

‘Thinking Skills’ and Admission to Higher Education

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Contents

Introduction

- 1. Background on ‘Thinking Skills’.**
- 2. What Prompts ‘Thinking Skills’ Programmes?**
- 3. What is the Evidence on Teaching Thinking?**
- 4. Why Assess Thinking Skills for University Admission?**
- 5. Measuring Intelligence v Assessing ‘Thinking Skills’**
- 6. Thinking Skills Assessment (TSA) or Scholastic Assessment Test (SAT)**
- 7. What is Critical Thinking?**
- 8. What is Problem Solving?**
- 9. Summary of the Argument.**
- 10. To Conclude**

Appendix: The notion of ‘effect size’ explained.

Bibliography

Introduction

This paper was commissioned by the University of Cambridge Local Examinations Syndicate to provide information for those with an interest in ‘thinking skills’ and the process of university admissions. It provides

- (i) a guide for ‘the policy maker’ (as opposed to ‘the student’ or ‘the research community’),
- (ii) a guide to ‘thinking skills’ and the research that underpinned their introduction - the foundations of the subject,
- (iii) a guide to the ‘different kinds’ of thinking skills,
- (iv) the evidence and arguments for claims that Thinking Skills are useful, especially why they are useful for higher education
- (v) an explanation of the similarities and differences between the North American Scholastic Assessment Test (SAT) and the Thinking Skills Assessment (TSA) developed by UCLES.

It argues that well-designed ‘thinking skills’ assessments could play an important role in discriminating among university applicants with very good A-level results - the problem faced currently by many universities and university courses in the UK.

1. Background on ‘Thinking Skills’.

There are many strands in what has become known as the ‘thinking skills’ tradition. An important one in the present context is the ‘critical thinking’ tradition, which is commonly traced back to John Dewey, the American psychologist, philosopher and educator (Dewey (1909)). On a related but different tack, the (mathematical) ‘problem solving’ tradition has rather obscure beginnings but the Hungarian mathematician Georg Polya is widely credited with originating it as a teachable skill; unusually for a book on mathematics, his classic *How to Solve It* (Polya (1945)) has sold over a million copies.

A quite different strand, which has been very influential in schools, derives from the work of the Israeli psychologist, Rubeen Feuerstein on ‘Instrumental Enrichment’ (Feuerstein et al (1980)). The work of Edward De Bono, especially on divergent thinking, otherwise often known as ‘lateral thinking’, is different again and has been widely implemented (De Bono (1976) and (1987)). There is also Matthew Lipman’s Philosophy for Children programme, which is similar to the critical thinking tradition in some respects (Lipman (1980) and (1991)). Again in the United States, the work on ‘multiple intelligences’ developed by Howard Gardner at Harvard, has been enormously influential and aims to develop different intelligences by teaching thinking skills (Gardner (1993)).

In Britain, one of the most significant developments has been the CASE programme (Cognitive Acceleration Through Science Education) developed by Adey and Shayer, and based on the work of Piaget (Adey, P and Shayer M. (1994)). There is also the Somerset Thinking Skills programme, derived from Feuerstein (Blagg et al (1988)), the work on critical thinking, embodied in the AS level examination in Critical Thinking (see Fisher (2001)) and the work emanating from the Newcastle School of Education (eg. Leat (1998) *Thinking Through Geography*).

These are only some of the strands in the thinking skills tradition. Some originate from work in psychology (e.g., instrumental enrichment and CASE) whilst others derive from philosophy (e.g., critical thinking and Philosophy for Children). In some programmes, thinking skills are taught in ‘standalone’ courses, separate from ordinary school subjects (e.g., instrumental enrichment, Philosophy for Children) whilst others are ‘infused’ into the teaching of ordinary school subjects (e.g., CASE, Thinking Through Geography). In all cases the teaching aims to teach thinking skills *explicitly* and *directly*, rather than assuming that they get developed *indirectly* and *implicitly* in the course of studying the normal school curriculum.

Whether thinking skills are taught through standalone courses or through being ‘infused’ into redesigned subject lessons, a key concern of all such work is to ensure that students ‘transfer’ the skills learned in one context to other contexts. This will involve ‘bridging’ work, in other words explicitly ‘teaching for transfer’. Despite their differences, the key to nearly all ‘thinking skills’ programmes is ‘metacognition’ - thinking about one’s thinking. They all require the participant to self-consciously adopt ‘good’ ways of thinking when faced with problems of whatever kind. For example, in the critical thinking tradition, if you face a decision, you need to ask yourself questions about objectives, alternatives, consequences, risks etc. In the same

way, Polya gives students key questions to ask themselves when faced with any mathematical problem.

There are many variations on the themes mentioned above and some of these will be discussed below. There is also growing evidence of the effectiveness of many of these programmes in delivering improved student performance and this is also given below.

2. What Prompts ‘Thinking Skills’ Programmes?

The basic motivation for all developments in the ‘thinking skills’ tradition has always been much the same, whatever the details of the resulting programme. Here are four, rather different, examples.

(2.1) Matthew Lipman, was a distinguished Professor of Philosophy in Columbia University in New York in the 60/70s. He became increasingly frustrated because he found that his university students lacked a number of basic thinking skills, like the ability to construct an argument, to clarify ideas, to see things from others’ points of view and the like. He was also convinced that it was too late to change their thinking habits at the university level so he designed the Philosophy for Children Programme which aims to teach these and other thinking skills to schoolchildren aged 5 - 15 (Lipman (1980) (1991)) This is a stand-alone programme - in which thinking skills are taught separately from normal school subjects.

(2.2) The impetus for the CASE (Cognitive Acceleration through Science Education programme) came from a survey of 14,000 pupils in 45 schools in England and Wales, which showed that only 16% of 16 year olds were showing evidence of even early ‘formal operational thinking’ (a fundamental idea of Piaget’s). Since this kind of thinking is required to understand how to test hypotheses effectively, to judge critically between the merits of two arguments or to cope with proportionality, the implication was clear - that the vast majority of pupils cannot think at the level required for the science curriculum (or indeed many other areas) (cf McGuinness ((1999) p.12). CASE is a programme where the teaching of thinking skills is embedded in the teaching of subject matter, namely the science curriculum for 12-13 year olds (see Adey and Shayer (1994))

(2.3) Rueben Feuerstein created his Instrumental Enrichment (IE) programme, which was initially developed nearly 50 years ago, explicitly to help overcome the thinking deficiencies in culturally disadvantaged, low-performing Israeli adolescents, many of who had been traumatised by their early experiences during and after the Second World War. Despite its distinctive origins, Instrumental Enrichment, which is a standalone programme, or programmes derived from it, are now widely used with a much wider range of abilities and ages, often with successful results (Feuerstein et al (1980)).

(2.4) Georg Polya, himself a brilliant mathematician and teacher, noticed that his students (even at Stanford University) didn’t know how to solve unfamiliar problems. He became convinced that, although they knew a lot of

2005-03-10

mathematics, they didn't know how to direct their own thought processes in ways that could be fruitful. They didn't realise that there are strategies for solving mathematical problems. That led him to write *How to Solve It* (and some other books) which explain what he calls *heuristic strategies* for solving problems. Though teaching Polya-type problem solving heuristics is not greatly in fashion at the moment, many university teachers refer their students to *How to Solve It* at some stage (Polya (1945)).

Similar stories lie behind the work of nearly all those who have contributed to the development of the thinking skills tradition. They notice some deficiency in the thinking of their students and devise some teaching interventions which aim at directly addressing those thinking deficiencies - ie at teaching thinking explicitly and directly. Of course, different original concerns can lead to quite different educational proposals - often for students at different stages of intellectual development and in very different contexts.

However the resulting programmes have similar objectives (to teach thinking skills directly) and usually have other similarities too, for example, as we said above, the key to nearly all of them is 'meta-cognition' - thinking about one's thinking and explicitly trying to direct one's thinking to follow some good model. (To explain with an analogy; just as you can try to improve your golf swing (a motor skill) by self consciously trying to swing like Tiger Woods, so you can improve your skill in decision making by self consciously trying to follow a good decision making model - and similarly with other thinking skills). Another common element is practice; just like any other skills, the way to develop thinking skills is to start with easy tasks and to practice the skill in more and more complex situations.

The thinking skills tradition argues that thinking skills *can* be taught and *should* be taught. Furthermore, it is claimed, these skills are *transferable*, i.e., if students learn general thinking skills in one context, they will be able to (and actually will) apply them to many other contexts, provided the teaching specifically aims at such transfer. Critics of the thinking skills tradition most commonly challenge this transferability claim. The most famous advocate of this opposition is John McPeck in his *Critical Thinking and Education* (1981). Rather than responding to his arguments directly we shall review the evidence for believing that 'teaching thinking' can deliver what it promises.

3. What is the Evidence on Teaching Thinking?

There is extensive evidence (both in the UK and elsewhere) that thinking skills can be developed through direct and explicit teaching, that they contribute to improved performance in a wide range of subject areas and that transfer does occur under the right circumstances.

Some of the most striking evidence comes from the work of Philip Adey and Michael Shayer on their CASE (Cognitive Acceleration Through Science Education) project. In this project, which builds on Piaget's work, thinking skills are taught to 12-13 year old pupils over a period of two years in carefully redesigned National Curriculum

science lessons. The results are fully documented in Adey and Shayer (1994). In short they show remarkable evidence that students who received this teaching did far better in their subsequent GCSE examinations than control groups of students who did not (on average, they obtained a whole grade higher). Furthermore, not only did they do better in their science examinations, but they also did significantly better in their other GCSE exam subjects, so transfer had occurred across a wide range of subjects.

Interestingly, when students who had received CASE teaching were tested immediately after the CASE programme, they showed relatively little improvement over the control groups, but the GCSE results suggest that the thinking skills interventions take time to have their effect. Features of the programme which are key to its success are listed by Adey and Shayer in (1994) chapter 4 and include the importance of ‘meta-cognition’ and teaching for transfer (‘bridging’), both of which are important to the other programmes mentioned above.

The most recent UK evidence on the effectiveness of teaching thinking skills comes from researchers in the Centre for Learning and Teaching, Newcastle University (Higgins, S and Hall, E (2004)). They conducted a ‘meta-study’, looking at hundreds of published papers reporting ‘thinking skills’ interventions with school pupils aged 5-16. The study investigated the ‘quantitative impact of thinking skills interventions on (i) pupils’ cognitive achievement, (ii) pupils’ curriculum attainment, and (iii) pupil’s affective states’ (eg., motivation and engagement). The authors expected that ‘intervention effects would be positive, since the vast majority of educational innovations have a positive effect’ but they were particularly interested in whether the effect sizes ‘would exceed the 0.4 level cited by Hattie (Hattie et al (1996)) as the average intervention size effect from his meta-analysis of 200,000 effect sizes’. Given that his study included interventions with effect sizes ranging from 0.6 to over 1 Hattie considers that 0.5 is a minimum for an intervention to be considered ‘educationally significant’ (for an explanation of the notion of ‘effect size’ see below, this page, and the Appendix p.18)

Though the Newcastle researchers reviewed hundreds of published papers, they restricted their meta-study to ones in which control groups had been used and effect sizes were (or could be) quantified. There were 30 of these and the results are summarised as follows:

‘Analysis of these studies indicate that thinking skills approaches are effective in improving pupils’ learning. A meta-analysis of this impact found an overall effect size of 0.71 on cognitive measures (such as tests of reasoning or non-verbal measures such as Ravens Progressive matrices) and an effect size of 0.66 for curriculum outcomes (such as mathematics or science tests). These effect sizes indicate that an ‘average’ class of pupils who received such interventions would move from 50th place in a rank of 100 similar classes to about 26th on curriculum tests and to about 24th place on cognitive measures.’

‘The identification of ‘thinking skills’ has identified a collection of research studies which have an above average impact on learning outcomes. This suggests that teachers’ interest and enthusiasm for such approaches is well-founded ... as such approaches tend to have a positive effect, over and above what you would usually expect from an educational intervention.’

2005-03-10

(Higgins and Hall (2002) p.9)

There is also extensive evidence from the United States, involving a similar meta-study methodology (Marzano et al (1998)). This evidence shows that adopting approaches which make thinking explicit, or which focus on particular kinds of thinking, are successful at raising attainment, particularly those based on metacognitive approaches or cognitively demanding interventions such as problem solving and hypothesis testing (cf., Higgins and Hall (2004) p.11)

The evidence cited here shows that significant educational gains are *possible* from teaching thinking skills. Of course, these positive results show what *can* be done - but it is equally obvious that 'teaching thinking' can be done poorly and ineffectively.

Carol McGuinness, in her DfES Research Report (1999) spells some of the conditions for success in this kind of teaching as follows,

‘..the general framework [of ideas for developing thinking skills] now includes: the need to make thinking skills explicit in the curriculum; teaching through a form of coaching; taking a metacognitive perspective; collaborative learning (including computer-mediated learning); creating dispositions and habits of good thinking; [and] generalising the framework to thinking curricula, thinking classrooms and thinking schools.’ (p.1)

Furthermore, whatever approach is adopted, [it] must maximise transfer, that is, adopt strategies (eg bridging, deliberate teaching for transfer) which ensure that learning transfers beyond the context in which it is learned.

Of course, even positive results like those cited above need to be interpreted with caution. This is partly because of the differences in the thinking skills programmes included in the studies and partly because a meta-study is only as good as its contributing studies. However, the important point is that there are many studies now giving incontrovertible evidence that 'thinking skills' interventions *can* be very effective in raising standards. (And poor quality interventions can obscure this evidence, as noted in the penultimate paragraph of section 7.)

4. Why Assess Thinking Skills for University Admission ?

No doubt the evidence just outlined will be welcome in universities for its own sake, but there is another reason why work on thinking skills is interesting to them.

Universities want to admit those students who will be most successful on their courses. In order to do this, they need information which helps them judge/predict how well applicants are likely to do once they are admitted - how well they are equipped to cope with the special demands of university work and of particular courses.

The UCAS form gives university admission officers quite a lot of information about students' ability to work hard and learn material in given subject areas from their A

2005-03-10

level results (either predicted or known). Indeed, A level results have been the main determinant of university admission ever since they were first introduced in 1951. Admissions officers also have information from head-teachers reports (on the UCAS form) and perhaps from interviews (which are notoriously unreliable, though few universities research the reliability of their interviews). Sometimes they set their own tests, though these are usually subject matter tests (like STEP papers taken for admission to mathematics in Cambridge and some other universities).

Given these sources of information, many university admissions are decided reasonably straightforwardly. However, in recent years there has been a tremendous increase in the number of university applicants who have very good A-level results. As a result, increasing numbers of universities and courses have been faced with the problem of choosing between 'too many' good applicants and their methods have generated considerable controversy. So, how might this be done both skilfully and fairly?

If one talks to admissions officers who are faced with choosing between 'very able' applicants, they commonly say something like the following,

'Of course our candidates are very good at learning what their teachers tell them (they have or are predicted to get very good A-level results), but they fall into two groups when you ask them questions outside what they have 'done for A-level', questions which require them to show how they think in such situations. Some candidates simply flounder - they haven't 'done it' so they have little to say about it. Others welcome such questions; they are ready to think about possible solutions, will talk around the problem, try different approaches - and so on. They show a readiness to think on their own account and they know how to do that. These are the ones we want to admit.'

To put the point differently, when students move from school to a university, many will find that they have to think a great deal for themselves. University teachers will assume a whole range of thinking skills - an ability to argue a case, to solve problems, to judge credibility, and much more. Other things being equal, students will perform better at university if they have been taught these skills explicitly and know how to deploy them in novel situations.

I have taught both critical thinking and mathematical problem solving skills at university level. After such courses, I have often been surprised by the number of students who say something like,

'Now I understand what I am supposed to be doing when I write an argumentative essay (or try to solve an unfamiliar problem); my grades have improved significantly; but why on earth was I not taught this kind of thing at school? It is not rocket science, but it is so helpful.'

There is no doubt that these 'thinking skills' are teachable (though not commonly taught), helpful (especially in the modern world where knowledge becomes obsolete so quickly and what is needed is people who are good at thinking things through for themselves), examinable (OCR/ CIE are already doing this quite extensively) and the

2005-03-10

kinds of things university admissions officers are looking for but receive little information about from the UCAS form.

Thus, an assessment of suitable ‘thinking skills’ could be just what university admissions officers are looking for if they are faced with the problem of too many able applicants. At present, universities have no direct information about how good applicants are at *thinking things through on their own account* - at tackling novel situations of just the kind they will often encounter in university and subsequently. This ability is just what the new Thinking Skills Assessment aims to measure.

Working back from what students have to do in university, it seems reasonable to assume that a reliable measure of this ability could be very helpful in the admissions process and evidence is beginning to emerge to support this view (Willmott 2005).

5. Measuring Intelligence versus Assessing ‘Thinking Skills’.

(i) Intelligence and the Scholastic Aptitude Test (SAT)

Work on *measuring* ‘intelligence’ is usually traced back to the pioneering work of the French psychologist, Alfred Binet (see Binet and Simon (1916)). This work was taken up and developed in the US in the 20s and 30s by Stanford Professor Lewis Terman and Harvard professor Robert Yerkes. In this tradition, ‘intelligence’ is usually taken to be a fairly fixed endowment and intelligence tests are taken to assess something fixed. Of course, intelligence develops over time - as one grows older - but an individual’s position in any overall ranking is likely to remain much the same at different ages. As a corollary, on this conception it is not thought possible to significantly ‘improve’ one’s level of intelligence through teaching.

By contrast, the thinking skills tradition believes that many of the skills commonly identified with intelligence can be taught and developed by direct teaching of the right kind.

Thus, there are quite different views about cognitive development underlying the two traditions and, as we saw in section 3, there is mounting evidence that the ‘thinking skills’ tradition is on the right track - that performance of school pupils can be considerably improved by teaching thinking skills - that it is possible to ‘really raise standards’ in this way.

Following in the tradition of Binet’s work, an instrument, called the Scholastic Aptitude test (SAT), was developed in the United States, to help with the process of university admissions. Its development began in 1926 but it became widely used after the second World War, when admissions to higher education in the US were greatly expanded. It is now called the Scholastic Assessment Test and has been well-established for over 60 years.

The problem faced by colleges in the United States was that there has never been anything like the UK National Curriculum or national examinations like the UK A-levels, so how should they compare applicants from different States, with different curricula, different examinations and different standards? The SAT was designed as

2005-03-10

an ‘objective’ measure of ‘intelligence’ (seen as a fairly fixed endowment), which would be a good indicator of academic aptitude and which could greatly assist admissions officers in North American universities.

It has long been designed to measure two abilities, ‘verbal reasoning’ and ‘mathematical reasoning’, which are seen as

- (i) developed abilities which grow slowly over the years,
- (ii) relatively independent of what the student is currently learning in the classroom and
- (iii) general academic skills necessary for successful college work.

The SAT is widely used in the United States and elsewhere (eg Canada, Sweden and Israel) to provide *supplementary* predictive information in the college admission process. It is combined with the Grade Point Average to predict performance and its predictive validity is usually measured in terms of performance one year after admission. (And there are now several similar instruments used for similar purposes, including the Graduate Record Examination (GRE), the Law Schools Admission Test (LSAT) and others.)

(ii) Thinking Skills and the Thinking Skills Assessment (TSA)

Arising out of the thinking skills tradition, instruments called the Biomedical Admissions Test (BMAT), a medical and veterinary schools entrance test, and the more general Thinking Skills Assessment (TSA) have been developed by UCLES, also to help with the process of university admissions. These tests have been developed on the basis of the work done by UCLES on assessing thinking skills over the past 25 years (see Willmott (2005)).

The problem faced by some universities in the UK and for which these instruments were designed is quite different from the problem for which the SAT was designed in the US. In short, the problem in the UK is to differentiate between very large numbers of candidates with similar and excellent A level results. The TSA and the BMAT are designed to assist admissions officers in British universities faced by ‘over-subscription’ in discriminating skilfully and fairly between such candidates.

The Thinking Skills Assessment is currently designed to measure two skills, ‘critical thinking’ and ‘problem solving’, which are seen as

- (i) skills/abilities which are *teachable* - (with significant pay-off for A levels and university work)
- (ii) skills which can be developed through special approaches to subject matter teaching or through stand-alone courses
- (iii) general/transferable academic skills which are vital to successful university work

The TSA is currently being piloted by 22 colleges in 5 disciplines in the University of Cambridge. It provides *supplementary* predictive information in the college admission process. Scores are combined with A-level scores to predict performance and the predictive validity of both tests is being measured in terms of performance one

2005-03-10

year after admission. The BMAT also has a thinking skills component and it is currently being used by faculties in five leading universities. For more details and evidence on their utility see Willmott (2005)

6. Thinking Skills Assessment (TSA) or Scholastic Assessment Test (SAT) ?

As we argued in the previous section, some extra information about students' thinking skills could be of great assistance in the admission process in British universities. Some people have suggested that the North American Scholastic Assessment Test (SAT) could be used to provide that extra information. But this would be a mistake, for several reasons:

(i) The British and North American educational systems are very different. In particular, there is nothing akin to the National Curriculum in the US and each of the 50 States has its own curricula and State examinations. As a result, there are no national examinations like our A-levels.

(ii) Furthermore, admission to university in North America is normally to the first year of a four year course, where the first year teaching is broader and more general in nature than the first year of most British university courses, which are more specialised. In that context, far more students will change direction or leave university during and at the end of the first year in North America than happens here.

(iii) Because there are no national examinations like A levels in North America, the problem faced by admissions officers in the institutions of higher education in the US is how to compare the qualifications of applicants from a huge variety of backgrounds. The SAT is designed to deal with this problem. Thus, it aims to provide an 'objective' standard with which to weigh different standards which might be applied in different schools, in different States across a large and very diverse country.

(iv) In Britain, the problem for institutions of higher education is quite different. A levels have existed since 1951; they are national examinations which are very well established - and are based on national curricula. Admission to British universities has been decided mainly on the basis of performance in these examinations ever since they were first introduced. Most university admissions are decided quite straightforwardly on the basis of predicted A-level grades and the Head-teacher's report provided on the UCAS form. However, increasing numbers of universities and courses need to discriminate between 'too many' able applicants. Thus, in the UK, the problem is to find a method of differentiating skilfully and fairly between candidates with very high A-level scores.

(v) The SAT is designed for the North American educational context. Educational Testing Service, who produces it, works very closely with educational institutions to ensure that it meets their needs. It is unlikely to

provide an ‘off the peg’ instrument to help selection in the very different UK context, where the problem to be addressed is different.

(vi) One of the most important differences between the SAT and the TSA is that the skills assessed in the TSA are teachable skills which are valuable in higher education. The SAT on the other hand has long claimed to measure ‘innate’ or ‘native’ ability. Of course, it is well known that candidates can be ‘coached’ to do better on the SAT than they would without such practice. Clearly, candidates taking any test will benefit from doing similar tests (usually past test papers), which show the structure of the test and the kind of questions it contains. However, most of the strategies for getting higher marks on the SAT do not involve gaining more knowledge or skills that will benefit students in the HE courses to which they aspire. They simply involve learning what to look for in the test and how to use its structure to the candidate’s advantage. By contrast, learning thinking skills leads to the enhancement of students’ performance in all parts of the curriculum as well as preparing them to get the best from Higher Education. Furthermore, such study will pay dividends in bringing candidates’ thinking skills up to a suitable level for the purposes of BMAT or TSA.

(vii) The SAT is commonly criticised for the effect it has on the attitudes of students to education - that it devalues real education, etc. This is not true of teaching and assessing thinking skills.

(viii). Thinking Skills assessments are also useful in being able to screen out those that have been ‘crammed’ for a knowledge-based test but do have the required level of thinking skill and are thus not likely to succeed at a selective faculty. They might also supply useful information about those without ‘standard’ ‘A’ Levels.

To summarise: the SAT is very well suited to the North American context and the problems it faces. The British context and problems are quite different.

7. What is Critical Thinking ?

The thinking skills assessed in the BMAT and TSA instruments introduced above are ‘critical thinking’ and ‘problem solving’. It is time to explain how these are conceived. A key reason for doing this is that these assessments of thinking skills are intended to have a ‘face validity’ for university academics (especially those involved in the admissions process). That is to say the questions are intended to look like the kinds of questions students need to address in university work and perhaps similar to the sorts of questions admissions officers would like to put to candidates in interview precisely to see how well they think in unfamiliar situations, when facing novel problems.

The thinking skills which are taught in the critical thinking tradition include arguing a case, decision-making, problem solving, explaining causes, evaluating, comparing and

2005-03-10

contrasting, judging credibility, clarifying and interpreting ideas and many other 'higher order' thinking skills (cf Bloom (ed) (1956) for an account of 'higher order' thinking).

In the UK, the Qualifications and Curriculum Authority has established 'subject criteria' for critical thinking teaching and examinations and these say that AS level specifications should require students to:

- understand the language of reasoning
- clarify expressions and ideas
- identify reasons and conclusions
- recognise and evaluate different kinds of claims
- judge the credibility of sources
- understand and use different patterns of reasoning as well as different standards for evaluating arguments
- recognise and evaluate special kinds of reasoning: causal explanations, justifying decisions, reasoning from different points of view, basic ethical reasoning
- recognise assumptions
- present relevant arguments
- understand basic forms of statistical reasoning appropriate to informed citizens.

In addition, A level students should be able to:

- evaluate rhetorical and persuasive language, including some classic fallacies
- understand forms of statistical reasoning appropriate to informed citizens
- understand and use features of hypothetical reasoning such as for example what if, suppositional reasoning, testing hypotheses
- identify and evaluate ethical arguments, making reference to principles
- recognise and apply some basic logical ideas, such as for example excluded middle, converse, contradiction, consistent, circularity, counter example, necessary and sufficient conditions, imply/entail, generalisation
- use images, symbols and other non-verbal stimuli in reasoning such as for example those in news reporting, advertising, political and similar cartoons.

It is not difficult to see from such a list that these are skills which are fundamental to many intellectual activities and are also skills which are taken for granted in many university courses. Thus, on the face of it, if one could get reliable information about applicants' critical thinking skills, this information could be very relevant in the university admission process.

The critical thinking tradition is now very well established. John Dewey (1909) is usually regarded as the founder of this tradition, but many other scholars have made important contributions. Edward Glaser conducted the first scientific experiment to see if critical thinking skills could be taught (1941) and was responsible for the

Watson Glaser Critical Thinking Appraisal, still the most widely used test of critical thinking in the world. Robert Ennis ((1958)and (1996)) has made many important contributions, as have Scriven (1976), Swartz (1998), Costa (2001) and many others in the last 30 years. In the United States, student reaction to the Vietnam War is widely credited with giving impetus to the teaching of critical thinking in universities and elsewhere (hence Kahane (1976)). Students demanded instruction in how to combat bad reasoning and how to construct good arguments - hence the development of many courses claiming to teach 'critical thinking'.

Despite all this good work, it is important to note however that when something like critical thinking becomes 'fashionable', as it has in the United States in the past two decades, poor quality teaching and testing becomes a serious problem and risk discrediting the good work, so measures of the effects of teaching critical thinking (like other thinking skills) need to take this into account..

Among UK organisations, UCLES has given a significant lead in developing assessments of critical thinking and of problem solving skills. The history of their involvement goes back to the 1980s when they devised a British version of the North American Law Schools Admission Test to assist in selecting students to read Law at Cambridge University. In 1997 they asked Dr Alec Fisher to design a new AS level examination in critical thinking. This was first piloted in 1999 and has been taught and examined successfully ever since. The number of students who took the examination in 2004 was 14,315. UCLES has also had an Advanced Extension Award since 2002 and the AS is currently being extended to an A-level to be first taught from September 2005 and first examined in June 2006.

8. What is Problem Solving ?

The basic idea behind this tradition is that reasoning and thinking about numbers, shapes, and other 'mathematical' objects and structures is quite different from verbal reasoning (in the 'intelligence' tradition) or critical thinking (in the 'thinking skills' tradition) and needs to be differently taught and assessed. In the tradition which owes so much to Polya, the kind of problem solving with which are concerned here includes the ability,

- to read and understand material with mathematical/quantitative/graphical content
- to clarify and interpret such information when it is unclear or ambiguous,
- to evaluate reasoning about such information,
- to identify assumptions,
- to identify counter-examples and other flaws in reasoning,
- to understand different logical relationships (negation, implication, quantifiers, etc)
- to construct solutions to (unfamiliar) problems which use such information,
- to identify *relevant* or *necessary* information for solving a problem,
- to differentiate between possible, necessary and other logical relationships,
- to compute, visualise and estimate,
- to find procedures for solving an unfamiliar problem,

2005-03-10

- to formulate hypotheses and conjectures (e.g., suggesting patterns from examples),
- draw conclusions from given data,
- to write and express themselves using mathematical/quantitative/graphical ideas.

(cf. Fisher (2002) and NFER (1976) p.128)

Again, it is not difficult to see that such skills are fundamental to work in many sciences, social sciences, engineering and other intellectual activities. They are also skills which are taken for granted in many university courses. Thus, on the face of it, if one could get reliable information about applicants' problem solving skills, this information could be very relevant in the university admission process.

Some people would trace the 'problem solving' tradition back to Binet's work on measuring intelligence. But, insofar as we are speaking of a teachable skill, most people who have worked in this field would identify Georg Polya and his book *How to Solve It* (Polya (1945)) as the origin of this tradition. Polya's work has since been taken up by various mathematics educators and much work has been done in this tradition, notably by the American mathematics educator, Alan Schoenfeld (see, for example, his (1992)). A good example of British work in this field is *Problem Solving: The School Mathematics Project 16-19*, published by Cambridge University Press in 1989 which remains a source of excellent ideas and material.

The critical thinking tradition includes the skill of 'problem solving' but this is normally a non-mathematical kind of problem solving, (like deciding which universities to apply to). So this should not be confused with the 'quantitative' problem solving with which we are dealing here.

The UCLES Thinking Skills Assessment (TSA) sees the problem solving skills it assesses as being 'parallel' to critical thinking skills - but about numerical, quantitative and spatial data or subject matter. Comparison of the two lists of skills above shows many similarities, though critical thinking uses only ordinary language whilst problem solving uses 'quantitative' language and different reasoning techniques. For example, a distinctive feature of the problem solving domain is that the reasoning skills involved are nearly all **deductive** reasoning skills, whereas in the case of critical thinking deductive reasoning is rare.

The 'problems' in the TSA currently fall into three groups, called Finding Procedures, Relevant Selection and Identifying Similarity (Willmott (2005) Appendices, B and C) but the fundamental point about them is that they are 'novel' problems, of a kind students will not have encountered at school and for which there is no ready 'off the peg' solution. To tackle these problems, students will have to have problem solving strategies available to them - of the kind Polya gives.

Of course, many university courses have among their admission requirements a pass in GCSE or A level mathematics (perhaps at particular grades), because they require the **content** and **problem solving skills** of GCSE or A level mathematics. But, again, it seems reasonable to assume that specific information about problem solving skills

could be of help to admission officers in many university fields, and evidence to that effect is beginning to emerge (Willmott (2005)).

Parallel to the case of testing critical thinking, testing problem solving skills could help admission officers distinguish between applicants who have been well-drilled to pass mathematics examinations and those who can solve quantitative problems of a novel, unfamiliar kind who have a skill which is needed in many university courses. Its problems would require that the candidate could use problem solving strategies and *understood* how to solve new kinds of problems (at a given level)

What is needed now is consultation with those for whom the TSA is intended, especially teachers in higher education, about the mathematical/quantitative/logical/problem solving skills which are needed in various areas of academic work with reference to questions of the types discussed above. As I said earlier, it is important that questions have 'face validity' for university teachers.

Clearly, some university subject areas require almost no problem solving skills of the kind outlined above (e.g., English Literature); others require a relatively low level and others quite a high level (e.g., Physics, Computing).

9. Summary of the Argument

There is a view among many involved in education that students' thinking skills simply develop slowly and fairly independently of what is being studied in their normal school subjects - history, physics etc. The 'thinking skills' tradition argues that these skills are better taught *explicitly* and that doing so can really *raise educational standards*.

There are many strands in what has become known as the 'thinking skills' tradition, including the *critical thinking* and *problem solving* traditions. Thinking skills programmes are nearly always prompted by the realisation that students lack some thinking ability and are designed to remedy that deficiency by teaching the skills in question *explicitly* and *directly*.

The essential ideas behind nearly all of these programmes is '*metacognition*' - self consciously directing ones own thinking to be more skilful - and practice (just as one can improve a motor skill, like a playing golf).

There is increasing *evidence* that thinking skills can be developed through direct teaching and that they can significantly improve performance in ordinary school subjects. And this evidence is outlined above, citing some important sources.

These results are welcome to universities for their own sake, but are also of interest to them for another, more specific, reason. In recent years there has been a tremendous increase in the number of university applicants with very good A-level results. Thus, increasing numbers of universities and courses have been faced with the problem of choosing from among 'too many' able candidates and their methods have generated considerable controversy. Some are now experimenting with tests of 'thinking skills'

to provide them with the extra information they need to make these choices *wisely* and *fairly*.

At present, candidates' UCAS forms give admissions officers a great deal of information, but provide no direct information about how good applicants are at *thinking things through on their own account* - at tackling novel situations of just the kind they will often encounter in university work. Thus, working backwards from what students will have to do in university, it seems entirely reasonable to assume that a reliable measure of this ability could be very helpful in the admissions process and evidence is beginning to emerge to support this view.

There is a question about what should be assessed by such tests. Should they assess '*intelligence*', thought of as being something *fairly fixed*, like the North American Scholastic Assessment Test (SAT)? Or should they assess 'thinking ability' seen as being both *teachable* and *fundamental to success in university work*?

This paper argues that the SAT works very well in the North American context but is not the instrument for the different problems faced in the UK. What is required here is a test of thinking skills; these are vital for success in university, teaching them would raise standards and assessing them gives information not otherwise available to admissions officers. Working back from the 'thinking skills' required by university, this paper argues that what is needed is a test of 'critical thinking' and 'problem solving' (and perhaps others).

These constructs are explained sufficiently fully for university teachers to see that they are fundamental to success in many university courses.

As we have argued, these skills can be taught and should be taught explicitly. They can improve performance in school subjects and are vital at the university level. The UCLES Thinking Skills Assessment, which is built on 25 years work in this field, is designed to assess just these thinking skills and could therefore provide valuable information to help in the admission process of many universities. Evidence on this instrument is published in Willmott (2005).

10. To Conclude

Thinking skills assessments of the right kind could be valuable to British universities in making admission decisions wisely and fairly. The BMAT and the TSA are already well-developed and evidence about their utility is emerging. UCLES also envisages producing *similar thinking skills assessments* (besides the TSA and BMAT) for other subjects, in consultation with interested academics. There is much work to be done but this is an interesting development which deserves to be taken seriously and followed up.

Dr Alec Fisher
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Appendix : The notion of ‘effect size’ explained

The general concept of ‘effect size’ derives from the school of methodology called meta-analysis. In our context, the term refers to an increase or decrease in the achievement of an experimental group by comparison with a control group; the former *does* and the latter *does not* receive the educational intervention in which we are interested.

Suppose we are interested in the effect of teaching students critical thinking skills. Then we identify a control group - who *have not* been taught these skills - and an experimental group - who *have* - and measure the critical thinking skills of both groups. Provided the groups are large enough we would expect the percentage scores for both groups to display a ‘normal distribution’ as shown in the diagram below:

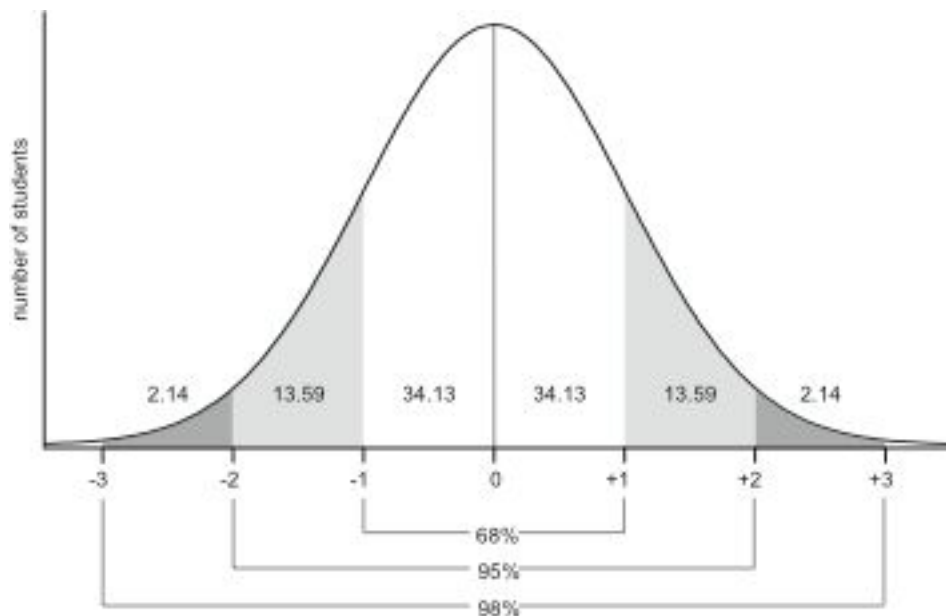


Figure 1: scores a ‘normally distributed’ group of students relative to their mean

The diagram illustrates the fact that a normal distribution has a range of about three standard deviations above the mean score and three below; about 34% of students will be found within the first standard deviation above the mean, 95% will be found within 2 standard deviations above and below the mean, etc.

Assuming the effect of teaching critical thinking skills is positive and significantly so we would expect the scores in the two groups to look something like the diagram below, which illustrates an effect size of about .75:

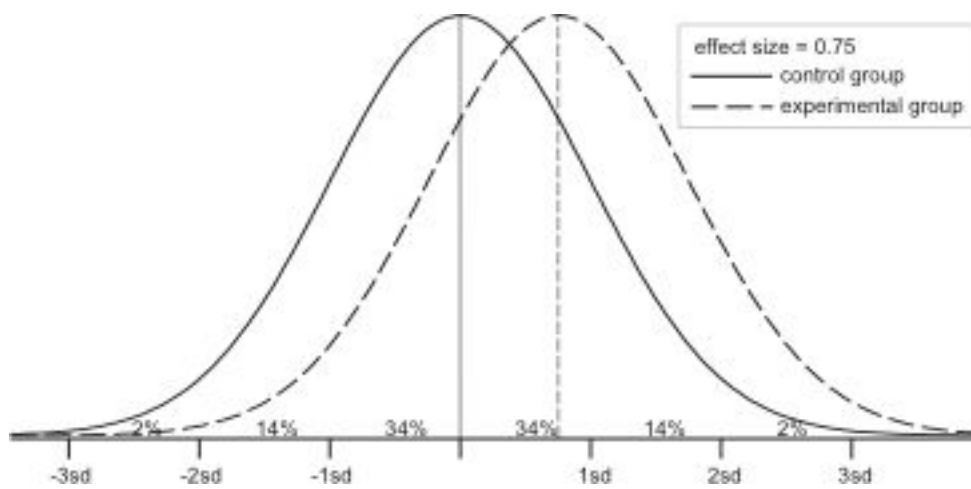


Figure 2: comparing two groups

There are various ways of computing effect sizes, but the basic formula is;

$$\frac{(\text{mean of experimental group}) - (\text{mean of control group})}{\text{standard deviation of control group.}}$$

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