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A Course in Technological Innovation for First Year Engineering students: Methodology and Outcomes.

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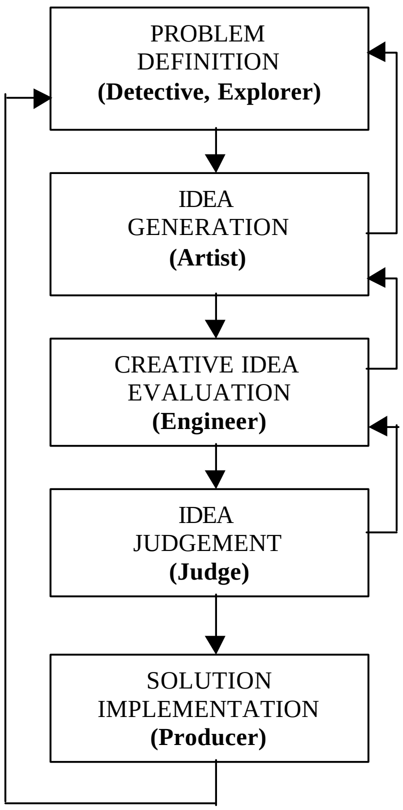
Abstract

The current paper presents the motivation, methodology and results of an experiment in Engineering Education aimed at stimulating creativity and innovation in first year engineering students in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria over the period 1998 to 2000. The experiment was conducted by means of a new course called *Technological Innovation*. The motivation for the teaching model used in the course is founded on research done earlier in the same department on the determinants of creative design in Electronic Engineering students[1,2]. The earlier research demonstrated the correlation between the students' own perception of their extrovertiveness and their ability to come up with innovative product ideas. The methodology used in the first year course which is the topic of this paper focused on group projects, the use of the Nedd Herrmann four quadrant brain model and the various mindsets of the creative problem solving heuristic of Lumsdaine[3]. The course guided the students through the identification and development of a technological product which addresses a real-world problem within given limitations of topic, time and cost. Examples are presented of the course content, the assignments, and the outcomes of this course. Outcomes include both the innovative technological products that students developed and statistics on the change in their perception of their own creativity as derived from surveys done at the beginning and end of the course. The systematic approach to problem solving presented in this course together with the development and delivery of a demonstrable product as the key outcome resulted in a significant increase in the self-perception of the creativity of the students who have taken this course.

1. Introduction

The objective of this study was to determine the effectiveness of a particular learning model to improve students' self-perception of their creative problem solving ability, henceforth referred to as self-perception of creativity (SPOC). The definition of problem solving models and their relationship to effectiveness in design has been the focus of recent research on engineering education[4,5]. The learning model for the first year course *Technological Innovation* is based on research on creative behaviour in Engineering students [1,2]. In Hattingh[1] the determinants of creative design in Electronic Engineering students was investigated in a sample of 165 third year Electronic Engineering students using 88 variables to measure personality, cognitive abilities, task orientation, environmental factors and different indices of creativity. The correlation of these variables with "quality in design", as inferred from the student's performance on a realistic Electronic Engineering design task, was determined using exploratory statistical data analysis techniques. "Quality in design" was related to the options, algorithms and implementation that reflect highly creative ideas that stand a good chance of working well. Self perception of extrovertiveness emerged as the best predictor for creativity and "quality of design". This observation provided the motivation to determine the improvement in the students' self-perception of their creativity (SPOC) through their experience in a first year problem solving course presented by the author and to find the correlation of their SPOC with their performance on the practical part of the course.

2. *Technological Innovation:* the course



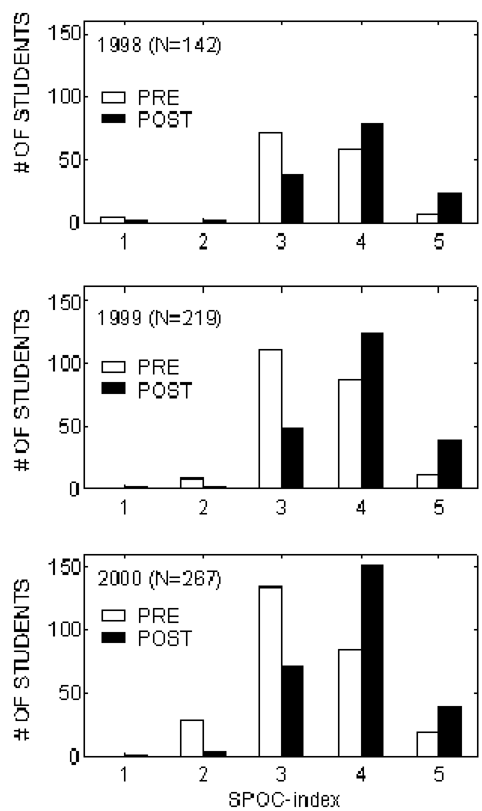


Figure 1 Creative problem solving steps and mindsets[3] **Figure 2 Increase in self-perception of creativity, SPOC**

The students who participated in the experiment were all enrolled for the compulsory first year, first semester course called *Technological Innovation*. This course was introduced in the Department of Electrical, Electronic and Computer Engineering in 1998 and has been presented by the author since then. The aim of the course is to give first year students practical exposure to design and innovation in a first year programme otherwise loaded with basic sciences. The course fulfils part of the "complimentary studies" requirements with respect to the development of communications skills. It is hoped that this course would improve the motivation and retention of engineering students. The focus of the course is creative problem solving and thinking skills rather than discipline specific technical design. The textbook for the course is *Creative Problem Solving: Thinking Skill for a Changing world*, by Edward and Monika Lumsdaine[3]. The title and content of the textbook is an embodiment of the theme of the course, i.e. to help the students discover their own creativity through an understanding of whole brain thinking and through training in problem solving based on a sequence of mindsets required to effectively address practical problems. Figure 1 presents a flow diagram of the creative problem solving process together with the mindsets associated with each of the steps. The course consists of one 50 minute lecture and one 90 min practicum per week. One of the early homework assignments for the course is a self-evaluation of the students' thinking preferences or brain dominance according to the Ned Herrmann four quadrant brain model for cognitive preferences. For the practical part of the course comprising the development of an innovative product, the students work in teams of three. This addressed other cross-disciplinary outcomes namely "team working" and "cooperative learning". The students are encouraged to consider brain dominance diversity in the selection of the members of their teams but such diversity is not enforced. The team size of three is an implementation of the recommendation of Richard Felder in his course on cooperative learning. The assignment for the semester project is stated as follows:

"Students must work in teams of three to develop, document, present and demonstrate a technological innovation which comprises one of the following: An educational device or toy for a child under the age of 7 or a rehabilitation or convenience aid for an aged or physically handicapped person.

Students may use any resources available. The prototype of the product must be constructed by the students themselves. It may not be an existing commercially available product, although it might be a similar, but clearly improved version of the existing product. The cost of the components, construction, and packaging of the prototype will be paid by the members of the team and may not exceed R150 ($21). The prototype of the product will remain the property of the team. A three minute presentation of which each group member will present one minute is required during the demonstration of the product at the end of the semester".

This course is linked to the course Introduction to *Information Technology*, which is offered in the same semester and attended by the same students who worked in the same teams they formed for *Technological Innovation*. The semester project for *Information Technology* includes the development of a Website to market the fictitious company formed by the team and the product which they develop for the project in *Technological Innovation*.

3. Lecturer philosophy

The underlying philosophy of the lecturer which dictates the approach to teaching and the relationship between the lecturer and students is explicitly expressed by the proverb: *"You can create, because you have been created with Designer genes"* (Author anonymous). The implication of this philosophy is that the students are equipped with the creativity they need to generate ideas and transform them into reality as part of their Creator's purpose for their existence. This philosophy is shared with the students on the first day of class and often referred to afterwards.

4. Research methodology

4.1 Self-perception of creativity survey.

The students are requested to voluntarily respond to the question "*How creative do you think you are ?* " by indicating their self-perception on a scale of 1 (not creative at all) to 5 (very creative). The question is posed on their course registration during the first class and during a course feedback survey at the end of the course. Their response to this question at these two occasions is here referred to as the pre-semester and post-semester SPOC-index respectively.

Only students who completed both the pre- and post-semester surveys are included in the statistical analysis for this paper. The pre- and post-semester SPOC-indices are statistically compared and correlated with the marks they achieved for the semester project.

4.2 Brain dominance assessment

The thinking preference profile of each student is determined as a homework assignment early in the course using the Ned Herrmann work turn-on indicator map. This assignment is given soon after the concept of four quadrant whole brain thinking from Lumsdaine[3] has been discussed with the students.

The Ned Herrmann work turn-on indicator map is not as accurate as the complete HBDI survey (Applied Creative Services, NC, USA), but is used as a qualitative indicator of brain dominance in lieu of the complete HBDI survey, which is expensive and time-consuming to administer.

4.3 Project evaluation

The marks for the project are allocated for the aspects given in Table 1. Several faculty members participate in the grading of the oral presentations and product demonstrations by the students. All the reports are graded by one faculty member.

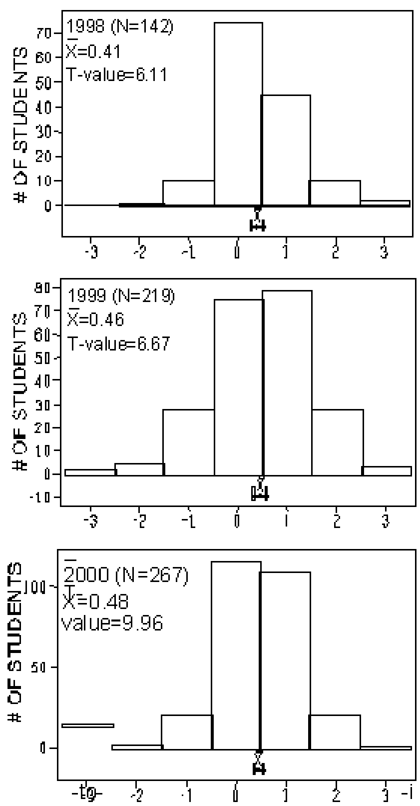
Table 1: Project evaluation criteria

Aspect	% of total
Oral presentation/demonstration of product.	16 %
Product evaluation based on presentation/demonstration: (criteria: functionality, completion).	16 %
Report: (criteria: structure & format, clarity, language, overall impression).	34 %
Product evaluation based on report: (criteria: problem definition, design alternatives, design optimization, implementation, functionality/user acceptance, novelty).	34%

5. Results

5.1 Self-perception of creativity (SPOC)

The distribution of the pre-semester and post-semester self-perception of the students' creativity over the past three years is shown in Figure 2. This indicates that the most frequent pre-semester SPOC-index was 3, while the most frequent post-semester SPOC-index was 4. There was a definite increase towards higher creativity in the post-semester SPOC-index. The pre-and post-semester distribution and the change in SPOC of the students was about the same for the three consecutive years that the course was offered despite a yearly increase in the student numbers. The results of a paired t-test on the pre- to post-semester increase in the SPOC- index are shown in Figure 3 as histograms together with the 95% t-confidence intervals for the mean increase of each year group. The trend and the mean value of the increase are very similar for the three years. A zero change had the highest frequency in each year group. In each year group the SPOC-index averaged over all students. Students who took the course showed a statistically significant increase, although only about 40% of the students indicated a higher post-semester than pre-semester SPOC-index. There was a slight increase in the mean value of the SPOC-index increase over the three years. A small fraction of the students (1998:11%, 1999:34%, 2000:8%) indicated a lower post-semester than pre-semester SPOC-index. The reason for this decrease was not investigated, but it may be that these students had an inflated perception of their creativity which was brought down to reality through their efforts during the course or they may have been disillusioned about their own creativity in comparison to that of the other members of their team.



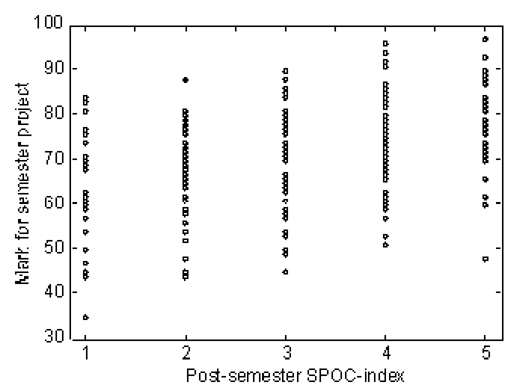


Figure 3 Paired t-test on pre to post semester increase in SPOC index

Figure 4 Correlation of project marks and post-semester SPOC-index

5.2 Correlation of SPOC with performance.

Figure 4 presents a scatter diagram to show the correlation between the post-semester SPOC-index and the performance on the practical part of the course. From the general trend of the diagram one could qualitatively infer that a higher SPOC-index was to some extent related to the student's ability to create meaningful products. The wide spread of marks for each SPOC-index is partly due to the fact that the presentation and the report contributed about half of the project mark, and the actual product the remainder.

5.3 Brain dominance profiles per class, per group.

The average brain dominance profile of the 239 students who completed the brain dominance survey in 2000 is shown in Figure 5. This demonstrates the preference for analytical quadrant A thinking which is typical of Engineers and Engineering students worldwide.

Of the 62 teams of three, 52% had at least two brain dominances represented among its members and 11% of the teams had three different brain dominances represented. The teams with the larger diversity of brain dominances tended to perform better on the design project than the teams with no brain dominance diversity.

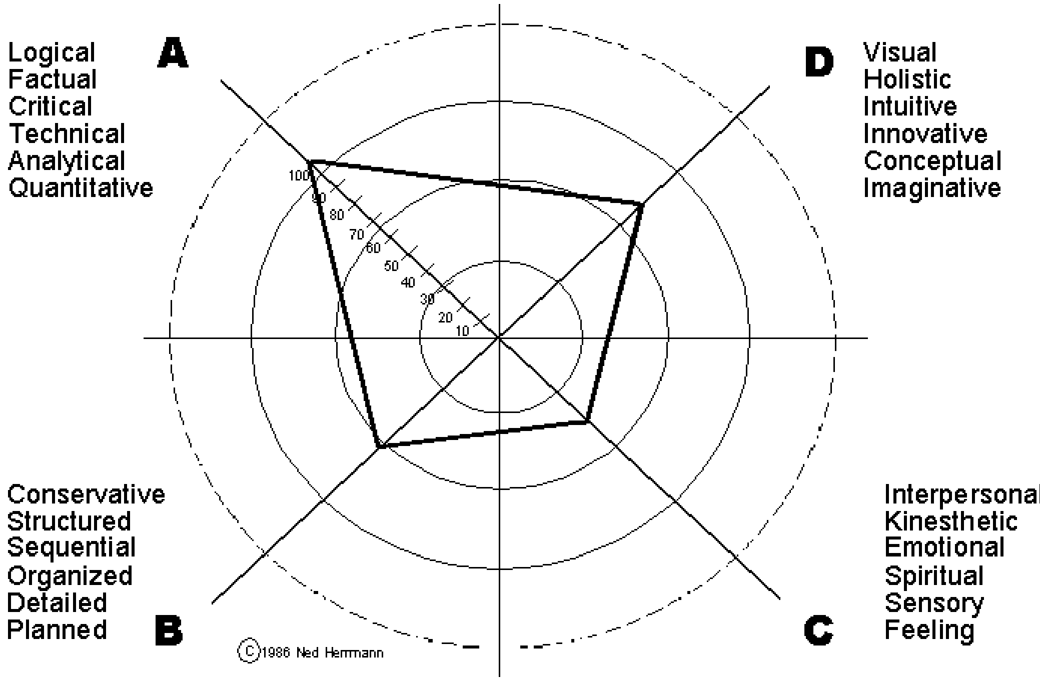


Figure 5 Averaged Herrmann brain dominance profile for students who took *Technological Innovation* in 2000

5.4 Examples of student projects

Table 2 lists some examples of the products developed by the students who took the course *Technological Innovation* in 1999 and 2000.

Table 2: Some of the products developed by students who took *Technological Innovation* in 1999 and 2000

Product name	Category and Description
Vibro Alarm	Aid for the handicapped: A wrist watch for the deaf which vibrates when the alarm goes off.
Rotachair	Aid for handicapped and elderly: The rotachair makes it easier to get a physically handicapped person in and out of a car seat. It consists of a rotating baseplate with an innovative stop to which the regular car seat is attached.
0 & X	Educational toy: 3D (3x3x3) noughts and crosses game
Easypaste	Aid for the handicapped: Spring operated wedge to squeeze a measured amount of toothpaste from a tube; for people with problem hands.
Servikale Onder-steuningseenheid ("Cervical support unit")	Aid for the handicapped: Cervical support unit for spastic quadriplegic children without cervical control. For use in a wheelchair to support head. Head support fully rotatable. Won the DM Kisch Prize for Technological Innovation (free patenting).
Geraamte in die kas ("Skeleton in the closet")	Aid for the handicapped: Adjustable mechanism for wheelchair bound persons which provides ability to lower and raise rail from which clothing is hung in a closet.
EasySort	Aid for the handicapped: Device which sorts coins in a purse
Easy Plug	Aid for the elderly: Device to easily and safely remove wall plug from socket by pushing in a button to activate a lever.
Going-up	Aid for the handicapped: Device which prevents a wheelchairs from rolling backwards in steep situations. Consists of a sprocket on the axle with a lever to disengage the brake arm.
E-bus	Aid for the elderly: Infrared link from mailbox to house to notify residents of mail delivery
Pluck Plug	Aid for the elderly: Insulating strap for any standard South African 15A mains plug to facililate removal.
Button Buddy	Aid for the handicapped: A mechanism to fasten a button with the use of only one hand
TIME-o-PHARM	Aid for the elderly: Reliable solution to remind an old or critical patient to take their proper medication at the prescribed time
EeZee-lift	Aid for the handicapped: A mechanical device to make it easy to lift, carry and empty heavy and/or hot pots, cookware or similar objects with the use of one hand.
The Tap Tool	Aid for the handicapped: A lever designed to firmly attach to any standard sized water faucet to allow a handicapped person to open and close it with minimal force.

6. Conclusion

The systematic approach to problem solving presented in the course *Technological Innovation* and the development and delivery of a demonstrable product as the key outcome resulted in a significant increase in the self-perception of the creativity of the students who have taken this course. The first year pass rate has not markedly improved since the course was introduced. Several other factors such as the changing demographics of the student population and the admission requirements may play a more important role in their pass rate. Hopefully the self-confidence gained through their experience in *Technological Innovation* will improve their performance in other engineering design courses. The first group of students who took this course are now in their third year and their performance on the third year course, Design and Manufacturing will be correlated with the SPOC-index they indicated at the end of their first year. The Lumsdaine textbook[3] has proven to be very useful and well liked by the students. It has been adopted for use in a course called Innovation which is to be taught as of 2001 to all students in the School of Engineering at the University of Pretoria.

7. Acknowledgements

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