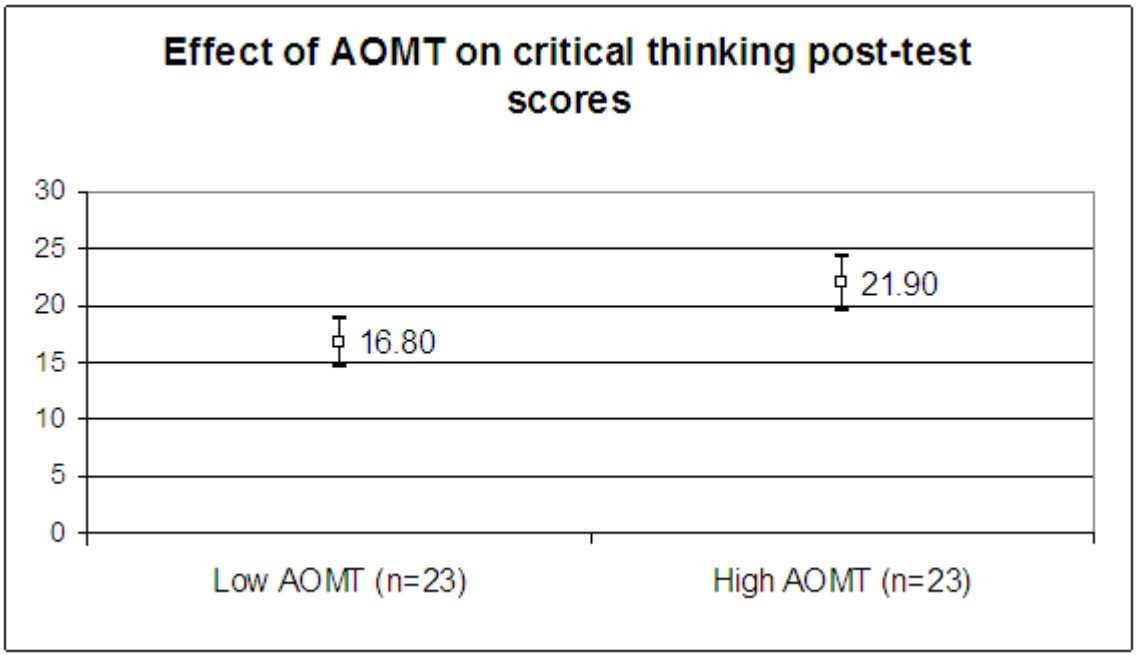
Pre-test GSA-TDQ correlation : r = **0.409**, n = 52. Significant at 0.01 level.

Post-test CCTST-TDQ correlation: r = **0.489**, n = 46. Significant at 0.01 level.

Post-test CCTST-GSA correlation: r = **0.48**, n = 46. Significant at 0.01 level.



Difference in CCTST pre-test scores for high and low AOMT groups

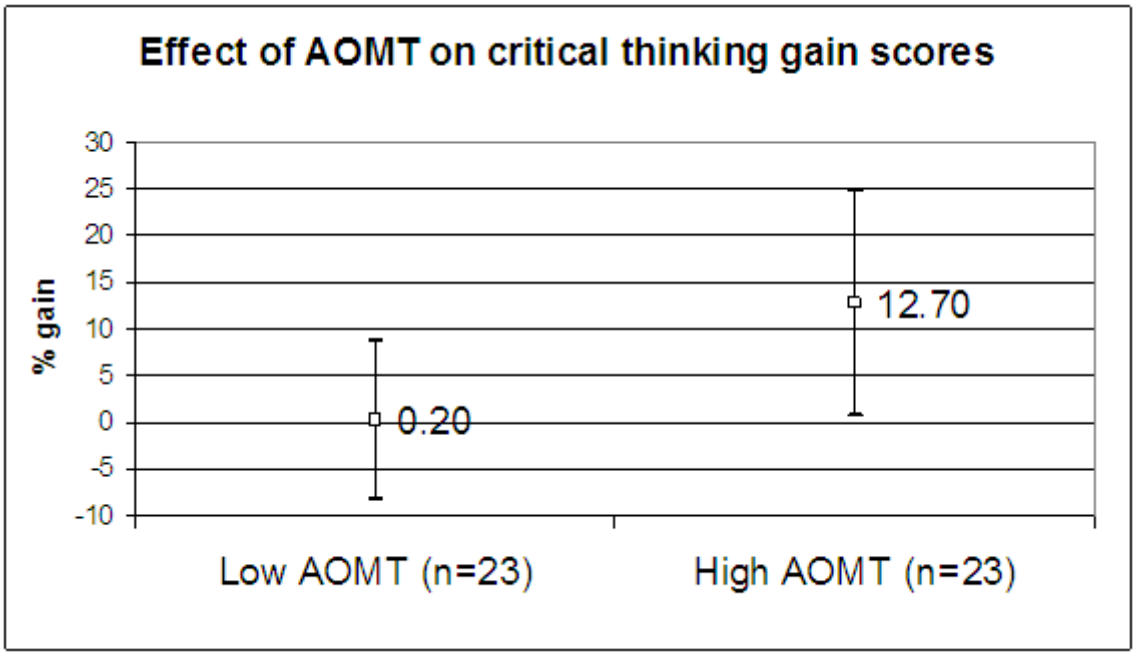


Difference in CCTST post-test scores for high and low AOMT groups

(High and Low AOMT groups obtained by median split on TDQ score).

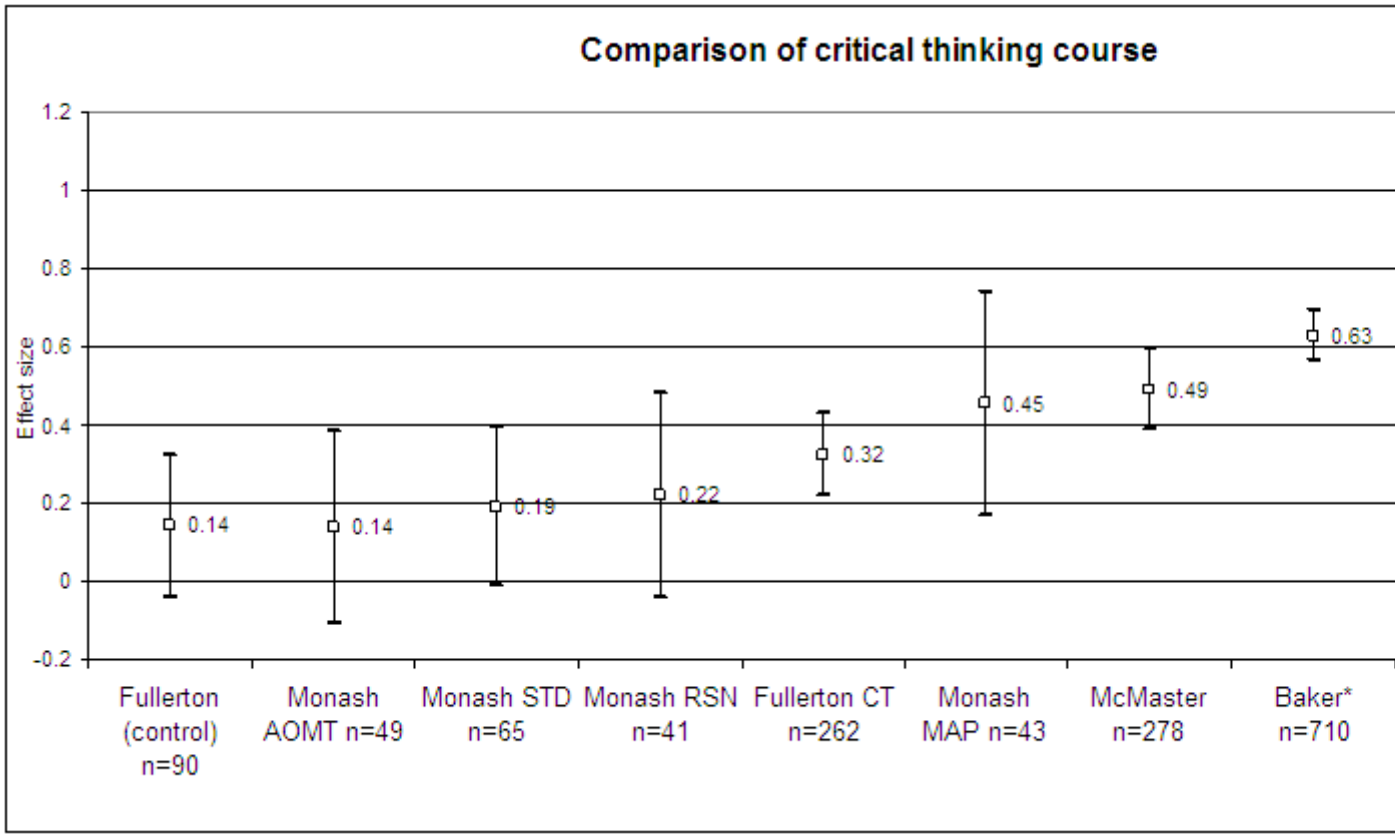
2. There was a significant correlation between pre-instruction open-minded attitudes and *improvement* in critical thinking scores on the CCSTST.

TDQ-CCTST gain correlation: r = **0.33**, n = 46.



Difference between CCTST gain scores for high and low AOMT groups

Comparison with other studies



Gains for all studies measured using the CCTST.

* Two semester course.

5. Peer Instruction

Description

Brief description

Results

Sample characteristics

Semester 1, 2006 sample (PI)	
Sample size	
Sex	
Age	
Year level	
Faculty	

Gains on critical thinking tests

CCTST (Max. score = 34)			
	Mean	95% confidence interval	Standard deviation
Pre-test			
Post-test			
Gain			
Effect size			
Percentage gain			

GSA (Scaled scores)			
	Mean	**95% confidence interval**	**Standard deviation**
Pre-test			
Post-test			
Gain			
Effect size			
Percentage gain			

Effect sizes calculated using pre-test standard deviation estimates of 4.45 CCTST points and 102.76 GSA (scaled) points.

Form distribution.

Student evaluations

Comparison with other studies

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