FINDING THOUGHT: AN INVESTIGATION INTO THE DEVELOPMENT OF CRITICAL THINKING SKILLS IN INDUSTRIAL DESIGN

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Abstract

In higher education today, it is imperative to equip students with the skills required by their future profession. One such skill, as required of a professional Industrial Designer, is the ability to find creative and suitable solutions to often complex problems. As decision making and problem solving are key elements of a professional industrial designer's practice, they should be developed and encouraged as part of the tertiary programme. The trend towards learner driven investigation and research, as well as interactive mixed methodologies, have facilitated many projects requiring thinking skills. But does the learning environment support and develop these skills?

Noticing a change in the students coming from the school environment, an investigation began into critical thinking skills. Understanding and evaluating information is the essence of critical thinking. The Think tank project began in 2010, with selected students completing the Ennis-Weir Critical thinking test, a means of measuring thinking skills. Given the surprising results, it was necessary to examine the studio-based learning environment; problem based learning, as well as the processes and critiques in design education. The attributes of the Generation Y students were also contributing factors to the results. The type of test used also needed to be considered in the multilingual South African environment, with many students having English as a second or third language.

The Think tank project thus needed to consider different types of thinking (including Design Thinking), in order to fairly assess whether the learning environment is conducive to the development of critical thinking skills. This paper is a detailed case study of the pilot project, run during July 2011, with second year Industrial Design students at the Cape Peninsula University of Technology. The findings of the case study are described here, as well as recommendations for future study and curriculum changes.
Key Words*:* critical thinking, industrial design, curriculum, design education

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Introduction

"Design is the central factor of innovative humanisation of technologies and the crucial factor of cultural and economic exchange", as described by the International Council of Societies of Industrial Design[1] (ICSID, 2008). The industrial designer gives shape to the idea or object or system that would form part of / the whole solution to a defined problem. The aim of the Industrial Design programme, at the Cape Peninsula University of Technology (CPUT), is to help develop the appropriate skills for students to function well as professional industrial designers. This means that they need to be able to (among other things) follow the design process of analysis, problem solving, evaluation and reflection; and communicate using verbal / visual skills. Therefore, they need the thinking skills to make appropriate and informed decisions, in relevant contexts. The aims of the Think tank project are to discover whether the students *can* think critically – as this is clearly a requirement for the profession, and whether the Industrial Design learning environment at CPUT is conducive to the development of

[1] A more complete description would be describing design as follows: "…a creative activity whose aim is to establish the multi-faceted qualities of objects, processes, services and their systems in whole life cycles. Therefore, design is the central factor of innovative humanisation of technologies and the crucial factor of cultural and economic exchange" (ICSID 2008).

critical thinking skills. Using this information can lead to recommendations to improve the critical thinking ability of Industrial Design graduates.

In 2010, the Ennis-Weir Critical Thinking test was completed by a group of students to evaluate their ability to think critically. The surprising results of this test necessitated the consideration of the characteristics of Generation Y students, different modes of thinking, as well as the existing curriculum. The next phase of the Think tank project was the pilot project in July 2011, which was run with second year CPUT Industrial Design students, and was focussed on public transport in Cape Town. It was designed to challenge the students to explore and analyse situations, as well as to evaluate and refine their solutions. In order to evaluate their ability to think critically, a focus group within the second year student group completed the Cornell Critical Thinking Test (level Z). The results of both these tests are discussed in this paper, in relation to the learning environment.

Generation Y students

Staff in the Industrial Design Department began to notice that students struggled to match relevant information with the assigned problem / project, and that students appeared to need more guidance in making design decisions, indicating an inability to evaluate the situation and make decisions based on that analysis. After many informal discussions about the students' perceived increasing need for affirmation and assistance, we conducted a survey with industrial design staff[2]. The results are detailed in Figure 1 below. These characteristics in the survey were aligned with the research that describes the characteristics of "Generation Y" (Gen Y) students.

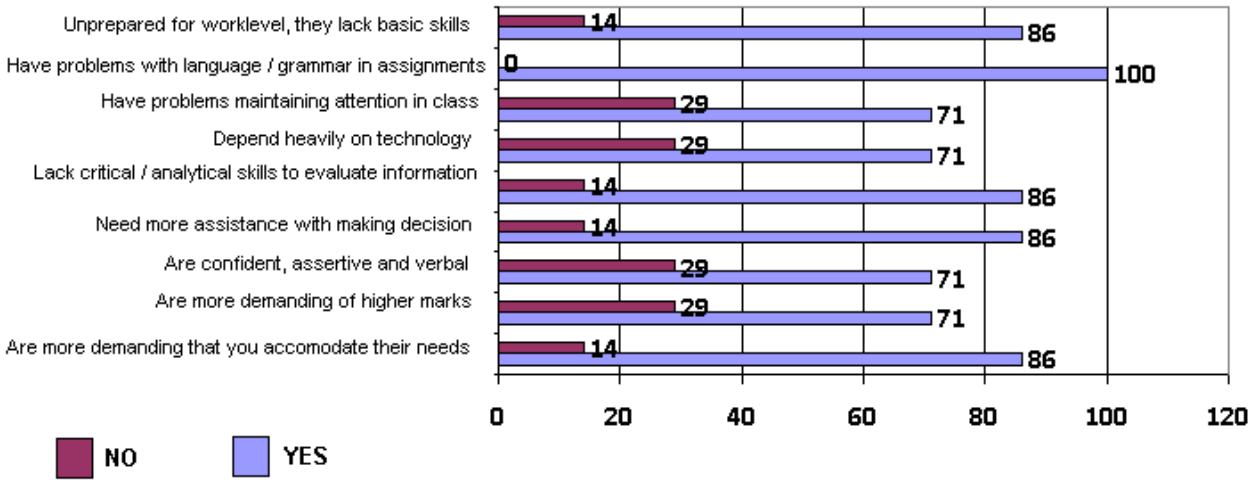

Figure 1. Current student characteristics, observed by staff. (Barnes & Du Preez 2011)

Generation Y students have grown up in a different world to that of Generation X. The differences between the generations are highlighted in Table 1 below. Broadly speaking, it is accepted that Gen Y students, also known as "the Millennial Generation" and "the Net Generation, Digital Natives, Echo Boomers, and Nexters", were born between 1977 and 1982 (Bracey, Bevill and Roach 2010:21). These students have been in environments with visual digital media all their lives, and this contributes to their need for instant gratification and preference for visuals rather than text (Black 2010:95). In the South African education context, these students are also the earliest products of an outcomes-based school education.

Black (2010:98) asserts that the "sheer volume of visual, auditory, and verbal information in today's world is forcing digital natives to edit, sift and filter more". In fact, it is this additional volume of information that contributes to what CIBER (cited in Black 2010:98) describes as the Gen Y's heavy reliance on computer technology. Students "view rather than read, and lack many critical or analytical skills needed to evaluate the information they find" (CIBER cited in Black 2010:98). Weiler in his

[2] Seven, of a possible nine, fulltime lecturing staff completed the survey. The most inexperienced lecturer has been teaching for 5 years, the most experienced, for 21 years.

article, “Information-Seeking Behaviour in Generation Y Students: Motivation, Critical Thinking, and Learning Theory”, describes these technologically-reliant students:

> The students currently on college campuses, as well as those due to arrive in the next few years, have grown up in front of electronic screens: televisions, movies, video games, computer monitors. It has been said that student critical thinking and other cognitive skills (as well as their physical well-being) are suffering because of the large proportion of time spent in sedentary pastimes, passively absorbing words and images, rather than in reading (Weiler 2005:46).

Some of the notable characteristics of Gen Y students are their “intuitive understanding of digital language” (Black 2010:95), excellent multitasking abilities and how easily they are bored (Bracey *et al.* 2010:22). Black suggests that these factors contribute to “students’ shorter attention spans and lack of in depth learning” (2010:98). Additionally, or perhaps consequently, they seem to need a considerable amount of personal attention. To staff, they appear to need more assistance and guidance, and thus less capable. In stark contrast, they see themselves as far more capable. Using results from *The American Freshman: National Norms for Fall 1999,* Soule (2001:3) describes Gen Y students as having “record levels of self-confidence” as they entered the tertiary institutions in America. While 60% of all students rated themselves as “above average” or “top 10%”, Soule suggests that this stems, not from academic knowledge levels, but rather from grade inflation. Emeagwali (2011:24) confirms that many Gen Y students believe they have what is required to succeed in tertiary education, discover that this is not true, and are “shocked by that realization”. Masie (2004 cited in Black 2010:92) goes as far as to describe the Gen Y students as “the “everyone gets a trophy” (or an “A”) generation”.

Generation X Students in 1969	Generation Y Students in 2009
General learning orientation	Vocational / career orientation
Family / self-financed	Government / family / self financed
Academically prepared	Lacking basic skills
Competitive	Collaborative
Worked, studied alone	Group work, team work
Lack of experience with diversity	Acceptance of diversity, tolerant
Unsure of self	Assertive and confident
Low debt after college	High debt and defaults on loans after college
Friendships bound by proximity	Friendships not bound by geography
Took responsibility for self	Growth of ‘helicopter’ parents who assume responsibility for college-age children
Acceptance of institutional structure	More demanding with customer expectations of immediate service
A privilege to attend college	An expectation to attend college; entitlement
Family stability	Family instability
Mentally healthy	Less mentally healthy
Dependent upon note-taking; paper and pencil	Dependent upon technology; “digital natives”

Table 1. Differences between Generations X and Y. (Amended from *Characteristics of Students*. Black, 2010:94)

Weiler (2005) warns that the Gen Y students that are already part of tertiary landscape demonstrate different “information seeking behaviors”.

> Critical thinking is a process that is widely acknowledged in the literature to be crucial to the learning process, to cognitive development, and to effective information seeking. Evaluation and effective use of information in any form is impossible without the use of critical thinking, and so the level and quality of critical thinking are of primary concern when speaking of information seeking behaviors in Generation Y students. (Weiler 2005:46)

This warning is given weight by observations in the History of Art and Design Department at CPUT (Barnes and Du Preez 2010) over the last two years. Examples include students asking questions that are answered in the written brief. They have a copy of the brief, but seem unable to read it effectively / absorb the contents / or they feel insecure about *their* understanding of the brief. In a different example, students are unable to see how information found relates to the assignment topic. This is despite the student having reviewed the information, which was presented in clear language. Still further students are unable to create a hierarchy of ideas in an argument, relying on repetition or summarising.

What is critical thinking?

Schafersman (1991:3) describes critical thinking as “higher order thinking”, and also as “reasonable, responsible, and skillful thinking, that is focused on deciding what to believe or do”. Understanding and evaluating information are the key features of critical thinking. Attributes of critical thinkers described by Nickerson (1987, cited by Schafersman 1991:4) include:

- “Uses evidence skillfully and impartially
- organizes thoughts and articulates them concisely and coherently
- distinguishes between logically valid and invalid references
- attempts to anticipate probable consequences of alternative actions
- applies problem solving techniques in domains other than those in which learned.”

Richard Paul even stated: "critical thinking is the art of thinking about your thinking while you are thinking in order to make your thinking better..." (Paul 1993:643), emphasising the importance of analysis and evaluation.

Why is critical thinking important to the design process and design thinking?

One of the key factors in design is the ability to analyse a situation and make appropriate decisions, within predetermined boundaries. In traditional universities professional disciplines like law, business and medicine are taught mostly in large group lecturing style. Design is different in that practical subjects are taught in a studio environment. The shared space in a studio encourages a sharing of ideas and a focus on exploration, reflection and peer engagement. It is the learning environment which best reflects the way in which design professionals work: “Like other types of pedagogies, design studio pedagogy conveys, conserves, and transmits the values of design professions and society at large” (Salama & Wilkinson 2007:3).

This studio teaching environment combined with a student focused teaching method, which mimics the design process itself, can be described as a continuous process of creative investigation, evaluation, reflection and adaption. This process, together with its theoretical underpinning is referred to as design thinking. Design thinking is aligned to critical thinking as explored by Ford and Profetto-McGarth (1994) who explained critical thinking, within the context of curriculum, as praxis. In their model, praxis is a relationship between action and reflection which goes beyond just investigating a problem situation to include knowledge systems, critical reflection and associated action: “knowledge and action are dialectically related through the mediation of critical reflection” (Ford & Profetti-McGrath 1994:342).

Design thinking has become a prominent method of investigation and review in many professions outside design. One reason for the extensive use of the method is that design thinking allows for intense situational analysis, combined with creative solution exploration[3]. Design thinking is a method of approaching problematic situations, then analysing that situation and establishing / suggesting actions to create a more beneficial scenario. It differs from other thinking methods in that it represents a range of creative components which are often overlooked in scientific thinking and other methods of inquiry (Owen 2007:16). The Industrial Design Department’s design process can broadly be broken up into three main sections: *1) Context, Calculation & Creative Exploration, 2) Selection & Production 3) Reflection, Adaption and Reflection.*

The first phase (*Context, Calculation & Creative Exploration*) covers identifying a design problem[4] or need and is followed by a thorough examination of the topic. Following this investigation, a design brief is written[5]. The second phase, *Selection and Production*, includes selecting an appropriate

[3] Warren Berger explores the concept of Design Thinking as a new way for varying industries to approach problems and find solutions in his 2009 book *Glimmer: How Design Can Change Your Life, and Maybe Even the World*, Penguin Press [http://glimmersite.com/]

[4] A design ‘problem’ is not necessarily an actual physical predicament. It could be how to improve an object or how to make an environment more accessible.

[5] The design brief is a detailed document between the designer and the client, outlining all the information relating to a design project. It outlines what is required of the design and the project timeframe. It may also include additional information such as material restriction, technology specification, intermediary deadlines, budgetary information etc. After both parties have agreed to the details outlined in the brief, the designer will find

design solution and producing the design. This stage in the design process depends on a student's ability to critically review the situation and extract the necessary information to proceed to the next stage of the design process, or decide that more exploration is required. Donald Schön (1987) refers to this process as *reflection-in-action,* because learners are reflecting on what they are doing as part of the learning process and making appropriate adjustments.

The final phase of the design process is *Reflection, Adaption and Reflection*. Reflection as part of the design process (*reflection-in-action*) is a natural process during which designers continuously review what they are doing. This process relies on a student's ability to think critically and make appropriate decisions. Once a design is finalised, *reflection-on-action* is encouraged*,* evaluating the entire process (Schön 1987). This reflection, leads to two situations: in the first the designer is satisfied with the solution and presents it to the client, in the second the designer evaluates the process and outcome and determines that the solution does not answer the original brief. The result of the second scenario is a return to the first phase of the design process, exploring possible solutions to the design flaw. This scenario links to McPeck's (1981) view of critical thinking as key to professions which require analytical and problem solving skills. In each of the design process stages, the learner must evaluate, critically, new knowledge and design choices – making critical thought a key skill for design[6].

Initial testing and findings

Industrial Design students at CPUT are required to make informed decisions throughout the design process and then express their solutions in three dimensional products. Although the process is supported and facilitated by lecturer consultation and feedback, students are expected to develop an understanding of the design process and required decision making skills whilst working on design projects. The importance of critical thinking in the design process is clearly linked to a student's ability to critically identify suitable solutions, and then make an informed decision regarding which solution is most appropriate. To establish whether Industrial design students were struggling with critical thinking, a group of students completed two established critical thinking tests. The first test was run during 2010 with first year students, to establish the basic level of critical thinking within the focus group. The selected test was the Ennis-Weir Critical Thinking Test, designed by Robert H. Ennis and Eric Weir (1985). In the following year students from the same group, now at second year level, completed the *Cornell Critical Thinking Test Level Z as part of an analytical workshop.*

Ennis-Weir Testing Focus Area	Design Activities and Processes	Cornell Critical Thinking Test Level Z
• "Getting the point".	Understanding the design 'problem' and what is being asked of the designer.	Identification of assumptions Semantics
• "Seeing the reasons and assumptions".	Analysing the reason for the design activity and identifying project constraints and details. Developing design brief.	Identification of assumptions
• "Stating one's point"	Analysing the design brief and formulating appropriate proposed solutions. Evaluating all proposed solutions to identify the most suitable design solution for the context and other criteria. Being able to visually and verbally communicate these proposals, and the reasoning for final selections, to clients and fellow designers.	Induction
• "Offering good reasons".		Deduction
• "Seeing other possibilities (including other possible explanations)"		Definition
• "Responding to and avoiding equivocation, irrelevance, circularity, and reversal of an if-then relationship, overgeneralization, credibility problems, and the use of emotive language to persuade".		Prediction in Planning Experiments

as many feasible solutions to the design problem. The design solutions should always adhere to the specifications detailed in the brief and thus the designer must have a critical understanding of the project parameters.

[6] Critical thinking is only one of the ways of thinking required during the design process. The focus of this project is critical thinking skills and not skills relating to other ways of thinking, such as creative thinking.

Table 2: Focal Criteria and Cognitive Elements of the Ennis-Weir Critical Thinking test, the Cornell Critical Thinking Test Level Z and the Design Process (Barnes & Du Preez 2011*)*

The Ennis-Weir test is aimed at learners from secondary school level to tertiary level. The test is formulated within an essay structure and requires the respondent to write an appropriate response based on a mock letter. Although the design process is not based in a written format, which is used as the medium in the majority of critical thinking tests, the link between cognitive skills tested are similar (see Table 2, overleaf). The essay response is evaluated against a framework. The test has a number of focus areas, including (Ennis 1985): "getting the point"; seeing the reasons and assumptions; stating one's point; offering good reasons; seeing other possibilities (including other possible explanations) and responding to and avoiding equivocation, irrelevance, circularity, reversal of an if-then (or other conditional) relationship, over generalisation, credibility problems, and the use of emotive language to persuade. To evaluate the basic skill of thinking critically, nine diverse (gender, culture and home language) Industrial Design students were selected to take the Ennis-Weir test[7].
The average score of the first year test group of Industrial Design students at CPUT was 9.6, out of a possible top score of 29. The variability of the result, measured as a standard deviation, is 4.9. The relatively low standard deviation means that the score of each individual respondent was not far from the average of the group (the mean) and supports the validity of the findings. The average of the 2010 CPUT findings, when compared to those of a Midwestern University (USA) study documented in 1993, is quite low. The Midwestern University's Ennis-Weir study resulted in an average score of 14.6 (Ennis 2005). Although the average score is significantly higher than that of the Industrial Design students at CPUT, the standard deviation is also higher, at 6.1 (Ennis 2005). The higher standard deviation implies that the individual scores, achieved at the Midwestern University, were more varied. Results of a 2000 / 2001 study completed at a community college in Florida (USA) also reported a higher group average than CPUT's students – the undergraduate test group had a mean of 11.91 with a standard deviation of 8.61 (Reed & Kromrey 2001).

Group	N	Mean	SD
198 undergraduates in an educational psychology course at a large Midwestern university: given a number of tests to see the relationship between critical thinking and certain academic and personality variables (Taube, 1993).	187	14.6	6.1
9 undergraduate students from the Industrial Design course at CPUT: given the test to document their skill level of critical analysis and thought, as well as formulation of structured arguments based on given information.	9	9.6	4.9

Notes: "SD" means standard deviation. "N" means number of students. (Ennis, 2005)

Table 3. Ennis-Weir User Norms for Students without Claimed Prior Critical Thinking Instruction Compared to Industrial Design Students at CPUT (Ennis, 2005)

The link to critical thinking and design, as documented in this article, highlights critical thinking as one of the modes of thinking required of a successful designer. While the original test group of first year Industrial Design students was small (9 students), the relatively low scores were surprising enough to fuel further investigation into students' thinking skills, rather than draw conclusions. To further investigate the situation, a research workshop was initiated with the same group of Industrial Design students during 2011. A larger test group and digitally managed test, the Cornell Critical Thinking Test Level Z[8], offered more defined findings regarding the level of critical thinking among students.

Public Transport Project: Critical Inquiry

[7] As the evaluations of the responses are completed by people, there is a risk of subjective or irregular assessment. To address this, the Cornell Critical Thinking Test (Level Z) will be used to review results and produce new data. The Cornell Test, designed by Robert Ennis and Jason Millman, is completed electronically, therefore eliminating the risk of subjective assessment. The test comprises multiple choice sections aimed at testing various aspects of critical thought

[8] Level Z is aimed at advanced and gifted high school students, college students, graduate students, and other adults.

During July 2011 a workshop entitled Public Transport Project: Critical Inquiry (PTPCI)[9] was run with the same group of students who took the Ennis-Weir test (as part of a larger test group). The week long workshop was constructed around activities, teaching and learning practices and assessments that had key critical thinking elements embedded, as documented in Table 4. During the workshop, the concept of critical thinking[10] was introduced to ensure all students understood the concept, as well as the important role critical thinking plays in design. Journal reflections were part of the project, to limit the impact of language issues. Students were free to express themselves using imagery, as opposed to just text.

Cornell critical thinking testing and results

During the PTPCI workshop, 28 second year Industrial Design students completed the Cornell Critical Thinking Level Z test. All students also completed a reflective questionnaire based on the workshop. The reflective questionnaires indicated that 86% of students considered themselves critical thinkers. The Cornell Critical Thinking Test consists of 52 multi-choice items, each with three choices and one correct answer. Students were given 60[11] minutes to complete the test. As with the Ennis-Weir test there are clear connections between the cognitive processes relating to the Cornell Critical Thinking Test and the design process (Table 2).

The test is scored in one of two ways: the first refers only to the right answers or *total right* (TR); the second refers to the formula *rights minus one-half the number wrong* (R-W/2) (Ennis, Millman and Tomko 2004). Frisby (1992) investigated the difference between the two methods of scoring and found that only scores from students with lesser abilities reflected a noticeable variable. The results from the Industrial Design group were compared to two sets of existing data sets: the first reflects the standard deviation in comparison to international examples (Table 5) and the second compares findings to national findings (Table 6).

	Community College, Canada (Money, 1997).	**Northwestern State University, USA (Krank, 2003).**	**Cape Peninsula University of Technology**
Year Level	Undergraduate	Undergraduate	Undergraduate
N	181	230	**28**
Mean	21.9	25.1	**24.9**
S.D.	5.7	5.3	**4.8**

*Scores used were "Right Only" - scores for CPUT also reflected as "Right Only"

Table 5: Total Right (TR) Results in Comparison to International Data (Barnes & Du Preez 2011*)*

When the focus group test scores are compared to those of other undergraduate students at international institutions, a clear alignment can be noted. The results are presented in a 'right only' format which does yield a higher result. However, as all three institutions used the same method, the results are comparable. The focus group scored an average correct answer score of 24.9 (out of a total of 52) which translated to an average score of 47%. In comparison, students from an American and Canadian institution, respectively scored 25.1 and 21.9. The standard deviation of the test groups' score was 4.8, which is 0.5 lower than the closest score of 5.3. While the results from the focus group are in line with those from America, it is important to note that since the1970's and 1980's, American (and international) authors have questioned the lack of thinking skills in the American educational system.

The comparison between the focus group's results and those from a 2004 study from the College of Education in Gauteng proved to be quite different (Table 6). The focus group scored an average

[9] The workshop was run with 40 second year Industrial Design students, and forms part of a larger practical project which aims to investigate possible solutions to travel between the commuter's home, the public transport route, and the end of the route to their workplace.

[10] The introduction to critical thinking was a 45 minute lecture / discussion based session to all participating students, even though 55% of students indicated that they understood or had previously used the method of thinking.

[11] The Cornell Critical Thinking Test Level Z is intended as a 50 minute exercise.

percentage of 22.73%, well below the 34.72% achieved by the Gauteng group. Both studies reflect the diverse education environment of South Africa. Both tests used the Cornell Critical Thinking Test Level Z, and both were scored using the (R-W/2) scoring method.

	College of Education, Gauteng (Lombard & Grosser, 2004)		**Cape Peninsula University of Technology**	
Level	**88 First Year Student (Undergraduate)**		**28 Second Year Students (Undergraduates)**	
Frequency distribution of Scores for the Cornell Critical Thinking Test	0 to 4	0	0 to 4	5
	5 to 9	3	5 to 9	4
	10 to 14	16	10 to 14	8
	15 to19	36	15 to19	7
	20 to 24	26	20 to 24	2
	25 to 29	7	25 to 29	2
	30 to 34	0	30 to 34	0
	35 to 39	0	35 to 39	0
	40 to 44	0	40 to 44	0
	45+	0	45+	0
Raw Test Scores and Average Percentages of Respondents	**Possible Test Total**	**4576**	**Possible Test Total**	**1456**
	Group Test Total	**1589**	**Group Test Total**	**331**
	Average Percentage	**34.72%**	**Average Percentage**	**22.73%**

Table 6: R-W/2 Results in Comparison to National Data (Barnes & Du Preez 2011)

The low results were surprising, as the current Industrial Design curriculum does include elements which support the development of critical thinking. In theoretical subjects, at second year level, students are required to complete academic essays, reports and critical reviews, and reflective practice is encouraged. In practical subjects, the design lecturers highlight the importance of research, analysis, evaluation and decision making, and reflective practice is encouraged. The low results in the Cornell Critical Thinking test supported the original findings of the Ennis-Weir test - that students were struggling to think critically. A study of a controlled group of American community college students by T. Solon (2003) offered insight which may help explain the situation (Table 7).

In Solon's (2003) study the control group was split into three groups:

- A group taking a course in critical thinking: with 40 hours of class room instruction and almost 80 hours of homework about critical thinking
- a group of introductory psychology students: with critical thinking elements built into the curriculum, with no definitely critical thinking training
- a group of rhetoric students: with no critical thinking elements in the course.

All students completed the Cornell Critical Thinking Test Level Z at the beginning and end of the testing. The results indicate that with explicit intervention, such as the course completed by the Critical Thinking students, students' scores improved by 6.56%. The psychology students' scores also improved, but only by 3.25%, while the Rhetoric students dropped by 0.96%. Solon noted that without clear structure and explicit coursework, student's critical thinking skills are less likely to improve, "The critical thinking course intervention had more impact than the infusion approach." (Solon 2003:33). This scenario may explain the low scores of Industrial Design students – even though the development of critical thought is embedded in the curriculum and teaching and learning practices, it may not be offered in a manner which is suitably explicit and defined.

Test Group 1	**Test Group 2**	**Test Group 3**
Critical Thinking Course	Introductory Psychology	Rhetoric

Time spent developing Critical Thinking skills	40+ hours class time (intervention) 80 hours homework		10 hours class time (infusion) 20 hours homework		None	
Pre-test Results (Cornell CT test Level Z)	Mean	23.76	Mean	23.63	Mean	24.23
	SD	4.51	SD	5.17	SD	5.19
Post-test Results (Cornell CT test Level Z)	Mean	30.32	Mean	26.88	Mean	23.27
	SD	3.67	SD	4.24	SD	5.51

Table 7: Solon's Pre & Post Test with the Cornell Critical Thinking Test level Z (Barnes & Du Preez 2011*)*

Conclusion

The results of the Think tank project have yielded several surprises in terms of test results. What is clear is that any critical thinking skills developed at school level do not reflect in undergraduate scores. The students appear to demonstrate characteristics of their generation, Y. Among these are difficulty in analysing and evaluating information, and also their inflated belief in their own ability. The discrepancy is highlighted here, in that students believe that they *are* critical thinkers, but the scores contradict this. Therefore, although the Industrial Design Department at CPUT plans projects that require critical thinking, analysis and evaluation skills, these are embedded, and not clearly defined. The research suggests that embedded critical thinking challenges in projects are not sufficient (Solon, 2003). Direct and defined coursework may be required for the improvement and development of skills in the students at second year level. To see any real improvement in the critical thinking skills of the students, a specific critical thinking course would need to be included in their curriculum. This is a theory that would warrant further investigation and possible testing. It would also be useful to test students at a different level of study, for example third or fourth year students, in order to compare data. This may reveal critical thinking skills that have developed over an additional year, through working with projects embedded with critical thinking requirements.

Another area that warrants further investigation is the *nature* of the critical thinking tests. While the limitations of language in the South African context have been discussed, it is important to consider the nature of test. It is unclear whether the use of existing tests is *appropriate* to assess the industrial design students' skills. The Cornell Critical thinking test was used in the pilot project, in the absence of more suitable tests. An ideal solution would be to investigate the development of a new non-written test. Further investigation into non-written thinking tests is therefore recommended. A further controversial proposal would be to use existing design project briefs as a form of assessing the embedded critical thinking challenges, and in this instance the scoring of the tests would need to be thoroughly interrogated.

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