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Development of a Learner-Focused, Sustainable-Engineering Subject

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Abstract

This paper looks at how the subject content, teaching method, and assessment techniques in an energy engineering subject were aligned to promote students' understanding of sustainability and to develop the graduate capabilities expected of reflective practitioners. The subject was structured as a "*Learning Organization*" [1], which emphasised student collaboration, negotiation and responsibility for learning. Student-focused learning and teaching methods were used to facilitate deep approaches to students' team learning and skill development.

Combined face-to-face, web-site and online discussion facilities were developed to provide an interactive learning environment where students learn in teams. Students demonstrate the quality of their understanding of the multidisciplinary nature of this subject through making links between theories of the subject and practice using self-selected case study projects which are developed throughout the semester. The case studies require them to develop their skills in critical reflection, analysis, synthesis, integration, creation and the application of ideas. Students are encouraged to be more pro-active and to consider economic, environmental, political and social factors in their technical decisions. The paper discusses ways in which we have examined the effectiveness of this approach by interviewing students, and analysing their reflective portfolios, case study reports, and feedback surveys. It therefore draws out the wider implications for extending student-focused-teaching and learning to all engineering subjects, including those offered by online delivery.

Keywords:

Online Engineering Education, Student-focused teaching and learning, Teamwork, Sustainability, Energy Conversion.

Introduction

The desire for a sustainable new millennium in the context of rapid global change has prompted rethinking about how university education can act as a catalyst for change. Universities increasingly have a social obligation to promote sustainability goals and encourage their staff and students' commitment and capacity to develop a sustainable environment. To meet the challenge of leading a rapidly changing integrated global community with changing social values and expectations, our graduates need to be lifelong learners who are sensitive to community needs, and have a proactive attitude towards developing team working and life long learning skills, reflective practice, and leadership in the society. Engineering education is increasingly being developed as a focal point for leading and addressing the needs of society. Significant cultural change is taking place within university Engineering Faculties, where student-focused-teaching and learning, and sustainability-based value systems are increasingly being asserted online.

Understanding Sustainability as a Desired Graduate Attribute in Engineering Education

Georg defines sustainability as the "triple bottom line of economic prosperity, environmental quality and social justice" which acts as the benchmark by which all engineering activities are being measured [2]. Agenda 21 of the United Nations at the Earth Summit in Rio addressed the important role of engineers and decision-makers in achieving sustainability through global partnership. The implementation of the Agenda demands a new kind of engineering graduates who are proactive community leader, and embrace and integrate technological, economic, social and environmental objectives to achieve sustainability and to avoid deepening economic divisions with continuing deterioration of ecosystems on which life on earth depends. This agenda is also reflected in global pressures for change in engineering education.

In the United States, backed by social demands, the American Society for Engineering Education called for a cultural change in engineering education [3]. The Board of Engineering Education of the National Research Council recommended that engineering schools align the faculty reward system more fully with the total mission and the purpose of their institutions [4]. To address social needs in Canada, the Canadian Academy of Engineering recommended broader, more integrated undergraduate programs with an increased emphasis on design and social context [5]. In Britain, Broers recommended extracurricular activities to develop communication and leadership skills in undergraduate engineering students [6].

Similarly in Australia, engineering education has been the subject of a number of reviews over the past decade. Skillington analysed engineering education and recommended an improvement in the quality of four-year engineering graduates through more focussing on students learning to maintain equivalence with world standards [7]. Bates *et al* suggested the need for a more appropriate balance between technology and non-technology skills, acceleration of the broadening of undergraduate engineering courses, and the development of cross-discipline and interpersonal skills in undergraduate education [8]. Hall reported on the disturbing state of teaching and research equipment in mechanical engineering departments around Australia, and warned that if the situation continued, graduates and future engineering leaders would not be able to compete with overseas competitors [9]. The Institution of Engineers, Australia IEAust Code of Ethics calls for the promotion of sustainability principles and ethics by the members. The IEAust also developed a handbook to guide engineers to incorporate sustainability requirements into their professional practice [10].

The cultural changes in Australian Universities are further enhanced by adoption of many of the recommendations of the IEAust National Review of Engineering Education [11]. At the University of Technology, Sydney (UTS), they have been applied through establishing the Institute for Sustainable Futures (ISF) to promote sustainable futures through research, consultancy and training. The IFS defines sustainability as a dynamic process in which the economy, environment and social equity are linked in decision making. UTS's commitment to sustainability and social fairness was formalised in November 1998 when the institution signed the Tallories Declaration, representing an alignment with the global universities who have committed to creating a just and sustainable future [12].

The Faculty of Engineering, at UTS was restructured and a process of re-evaluation of values and missions took place. Sustainable development and life cycle analysis were incorporated as key elements in the newly developed broader undergraduate engineering courses which also consider environmental, social and economic impact analysis of technical decisions made. The Faculty restructured, to address the cultural changes and to promote practice-based, learner-focused teaching and learning curriculum, and sustainability principles as a desired value system [13]. Sustainability became the foundation idea in the new curriculum, a basic ethic, and the fundamental rationale for education. Generic graduate professional and personal capabilities such as critical thinking, interpersonal and communication skills, and reflective practice are also incorporated in the course design to enable engineering graduates to be reflective practitioners with capabilities to analyse, synthesis, create, and apply knowledge. The UTS Faculty of Engineering won the 1998 IEAust Award for Cultural Change in Engineering Education.

The promotion of sustainability as a desired value system in engineering courses requires action for change at all levels, especially by academic staff in the development of new subjects. All these recommendations, reviews, achievement and expectations, place enormous pressure and responsibilities on engineering educators to provide quality technical and non technical learning, and to develop required skills and value systems.

The aim of this paper is to highlight progress towards addressing desirable cultural changes in engineering education and establishing student-focused learning patterns and processes in the development of an engineering subject. The subject's development was influenced by a combination of global, national professional, institutional and moral factors which together set the educational standards for the subject.

A Reflective Approach For Developing The Subject And Improving Teaching

We believe enhanced learning is more likely to occur in subjects which are designed using a student-focused approach, where the emphasis is on creating an environment which facilitates learning [14][15][16][17]. Student focused teaching includes taking students' prior ways of experiencing the subject into account, engaging them in experiences which challenge and change their understandings, and putting a greater emphasis on what students do in order to learn [18]. Teaching and learning are seen as two sides of a coin, in which teaching methods, student learning, subject materials and assessment need to be linked to address learning objectives [19].

Our understanding of teaching is also expressed in a similar way to that of Bruner [20]:
"*We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as an historian does, to take part in the process of knowledge-getting. Knowing is a process, not a product".*

Improving teaching as an integral part of this approach involves improving the teachers' understanding of students' learning in the subject. Studies by Hargreaves, Woodruff and Wallis have indicated that mechanical engineering students in Australia adopted a surface approach to learning as they progressed through their courses [21][22]. This creates a challenge for staff who seek to encourage a deep approach. When students pass a subject through surface approaches to learning at early stage, it is hard to discourage them from repeating the process in similar situations at later stages of their course. Students' conceptions of learning also vary from learning as an increase in knowledge, and learning as memorising through to learning as changing as a person [23]. In engineering subjects, we need students to be capable of engaging in learning as abstraction of meaning, understanding of fundamental principles and concepts, which can be applied to both familiar and unfamiliar real cases, and ultimately changing student views, behaviour, and performance. This highlights the fact that the key for improved learning lies in students' conceptions, perceptions and ownership of learning. Often this means we need to change the conceptions of learning that students perceive to be required by our subjects. As stated by Marton and Ramsden "learning should be seen as a qualitative change in a person's way of seeing, experiencing, understanding, conceptualising something in the real world rather than as a quantitative change in the amount of knowledge someone possesses" [24]. Changing prior learning perceptions and cultures require continuous efforts, in collaboration and partnership with other staff and students. To encourage these conceptual changes, engineering subjects are increasingly emphasising opportunities for students to explicitly reflect on their own learning of the subject, compare their understandings with others, engage in collaborative learning with peers and test out new ways of understanding in real world situations.

The next section of the paper describes the design of the Energy Conversion subject, which explicitly aimed to develop students’ understanding of sustainability in energy engineering, and which incorporated student focused learning approaches. Following this, we present findings from the subject evaluation, then recommendations for others seeking to develop similar approaches.

Design of the Energy Conversion Subject.

Energy Conversion is a postgraduate subject covering many disciplines with rapidly changing knowledge bases. The area is affected by social and political decisions and governmental regulations. These make it controversial and difficult to learn. Our main goal was to help students to understand the basic design of renewable, non-renewable, and alternative energy conversion systems, in the context of relevant environmental, economic, social, and technological factors. This subject undoubtedly generates some controversy as different factors are quantified and valued differently by different people in different setting. For example, nuclear power generation may offer advantages in relation to global warming but factors such as social acceptance can play tremendous impacts on developments and application of this energy system. Students need to learn to think critically about the relationships between these complex and interdependent factors in order to make informed professional judgements. Within the Energy Conversion subject students were encouraged to learn the fundamentals of a sustainable energy conversion system, and to develop reflective skills to recognize conditions which a system is sustainable when social, economic, environmental, and technological factors are taken into account appropriately. The objective of the subject also was for students to work in groups to co-create a common understanding of the quality standards in the selection and promoting of a sustainable energy system.

Encouraging high quality student learning involves all aspects of developing, monitoring, assessing and improving the effectiveness of the curriculum, teaching methods, and assessment. The re-design of the subject emphasised alignment between subject objectives, teaching and learning activities and assessment [18][25]. In order to promote collaborative learning between students and encourage reflection on learning, the subject structure was based on "Learning Organization" where students learned in teams and took more responsibility for making decisions about their own learning. As stated by Senge [26]

> "*As the world becomes more interconnected and business becomes more complex and more dynamic, work must become more 'learningful'. It is no longer sufficient to have one person learning for the organization and have everyone else following the orders of the 'grand strategist'. The organizations that will truly excel in the future will be the organizations that discover how to tap people's commitment and capacity to learn at all levels in an organization*".

A team case-study project-based approach was developed, to engage students in a simulated real-world experience. Real-world experience was perceived to be important for students' professional development as Engineers, and for encouraging students' perceptions of subject relevance. The important role of case-study based learning is derived from the students' own control of their learning, from identification of the problem, planning the process of investigation, evaluation of alternative solutions, regular progress reports which lasts the whole semester, and finally concluding the project on time. Our views on effectiveness of case study based learning were also shared by a panel of independent national and international reviewers, evaluated the 20 years project-based engineering education in Aalborg University, Denmark Tkjersdam [27]. They concluded that the graduates are more readily adaptable, with strong qualities in the field of problem shooting, cooperation, communication and synthesising project work.

To make students' achievement of the learning objectives possible, a wide variety of teaching and learning experiences were linked to case study based assessment approaches. The subject included three-hour face-to-face interactive classes and use of a subject web-site and the *TopClass* course management environment. We developed and tried student-focused learning strategies through facilitating group discussions both in class and online, emphasising the creation of an environment of collaborative team learning and reflection amongst the students. Table I shows the relation between learning objectives, teaching and learning activities and assessment in the subject.

In the first hour of the face-to face classes, brief lectures provided some reference information on the impacts of energy related decisions and actions on society and environments, as well as some appreciation of the important role of non-technological factors and interest groups in shaping the development of energy technologies. The lecture focused on developing students' understanding of key aspects of the subject, selected from a large body of multidisciplinary technical information. Presentation by the lecturer was interspersed with buzz group discussions and followed by students' active reflection on their own learning in a portfolio. The rest of the class time was allocated for team learning, presenting, assessing and reflecting on student-selected case study projects.

Students were encouraged to engage in scholarly team activities online, using the *TopClass* course management system. Students' individual weekly progress reports were submitted in *TopClass* to be reviewed and commented by other students. The reports were judged on the level of intellectual and imaginative powers, soundness, understanding, judgement, problem solving skills, ability to communicate and market/justify solutions and the ability to find relationships between what students have learned and to predict what will happen in future.

Assessment Mechanisms

Students' perceptions of assessment requirements are strongly related to their approaches to learning and learning outcomes [14][18][19][25]. Students focus on assessment requirements, so subjects which seek to develop students' graduate attributes must show how these are related to success in assessment tasks. Assessment approaches in this subject were aligned with the learning objectives for the subject, following the principles suggested by Biggs [18][25]. Table I shows the selected assessment tasks which guided and enhanced student learning, including a progressive case study, reflective journal and final examination. A critical process, which in many ways underpinned our whole approach, was the integration of critical reflection and the development of academic and professional attributes into the portfolio and case study. Self-assessment, peer, assessment, group assessment, class assessment, and lecturer assessment were a variety of approaches for assessment and feedback.

The case study projects where designed to be original, innovative, and individual, and were developed progressively over the semester. They focused on integrating the development of students' understanding of sustainable energy systems with the development of a range of professional and personal graduate attributes. Although the case studies were submitted by individuals, the process of developing them involved students in scholarly team activities including discovery, co-creation, analysis, synthesis, integration, and application of knowledges, taking into account the technological, environmental, economic, political, and social factors in their decisions. Students were formed into teams of four to five members. Each week, individual students prepared progress reports, which were presented orally and in writing to their team members for peer feedback. Academic reading and writing, and making the connections between the two, are complex processes which students were expected to demonstrate, drawing coherent conclusions from all of the sources. Feedback used to further improve their developing case study. The report was expected to identify energy problems from a number of different perspectives, to analyse, to gather evidence, to synthesise and come up with imaginative suggestions and short term/medium term/and long term recommendations. The report was judged on the level of intellectual and imaginative powers, soundness, understanding, judgement, problem solving skills, ability to communicate and market/justify solutions and the ability to find relationships between what students have learned and to predict what will happen in future. The final semester examination focused on assessing students' understanding of the basic design and analysis of energy conversion systems, drawing on understandings that were developed thoughout the case study process.

The reflective portfolio was used to encourage students to identify their own strengths and weaknesses, to reflect on their own performance and learning, to take notice of the feedback they received, to be systematic in using this information, and to make a commitment to attend to these issues in future tasks.

We recognised that it was challenging to assess portfolio and case study reports on the quality of the written work. Quality standards (assessment criteria) for assessing the quality of students' learning and skill development from the reports and case studies were developed in consultation with students. To develop these quality standards, students were encouraged to reflect on the qualities of scholarly works as identified in literature [28]. The list of criteria is given in Table II. Self-grading and assessment were used to develop a capacity in students to judge the adequacy of their work in meeting the standards. Students were invited to make judgments about the extent to which they met those criteria and standards and email their self-assessment form to us or post it on TopClass for further group discussions. The application of standards is a task which involves considerable critical thinking and the ability to select and interpret criteria in ways which allow them to be applied to the case study. Discussions in class and online assisted students were assisted in this process.

Regular feedback on student activities, as a central feature of learning, facilitated effective and deep learning, encouraged understanding, integration, and application of ideas in the self-selected case study, and supported their development as self-directed, lifelong, independent reflective engineers. Regular progress reports on case study projects were used to guide and promote student progress towards achieving learning goals. Timely, structured, consistent and informative feedback, and suggestions about techniques to improve student performance were provided from a range of sources (self, peers, group, and lecturer).

Developing students' ability to assess their own work is an essential skill for lifelong learning, and a desirable component of student-focused-teaching and learning. Self-assessment played an important role in encouraging student deep learning in this subject. Throughout the case study process, students were encouraged to develop the ability to be realistic judges of their own performance and to monitor their own learning effectively. Students were asked to identify what needed be learned, compare it with what was known, and apply this approach in the case study. The progressive nature of the case study allowed students to recognize how they were addressing the various elements of the assessment criteria (eg evidence of originality, critical review of existing literature, knowledge creation, integration and application, development, selection of an appropriate approach from analysis and evaluation of alternative solutions). The portfolio was an indication of students' capacity to reflect on and assess their own work.

Subject Evaluation

Our evaluation of the learner-focused approaches in teaching energy conversion was done to see how the new design of the subject was perceived by students and to improved the subject where necessary, in order to improve the learning outcomes for students. Multiple evaluation methods were triangulated to indicate the effectiveness of the approach in assisting and enhancing student learning. These included:

- Analysis of students' assessment responses. Student portfolios provided information about what students had learned and their capacity to reflect on their own learning. Students' case study reports provided information about their understanding of key aspects of the subject and their ability to apply their understandings in a realistic setting.
- Student surveys, to assess students' perception of different aspects of the subject.
- Student interviews, focused on students' perceptions on what they had learned and what aspects of the subject had helped them to learn.

Findings from each of these methods are reported below.

Portfolios

The analysis of portfolios provided a way of getting to know and learn from students, as well as evidence about the evolutionary process of their learning through the semester. In general, students' portfolios started with notes from lectures and relevant literature with little reflection. Later on, students included reflections on their goals, plans, processes for achieving milestones in case studies, performance, strengths and weaknesses, and responses to feedback. Finally they expressed their critical understanding of the sustainability principles in practice, only at later stages of the semester. This indicated that the benefit and necessity of reflective practices were noticed in the last quarter of the semester. While we will make changes to encourage more reflection earlier, we expect that we will continue to see a pattern of development through the semester.

Case study reports

The evaluation of case study reports indicated enhanced students learning when compared with case study reports done by students in other, less student-focused, subjects. The qualitative standards appear to have guided students learning and skill development. However, students had difficulties in quantifying social and environmental aspects, and in making a definite and justifiable decision in the design of a sustainable energy system. This is an aspect of the subject, which we will continue to modify with the aim of achieving better learning outcomes.

Student Feedback Survey

In conjunction with *the Centre for Learning and Teaching (CLT),* we designed a set of questionnaires to monitor students' perceptions of aspects of the subject designed to encourage their learning. The analysis of those responses is shown in Table III. Responses were largely very positive. We were particularly pleased that 88% of students seemed to see the value of the reflective exercises, 94% valued the case study, 87% felt they had been able to pursue areas of interest and fewer than 10% disagreed with the value of class discussions and group activities.

Student interview:

Students in Energy Conversion were interviewed at the beginning and the end of the course in order to evaluate the quality of their learning and skill development, and also their reactions to the group work and assessment procedures. They were asked to describe what they learned, and what aspects of the subject enhanced their learning.

Students' perceptions of learning and skill development in the subject

The result of the interviews showed that students perceived that they had gained and valued both understandings of the subject matter and broader professional and personal attributes. In terms of the subject of sustainable energy conversion systems, students generally perceived that they had gained:

1. Familiarity with the technology of power generation from a variety of renewable, non-renewable, and alternative energy sources including wind, hydro, tidal, solar (PV and thermal) energy, biomass,

geothermal, co-generation, combined cycles, advanced clean coal technologies, coal, oil, alcohol, or gas fired power stations, nuclear (fission and fusion), and fuel-cell technologies.

2. Awareness of the significance of global, Australian, and local issues in energy conversion, including privatisation, global warming, and CO_2 emission from different energy conversion systems.
3. Familiarisation with the concept of the global-picture of a sustainable paradigm as a desired value system to promote and shape appropriates action.
4. Understanding the significance of sustainable energy systems and implementing its principles through simultaneous consideration of technology, environment, economy and society factors in their case study projects.

In terms of broader skills and attributes, students perceived that the subject had assisted them to:

5. Gain the capacity to self-select suitable case studies project to demonstrate the quality and the quantity of their learning in the subject.
6. Develop their skills to analyse, synthesise, integrate, create, and reflect on materials and apply them in their case studies.
7. Develop skills in team working, and structured and constructive discussion.
8. Improve their self-discipline and the ability to self-organize.
9. Experience and appreciate different value-and-assessment systems through real-life simulation.
10. Develop their capacity to be a reflective lifelong learner and practitioner, through encouraging reflection in the reflective journal.
11. Take more responsibility and control for their own learning, using negotiated assessment standards as guides.

Interestingly, several students reported that in doing the subject they had learned things which they could discuss with their family members and the general public, indicating that they had perceived the broader relevance of the subject to society in general. Some also believed that they could make use of what they had learned to give themselves the edge in future job interviews.

Aspects of the Subject that helped Students Learning

Students used a wide variety of learning methods and reported that they developed skills through actively engaging in learning individually, with a peer, with a team, with the whole class, and through consultation with lecturers. Individual activities reported to particularly help learning included:

- Reading and searching widely [surveying literature, Internet, library, web sites, site visits, and private communications and contacts (eg. power station managers, Aboriginal studies staff in the UTS Indigenous Study Unit, etc]. , and analysing of their critical readings and reflections for their weekly reports
- Synthesis, integration, and application of their reflections in their case study.
- Weekly reflections of their personal experiences, noted in portfolios from lectures, handouts, external surveys and feedback.
- Critical reflection on the evolution of their proposed learning contract for the case study.
- Preparation of their weekly oral and written progress reports.
- Self-assessing against learning criteria.
- The need to compare and justify alternative solutions for energy problems.

Peer or team activities most often reported as helpful were:

- Learning from each other in-group discussions during the weekly presentation of progress reports.
- Consultation with their classmates and lecturer (in class, through email, phone, web site, and Topclass.
- Feed back from their own reflections, their peers, their team, their lecturer during interviews and during their weekly oral presentation, and progress reports.
- Critically reflecting on, observing, listening to, questioning, and assessing peers' case study projects.
- Transparent online peer review and discussion processes which enabled students to read each other’s work and gain feedback.

Conclusions

Developing the subject to emphasise sustainability and use student-focused approach to teaching and learning was a challenge which proved well worthwhile. Our own reflections on the experience of teaching the subject and analysis of both portfolios and case studies, together with student interviews, and questionnaire results gave us a clear picture of the effectiveness of the subject. Our overall conclusions were:

- Students had developed their understanding of the complexity of sustainability and their valuing of sustainability as an important aspect of Engineering.
- Students' assessment results showed that they had achieved the overall learning objectives for the subject, including those related to the specific content and professional and personal attributes.
- Students clearly enjoyed and learned from the challenges faced in the subject.
- Students agreed that the student-focused-approach enhanced their learning and skill development.
- We and they perceived that they learned effectively through developing their reflective portfolio.
- They enjoyed the flexibility of choosing a case study in the area of their interest.
- They appreciated being treated as adult learners and being consulted throughout the subject design and evaluation.
- The quality and quantity of learning improved over similar but more strongly content-oriented subjects.
- Students commented positively on their experience of team working and team learning,
- Colleagues in the Faculty were approached by students who requested similar approaches in their subjects.

As the above points indicate, there were many benefits for students in the way that the subject was designed and implemented. Alignment of the learning objectives, teaching and learning activities and assessment meant that students perceived understandings of sustainability and the development of graduate attributes to be valued and they responded accordingly. This differed considerably from the experience in many Engineering subjects where assessment focuses students' learning on narrow technical content and tacitly encourages them to ignore or devalue broader learning objectives. Student portfolios described how developing their skills in reflective critical learning changed their understanding of concepts and their conceptions of learning. These indicators showed positively that the subject had achieved many of its goals. Difficulties experienced by students related to their relative lack of familiarity with the reflective and team-based components of the subject. By the end of the subject they strongly valued the learning which came from team activities, but on the other hand, it was clear that some students found their early experiences in the teams unsettling. As a result, we now recognize a need to spend more time on developing student confidence and expertise in teamwork, both in prerequisite subjects and in the future offering of the subject.

For the subject lecturers, there were also benefits and disadvantages. The major benefit was the satisfaction gained from improving students learning and seeing them developing the professional and personal attributes required of good Engineers. The main disadvantage was that the initial development and implementation of student-focused approaches in the subject was very time intensive. Effective student learning outcomes were achieved but involved considerable consultation, attention, and prompt response and feed back, especially online through *TopClass* outside of class hours. However, we believe that much of this time related to issues arising during the first offering of the subject, such as team anxiety, which can be addressed in future offerings of the subject. Any new approach to teaching requires a commitment of learning time by teachers, and we are confident that this additional time commitment will reduce as we gain more experience in student-focused approaches learning and teaching.

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Table I. Relation between learning objectives, teaching and learning activities and assessment in Energy Conversion

Learning objectives - which are related to the desired graduate attributes	Teaching and Learning activities	Assessment techniques
• Understanding the basic design of energy conversion systems, in the context of relevant environmental, economic, social, and technological factors. • Appreciation of different value systems • Problem formulation and problem solving. • Understanding and selecting relevant information • Self-management skills (e.g. time-management, professional skills and self-discipline) • Critical reflection, Communication skills • Knowledge creation, creativity, innovation, and originality • Evaluating, organizing, and structuring information • Research methodology, research widely • Professional skills (Critical evaluation, judgement and decision making, and team working) • Independence and self monitoring	• Buzz-group discussions • Original, innovative, and individual case study projects • Team discussion, review and reflection • Active reflection on learning and learner-focused strategies • Co-create and understanding of the quality standards. • Responsive feedback • Interactive lecture segments emphasizing the multi disciplinary and changing nature of the subject with technical factors influenced by social values and governmental regulations	• Staged case study project with Seminar presentations Regular written reports Self, peer and lecturer feedback • Reflective Journal • Interview • Final Examination

Table II: Qualitative standards for the case study

- Understanding what was required
- Clear goals and objectives.
- Definition, introduction and identification of problems.
- Adequate preparation, wider search, evaluation, justification and significance of the case study objectives.
- Appropriate methodology for investigating and resolving the problem, and making comparisons with alternative methods and techniques.
- Significant results through exploring the full potential range of solutions.
- Reflective critique, learning from mistakes and misconceptions.
- Effective oral and written presentation.
- Contribution in improvement and education of both self and team members. Co-creation of innovative ideas and techniques in team.
- Participating actively in debates with stimulating comments and suggestions.
- Challenging team members with ideas and helping them to apply those ideas in their case study.

Table III. Student feedback survey to evaluate the effectiveness of the course (no of responses: 34): Percentage Strongly agree (SA), Agree (A), Neutral (N), Disagree (DA), Strongly disagree (SD)

Survey Questions	**SA %**	**A %**	**N %**	**DA %**	**SD %**
Class discussion was a valuable part of the course.	30	42	18	9	0
Exercises which required me to reflect on my own experiences made the subject more relevant.	38	50	9	3	0
Students were encouraged to learn from each other	44	53	3	0	0
The methods of assessment used were appropriate for the subject	12	61	9	12	6
There were sufficient opportunities for students to pursue areas of interest in the subject	42	45	9	0	3
Group activities assisted my understanding	24	48	21	6	0
The case study was a valuable part of the subject	55	39	6	0	0
Assignments encouraged me to read widely	36	58	6	0	0
It would be possible to pass this subject by just working hard around exam time.	9	3	9	24	56
All thing considered, I rate this subject flexible.	39	24	27	6	3

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