INCULCATING A CULTURE OF INNOVATION AMONGST ENGINEERING STUDENTS

D.C. Kallis [1], W.L.O. Fritz [2]

Abstract- *Engineering, by its very nature, is a highly creative discipline. The working engineer is constantly called upon to solve a variety of problems, and while many of the solutions are based on existing technologies and processes, the design constraints are often such that an alternative and novel solution emerges. The products of innovative engineering design are to be found all around; some in the public eye such as major civil engineering projects, whilst others are hidden below layers of superficial wrapping, such as the MEMS devices within a game console interface. The creation of innovative solutions, for many, involves a conscious shift in the type and level of thinking about the problem and is not necessarily a function of intelligence. This paper discusses the methods employed to raise the level of innovative thinking amongst students within an Electrical Engineering programme and the outcomes of such interventions.*

I. INTRODUCTION

Most engineering programmes include a final module comprising a major project or design intended to encapsulate the students' acquired skill set into a working project intended to solve a given problem. The implementation of the final design project varies across institutions; in many cases the selected projects feed into existing post-graduate research activities while in some the choice of the project is left to the student. Invariably, the final project is expected to have a certain degree of novelty that one would attribute to the student. In line with our national curriculum, the Department of Electrical Engineering (Bellville) at the CPUT has offered the module Design Project III, a compulsory offering of the National Diploma in Electrical Engineering. The module is one semester in duration and comes at the end of the 2-year theoretical unit of the programme. The module has been running for over 16 years in its current form and has seen a number of iterations in project type and choice over this period, in an attempt at keeping the course relevant and exciting. In addition to written submissions that document the entire design process, from proposal to user-manual, the student is required to demonstrate the final device and deliver a formal presentation.

II. THE PROJECT SELECTION PROCESS

At first, students were required to identify and select an appropriate project in line with the stated requirements of the subject. As an aid in the selection process, we identified broad application categories, such as poverty alleviation, renewable energy, science awareness/education and remedial engineering in an attempt to steer the student towards solving real-life community issues, given the harsh realities in our country. Using classic brainstorming techniques such as De Bono's Six Thinking Hats [1], students were tasked with generating at least 6 viable project ideas that could fit into the afore-mentioned categories. The final project would then be selected through a one-on-one consultation with the course leader. Despite initial student enthusiasm, the generated projects were usually of a low standard, lacking original input and innovation. Out of a class size of about 60 per semester, we would have, on average, about 3 that could be classified as being truly innovative and worthy of being developed into viable products. The majority would simply consult popular magazines and/or the internet for sources of inspiration, invariably copying the bulk of the design.

The current project selection process is based on typical real-life problems, as supplied by various 'clients'. These projects are divided according to the programme streams offered by the institution; viz. general electronics, instrumentation and control, power engineering and communication electronics. This real-life, project-based approach has many advantages;

- It phrases the problem statement as one would expect in the real-world,
- It opens the possibility for many solutions,
- The student is forced to shift their thinking preferences from one of analytic to the more imaginative and innovative,
- Plagiarism is reduced since the problem statements are generally unique,
- It fosters collaboration between industry and the institution, and,
- Depending on the success of the final prototype, the student can possibly develop the artifact into a commercial product.

Two examples of typical client problems are outlined below.

"*The client is responsible for the maintenance and repair of roadside emergency telephones. These are fixed-line systems that use the Telkom infrastructure. When repairing these modules, the client is required to make a telephone call to the call-centre in order to verify the correct operation of the module under test. In order to cut costs, the client requires a*

[1] *D.C. Kallis, Department of Electrical Engineering, Cape Peninsula University of Technology (CPUT), South Africa, kallisd@cput.ac.za*
[2] *W.L.O. Fritz, Department of Electrical Engineering, Cape Peninsula University of Technology (CPUT), South Africa, fritzw@cput.ac.za r*

telephone line simulator that will enable him to verify the correct operation of the module under test without him having to make the physical call."

"The client runs an adventure centre in a remote and pristine natural location. She needs to determine wind speed and direction using a non-obtrusive device and has insisted that no mechanical (moving) parts be used. The data from the device must be capable of being downloaded to a PC (preferably wirelessly) and must be time-averaged over 1 hour at 1 sample per minute."

As always, the students are introduced to common brainstorming and idea creation techniques in order for them to come up with original and innovative work, but the results are usually the same – about 5% of the designs are worth pursuing as original commercial entities.

III. STUDENT THINKING PREFERENCES

As part of the brainstorming sessions, students are introduced to the brain dominance model of Ned Herrmann [2], where an individual's thinking is categorized according to 4 modes; Analytical, Sequential, Interpersonal and Imaginative. According to this model, an individual will have a preference for thinking in one of the afore-mentioned modes. Using a shortened questionnaire based on the Herrmann Brain Dominance Instrument (HBDI) to identify the strongest thinking mode amongst students, figures 1 to 4 graphically illustrate the measured responses of a group of first-year engineering students. The axes are labeled according to the preferred thinking mode, with A – Analytical, B – Sequential, C – Interpersonal and D – Imaginative. The survey on the electrical engineering cohort (fig. 1) was done during a scheduled class and involved the entire semester group. The dominance of the analytical thinking mode is expected within an engineering group, but the fact that the imaginative mode ranked lowest is concerning.

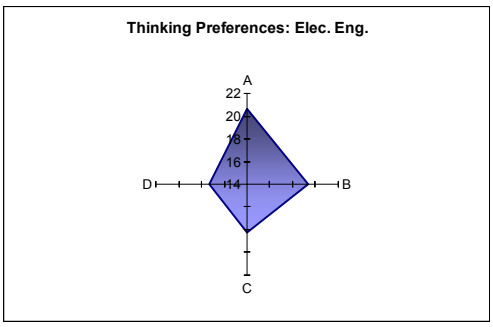

Figure 1: Radar plot of thinking preferences of first-year Electrical Engineering students.

The responses in figures 2 to 4 were participants in an innovation workshop held within the Faculty of Engineering.

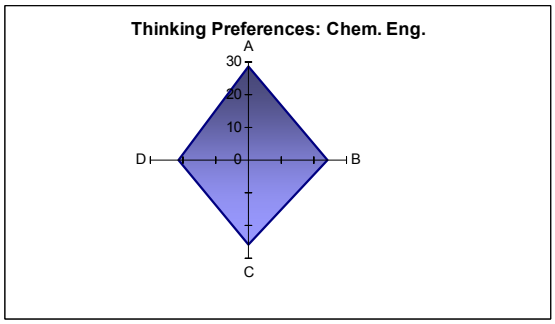

Figure 2: Radar plot of thinking preferences of first-year Chemical Engineering participants – Innovation Workshop.

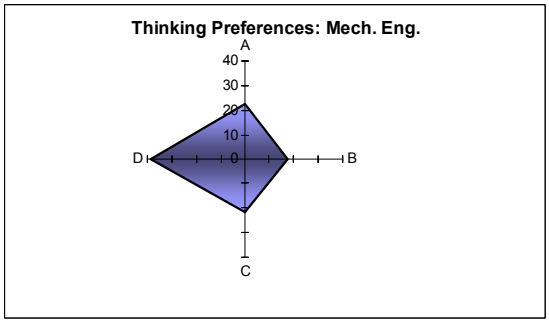

Figure 3: Radar plot of thinking preferences of first-year Mechanical Engineering participants – Innovation Workshop.

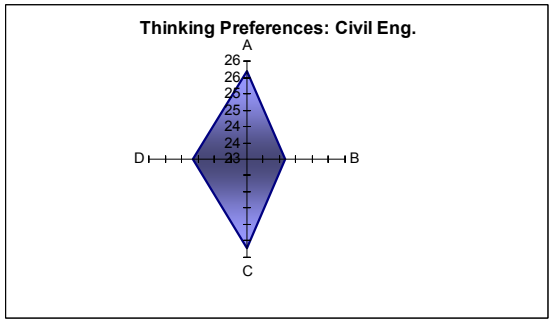

Figure 4: Radar plot of thinking preferences of first-year Civil Engineering participants – Innovation Workshop.

A quick survey amongst 53 final-year EE Design students using the classic "paperclip creativity test" yielded an average usage for the clip at 6, with a maximum of 13. These responses, together with student consultations and the quality of project outputs, highlights the lack of innovation amongst electrical engineering students in our faculty. To shift thinking styles to include that of the imaginative involves a barrage of interventions that involve changes to the entire curriculum and the institutional environment. Fortunately, these can be implemented at minimal cost and disruption to the programme.

IV. INNOVATION INTERVENTIONS

It is unreasonable to expect radical shifts in innovative outputs amongst students through the implementation of appropriate interventions. In many cases, small nudges in the right direction is sometimes enough to get the creative processes working.

Over the years a number of interventions have been identified and used with varying degrees of success. A few of these are discussed below

A. Creating an Innovation Environment

Identify *technology innovation champions* amongst staff and students. These individuals serve as key contacts for both student and industry consultations. They do not necessarily get involved with all project-related queries, but they ensure that the prospective client speaks to the right persons and that the department becomes known as a technological access point.

In some institutions, students are taught in a studio environment similar to situations where the apprentice is under the watchful eye of the master. [3]

Identify and *promote technologically-related competitions* amongst students and staff. A number of national and internal technology competitions are promoted within the department and staff avail themselves as mentors for participating groups. These competitions are usually introduced to our students by way of posters and institutional workshops.

Promote technology through initiatives such as museums, simulation software, past projects and posters. Students must be immersed in the relevant technology, and although we are primarily in the business of electrical engineering, we cannot ignore the influence of all the sciences. Our corridors are adorned with posters highlighting the history and accomplishments of the basic and applied sciences.

B. Identify and nurture innovative students

It's relatively easy to pick out the creative innovators in the first-year cohort. They might not be the high scorers, but their class questions and responses often point to a different mode of thinking. While the rest of the class will find any excuse to avoid a practical assignment, these individuals will often request their own work space for conducting experiments. They do not require any external push to get involved with extra-curricula activities and will enter most competitions as a matter of course. Preferring to work on their own, we encourage them to work with individuals that have complementary skills to their own. These students become excellent role-models for their peers, not only as subject content tutors, but as design consultants amongst fellow students.

C. Identify challenging, real-life and exciting projects. Make all subjects project-based

Many students choose electrical engineering because they grew up dismantling old radios and other electronic equipment in an attempt to find out how they work. When they enter higher education, they are bombarded with so much theory that they loose sight of their original and noble intentions and the learning process becomes one of simply getting through the next assessment. In addition to the project-based final year subject discussed earlier, all subjects / modules should be able to be linked to a working artifact. Now while this might take some time in getting acceptance within our department, it is argued that any subject within our current curriculum can be made to be project-based, so that at the end of a typical semester module, the successful student will leave with a working artifact that best represents the outputs of that module.

D. Encourage the "limited toolbox" approach for project solutions.

When confronted with a problem statement, the majority of students tend to simply throw all their taught skills at the problem. As an example, for an adaptive microphone project that involved position control, many first round solutions involved devices and components that they had used before, but had no part in this design. 555-timers were all over the show. Again, when confronted with the requirement for attenuating an audio signal in another project, many went hunting for voltage-controlled amplifiers, only to discover that these were not stock items amongst local suppliers and that the lead times were beyond the deadlines.

This necessitated having to systematically go through the initial design process, isolating the key specifications and generating a possible system in block diagram form. Possible technologies were then identified to provide the functionality of the various blocks. Students were then on their way once they realized that these functionalities could easily be realized through a number of different technologies.

E. Use Reverse Engineering to Get Ahead.

Although it is encouraging to see original approaches to the problem sets, it is sometimes advantageous to use existing solutions, particularly when deadlines are tight. In many cases an existing idea might require extensive modification to comply with new specifications. The message to students is always one of acknowledgement, and although we do not cover patent and other legal aspects in the course, these issues will come to the fore if the artifact has commercial potential.

F. Use Games

Constructive, object-driven game playing can be used to break-down the mental barriers in many of us. Nothing can be more rewarding than interacting with your peers in a collective attempt at solving some nonsensical and fictitious problem, particularly after a heavy theoretical class.

Many computer strategy games are good at reinforcing the design processes typical of an engineering project. An example of one such game is "The Incredible Machine" and its sequels [4]. The game play involves the use of limited "gadgets" to solve ever increasingly complex problems. The bulk of the gadgets are mechanical in nature (levers, pulleys, inclines, motors) and the bulk of the problems have only one solution. To solve the problem, the player has to work out a clear strategy within the given constraints. The player knows what the end result should be, and needs to carefully manipulate the gadgets to realize this objective. The game play closely mimics many real-life problem solving scenarios and the first-time student player often presents similar difficulties in the game as he would when confronted with a real-life project problem.

G. Use Groups Wisely

Ranking low on interpersonal thinking, engineers tend to shun group work, not realizing that these are skills that are required and valued in the workplace. Class groups tend to be constituted randomly, conveniently divided according to a class list or seating arrangements. Given the variance in thinking preferences amongst students, it would be advantageous to constitute groups according to individual strengths. Having a group of predominantly imaginative thinkers will probably generate lots of ideas and end just there. Taking the ideas to the next level involves combinations of analytical and sequential thinking processes. Groups constituted along complementary thinking skills, as determined through an HBDI or similar instrument should provide a better dynamic that for overall success.

V. CONCLUSION

Accepting the notion that all engineers are staid in their approach to project design is a grave disservice to this noble profession. The interventions discussed above play but a small role in attempting to bring out the best in the individual student. It seems at times a wasted effort, but now and again we are rewarded through a commercially viable project, or a competition winning project, or simply an acknowledgment from the student for the learning experience attained whilst working on the project.

REFERENCES

[1] E. de Bono, *Mind Power*. Great Britain: Dorling Kindersley, 1985.

[2] N. Herrmann, *The Creative Brain*. The Ned Herrmann Group, 1989.

[3] P. Weilerstein, F. Ruiz and M. Gorman, "The NCIIA: Turning Students into Inventors and Entrepreneurs," *IEEE Antennas and Propagation Magazine, vol.45, No. 6, pp 130 –134, December 2003.*

[4] *The Incredible Machine.* [CD-ROM]. Sierra Entertainment, 1992.