Controlling Technology: Engineering Education is not a Virtual Reality Game.

George J Gibbon
University of the Witwatersrand, Johannesburg.
g.gibbon@ee.wits.ac.za

***Abstract* – Controlling the role of technology, during course presentation, is as important as it is for academics to reset themselves at the start of each academic year. If this is not done that gap between the students' ability and presented material will continuously widen. As the students entering university come from an ever increasing "virtual reality" background the introduction of virtual reality in both the laboratories and classrooms widens the gap between the real world of engineering and the students' perceptions of what they are learning. Practical, hands-on laboratories are discussed as part of an engineering curriculum designed to expose students to real engineering problems and, at the same time, develop their imagination, visualisation and exploration skills.**

Key Words- Engineering education, computer modelling, virtual reality, engineering laboratories.

INTRODUCTION

Resetting yourself at the start of each academic year is one of the more difficult tasks for a lecturer presenting the same course year after year. If this is not done you will find you are now presenting "the most difficult course" in the degree programme.

The same is true with the advancement of technology, both in the subject being presented and in the "teaching aids" available. Most lecturers are still amazed by the ability to take a complex system, such as an electric motor, and simulate the system with a computer model. Of course these models and "video" outputs are totally meaningless to students with no idea what a real motor looks, sounds or smells like. To them it is just "another" computer game with no connection to reality.

The problem of technology advancement is especially true in engineering disciplines such as information and/or computer engineering. It is too easy to loose sight of the objectives (outcomes) of a course and drop the engineering basics, while in pursuit of the latest technology.

Advanced, computer based, teaching aids have now been introduced into the classroom. Controls, in the hands of each student, allow the lecturer to get "real time" feedback from the students during a lecture, allowing for instant adjustment of the presentation. Is this not just another computer game?

The dangers of having "too much" virtual reality, for students with a virtual reality background, in an engineering curriculum as well as changes, in the first and final years of study, to introduce students to the "real world" are discussed in this paper.

COMPUTER SIMULATION

A scan through recent publications of International Network for Engineering Education and Research (iNEER) [1, 2] and the International Conference on Engineering Education (ICEEE) conference proceedings [3] revealed numerous examples of computer simulation and virtual reality projects to aid in the teaching of engineering students. Some examples are the simulated construction of a wall [4], remote physics experiments [5] and simulated control experiments [6].

In the Control I course, presented by the School of Electrical and Information Engineering at the University of the Witwatersrand, real control experiments, such as the TECQUIP's coupled electric drive system shown in Figure 1, have been replaced with a MATLAB based computer simulation of the system. Students are no longer experiencing the real life problems of broken belts, vibrating motors and resonance problems and are only concerned with getting the "mathematics" to work on a computer.

FIGURE 1
A "REAL" CONTROL EXPERIMENT

The move to computer simulation is not only driven by the lecturer's fascination of computer modelling of real life problems and the perception that more advanced experimentation can be undertaken, but also by available financial resources to develop and maintain large laboratories. New equipment is expensive and maintenance personnel even more so.

The extent of this problem was reported on by a colleague [7] after visiting three universities in Australia in 2006. His interest is mainly in the area of power engineering, power electronics and machines, all requiring the existence and maintenance of capital intensive laboratories. Most of the groups working in these areas have suffered with reduced government funding as the research was "out of fashion" and the money going to areas such as information and computer technology (ICT), biotechnology and other "fashionable" areas.

Electrical Engineering at the University of Sydney have effectively closed the machines laboratory and mechanical workshop and are only using small (desk-top) machine sets for undergraduate teaching. The Sydney Technical University still has excellent machines laboratory facilities, but this is only because of the strong ties the university has with industry in China through their research programmes.

TECHNOLOGY BASED TEACHING AIDS

Technology is also being introduced into course presentation to aid both the lecturers and students. Again a scan of iNEER [1, 2], ICEEE conference proceedings [3] and other conferences and journals reveal a number of papers covering this subject. These innovations cover a wide field including interactive learning tools including the Open Learning System (OLS) and WebCT [8, 9], automated frequently asked questions (FAQ) [10], an "interactive" text book [11] and tutorial software [12] to name a few.

Controls, in the hands of each student, have also been introduced into the classroom [13, 14] to allow the lecturer to get "real time" feedback from the students during a lecture, allowing for instant adjustment of the presentation.

An example of this "virtual reality" creep in teaching was found in our first year Engineering Design course. Six years ago it was decided to drop the Engineering Drawing course for first year electrical engineering students and include a section on graphic communications into the Engineering Design course. The task was to research the requirements for technical drawings and then disassemble an electrical product such as a disk drive, multi-meter or compact disk (CD) player and draw, pencil and ruler, all the required projections to enable the product to be re-assembled by another student.

Over the years a few of the students "mastered" the use of drawing packages and as these "looked" better than the hand drawn versions students were encouraged to use a drawing package, not supplied by the university, disadvantaging the students without the resources. This year the requirement was that all the submission, text and graphics, should be in electronic format. This ruled out any hand-drawn drawings.

The whole point of the graphics component of the course has now been lost to technology. Students are no longer required to research and learn about technical drawing as a communication tool and a way to explain their product, as they are desperately trying to learn some sort of drawing package before the hand-in date. It is not possible to draw a meaningful technical drawing using the Microsoft Word drawing tool!!

INTERNATIONAL AID

Having attended the 3rd African Regional Conference on Engineering Education in September 2006 it was clear that international aid for Universities in developing countries concentrates almost exclusively on "high level" technology such as computer laboratories, information infrastructure and software [15]. Most of the "donations" are one time only and do not include maintenance personal or the resources to upgrade.

Funding seems to be readily available for contract research but as this is generally encumbered and therefore not available for the development of undergraduate laboratory facilities.

THE STUDENTS

The present generation of students entering the first year of the engineering programme at the University of the Witwatersrand have either been brought up on virtual reality or come from rural or impoverished backgrounds.

A brief walk around a toy shop will show that most of the toys require nothing more than a push of a button to get entertainment. You can even build LEGO on your computer [16]! Twenty years ago when a parent said "my child must do engineering as all they do is play on the computer", it was an indication of an aptitude towards problem solving and an interest in technology. Today the same comment means that the child plays virtual reality games and probably only has fast reflex reactions.

Problem solving is a requirement for engineers [17] and to be a successful problem solver you need to visualise and have an imagination [18]. Students from this virtual reality background are struggling in our first year with both the visualisation of the basic sciences and circuit theory and have no imagination when finding solutions to unseen problems.

Lack of visualisation is also the main problem experienced by students from rural or impoverished backgrounds. They have no experience of the technologies we use as examples, having only learnt the facts needed to pass the secondary school exams. Having not been exposed to the virtual reality of their peers they do appear to have a better functioning imagination. This is probably due to the different skills required to build and push a car made from scrap fencing wire to the skills required to use a joystick to drive a radio-controlled model car or race in a computer game.

ENGINEERING EDUCATION

Curriculum development, especially in the early years of the degree course, needs to address the lack of imagination and visualisation apparent in our students. It is very easy for lecturers to get engrossed in technology and technological developments.

It really is fascinating to see models of real life components such as motors, complex electronic circuits and electrical reticulation systems on the computer and be able to change inputs and observe the results. However it only makes sense if the viewer can visualise what is happening and imagine the real-life disaster when things go wrong. These models are more appropriate at the postgraduate level, where the fundamental understanding is already in place.

Colleagues introducing computer based laboratory experiments to replace the real-life experiments argue that it easier for the students to visualise the mathematics when they can easily see the results of changes to the inputs or the algorithm. Of course the mathematics is also useless if not related to real applications. The real-life experiment together with a computer simulation would be the first prize, if time and funds were available.

The use of small universal motors in the laboratory does not prepare students for the large three-phase asynchronous motors some will experience in their first job in industry.

I. In the Laboratory

Laboratories, especially in the early years, must introduce the students to the basic components and allow them to experiment, on their own, with the components to develop their imagination and exploration skills. This will enable them to visualise the real components when they use the mathematical based computer models later in the degree programme.

Not all laboratories have been replaced with virtual reality. Extended essays, practical exercises and tutorials have been combined in a programme to develop team work at the University of Sierra Leone [19] and the use of functional modules for the teaching of hands-on skills at the University of South Carolina [20] to name two examples.

At the School of Electrical and Information Engineering, University of the Witwatersrand the first year Electric Circuits course introduces students to three circuits at component level. Both circuits are built on a bread-board by each student, no group work here.

The one circuit is an audio amplifier, complete with microphone and speaker, and the students have to demonstrate the output on an oscilloscope with a signal of their choice applied to the microphone [18]. They have to learn how to use the oscilloscope to demonstrate their amplifier and also how to use a signal generator and multi-meter during the construction and testing phases.

The second circuit, introduced in 2007, is shown in Figure 2. The Electric Circuits course is presented around this circuit with the first lectures introducing the symbols used, what they represent and ideal operational amplifier (Op Amp) circuits. In the lectures each amplifier section is then reduced to a two-port element and the whole "complex" circuit solved using all the standard electric circuit models such as sources (ideal, real, independent, dependent), passive components and techniques such as nodal analysis. The real advantage is that the students can actually build the circuit, each section separately, and test whether the models and analysis techniques are valid. They are also introduced to experimental errors and real components that do not necessarily obey all the "rules". The students are also encouraged to experiment with other component values to see "what will happen". There is also an incorrect component value in the circuit that introduces the student to the concept of "clipping" and Op Amp power supply values.

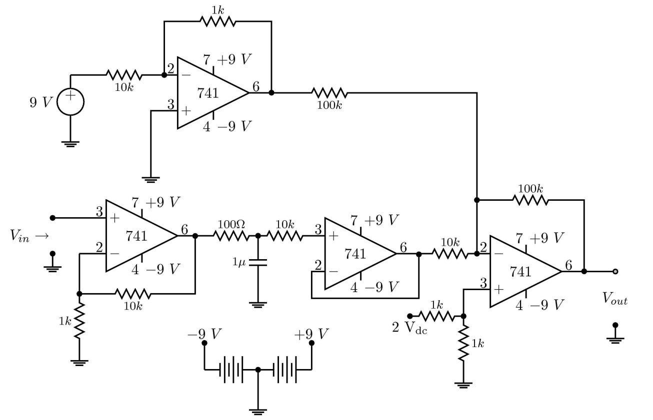

FIGURE 2
OPERATIONAL AMPLIFIER CIRCUIT

A third circuit, shown in Figure 3, involves resonance. Nothing brings the concept of resonance into reality as measuring 120 Volts across the capacitor or inductor with only 9 Volts applied to the circuit.

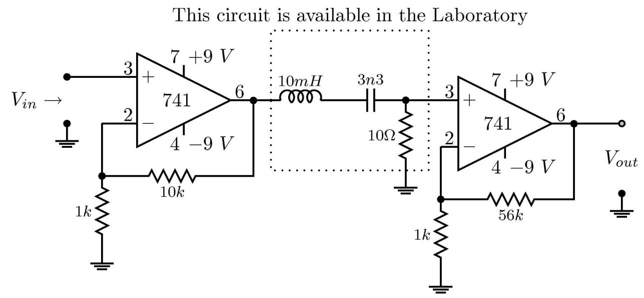

FIGURE 3
RESONANT OPERATIONAL AMPLIFIER CIRCUIT

The major advantage of combining the practical aspects of the course with the presentation of the theory is that the students can relate to the actual components, having burnt their fingers on hot integrated circuits and exploding capacitors, learning at the same time the importance of polarity and current conventions.

Traditionally students undertaking the two practical laboratories in the final year Measurements Systems course have had to submit a pre-laboratory report, undertake the experiments and then submit a final report with their results and analysis. The mark for the laboratory was dependent on the students report writing skills and very little emphasise was placed on the student's actual experimental and measurement skills, two of the outcomes for the course.

This year the "tradition" was changed with only the pre-laboratory report required and then, after conducting the experiment, an oral examination at the work-bench where the students' are required to explain and demonstrate their techniques, results and analysis. Hand drawn plots of their measurements are required for this explanation. Marks are allocated at 100% for meeting the outcomes and 0% for not meeting the outcomes. Students failing to meet the outcomes, the first time, may redo the experiment, and if successful will receive a mark of 50%. The third laboratory, a MATLAB based simulation, still requires a full report meeting one of the other outcomes for the course.

II. In the Classroom

I still believe that "chalk and talk" is the most efficient way of lecturing, if combined with continuous two-way interaction with the class. There is a place for overhead slides (you don't have to write the same thing every year) and computer presentations but the two-way communication (verbal or body language) is the most important aspect that must be encouraged and managed.

Felder [21] and Mazur [13] both describe methods to encourage student participation during lectures by allowing them time to work in groups to discuss and come up with solutions to the problem being presented. I am concerned that the introduction of a computerised voting system tied in with computer presentations [13, 14] will just reinforce "virtual reality" turning the classroom into a computer game where the lecturer can be controlled by a joystick and/or buttons.

Curriculum changes such as an English literature course in first year [22], to develop the students' ability to communicate and their imaginative and visualisation skills, should also be incorporated into the degree programme.

A PLAY-PEN

In an attempt to make the students entering university engage with "real life" the author is lobbying for the introduction of a "Play-Pen" for the use of all first year students. The concept is just what the name implies, put the students in an enclosed space and throw in a large number of "toys" and see what "grabs" their attention.

A survey amongst last years first year students returned a number of ideas such as:

- Model electric car racing track. (Students could modify the motors and run a series of "Grand Prix" races.)
- A robotic area. (Again competitions could be held.)
- A hobby area with soldering iron, multi-meters, oscilloscopes etc.
- A computer club (including adventure/war games competitions).

The author's vision is that the space would be large enough to accommodate all the registered students, not only first year, and physical experiments would be available for students to "play" on. These would be designed to help students visualise the mathematics and algorithms covered in perceived difficult courses such as Signal and Systems and Control. A final year project this year is to build an analogue system, no computers, to demonstrate one or more of the more difficult concepts, for the students, covered in either of the two Signals and Systems courses.

Of course the most difficult aspects of the implementation of the Play-Pen are convincing the administration that it is even necessary, and obtaining the funding and the required space (Our machine's laboratory is not closing!). Maybe we should learn from the Sydney Technical University and use industry funding even if it is sourced from a foreign country?

Time constraints on our students would also present a problem in the use of the Play-Pen. The curriculum would have to be adjusted to allow time for "playing" as the students most in need of the play-pen, are the students normally struggling with their other courses.

CONCLUSION

Academic staff and their institutions should approach technological advancements with caution. We now have a generation of students brought up on "virtual reality" with low exploration, visualisation and imaginative skills.

State education authorities and university administrations need to be aware of the difficulties that our students experience coping with the realities of engineering education. They must be prepared to invest in hardware to empower engineering schools to redress the problems that have been identified in this paper.

We need to introduce more real life laboratories, not withstanding the cost implications, to prepare our students for their career in engineering where motors actually turn, make noise and smell and you are required to communicate with other humans without a joystick and the "fire" button.

REFERENCES

[1] W. Aung, R. King, J. Mościński, S. Ou, and L. M. Sanchez Ruiz, Eds., *Innovations 2005 - Special Edition: World Innovations in Engineering Education and Research.* Arlington: iNEER, 2005.

[2] W. Aung, C. Crosthwaite, R. Vasquez Espinosa, J. Mościński, S. Ou, and L. M. Sanchez Ruiz, Eds., *Innovations 2006: World Innovations in Engineering Education and Research*. Arlington: iNEER, 2006.

[3] J. Mościński and M. Maciążek, Eds., *Proceedings of the International Conference on Engineering Education, ICEE'2005*, ICEE. Gliwice: Silesian University of Technology, July 2005.

[4] A. Z. Sampaio, P. G. Henriques, and P. S. Ferreira, *Innovations 2005 – Special Edition: World Innovations in Engineering Education and Research.* Arlington: iNEER, 2005, ch. 7: Virtual Reality Applied in Civil Engineering Education: Simulating the Construction of a Wall, pp. 69–79.

[5] M. Ožvoldová, P. Čerňanský, F. Schauer, and F. Lustig, *Innovations 2006: World Innovations in Engineering Education and Research.* Arlington: iNEER, 2006, ch. 25: Internet Remote Physics Experiments in a Student Laboratory, pp. 297–304.

[6] J. Su, J. Hu, and Y. Ciou, *Innovations 2006: World Innovations in Engineering Education and Research.* Arlington: iNEER, 2006, ch. 35: Low-cost simulated control experimentation conducted in

Electrical Engineering Department of National Yulin University of Science and Technology, pp. 397–408.

[7] W. Cronje, University of the Witwatersrand, Johannesburg, 2007, private communication.

[8] V. Kroumov, K. Shibayama, M. Ishida, A. Inoue, and H. Narihisa, *Innovations 2006: World Innovations in Engineering Education and Research. Arlington:* iNEER, 2006, ch. 16: Enhancing education in control engineering via interactive learning tools, pp. 193–20

[9] B. Pitout, "Facilitating electronic learning activities for first year town planning students in an open learning system: Is it worth the effort?" in *Engineering Education for Sustainable Development. Pretoria: 3rd African Regional Conference on Engineering Education*, Sept 2006, pp. 177–185.

[10] F. E. Sandnes, B. H. Renh Johansen, N. E. Eide, and A. N. Blaafladt, *Innovations 2005 - Special Edition: World Innovations in Engineering Education and Research*. Arlington: iNEER, 2005, ch. 5: The FAQ robot - Managing large-class E-mail correspondence, pp. 43–56.

[11] M. Ožvoldová, P. Čerňanský, I. Cerven, J. Budinsky, and R. Riedlmajer, *Innovations 2006: World Innovations in Engineering Education and Research.* Arlington: iNEER, 2006, ch. 24: Introduction to engineering physics - a multimedia CD tool for students entering Slovak Engineering Universities, pp. 287–295.

[12] D. Mayer and J. Kus, "Teaching electric circuit theory with the help of tutorial software," *Global Journal of Engineering Education*, vol. 2, no. 1, pp. 77–85, 1998.

[13] E. Mazur, "Peer instruction: Getting students to think in class," in *Proceedings of ICUPE*, E. F. Redish and J. S. Rigden, Eds. The American Institute of Physics, 1997, pp. 981–988.

[14] D. Epstein, "Peer to peer," March 15 2006. [Online]. Available http://www.insidehighered.com

[15] R. C. Jones, "Engineering capacity building in developing countries," in *Engineering Education for Sustainable Development. Pretoria: 3rd African Regional Conference on Engineering Education*, Sept 2006, pp. 1–4.

[16] The LEGO Group, "Premium games," April 6 2007. [Online]. Available: http://www.lego.com/eng/premiumgames/default.aspx

[17] Washington Accord. (2005) *Washington accord: A multinational agreement signed in 1989.* Revised August 17, 2005. [Online]. Available: http://www.washingtonaccord.org

[18] G. J. Gibbon, I. R. Jandrell, and D. Rubin, *Innovations 2006: World Innovations in Engineering Education and Research*. Arlington: iNEER, 2006, ch. 4: Shifting the Responsibility of Learning in First-Year Electrical Engineering Students, pp. 27–38.

[19] J. A. S. Redwood-Sawyerr, "Developing team work in an undergraduate engineering programme through extended essays, practical exercises and tutorials," in *Engineering Education for Sustainable Development. Pretoria: 3rd African Regional Conference on Engineering Education*, Sept 2006, pp. 223–233.

[20] V. Giurgiutiu and W. Liu, *Innovations 2006: World Innovations in Engineering Education and Research*. Arlington: iNEER, 2006, ch. 19: The use of functional modules in the Mechatronics education, pp. 233–246.

[21] R. M. Felder and R. Brent, "Navigating the bumpy road to student-centred instruction," *College Teaching*, vol. 44, no. 2, pp. 43–47, 1996.

[22] G. J. Gibbon, K. Nixon, and M. Nixon, "Analysing the raw material: Who are our first years?" in *Engineering Education for Sustainable Development. Pretoria: 3rd African Regional Conference on Engineering Education*, Sept 2006, pp. 399–407.