SOME PROBLEMS AND MEASURES FOR IMPROVING MECHANICAL ENGINEERING EDUCATION AT THE PNG UNIVERSITY OF TECHNOLOGY

M.A. Satter and J. Pumwa

Department of Mechanical Engineering
Papua New Guinea University of Technology,
Lae, PAPUA NEW GUINEA
masatter@mech.unitech.ac.pg

Abstract

The paper considers some problems of undergraduate mechanical engineering education at the Papua New Guinea university of Technology with a view to improving academic quality and relevance to the needs of industry. It identifies several problems that act as inhibitors to learning. As a result, there had been high failure rate, between 20 to 30%, at every level of the four-year undergraduate program. The paper analyses the problems of the Foundation Year Engineering (FYE) program, a common program for all engineering departments of the university. Some of the problems seem to be related to student's weak high school background, ad hoc design of the FYE curriculum, and teaching methodologies. The paper discusses some of the corrective measures already undertaken, and also those being planned.

Introduction

Engineering education in Papua New Guinea (PNG) is challenging for students as well as teachers for a number of reasons. For students, the reasons being new university environment, new engineering curriculum, teaching and learning styles and socio-cultural influences. For teachers, the reasons may include having to teach students with diverse socio-cultural background and weak analytical ability, changing technological curriculum and its relevance to industry, and financial constraints.

The challenges faced by students and teachers seem to be partly related to geographic, socio-cultural and economic factors. Papua New Guinea comprises the mainland Papua New Guinea and over 600 offshore islands with total land area of about 465,000 km^2. Most islands are volcanic and rugged mountainous land covered with thick forests. Surface transportation is extremely limited and the most common form of travel is by air. About 80% of the four and a half million PNG population is thinly distributed across the land in the form of small tribal communities isolated from each other making provision of infrastructure such as electricity, telephone, water supply and roads to these communities very difficult and costly. Papua New Guineans speak over eight hundred languages. Each tribal community has its distinct language and cultural trait. Rural inhabitants are mostly subsistence farmers. About 20% of the PNG population lives in 10 urban centers.

Engineering Programs

PNG University of Technology, also known as Unitech, is the only university in the country, which offers degree level courses in engineering. There are four departments of engineering, namely, civil, electrical, mechanical and mining. All engineering programs are of four-year duration. The first year is common, and until recently it was known as the Foundation Year Engineering (FYE). On successful completion of the FYE program, students had the freedom to choose any of the four disciplines of engineering.

The FYE program was introduced in 1976 when the engineering departments were all under the faculty of engineering. The faculty structure was dismantled in 1980, but the FYE program was retained to operate under the supervision of an FYE committee, headed by a chairman. Members of the committee were drawn from the four engineering departments and relevant service departments such as mathematics, language and science. A coordinator, appointed from one of the four engineering departments, was to coordinate the day-to-day activities of the FYE program. The coordinator directly reported to the FYE committee chairman.

The FYE curriculum comprised of the following subjects [1]:

1. EF140: Concepts of Engineering (6 hrs/wk)
2. EF150: Engineering Mathematics (6 hrs/wk)
3. EF160: Engineering Analysis (6 hrs/wk)
4. EF170: Engineering Drawing and Practice (4 hrs/wk)
5. EF180: Language and Communication (3 hrs/wk)
6. EF190: Chemistry for Engineers (2 hrs/wk)

Each subject was yearlong, taught across two semesters, and examined at the end of each semester. EF140 was basically physics. EF160 was a mixture of statics, dynamics and electrical engineering. EF190, chemistry, was optional for all students except for mineral processing students within the Mining Engineering Department. Teaching hours for each subject was divided into lecture, tutorial and laboratory/practical (where applicable). A detailed exposition of the teaching load is shown in appendix-1. It shows a total of 2265 man-hr/semester is required [2]. Taking an average of 10 hrs/week of teaching load, a total of 15 teaching staff members were required per semester to run the FYE program. Out of the total load, 6.6% (150 man-hr) is devoted to lectures and 93.4% (2115 man-hr) to tutorial and laboratory sessions.

An analysis of pass/fail of FYE students over 1990-94 period showed that the average failure rate in one or more subjects was 41.2% and 10.5% at the end of semester I and semester II respectively. These give an average failure rate of 25.85% per semester.

A further analysis over the same period showed that, on average, 82% of all failures occurred in the three analytical subjects, namely, physics, mathematics and engineering analysis. Of these, mathematics proved to be the hardest to pass.

Students who failed up to two subjects with individual subject score of 45% or more were given supplementary examinations. This reduced the failure rate to 23.3% per semester.

The post-FYE programs comprised those of 2nd, 3rd and 4th year studies. Successful FYE students branched out to various departments of their choice. Engineering departments had no control over the entry standard of their new students. The subjects in post-FYE programs were more engineering oriented, and therefore department-specific. For example, the subjects in mechanical engineering would emphasize thermal, fluid and materials sciences, mechanics, control and design. The overall yearly failure rate in the post-FYE program varied from 20% to 30%. The failure rate was again the highest in analytical subjects.

Students who successfully completed a four-year engineering program graduated with a bachelor degree in the 'pass' grade; there is no degree classification such as first class, second class, etc. But, a department might recommend an award of a 'degree with merit' to a student who does consistently well over the four-year engineering program. Actual performance of a student is reflected in the transcript where a letter grades A, B, C, etc. is shown for each subject.

Observations

Engineering departments have expressed concern over the relatively poor performance of students at every level of the four-year program. In general, students perform relatively poorly in analytical subjects and those that require visualization in space. Thus, students tend to be weak in subjects such as mathematics, mechanics, dynamics, electricity, material science, drawing etc.

Other observations by lecturers include: 'students are slow in understanding', 'slow in note taking from board', 'lack drive and motivation', 'can't remember simple formula', lack confidence, lack of time management skills.

We have also received comments from industry about the attributes of engineering graduates. In one specific instance an interviewer commented about graduates who applied for jobs: 'communication skills were poor', 'can't answer specific questions asked', 'lack planning and scheduling skills' etc.

Sari [3-6] of the Teaching and Learning Methods Unit (TLMU) of the University has conducted a number of studies on teaching and learning problems of PNG students. The reports are internal publications of the TLMU. One of the reports [6] deals with teaching methodologies for the Foundation Year Engineering (FYE) students of the university. According to Sari, some PNG customs act as inhibitors to learning. He identifies these PNG customs as "indirectness, passiveness and respect for seniority". PNG students with these cultural background tend to be 'silent listener', 'passive' and devoid of self-inquisition. These, in turn, lead to rote learning or 'surface learning' relying mostly on memory and recollection, as against critical analysis of the learning material resulting in lower level of learning outcome.

Sari also suggests other factors that inhibit self-inquisitive learning. These include teaching methods and approaches and personality of the teacher [4]. Sari suggests certain teaching behavior based on several well-known educational psychology publications [7-10]. The psychological approaches include: the teacher winning the confidence of his/her students at the commencement of the semester, and developing students' self-esteem. For confidence building, the teacher should demonstrate genuine interest in the affairs and well being of his/her students. He must project a positive, caring and concerned attitude to the class in the first few weeks of teaching. As for developing self-esteem, Sari suggests the use of positive reinforcements; democratization in the classroom approaches, treating students' opinions confidently and respectfully.

Attributes of Engineering Graduates

As mentioned earlier, comments from industry indicate that engineering graduates tend to lack relevant attributes. It is important to define what should be the relevant attributes of engineering graduates. These attributes may comprise of both technical and non-technical elements. Technical attributes are those related to engineering curriculum while non-technical ones are mainly related to social science discipline. For engineering graduates, technical attributes are those related to the ability to design and develop a new product or process [11]. These are (a) technical knowledge (b) the ability to synthesize (c) the ability to elucidate principles and (d) the evaluation ability. Technical knowledge is the most important attribute of an engineer. It consists of the natural laws and principles. The more natural laws and principles an engineer knows, the greater the choices available to him or her for devising efficient methods to achieve the desired objectives. The second most important attribute of an engineer is the ability to synthesize or combine natural laws and principles to achieve the desired objectives. The ability to elucidate is the third important attribute of an engineer. With this attribute, an engineer is able to discover underlying principles by interpreting data correctly and conducting effective experiments. The fourth most important attribute of a good engineer is the ability to judge between alternative solutions and choose the best one.

The non-technical attributes are mostly related to personal abilities and skills. These include abilities and skills in report writing, team work, management planning, problem solving, working under pressure and meeting deadlines, willingness to work overtime, interpersonal behavior, communication, and so on. Although these attributes are not directly related to engineering subjects, they are essential for an engineer to work in competitive manufacturing and business environments.

The question arises 'how could we train PNG engineers to acquire both technical and non-technical attributes?' The answer lies in the selection of students with right entry requirement, good design of engineering curricula, selection of suitably qualified teachers, use of appropriate teaching methodologies and creation of an appropriate learning environment. These are the issues faced by the engineering educators at PNG University of Technology.

Remedial Measures

A number of remedial measures have been introduced to improve engineering education at Unitech. The FYE committee recommended some policy decisions as well as changes in the FYE curriculum to address various problems mentioned earlier. Two major issues were considered toward reshaping the FYE program. Under the FYE arrangements, students did not enroll in any of the specific disciplines of engineering until at the beginning of second year of their study. Thus, they lacked any specific objectivity and orientation toward a particular discipline while entering the university for the first time. There was a further issue on administering a new intake of over 150 FYE students by the coordinator single handedly. To address these issues, the university decided to restructure FYE and renamed it as First

Year Engineering. Under the new arrangement, each of the four engineering departments would enroll its first year students. Each department was allowed to introduce one or two department-specific subjects in addition to common subjects in mathematics, physics and language for its student intake. The effect of this policy change was that students knew from the beginning in which discipline they would be studying. Thus, the first year students had definitive objective and orientation to the discipline of their study. The departments knew their own students, and were keen to provide counseling and guidance to their students through appointment of mentors. The departments also had a level of control on the entry standard of their students. Engineering departments were able to choose high school graduates with good analytical background. This was not the case under the FYE program. A better way to select students would be through an entrance examination. The idea is being considered. Moreover, the primary and secondary school curricula should be reviewed to be at par with the requirements of the university. As an alternative, the university could also introduce a remedial program in relevant analytical subjects. The following is a summary of the proposed changes in the FYE program:

- Change each yearlong subject to two one-semester subjects with revisions of contents.
- Relocate EF 160: Engineering Analysis to second year program
- Rearrange the proportion of lecture, tutorial and laboratory sessions
- Reduce weekly formal contact hours
- Keep common subjects.
- Make chemistry compulsory.
- Introduce new and department-specific subjects.
- Let each engineering department select and admit their new students into the first year.
- Allow interdepartmental transfer of students at the end of the first year program.

The university accepted the recommendations of the FYE committee for stage-by-stage implementation. The policy decisions on FYE allowed engineering departments the necessary freedom to redesign their curricula. Mechanical engineering took the opportunity to revise its curriculum and the details of the revision appear in the Courses Handbook 2002 of the PNG University of Technology. Several important changes were introduced in the first year engineering curriculum. The revisions were done in consultation with the departmental advisory committee. The majority members of the advisory committee come from various industries and government departments of the country. The major changes are: reduction of contact hours, revision of mathematics, physics, language, and engineering drawing syllabus, introduction of new and department-specific subjects at the first year level. The First Year Engineering program started functioning from the academic year 2000. The revised course structure of the first year mechanical engineering program is shown in appendix-2. In fact, the department of mechanical engineering revised its entire four-year program with a view to developing engineering attributes outlined earlier. This paper, however, considers only the first year mechanical engineering program.

At first, all yearlong subjects were changed to semester subjects. The contents of each subject were also reviewed and updated where necessary. Engineering analysis was a subject with materials from statics, dynamics and electrical engineering. This subject was eliminated because the same materials could be studied in their core subjects being offered at second-year program. There was the need to rearrange the proportion of lecture, tutorials and laboratory sessions. As shown in appendix-1, formal tutorials dominated the total teaching load, leaving very little time for theory lectures. The imbalance was reversed by substantially replacing formal tutorials with informal voluntary consultations, posting of solutions of problems on notice boards, and cooperative learning practice. The weekly formal contact hours were also reviewed. In the FYE program, the average weekly contact hour was 27. This figure was high as students had very little time for self-study. In the revised first year program, the weekly contact hour was reduced to 23.5. Reduction of contact hour was possible mainly through elimination of overlap of contents, and reduction of tutorials and laboratory sessions. The common subjects of the FYE program were retained. They were subjects in mathematics, physics, language, and engineering drawing. The contents of these subjects were revised, and weekly contact hours were reduced in some cases. Chemistry was optional, but made compulsory in the revised curriculum. Three new subjects were introduced: 'introduction to computing and problem solving', 'workshop technology and practice', and 'introduction to mechanical engineering systems'. The new subjects were intended to upgrade students' knowledge and orient them toward mechanical engineering discipline. Most of the high school 12th grade graduates who came from rural areas had practically no knowledge in computing. They also lacked knowledge of mechanical engineering processes and systems.

Special mention may be made of the subject 'introduction to mechanical engineering systems' that proved to be popular with first-year students [12]. It was intended for developing both technical and non-technical attributes of engineering students described earlier. The contents of the subject included mechanical elements such as fasteners, power transmission elements; manufacturing processes such as casting, welding, machining; mechanisms and linkages; pneumatic/hydraulic systems; electrical and electronic elements and systems; energy conversion systems such as I.C. engines, turbines, and so on. Mechanical elements and systems mainly from the field of automotive engineering were made available to students to study. The course was conducted as a practical session of 3 hours per week. Cooperative leaning was encouraged through group discussions. Students worked in a group of four for four weeks at a time before forming new groupings. Over a period of one semester, every student would have worked in three different groups thereby coming in contact with nine different students. Product based learning was also encouraged. In some sessions, students were asked to dismantle an assembly, identify the elements and reassemble them. Each student was required to submit a report per session describing the name, function, shape, size, material, manufacturing method and approximate cost of the element/system under study. Freehand sketches of shapes were a requirement in the report. A student would have done at least 12 reports in a semester. At the end of the semester, each student was required to present a seminar on his/her experience of the subject.

This subject is an example whereby students had the chance to develop both technical and non-technical attributes discussed earlier. Product based learning practice lend to the development of technical attributes. Cooperative learning practice can help in developing non-technical attributes such as interpersonal and communication skills, teamwork and problem solving abilities.

Quality Improvement Initiatives

PNG University of Technology has already initiated several measures to improve academic quality. It has set up the Teaching and Learning Methods Unit (TLMU) with the purpose of monitoring academic quality and training of lecturers on best teaching practices. It is mandatory for national lecturers to undergo training on their first teaching appointment.

Expatriate lecturers also undergo some training at TLMU. Recently the university has embarked on a total quality philosophy drive. The initial preparatory activities are being coordinated by TLMU. The university is also liaising with the National Upper Secondary Board of Studies for revising high school curricula in science and mathematics.

Cost Reduction

Many teaching activities can conceal large amounts of wastes, which are not normally obvious to many academics. By careful analysis of programs and curricula such wastes can be discovered and, actions taken to eliminate them. This will result in cost reduction while improving academic quality. Wastes can be in the form of overlap of syllabus, unnecessary tutorials and laboratory sessions. It was pointed out earlier that the total effort required to teach the six FYE subjects was 2265 man-hr/semester with only 6.6% (150 man-hr) for lectures and 93.4% (2115 man-hr) on tutorial and laboratory teaching. It is apparent that the ratio between lectures and tutorial/laboratory is disproportionately distributed. According to research findings on the effectiveness of lectures, small group teaching (tutorials) and laboratory teaching, only lectures seem to be the efficient and cheap way of transferring knowledge [13]. Small group teachings are no better than lectures but more costly; they are often dominated by tutor talk. Laboratory teaching seldom achieves its real objectives such as scientific enquiry and performance testing of new products/processes. If the objective is only to develop skills in conducting experiments, then a few experiments will suffice. The First Year Engineering was revised to eliminate unnecessary laboratory sessions and formal tutorials. The total teaching load in the revised program came down to 1140 man-hr/semester, a reduction of manpower requirement by about 50%, and hence reduction in cost.

Conclusions

The paper has identified a number of problems that act as inhibitors to learning of engineering at the PNG University of Technology. The most serious problem appears to be the weak analytical background of new students. It is also noted that students who come from the rural environment tend to be shy, indirect and passive learners because of their cultural values such as the respect for seniority. Some consider these personality traits as inhibitors to learning. Several specific measures have been introduced in the engineering programs. These include curriculum revision, introduction of cooperative and product based learning, and policy shift for admitting new students.

Further measures are being planned for academic quality improvement. These include monitoring of academic quality, training of lecturers, and liaising with National Upper Secondary Board of Studies for high school curriculum revision. Finally, it has been shown that significant cost reduction can be achieved through curriculum design.

Acknowledgments

The authors wish to express their sincere thanks and appreciation to the Research Committee of the Papua New Guinea University of Technology for providing the funds for this research. The authors would also like to thank Mrs. Grace Gialom and Ms. Runeo Botienu for typing and assisting with the preparation of this manuscript.

References

1. PNG University of Technology. Courses Handbook
   Published by the PNG University of Technology, Lae, Papua New Guinea. (1995)

2. SATTER M.A. "A FYE Improvement Plan" Dept of Mechanical Engineering, PNG University of Technology, Lae, Papua New Guinea, pp1-17 (1995)

3. SARI, J. "A Course Evaluation and Social Survey Report of the Foundation Year Accounting and Business Studies Students of UNITECH" TLMU Report No.3, pp1-38, (1993)

4. SARI, J. "Problems in Learning of PNG Students in Formal Education Institutions: An open discussion on students reluctance in asking or answering questions in class" Teaching and Learning Methods Unit, PNG University of Technology, Lae, pp1-17 (March 1994)

5. SARI, J. "A View on Teaching and Learning Effectiveness for PNG Secondary and Tertiary Teachers as a Form of Quality Assurance in Education." TLMU, PNG University of Technology, Lae, pp1-41 (1996)

6. SARI, J. "Teaching Engineering Courses at Foundation Year at PNG University of Technology: A View on Teaching Methodologies" TLMU, PNG University of Technology, Lae, pp1-10 (1997)

7. Lindgren, H.C. Educational Psychology in the classroom: Understanding the Psychology of Classroom Teaching and Learning. (6^{th} Ed), Oxford Press New York, USA, (1980)

8. Flanders, N. Analysing Teacher Behaviour, Reading Mass. Addison Wesley (1970)

9. Springthal, N.B Springthal, R. "Methods and Models of Teaching; Teaching Effectiveness" *Educational Psychology: A Development Approach* (4^{th} Ed) Chap 13, Random House New York, pp286-305

10. Ramsden, P. Learning to Teach in Higher Education Routledge, New York, pp1-38, (1992)

11. Shimizu, M and Kume, H. "The Training of Engineers." KENSHU, No. 150 Winter 1998-99, Published by AOTS, pp25-30

12. Satter, M A and Michael, L "Some Experience from the Revised First-Year Mechanical Engineering Curriculum." Proceedings of Australasian Association for Engineering Education 12^{th} Annual Conference, 26-28 September 2001, Queensland University of Technology, Brisbane, Australia, pp 34-37.

13. Brown, G. "Effective Teaching", Quality Assurance for University Teaching, Edited by Roger Ellis, The Society for Research into Higher Education, ch. 13, pp211-232 (1993).

Appendix-1: Analysis of FYE Curriculum Teaching Load

EF 140: Concepts of Engineering (6 hrs/wk)

Lecture:	2x1x15*	=	30 man-hr/semester
Tutorial:	2x8x15	=	240 " "
Lab. :	2x8x15	=	240 " "
	Total:		510 man-hr/semester

EF 150: Engineering Mathematics (6 hrs/wk)

Lecture:	3x1x15	=	45 man-hr/semester
Tutorial:	3x8x15	=	360 " "
	Total:		405 man-hr/semester

EF 160: Engineering Analysis (6 hrs/wk)

Lecture:	2x1x15	=	30 man-hr/semester
Tutorial:	2x8x15	=	240 " "
Lab. :	2x8x15	=	240 " "
	Total:		510 man-hr/semester

EF 170: Engineering Drawing and Practice (4 hrs/wk)

Practice:	2x8x15	=	240 man-hr/semester
Project:		=	390 " estimated
	Total:		630 man-hr/semester

EF 180: Language and Communication (3 hrs/wk)

Lecture:	2x1x15	=	30 man-hr/semester
Tutorial:	1x8x15	=	120 " "
	Total:		150 man-hr/semester

EF 190: Chemistry for Engineers (2 hrs/wk)

Lecture:	1x1x15	=	15 man-hr/semester
Tutorial: and Lab.	1x3x15	=	45 " "
	Total:		60 man-hr/semester

Grand Total: 2265 man-hr/semester

*Man-hr/semester calculation:

Man-hr=(no. of hrs/week)(no. of groups/class)(no. of weeks/semester)

Appendix-2: New First Year Mechanical Engineering Course Structure

Code	Subject	Average Weekly Hours
Year 1	**First Semester:**	
MA167	Engineering Mathematic	5
PH141	Principles of Physics I	5
CH181	Chemistry for Engineers I	2
LA101	Learning & Communication Skills	3
ME161	Workshop Technology and Practice	3
ME171	Engineering Drawing I	3
EE101	Introduction to Computing & Problem Solving I	2
		23
Year 1	**Second Semester:**	
MA168	Engineering Mathematics II	5
PH142	Principles of Physics II	5
CH182	Chemistry for Engineers II	3
LA102	Study & Academic Skills	3
ME172	Engineering Drawing II	3
EE 102	Introduction to Computing & Problem Solving II	2
ME122	Introduction to Mechanical Engineering Systems	3
		24