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Postgraduate Students and Critical Thinking: Some Validation

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ABSTRACT

Sustainability in higher education is an interesting idea because the nature of the concept changes depending on the viewpoint of the stakeholder. For an academic, a key aspect of sustainability is about facilitating life-long learning. One way to do that is to provide students with opportunities to think for themselves and to nurture that ability.

This paper describes the second stage of a research programme whose focus was critical thinking (CT) and explores how information technology (IT) Masters-level students model problems. Results from a prior study suggested that IT students appear to improve their problem-solving ability by undertaking structured CT exercises. This study provides some validation of the first study and suggests future directions for the research programme.

Critical thinking, as taught in a university setting, is often structured as a formal logic subject. While there is nothing intrinsically wrong with teaching students logic, that does not necessarily equate to critical thinking, and also raises the question of the place of lateral 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. The solution used in this research is to apply a formal critical thinking assessment instrument in a pre/post treatment experiment, the treatment being the CT exercises.

This study evaluated the CT skills of Masters-level students. The participants were a class of coursework Masters students at an Australian university. Two tests were administered that targeted CT skills regarded as essential elements in a university education. The research design was a classic pre/post treatment experiment, with the treatment being the CT exercises. The results indicate that the students' problem-solving ability improved over time which suggests that the exercises were effective, thus validating (in part) the initial study.

INTRODUCTION

Sustainability in education is a challenging idea because the concept changes depending on the *Weltanschauung* of the stakeholder. Wals and Jickling (2002, p221) assert that the "education community is divided on how to respond to the emergence of education for sustainability" and further suggest that "it is not uncommon to find that scientific, political and symbolic meanings of sustainability are used interchangeably by one and the same person or group". This clearly makes debate about sustainability lively, if confusing. Wagner and Dobrowolski (cited in Wals and Jickling, 2002, p228) make a connection between sustainability and critical thinking and indicate that "sustainability requires a focus on competencies and higher thinking skills…appreciation of holistic principles…[and] requires critical reflection on one's own teaching". Clegg (2008) suggests that universities themselves need to use creativity and critical thinking in response to changing markets and world conditions. Natale (2006) also affirms the importance of critical thinking, especially in small-group situations, and suggests that critical thinking will improve organisational performance.

There are many definitions of critical thinking. Huitt (1998) reviews a range of existing 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 definition which will be used hereafter.

DETYA (2000) report that many employers want university graduates that are able to demonstrate and use 'critical thinking or problem-solving skills'. The conventional means for universities to embed critical thinking in students is by means of classes in symbolic or formal logic, but logic problems are not always the types of problem that are faced in the workplace. Students may also learn critical thinking by using other techniques other types of problem such as case based reasoning or lateral thinking exercises.

How 'critical thinking skills' might be taught to graduates is the subject of much debate. This research explores how to promote critical thinking in postgraduate students, using a single unit (subject) 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 details of this study it is beneficial to review research on critical thinking.

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'. Comparable to the DETYA study, Field (2001) examined the skill requirements of Australian workplaces, interviewed senior staff from thirteen large enterprises across a range of sectors and concluded that "all of the jobs considered in this research had a strong cognitive component, and interviewees confirmed the importance of thinking skills".

This is not a localised phenomenon. Duoc and Metzger (2007) found that of the variables which represent the graduate quality in business masters programmes in Vietnam, *critical analysis, problem-solving skills* (my italics) and overall quality of work are the most important indicators. Jacob et al. (2006) found that critical thinking skills were perceived as being important by Malaysian employers. 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.

Clough (2008) decries that at Georgia Tech in the USA, "applicants…often are not as proficient as they need to be at valuing or making sense of the information to which they have instant access. Too many do not have depth of understanding …and they lack skills in critical thinking". To address this issue, many universities seek to embed critical thinking as a graduate attribute in their courses.

For example, at Edith Cowan University (ECU, 2006), "graduates will be valued for their Critical appraisal skills – planning, organising, problem solving and decision making.'. Similarly, at the University of Western Australia, it was noted that "several other fundamental generic skills (e.g. thinking critically, analysing and interpreting information accurately, and solving problems collaboratively) depend on a confident command of the resources of language" (UWA, 2008).

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 wrong with teaching students formal logic, but logic is not the sole tool of the critical thinker. De Bono (1970) argues that 'lateral' thinking is related to insight, creativity and humour, and 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 (as in deductive logic). 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 contends that only the first type of problem can be solved with logic, the other types require lateral thinking.

Tucker (1996) speculates whether one can become a better critical thinker through practice, an idea obviously supported by de Bono (1970). This research also makes that same assumption, although it is by no means conclusively proven.

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. Ennis (1989, 1990) is a critical thinking generalist and suggests that "needed research includes extensive specific studies of the degree of successful application to a topic of a critical-thinking aspect developed in one or more topics, with attention to the variables that affect this degree of success".

Of the two schools of thought regarding critical thinking, McPeck (1990a, 1990b) holds the latter viewpoint 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).

Having established that employers want graduates to have critical thinking skills and that there is debate concerning the nature of critical thinking, it is constructive to examine some field research that involves undergraduates, simply because there is little research involving postgraduates (a shortcoming which this study aims to address). 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 elaborate 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.

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 primary research question to be investigated is 'Does the use of critical thinking exercises improve the critical thinking abilities of postgraduate students'? A secondary question is "Is the test instrument weighted unfairly towards students with English as a first language"? These questions can be explored quantitatively by using a form of within-subjects experiment amenable to analysis by statistical method.

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 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 a class of coursework Masters students at a large Australasian university. The students were administered two Mensa-style tests that targeted critical thinking skills regarded as essential elements in a university education. To answer the first research question, the design used was a classic pre/post treatment experiment, with the treatment being the intervening structured critical thinking exercises. The secondary question was examined by combining the final results for both phases (see below) and splitting the test scores based on whether the test element involved interpretation of a mathematical problem or an English-language problem.

THE STUDY

This study, which represents the second phase of a larger research programme, evaluated the critical thinking skills of coursework Masters-level IT students. The first phase, reported in Johnstone (2006), involved both qualitative analysis of student perceptions of the efficacy of various types of problem and quantitative analysis of the critical thinking skills of a second group of students in the same unit in the following semester.

The second phase (this study) involved quantitative analysis of the critical thinking skills of another group of students in the same unit in a subsequent semester. These students were given two tests, the first test being administered prior to the students beginning the suite of critical thinking exercises and the second at the conclusion of the suite.

In both studies, 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. Also, in both studies more students took the second test than the first, but these data were excluded (initially) as both pre-test and post-test data elements were required for the statistical analysis.

ANALYSIS OF FINDINGS

The suite of CT exercises comprised a set of logic-based exercises and a second set of lateral thinking exercises, the latter being drawn from de Bono (1968). The logic exercises varied from classic logic problems (for example, the Man, Goat, Wolf and Cabbage problem) that could be modelled or simulated in various ways through to "thought-only" problems that could only be solved with mathematics. The students attempted the logic problems first (over the first half of semester) and then embarked on the lateral thinking problems in the second half of the semester. The students exhibited a general preference for the lateral thinking exercises, probably because they are quite tactile in nature.

Recall that the primary 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:

$H_0 : \mu_1 = \mu_2$ (i.e. the exercises make no difference to the CT abilities of postgraduate students)
$H_a : \mu_2 > \mu_1$ (i.e. the exercises improve the CT abilities of postgraduate students)

Table 1 shows that the students displayed a statistically significant increase in their critical thinking skills ($t_{crit} = 1.86$, $t = 3.11$, $p < 0.05$). 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.

	Pre-test	*Post-test*
Mean	2.222222222	4
Variance	1.944444444	1.5
Observations	9	9
Pearson Correlation	0.146385011	
Hypothesized Mean Difference	0	
df	8	
t Stat	-3.10811476	
P(T<=t) one-tail	0.007243377	
t Critical one-tail	1.859548033	
P(T<=t) two-tail	0.014486754	
t Critical two-tail	2.306004133	

Table 1: Paired Two Sample t-Test of Masters Students.

This is an encouraging result and acts to provide some validation of the results obtained in the first phase (Johnstone, 2006). This result may not be easily generalisable due to the small sample size (nine students). One solution is to consider the data as independent samples and assume unequal variances. This would allow the non-pair data previously excluded to be considered as part of the analysis. This second analysis was done, the result being effectively no different than the paired test ($t_{crit} = 1.75$, $t = 2.99$, $p < 0.05$), which also acts to provide some assurance that the results are valid.

A further issue that must be considered is the expected magnitude of the treatment effect, or put another way, what is the resolving power of the statistical test? Cook (1999) states that 'because of this dependence on sample size, statistically significant results cannot always be equated with meaningful results'. Therefore 'effect size' is used as a measure of the magnitude of a treatment effect. Cohen (1988) provides a simple, but commonly accepted taxonomy of effect size thus: 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:

$d = (m_1 - m_2)/\sigma_{pooled}$ where m_x is the relevant sample mean and $\sigma_{pooled} = \sqrt{(\sigma_1^2 + \sigma_2^2)/2}$

Applying this formula to the data in table 1, the effect size (*d*) is calculated to be 1.35, 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.

The secondary research question is 'Is the test instrument weighted unfairly towards students who have English as a first language"? The question arose from the researcher observing that, for the classes involved, approximately 80% of the students came from a non-English speaking background or from an English as a second language background. This, in itself, is not a problem, but it was also noted that the CT tests predominately contained two types of question, one type relating to mathematics and the other consisting of some manipulation of English language symbols. An example of the latter is: "Find a six letter word made up of only the following four letters G, M, N, O". This research sought to explore this issue by examining the post-test scores of both phase one and

phase two students combined (thus increasing the sample size). The scores for each student were split by the type of question in the post-test (i.e. mathematics or English).

The secondary research question can also be framed in terms of statistically-testable hypotheses thus:

$H_0 : \mu_1 = \mu_2$ (i.e. the type of test question used makes no difference to the CT scores of postgraduate students)

$H_a : \mu_1 \neq \mu_2$ (i.e. the type of test question used affects the CT scores of postgraduate students-either positively or negatively)

Table 2 shows that the students did not exhibit a statistically significant difference when their mathematics and English CT questions are compared ($t_{crit} = 2.03$, $t = 0.57$, $p > 0.05$). Thus the null hypothesis is accepted therefore the type of test question used does not affect the CT scores of postgraduate students, at least in the sample group. Again, calculating Cohens's *d* statistic gives a value of 0.19, thus if there is an effect that was not detected by the test, the sample size would need to be increased markedly to have any chance of detecting such a small effect.

	Maths score	*English score*
Mean	1.947368421	1.789473684
Variance	0.719298246	0.730994152
Observations	19	19
Hypothesized Mean Difference	0	
df	36	
t Stat	0.571500572	
P(T<=t) one-tail	0.285605777	
t Critical one-tail	1.688297694	
P(T<=t) two-tail	0.571211554	
t Critical two-tail	2.028093987	
Mean	1.947368421	1.789473684

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

CONCLUSIONS AND FURTHER WORK

The results validate earlier work and indicate that undertaking critical thinking exercises has a positive effect on the critical thinking skills of coursework Masters-level IT students. Further, there is some evidence to suggest that the type of test CT question does not matter (with respect to students English language proficiency). Future work will involve cross-correlating critical thinking exercise type preferences with student learning style and also collecting other forms of data (e.g. video records of students solving the exercises which would show the stages that students move through as they attempt to solve problems). It would also be useful to know if the increase in critical thinking skills was related to other measures of student performance such as final examination scores.

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