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Augmenting Postgraduate Student Problem-Solving Ability by the Use of Critical Thinking Exercises

M N. Johnstone
Edith Cowan University

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MN Johnstone

School of Computer and Information Science
Edith Cowan University, Australia,
E-mail: m.johnstone@ecu.edu.au

ABSTRACT

This paper describes the results of a research programme whose focus was critical thinking and explores how information technology (IT) postgraduate students model problems. Some results from the programme show that IT students appear to improve their problem-solving ability by undertaking structured critical thinking exercises.

An AC Nielsen survey commissioned by DETYA in 2000 sought to gauge employer satisfaction with graduates using a variety of methods including questionnaires, focus groups and in-depth interviews. A key finding was that 'the skills employers consider to be most important in graduates are creativity and flair, enthusiasm and the capacity for independent and critical thinking'. Similar conclusions were drawn in earlier work from the UK and USA.

Generally, critical thinking, if it is taught in a university, is taught as a formal or symbolic logic subject, usually by the philosophy or mathematics department. While there is nothing inherently wrong with teaching students the syllogisms of Aristotle, as formal logic has its uses, that does not necessarily equate to critical thinking.

The assessment of critical thinking skills is also somewhat problematic. There are several generic assessment tools available but if critical thinking is discipline-specific, then such tools may not be particularly useful. One solution is to use a formal critical thinking assessment instruments in a pre/post treatment experiment, the treatment being the exercises.

This study evaluated the critical thinking skills of Masters-level students. The participants were a class of coursework Master students at an Australasian university. These students were administered two Mensa-style tests that targeted critical thinking skills regarded as essential elements in a university education. The design was a classic pre/post treatment experiment, with the treatment being the intervening structured critical thinking exercises. The results indicate that the students' problem-solving ability improved over time which suggests that the exercises were effective.

INTRODUCTION

Many employers (DETYA, 2000) appear to want university graduates that are able to demonstrate and use 'critical thinking skills'. Universities have traditionally cultivated critical thinking in students by means of formal logic classes, but logic problems are not always the types of problem that are faced in the workplace. Students may also potentially learn critical thinking by solving of other types of problem such as case studies and lateral thinking exercises.

Perhaps the place to start is a definition of critical thinking (of which there are many). Huitt (1998) reviews a range of extant definitions and proposes: "Critical thinking is the disciplined mental activity of evaluating arguments or propositions and making judgments that can guide the development of beliefs and taking action", a suitable definition which will be used hereafter.

Exactly how to transfer 'critical thinking skills' to graduates is the subject of some debate. This research explores how to foster critical thinking in postgraduate students, using a single unit as the vehicle for action learning. A combination of logic problems and lateral thinking exercises are used to potentially enhance the critical thinking skills of students. The expected outcome is that students are able to demonstrate enhanced critical thinking skills. Before discussing the detail of this study it is useful to review the research on critical thinking skills.

CRITICAL THINKING

An AC Nielsen survey commissioned by DETYA (2000) sought to gauge employer satisfaction with graduates using a variety of methods including questionnaires, focus groups and in-depth interviews. A key finding was that 'the skills employers consider to be most important in graduates are creativity and flair, enthusiasm and the capacity for independent and critical thinking'. Further, '[critical thinking] is of great importance to employers and seems to be the skill that most sets apart successful from unsuccessful applicants; in other words, employers value this skill and can find it but it is rare'.

Similarly, many universities use a set of graduate attributes that define skills or characteristics that each graduate of the university will be able to demonstrate. For example, at Edith Cowan University, graduate attribute five is defined as: 'Problem Solving/Decision Making: critical thinking, logical reasoning, well-developed problem-solving skills, and making and implementing sound decisions.'

Therefore it is reasonable to say that the university expects graduates to be critical thinkers and, more to the point, that employers want this skill. Barnett (1997) suggests that Western universities are based around the idea of 'critical thinking', but points out that they don't live up to the ideal. In later work, Barnett (2004) presents an argument that the world is changing at such a pace that adding resources or time does not solve problems (such as how to effectively embed critical thinking in the curriculum). Universities are held partly responsible for this 'super-complexity' and thus are expected to contribute to the solution.

Similar to the DETYA (2000) study, earlier work by Harvey (1993, cited in Bowden and Marton, 1998) reported on a UK study which found that employers want communication skills; problem-solving abilities; analytical skills; and team work as graduate skill sets. The combination of problem-solving abilities and analytical skills could be construed to be 'critical thinking' skills. Knoll and Wilkins (2002) also noted that US employers wanted particular core skills in graduates including the ability to interpret business problems.

Generally, critical thinking, if it is taught in a university, is taught as a formal or symbolic logic subject, usually by the philosophy or mathematics department. There is nothing inherently wrong with teaching students the syllogisms of Aristotle, as formal logic has its uses, but that does not necessarily equate to critical thinking. For example, de Bono (1970) argues that what he terms 'lateral' thinking is related to insight, creativity and humour, but that lateral thinking can be taught. De Bono differentiates between lateral thinking and logic and likens logic to 'vertical' thinking where conclusions follow directly from their antecedents. De Bono classifies problems into three types: those that require more information to be solved; those that require a rearrangement of existing information to be solved; and those that are 'no problem' i.e. those problems that already have solutions. He points out that only the first type of problem can be solved with vertical (i.e. logical) thinking, the other two types require lateral thinking. The last type is the most interesting as potentially optimal solutions are blocked by the existence and continued use of merely adequate ones.

Tucker (1996) raises some useful questions about critical thinking and highlights the necessity for clearly defining what is meant by 'critical thinking' on a per-discipline basis. The questions raised include: can one become a better critical thinker through practice?; is there a set of tools that can be used to assist one to think critically?; and can one be a good critical thinker in one area but a poor one in another-or are critical thinking skills above such distinctions?

Moore (2004) reviews the generic vs. discipline-specific critical thinking argument and suggests that generalist approaches, whilst they have a place, tend to be too positivist to be of significant use in solving real-world problems. Of the two schools of thought regarding critical thinking, McPeck (1990) is a champion of the latter and contends that having knowledge of a subject is intimately connected with being able to think critically about it. For example, 'the critical thinker, therefore, knows what and when it might be reasonable to question something. *But this requires comprehensive understanding of the kind of information that it is*...' (my italics). Postman (1979, cited in McPeck) clearly differentiates between a subject, the language of a subject and the real thing that the subject describes using Astronomy as an example of this phenomenon, i.e. 'Astronomy is not planets and stars. It is a way of talking about planets and stars'.

Having established that employers want graduates to have critical thinking skills and that there is debate concerning the nature of critical thinking, it is useful to examine some field research that involves undergraduates. Phillips and Bond (2004) also note the difficulty in establishing the exact nature of critical thinking and discuss the difference between generic and discipline-embedded critical thinking. They interviewed 13 second-year management students, firstly to elabourate what they thought of 'critical reflection' and secondly, to discuss some aspects of problem-solving tasks that were set. The data were analysed using the framework of Marton and Booth (1997). This framework is remarkably similar to the taxonomy of approaches to learning used by Ramsden (2003). Although this study has a limited sample, the results suggest that simply inserting critical thinking in the curriculum is not sufficient to embed in graduates the critical thinking skills either desired or expected by employers.

Tapper (2004) reports on the perceptions of undergraduates about critical thinking. First-year students were taught elements of critical thinking using supporting software (see van Gelder, 2001). A sample of these students (21) were then interviewed at various stages later in their degree programme as to their views on critical thinking. Tapper concludes that everyone wants students to have critical thinking skills but it is difficult to a) allow students to learn them; and b) assess that they have been learned.

Similarly, Knoll and Wilkins (2002) questioning various stakeholders about their perception of critical skills for various related occupations in the field. The two stakeholder groups were employers of information systems graduates and recent alumni/alumnae of a midwestern US university. The critical skills factors that were identified were: business knowledge, advanced IS applications, user support, programming and systems planning. The results were unsurprising in that programmers rated programming highly and CIOs and analysts rated business knowledge highly for analysts etc. What did emerge was a model curriculum with core skills, followed by role-specific education. Core skills included the ability to interpret business problems and develop appropriate technical solutions; and the ability to work collaboratively in a team project environment.

There appears to be a substantial amount of literature on critical thinking in universities that examines undergraduates (van Gelder, 2001; Tapper, 2004; Phillips and Bond, 2004) but little that examines the perceptions or abilities of postgraduates. The purpose of this research, therefore, is to explore how to foster critical thinking in postgraduate students.

RESEARCH METHOD

The research question to be investigated is 'Does the use of critical thinking exercises improve the critical thinking abilities of postgraduate students'? This question can be explored qualitatively i.e. by using interviews or surveys as part of an action learning programme or quantitatively by using some form of within-subjects experiment amenable to analysis by statistical method.

There is a considerable body of literature in the physical sciences where research is firmly rooted in the quantitative paradigm. This is an indication that research based on another (not necessarily opposite) paradigm (namely qualitative research) is not considered 'science' as it is not (normally)

measured by statistics. Weick (1984, p129) confirmed this when he said that the scientific approach assumes that 'if it can't be measured, it's not real'. Morgan and Smircich (1980), however, assert that the qualitative-quantitative divide is somewhat oversimplified and suggested that a spectrum of views was more appropriate. At approximately the same time, Jick (1979) argued that mixing qualitative and quantitative methods was actually beneficial, a view also held by Mingers (1997) and Dick (1998). As Bergsjø (1999, p561) puts it 'Although the rules and approaches differ, quantitative and qualitative methods are not mutually exclusive'.

This research uses a combination of qualitative and quantitative techniques viz. survey and experiment. The purpose of a survey is to gather a 'snapshot' of practices at a given point in time via questionnaires or structured interviews. The data gathered in this way may then be subjected to quantitative (statistical) analysis and inferences drawn from the results. Surveys have some advantages, viz. they based on real-world experience; the results are amenable to treatment via statistical methods if there are a significant number of questionnaires; and they can be delivered, assessed and the results evaluated in a relatively small time frame. A disadvantage of this method is that the researcher will be unaware of potential bias introduced by the respondents if the survey is a questionnaire i.e. the effect of self-selection. Also, surveys can be a comparatively crude instrument as they tend to be superficial because eliciting detailed knowledge of a problem situation and ease of completion of a survey are mutually exclusive goals. If this is an issue, surveys could be used initially to discover key issues that can then be followed with more rigorous techniques.

The main advantage of a laboratory experiment is control over both the environment and the variables being studied but its major weakness is that behaviour exhibited under controlled conditions may bear no relationship to what occurs in a real-world scenario. This is because the variables being studied are isolated from their real-world context. Nonetheless, if only a small number of variables are to be controlled/examined and the object of interest is the quantitative relationship between those variables then a laboratory experiment may be appropriate. Field experiments are an attempt to address the shortcomings of this method by placing the 'experiment' in a real-world situation.

In this study, the participants were two classes of coursework Masters students at a large Australasian university. The first group was assessed qualitatively by means of two surveys that sought to gauge their perceptions about the value of various types of critical thinking exercises. This acted as a pilot study for the second (quantitative) phase. The second group of students were administered two Mensa-style tests that targeted critical thinking skills regarded as essential elements in a university education. The design was a classic pre/post treatment experiment, with the treatment being the intervening structured critical thinking exercises.

THE STUDY

This study evaluated the critical thinking skills of coursework Masters-level IT students in two stages over several semesters. The first phase involved qualitative analysis of student perceptions of the efficacy of various types of problem. The problems could be broadly classified into either 'classic' logic problems or lateral thinking problems selected from de Bono (1968). Questionnaires were administered to the students after the completion of the first (classic) set of problems and then also once again when the lateral thinking problems were completed (see Appendices). The purpose of this stage was to evaluate the perceptions of the students towards the efficacy of the exercises in augmenting their critical thinking skills and to examine any preferences expressed for the different types of exercises.

The responses (15) obtained from the open-ended questions in the survey indicate that while the majority of the students perceived both the classic and lateral thinking exercises to be of value, there was a distinct preference for the latter type of exercises. The reasons behind this preference were not clear and the students were not able to express precisely why they preferred the lateral thinking exercises. It could be hypothesised that the preference exists because the lateral thinking

exercises were tactile in nature, but this remains unproven. A future study may use an evaluation of learning styles to examine any effects in this area.

The qualitative analysis also involved the students posting their reflections about the problems on a discussion board. Figure 1 indicates the process which could also be expressed as an action (practice)/reflection (theory) cycle common in action learning/action research.

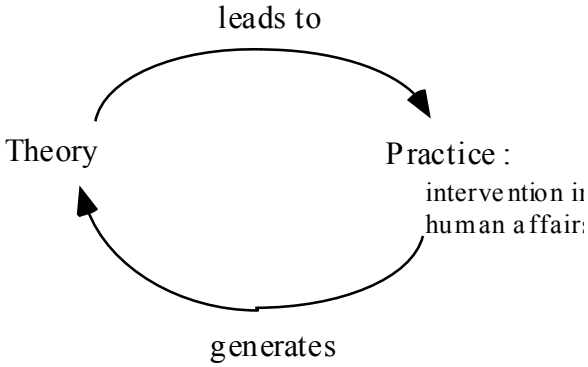

Figure 1: The Balance between Theory and Practice (Checkland, 1985).

The second phase involved quantitative analysis of the critical thinking skills of a second group of students in the same unit in the following semester. These students were given two Mensa-style tests that targeted critical thinking skills regarded as essential elements in a university education. The first test was administered prior to the students beginning the suite of critical thinking exercises and the second at the conclusion of the suite. In both phases, participation was voluntary and anonymous and it was emphasised that the exercises were not part of the formal curriculum and would not be assessed as such. Interestingly, in the second phase more students took the second test than the first, but these data were excluded as both pre-test and post-test data elements were required for the statistical analysis.

ANALYSIS OF FINDINGS

As noted in the previous section, in the pilot study (phase one), the students expressed a preference for the lateral thinking exercises over the more traditional logic problems. It was clear that the students perceived that the exercises were worthwhile. This was made obvious by their participation as the problems were posed at the conclusion of formal classes each week. The students were given the choice of solving the problems as individuals or in groups, with the result that the traditional logic problems were done individually and the lateral thinking exercises were solved in groups. The students were obviously engaged in the problem-solving activities to the extent that when a group found a solution to a particularly difficult lateral thinking problem they took photographs of their achievement to record the event. At the completion of each weekly session, the students posted their reflections about the problems on a discussion board. An example of the reflections expressed by the students is shown in table 1.

Lecturer	I noticed that the solutions for the 3-box problem did not appear to come as easily as the 2-box problem. Why do think this is so? Did the relative ease of the 2-box problem give you confidence that you could solve the 3-box problem or did it get in the way of solutions for the 3-box problem?
Group 1-1	I think it was not easy because it was a more complex problem in nature. And I kinded of [sic] agree with the idea that the 2-side touched box problem was kind of getting in the way a bit, but not really. It's bad because they're two different problems which has some tricky similarities. Since I felt that I kinded [sic] of related the two problems together and was trying to find any similarities that would lead to solutions of the 3-side touched box from the 2-side touched box solutions, I found that the two solutions had nothing in common.
Group 2-1	Three box problem is more complex than the 2-box because: more variables are included. 3 sides compared to 2 sides designs made on the 2-box exercise made it a bit complicated because we used pretty much the same technique on doing the 3-box.
Group 3-1	We think that the second one is worse than the first one, because our minds got the fixation by the first one, therefore, second one become more complicated and tedious.
Group 1-2	from the previous exercise experience, we dint [sic] have much difficulty in finding the solution for 4 match boxes. We got 2 solutions in less than 5 minutes.
Group 2-2	we find it easier now to do the 4-box than the 3-box exercise: 1. we didn't follow the approach we've been doing on the 3-box. 2. 4-box is an even number which we think it's more easy to deal than the 3-box thing 3. we just completely took 4-box as fresh exercise. didn't compared with the other exercises.
Group 3-2	4 box problem made it more obvious reducing the degrees of freedom and as the total number of boxes are few so it is obvious that the arrangement is limited and reduces the manoeuvring of the boxes and limits it to less degrees of freedom

Table 1: Sample Discussion Board Posts.

The sample discussion board posts in table 1 indicate that the students are reflecting about the nature of the problems. For example, groups one and three recognise that the “3-box” problem is more difficult and that building on the solution to the previous problem did not assist at all, whilst group two deliberately chose not to use the knowledge of solutions to previous problems. Group three also noticed that the “4-box” problem was simpler than its precursors due to the reduced degrees of freedom-a significant insight as the problems appeared to be increasing in difficulty as time progressed.

A post-hoc observation is that it would have been extremely valuable to video-record the students as they group problem-solved these exercises. This would have generated precise data on time to solution, exactly how the solution was generated and the nature of the solution. For example, when solving the “4-box” problem alluded to previously, a particular group came extremely close to a solution three times but veered away at crucial moments. Whilst the students complete surveys about their experiences at defined times during semester and also use the discussion board to record their immediate observations about each exercise, these data collection methods are not nearly as rich as an audio/video record of what they said and did to actually solve a problem.

Given the perceived value of the exercises (from the student point of view) and the level of interest generated by the exercises (as shown by the participation in voluntary, after-class activities), it was time to consider whether any quantitative evidence could be gathered that supported the findings

thus far. These thoughts led to phase two, where a more formal evaluation of student critical thinking abilities was undertaken.

Recall that the research question is 'Does the use of critical thinking exercises improve the critical thinking (CT) abilities of postgraduate students'? For phase two, the question can be framed in terms of statistically-testable hypotheses thus:

H_0 : $\square_1 = \square_2$ (i.e. the exercises make no difference to the CT abilities of postgraduate students)
H_a : $\square_2 > \square_1$ (i.e. the exercises improve the CT abilities of postgraduate students)

Table 2 shows that the students displayed a statistically significant increase in their critical thinking skills (t_{crit} = 1.83, t = 4.4313, $p < 0.05$). Thus the null hypothesis is rejected and the alternative accepted. This suggests that, in the absence of any other confounding factor(s), the critical thinking exercises were of direct benefit to the students. Whilst this is an encouraging result, it may not be easily generalisable due to the small sample size (ten students). The sample size may also be problematic in terms of the normality of the distribution of the scores, which is a key assumption for many parametric statistical tests. Fortunately, the t-test is remarkably robust and is not significantly affected by deviations from normality (Huntsberger and Billingsley, 1977).

	Pre-test	*Post-test*
Mean	1.1000	3.5000
Variance	1.4333	0.9444
Observations	10.0000	10.0000
Pearson Correlation	-0.2387	
Hypothesised Mean Difference	0.0000	
df	9.0000	
t Stat	-4.4313	
P(T<=t) one-tail	0.0008	
t Critical one-tail	1.8331	
P(T<=t) two-tail	0.0016	
t Critical two-tail	2.2622	

Table 2: Paired Two Sample t-Test of Masters Students.

As Cook (1999) points out, 'because of this dependence on sample size, statistically significant results cannot always be equated with meaningful results'. Therefore the 'effect size' is used as a measure of the magnitude of a treatment effect. A commonly accepted categorisation of effect size from Cohen (1988) is: small (effect size = .2), medium (effect size = .5) and large (effect size = .8).

Becker (2000) asserts that there is some debate about how to compute effect sizes when the two groups are dependent (as is the case in a pre-test/post-test scenario such as this research). Dunlop et al. (1996, cited in Becker) indicate that the original standard deviations should be used to compute the effect size in this scenario. Therefore, the appropriate formula for Cohen's *d* statistic for effect size is:

$d = (m_1 - m_2)/ \square_{pooled}$ where m_x is the relevant sample mean and $\square_{pooled} = \sqrt{(\square_1^2 + \square_2^2)/2}$

Applying this formula to the data in table 2, the effect size (*d*) is calculated to be 2.20, which would be considered to be a large effect in Cohen's taxonomy. Consequently, despite the small samples, the effect is significant and thus it can be concluded that the critical thinking exercises were of direct benefit to the students.

CONCLUSIONS AND FURTHER WORK

The results indicate that undertaking critical thinking exercises has a positive effect on the critical thinking skills of coursework Masters-level IT students. Future work will involve repeating the experiment to aid in generalising the results and cross-correlating critical thinking exercise type

preferences with student learning style. Given the large effect size, it would be expected that the experiment can be repeated successfully. It would be useful to know if the increase in critical thinking skills was related to other measures of student performance such as final examination scores. Another valuable extension would be to video-record students as they perform the exercises. This will provide a richer dataset and show the stages that students move through as they attempt to solve problems.

REFERENCES

Barnett, R. (1997). Higher Education: A Critical Business. Buckingham, UK, Open University Press.

Barnett, R. (2004). 'Learning for an Unknown Future.' Higher Education Research & Development 23(3): 247-260.

Becker, L. A. (2000). 'Effect Size (ES)', Available [WWW]: http://web.uccs.edu/lbecker/Psy590/es.htm.

Bergsjø, P. (1999). 'Qualitative and Quantitative Research: Is there a gap or only verbal disagreement'. Acta Obstet Gynecol Scand, 78, pp. 559-62.

Bowden, J. and F. Marton (1998). The University of Learning: Beyond Quality and Competence. London, Kogan Page.

Checkland, P. B. (1985). 'From Optimising to Learning: A Development of Systems Thinking for the 1990s.' Journal of the Operational Research Society 36(9): 757-767.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Cook, L. B. (1999). 'Effective uses of effect size statistics to demonstrate business value.' Quirk's Marketing Research Review. Oct.

de Bono, E. (1970). Lateral Thinking. Harmondsworth, UK, Penguin.

de Bono, E. (1968). The 5-Day Course in Thinking. Harmondsworth, UK, Penguin.

DETYA (2000). Employer satisfaction with graduate skills. Evaluations and Investigations Program report 99/7. Canberra, Higher Education Division Department of Education, Training and Youth Affairs.

Dick, B. (1998). 'Qualitative and Quantitative'. Occasional pieces in action research methodology, #15, Available [WWW]: http://www.scu.edu.au/schools/gcm/ar/arm/op015.html.

Fisher, K. (2003). 'Demystifying Critical Reflection: Defining Criteria for Assessment.' Higher Education Research & Development 22(3): 313-325.

Huitt, W. (1998). Critical thinking: An overview. Educational Psychology Interactive. Valdosta, GA: Valdosta State University. Retrieved [3rd November, 2006] from, http://chiron.valdosta.edu/whuitt/col/cogsys/critthnk.html. [Revision of paper presented at the Critical Thinking Conference sponsored by Gordon College, Barnesville, GA, March, 1993.]

Huntsberger, D.V. and Billingsley, P. (1977) Elements of Statistical Inference. Boston, MA, Allyn and Bacon.

Jick, T.D. (1979). 'Mixing Qualitative and Quantitative Methods' Administrative Science Quarterly, (24), pp. 602-11.

Kolb, D.A., Rubin, I.M., and McIntyre, J.M. (1979). Organizational Psychology: An Experiential Approach. Englewood Cliffs, New Jersey: Prentice-Hall.

Knoll, C. L. and M. Wilkins (2002). 'Critical Skills of IS Professionals: A Model for Curriculum Development.' Journal of Information Technology Education 1(3): 143-154.

Marton, F. & Booth, S. (1997). Learning and awareness. Hillsdale, N.J.: Lawrence Erlbaum Associates.

McPeck, J. E. (1990). Teaching Critical Thinking: Dialogue and Dialectic. New York, Routledge.

Mingers, J. (1997). Multi-paradigm Multimethodology. pages 1-20 of: Mingers, J. and Gill, T. (eds.), Multimethodology, Chichester, UK: John Wiley & Sons Ltd.

Moore, T. (2004). 'The Critical Thinking Debate: How General are General Thinking Skills.' Higher Education Research & Development 23(1): 3-18.

Morgan, G. and Smircich, L. (1980). 'The Case for Qualitative Research', Journal of Management Review, 5(4), pp. 491-500.

Phillips, V. and C. Bond (2004). 'Undergraduates' Experience with Critical Thinking.' Higher Education Research & Development 23(3): 277-294.

Ramsden, P. (2003). Learning to Teach in Higher Education. London, RoutledgeFalmer.

Tapper, J. (2004). 'Student Perceptions of How Critical Thinking is Embedded in a Degree Program.' Higher Education Research & Development 23(2): 200-222.

Tucker, R. W. (1996). Less than Critical Thinking. Assessment and Accountability Forum.

Van Gelder, T. (2001). How to Improve Critical Thinking using Educational Technology. Proceedings of the 18th Annual Conference of the Australasian Society for Computers in Learning in Tertiary Education (ASCILITE), Melbourne, University of Melbourne.

Weick, K. E. (1984). 'Theoretical Assumptions and Research Methodology Selection'. Pages 111-134 of: McFarlan, F.W. (ed), Proceedings of the Harvard Business School Research Colloquium Systems, Boston: Harvard Business School Press.

APPENDIX 1 Critical Thinking Questionnaire#1

1. Have you attempted any of the non-assessable logic problems? If so, which ones and did you do it or them on your own or in a group?
2. Which of the problems did you find most challenging and why?
3. Do you think these exercises are helping to develop your critical thinking skills (why/why not)?
4. How do you know that these exercises are helping to develop your critical thinking skills?
5. What was it about the problems that surprised you the most?

APPENDIX 2 Critical Thinking Questionnaire#2

1. Was there a difference between the first and second series of problems? If so, describe the difference.
2. Which of the problems in the second series did you find most challenging and why?
3. Do you have a preference for one set (of exercises) over the other? Why do you think that is so?
4. How do you know that these exercises are helping to develop your critical thinking skills?
5. What sort of test could be used to evaluate your critical thinking skills? Give an example.