TEACHING STRENGTH OF MATERIALS AT DISTANCE:

INSTRUCTIONAL DESIGN

FOR

A COMPUTER-BASED SOLUTION

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Gamini A. K. Padmaperuma

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Abstract

The concern of the academic staff at the Open University of Sri Lanka (OUSL) regarding the continued poor student performance in a core course in engineering (Strength of Materials) has prompted the researcher to undertake a research to solve this problem. Solutions to the student performance problem were sought using a general approach known as ADDIE (Analysis, Design, Development, Implementation, and Evaluation) process and the specific instructional model of Smith and Ragan. Analysis phase identified the learner profile and specific learner needs and they also pointed to a computer-based solution. The analysis of the learning task was done using the Revised Bloom's taxonomy (RBT) and it resulted in a set of classified learning objectives. This classification helped in the selection of instructional strategies that were incorporated in the design of the CAL module. The identified learner profile and the learner needs were also considered in the design. An evaluation on the effectiveness of the CAL module showed that there has been a highly significant improvement in the student performances. Other evaluations carried out on the use of the CAL module and its user-interface also produced high satisfaction ratings. As result of this research a tested model for CAL module development to address learning performance problems at the OUSL and elsewhere has been produced. Also, a draft framework for selecting instructional strategies to suit different learning outcomes has been introduced as an outcome of this research.
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Chapter 1

Introduction

1.1 Background

Strength of Materials is a core course in many engineering disciplines. It is an analytical course requiring good mathematical skills and understanding of abstract concepts making it particularly unpalatable and difficult for those learning this at distance. Continued poor student performance in a first course in Strength of Materials has been a concern for those who teach this course at the Open University of Sri Lanka (OUSL). While the students follow this course in English, their medium of instruction at school is in the vernacular. They often find this transition in the medium of instruction challenging, and it is particularly so in the technical courses due to their lack of exposure to technical vocabulary.

The student performance in this course is comparatively low among the courses at the same level with a failure rate of more than 50% in the period between 1999 and 2002. This served as the motivation to undertake research to formulate a suitable strategy for improving the learning of such analytical courses through distance. The researcher's awareness of this performance problem gained during his previous employment as a member of the academic staff at the OUSL and his personal interest to find a solution to this problem also influenced this undertaking.

The Open University of Sri Lanka (OUSL) was established in 1980 by an act of Parliament. It is the only recognised university in Sri Lanka where students are able to pursue further education by distance. The OUSL enjoys the same legal and academic status as any other national university in Sri Lanka. It has over 20,000 students with varied profiles spread throughout the country. About 85% of its students are employed. The main campus of the OUSL is located just outside the capital and four regional centres and sixteen study centres are located throughout the country to serve the students around those areas. The main teaching
methods used are printed material and audio visual aids. In addition to the use of these methods, the students are supported with face to face discussions, day schools, consultancy sessions, tutor clinics, laboratory sessions, seminars, etc. but these are limited due to the high cost of human resources. The OUSL has four academic faculties, namely, Engineering Technology, Natural Science, Humanities and Social Sciences, and Education. These faculties offer about 40 programmes of study leading to Certificates, Diplomas, Degrees and Postgraduate Diplomas and Degrees. The Faculty of Engineering Technology, among other programmes, conducts undergraduate programmes leading to Diploma in Technology and Bachelor of Technology awards in Mechanical Engineering, Civil Engineering, Electrical and Computer Engineering, Agriculture and Plantation Engineering, and Textile and Apparel Technology.

1.2 Overview of the study

The researcher’s background as an Industrial Engineer and his familiarity with various general performance improvement tools and techniques encouraged him to look for ways to solve this performance problem of the students at the Mechanical Engineering department of the OUSL. However, he was not aware of any methods or techniques relating to performance improvement specifically in education. Although this presented a challenge to the researcher, he was confident of finding a solution as he believed that there would be many common approaches to performance improvement that work across different fields.

In searching for an approach to solve the performance problem, current literature relating to the engineering education was reviewed. This review revealed two foci in engineering education research, namely, teaching methods and use of computers. Also, two major trends in engineering education were identified: increasing prominence gained by the distance education and the shift of focus from teacher-centred learning to student-centred learning. In addition to these findings the survey also revealed, a major concern among the engineering educators that insufficient effort was devoted to designing instructions in engineering. All these findings reassured the researcher of the relevance of searching for a solution to the identified performance problem.
Consequently the researcher started looking for typical approaches used in education to address learning performance problems. In this effort, a process known as ADDIE (Analysis, Design, Development, Implementation, and Evaluation) was found. This process was found to be popular among the instructional designers and has been used as the basis of many instructional design models. The researcher too was in favour of using the ADDIE process due to its logical structure and generic nature and adopted it for use in this study. It should be noted here that in addition to the findings from the literature survey, the potential of computers in addressing the problem became apparent to the researcher through his personal experience. In this connection, pilot studies were conducted at the OUSL and the University of Canterbury to evaluate the student perception about using computers in their learning. All students responded very favourably towards the use of computers in their studies. This encouraged the researcher to consider computer-aided learning as a possible approach to addressing the performance problem.

While the ADDIE process was adopted as the overall approach for finding solutions to the problem, a need for a specific instructional design model to guide the design effort was felt. After reviewing a few models in the literature, Smith and Ragan’s model, which is also based on the ADDIE process, was selected for use in this study due to its clear guidelines and descriptions of the instructional design process and instructional strategies. This model emphasises the importance of the analysis phase in the instructional design process. The analysis phase includes the analyses of the learning context, the learners, and the learning task (task analysis). Analyses of the learning context and the learners produced useful information about learner profiles, learner needs which need to be considered in the design of instruction. These analyses also pointed to a computer-based solution due to limited resources available for human tutor support at the OUSL and a decision was made to adopt a computer based solution.

The question then arose, how is a computer based solution designed, following the model of Smith and Ragan. The learning task associated with the performance problem has to be analysed and classified, and instructional strategies need to be selected for designing instructions. The task analysis is considered the most crucial component in the analysis phase.
An appropriate tool to classify the learning objectives identified through the task analysis was needed. The search for a suitable tool for use in the task analysis was launched. In this search, the revised Bloom’s taxonomy (RBT) was found. The RBT had just been published then. The RBT attracted the interest of the researcher initially due to its novelty and then due to its detailed and clear descriptions, which facilitate its application to task analyses. However, it was not clear how well the RBT could inform task analysis as, according to the researcher’s knowledge, there were no prior applications of it to task analyses in the literature. Therefore, the suitability of the RBT for the task analysis through its application to the learning tasks associated with this study became an interesting question. The researcher considers the selection of the RBT for task analysis a major turning point in this study.

Then the selected tasks were analysed and the resulting learning objectives were classified using the RBT. The RBT classification of objectives introduced two dimensions to an objective, type of knowledge and cognitive process. During the search for instructional strategies it was not initially clear how the two dimensions of the learning objectives (outcomes) affect the choice of instructional strategies used to teach them. The available strategies for the learning objectives were mostly named according to the type of knowledge but they seemed to be more dependent on the cognitive process. This led to the question how the individual dimensions of a learning outcome (objective) are related to the instructional strategies.

The search of the literature indicated that the instructional strategies are generally based on a combination of both, the type of knowledge and the cognitive process. Accordingly, it was possible to select instructional strategies for different learning objectives classified using the RBT’s two dimensions. The strategies thus selected were used in the design of the computer-aided learning (CAL) module. Many of the user needs identified in the analysis phase were also considered in the design of the CAL module. However, the effectiveness of the CAL module developed in solving the original performance problem, was uncertain. Therefore, evaluations were conducted to find the effectiveness of the CAL module in addressing the performance problem. A questionnaire and a usability test were also administered to evaluate the overall satisfaction of the users with the CAL module and its user-interface.
1.3 Aim of the study

The search for a solution to the student performance at the OUSL has thus led to the following three interesting research questions, and addressing these questions constitutes the overall aim of this thesis.

1. In what ways does the Revised Bloom’s Taxonomy inform Task Analysis?
2. What is the relationship between the type of learning outcome and the instructional strategies used to achieve that learning outcome?
3. What is the effectiveness of the computer-based instruction?

1.4 Contents

The Chapter 2 deals with the findings of the literature review relating to the topics leading to task analysis. (The literature review relating to task analysis, design and development, and evaluation is presented in respective chapters). The findings of this review pointed to a lack of pedagogical input in instruction and a need for systematic design of instructions in engineering education. The identified performance problem was then analysed and further explorations were made by analysing the learning context and the learners, to search for instructional solutions to address the performance problem - these analyses are explained in Chapter 3 (Exploratory studies). The analysis of the learning task which is a major consideration in designing instructions is explained in Chapter 4. This chapter answers the first research question. Chapter 5 explains the details of the design and development process of the computer-based instruction and addresses the second research question. The evaluation of the effectiveness of the developed computer-based instruction is dealt with in Chapter 6, providing an answer to the third research question. Finally, the Chapter 7 presents the conclusions, limitations, and suggestions for future studies. Some of the references described in the Literature Review chapter are also mentioned again in other chapters. This has been done to emphasise certain points in the context of the other chapters.
Chapter 2

Literature Review of Topics Leading to Task Analysis

This chapter presents the literature review on topics leading to task analysis, and the literature relevant to task analysis and the Revised Bloom's Taxonomy is covered in Chapter 4: Task Analysis. The literature relevant to design and development, and evaluation is presented in Chapter 5: Design and Development and Chapter 6: Evaluation, respectively. Based on the findings of the literature review presented in this chapter, two research foci and two major trends in engineering education were identified. Along with the findings an instructional design issue was also identified. In order to address this issue, relevant learning theories and instructional design models are reviewed. Based on the findings of this review, an instructional theory and instructional design model are chosen for addressing the identified issue.

2.1 How the literature review was conducted

First, analyses or surveys conducted on research and trends in engineering education were searched. In this search, a few analyses carried out by the Journal of Engineering Education were found. These analyses pointed to some research foci and issues in the engineering education. Articles in two other major engineering education journals, namely, International Journal of Engineering Education and Journal of Computer Applications in Engineering Education were reviewed and the existence of the identified issues was confirmed. In addition to the above, various other relevant literature were also reviewed and some emerging trends in engineering education were identified.

2.2 Current research foci and trends in engineering education

Based on the literature review two research foci and two major trends were identified. The two research foci are i) teaching methods, and ii) use of computers in engineering education, and
the two major trends are i) increasing prominence for distance learning, and ii) shift of focus from teacher-centred learning to student-centred learning.

The two research foci were identified through the two analyses carried out by Wankat (1999a and 2004) of articles published in the Journal of Engineering Education. In his analyses, three keywords representing the areas of research in engineering education were identified. They are teaching, computers, and design. Teaching implies the existence of a teaching component in the article. Computers imply the use of computers, computer software and other computer facilities (e.g. Internet) in engineering education. By design what was meant is the area of engineering design. In this study, only teaching and computers will be further considered as research foci due to their direct relation to teaching and learning.

Wankat (2004) elaborates that the articles categorised under teaching keyword included many teaching methods and the most popular teaching methods during 1993-1997 and 1998-2002 periods were cooperative group learning and computer-based learning, respectively. Whitin and Sheppard (2004), who conducted a similar study report that the common topics included under teaching category were teaching methods and strategies, educational theories, group learning techniques, use of technology, and distance education. Wankat (2004) also states that an increasing number of articles focused on student assessment and ABET (Accreditation Board for Engineering and Technology). The increasing popularity of the term assessment indicates the engineering educators’ growing awareness of the importance and the sophistication in assessment methods in engineering education (Wankat, 2004). Appearance of ABET as a popular term is a reflection of the ongoing course and curriculum redesign in engineering education and the emphasis on accreditation process which is intended to ensure that all engineering graduates possess necessary technical and communication skills and they understand contemporary issues, professional and ethical responsibility, and the impact of engineering solutions in a global/societal context (Whitin and Sheppard, 2004; Felder, 1998). Interestingly, Wankat (2004) also states that although 60 percent of the articles included a teaching component, only about 13% of these articles used an educational theory. This indicates that the engineering educators are concerned about the quality of teaching in engineering institutions and yet they do not look at it from an educational viewpoint using any
relevant educational theories, etc. Whitin and Sheppard (2004) too confirmed this position based on their analysis of articles published in the Journal of Engineering Education during 1996 and 2001. They recommended to engineering educators that they continue to be innovative and imaginative in their work of designing the educational systems for future engineers.

The second research focus identified by the literature review is computers (Wankat, 2004). The increasing use of computers in engineering education has obviously caused computers to be another keyword commonly used in engineering education research literature. It is observed, that computers are used in engineering education at least in two ways. One way is to use them as a tool for computing (numerical analysis), designing, simulating, etc. and the other is their use in computer-based tutorials and drill and practice sessions. Gagne and Driscoll (1988) emphasise that instructional functions performed by other media can be combined by the use of a computer and suitable software. Gagne and Driscoll (1988) also state that computer is by far the most versatile equipment for instruction. Further, a study conducted by Bitter and Wighton’s (1987), which produced a ranked list of characteristics of quality educational software, listed pedagogical considerations as the second most important one (the correctness of the content was the first) out of a list of 22 characteristics. While the importance of using computers in engineering education is recognised, the engineering educators are of the view that sufficient review and design are not applied in their use (Marks, 2002).

Review of literature under both identified research foci points to a lack of pedagogical consideration in teaching and use of computers. Review of publications in two other major journals of engineering education, namely, the journal of Computer Applications in Engineering Education and the International Journal of Engineering Education (IJEE), also confirmed this observation.

Three separate searches on full texts and abstracts of the journal of Computer Applications in Engineering Education were carried out using phrases “computer aided learning”, “learning theory”, and “instructional design”. They produced 13, 21, and 32 results, respectively. Analysis of these results identified only one single article which referred to a learning theory.
Further, the review of articles published between 1994 and 1998 in the International Journal of Engineering Education (IJEE) identified only two articles that carried any reference to a learning theory or a pedagogical issue. This indicates an enormous gap in the literature on pedagogical considerations in the design of instruction in engineering education.

Further review of relevant literature identified two major trends in engineering education. They are i) increasing prominence gained by distance education, and ii) shift of focus from teacher-centred learning to student-centred learning. These trends too appeared to have an influence over the above issue and are relevant to the researcher's objective of finding a solution to the problem in teaching Strength of Materials at a distance.

According to Hurst (2001), distance education, which was traditionally a peripheral activity, is now recognised by educational institutions as a vital factor in teaching and learning. He states that distance learning is gaining prominence and moving from periphery to the centre of educational institutions. Bates (1997) states that the word distributed learning is used frequently in place of distance learning. He elaborates that distributed learning, which is a student-centred approach, integrates all campus-based, open and distance learning while using appropriate technologies for different situations while satisfying needs of diverse student populations. Bates (1997) argues that the distinction between distance and campus-based learning is becoming blurred, the two types of learning converge. CAL is a powerful approach to learning that is useful in both on-campus and distance learning, i.e. distributed learning. Properly designed CAL can benefit both on-campus and distance learners.

The second trend identified in engineering education is the shift of focus of teaching and learning, i.e., the education is changing from a teacher-centred one to a student-centred one, which relies on successful self-learning practices. According to Jean (1995), self-learning environments are important for first education, life-long education and professional development of engineers. Jean (1995) emphasises that engineering educators need to imagine, create and develop methodological and pedagogical components of a new educational perspective for the education and training of future engineers. According to Kim and Sena (2001), through its unique ability to interact directly with the individual learner, technology
can be used as means to create new teaching-learning paradigms. McDowell (2001) argues that with modern information technology CAL can be an alternative to lectures and laboratory classes. However, according to Broadland and Welstead (1991), students like to see CAL only as a supplement rather than an alternative to traditional teaching methods, such as face-to-face meetings. The findings of the present study too confirmed this position of the students.

It is now appropriate to further investigate into the issue of lack of pedagogical considerations in the design of instructions in both traditional teaching and teaching using CAL materials. The importance of this issue is increased in light of the two major trends identified as they are also associated with the use of CAL materials in accomplishing their objectives. For need of an abbreviated version, the issue will be called improper design. The issue of improper design will be further discussed using following sub-issues. They are i) futile media comparisons, ii) debate over media vs. design, and iii) Lack of training in and insufficient priority for instructional design.

Comparison of media to measure their effectiveness on learning outcomes has been found futile. Many studies (e.g., Merino and Abel, 2003; Lockee et al., 1999) have been conducted to compare the effect of different media might have on learning outcomes. Most of these studies, known as “media comparisons” in the literature, have produced “no significance” results, suggesting that the type of medium used to deliver instruction does not significantly impact the learning outcome. Lockee et al. (1999) state that media comparisons are now an issue of the past as in the field of instructional technology comparisons of media to measure their effectiveness on learning outcomes are well recognised as futile.

There is however an ongoing debate over whether medium has an effect on the learning outcomes in addition to effect the design has on them (Lockee et al., 1999). Timothy and Maxine (2001) also emphasise that although multimedia is intuitively attractive as an enhancement to learning there are no reliable research findings to indicate significant benefits despite the many studies conducted. Lockee et al. (1999) suggest that it is the instructional method that impacts the learning outcomes most.
It is observed that improper design is also caused by the engineering educators’ lack of training in instructional design and insufficient priority given to instructional design in terms of time and effort. Bates (1997) emphasise that academics are often driven by the attraction of a particular technology and they often do not recognise or accept the need for instructional design. Shellnut and others (1999) attribute the deficiencies in CAL materials to the fact that they are developed by faculty developers who are experts in their engineering fields but are not experienced in instructional design. They emphasise that faculty developers need consistent guidelines, standards, or professional support for the design and development of effective CAL materials. Wankat (1999b) stresses the importance of training the engineering professors in pedagogy, which they presently lack, and the benefits pedagogy brings to teaching and learning. He elaborates that in order for engineering instructions to be effective they need to be given attention to an extent that is similar to what design engineers give in ensuring design quality, detail, and completeness. However, Marks (2002) argues that engineering academics do not spend sufficient time and effort and often do not consider all aspects of learning experience in designing instructions.

Through the foregoing discussion the need for proper design of instruction to improve learning outcomes is recognised. It then becomes relevant to look at how instructions can be properly designed and delivered. The process of designing instructions is known as Instructional Design. Barry (1992) describes instructional design as a procedure and framework for systematically planning, developing, and adapting instruction based on identifiable learner needs and content requirements. Smith and Ragan (1999) defines Instructional Design as ‘the systematic and reflective process of translating principles of learning and instruction into plans for instructional materials, activities, information resources, and evaluation’. Smith and Ragan (1999) also state that instructional design is about promoting cognitive processes that lead to learning. Therefore, instructional designers need to be interested in principles of learning or learning theories; those theories that attempt to describe, explain, and predict learning. It becomes then worthwhile to look at the role of learning theories that impact the process of designing instructions.
2.3 Learning theories

In this section, various categories of learning theories and their relevance to designing instructions are reviewed. Different categories of learning theories are compared and contrasted to determine the learning situations that will benefit most from one category or another.

Learning theories provide different strategies for achieving educational goals. According to Gagne and Driscoll (1988) learning theories provide an explanation of several specific facts that have been independently observed, by relating these facts to a conceptual model. There are numerous learning theories developed by various researchers in the field of education. Leonard (2002) has done an extensive research over several years and categorised the learning theories under four main learning theory schools, namely, Behaviourism, Cognitivism, Constructivism, and Humanism. Of these, most common are the first three, Behaviourism, Cognitivism, and Constructivism. Leonard (2002) has described the typical features of each of the learning theories and pointed out the main variations among them. Nevertheless, he emphasised that each of these learning theories is duly recognised and applied in appropriate teaching and learning settings.

The three learning theories, Behaviourism, Cognitivism, and Constructivism are discussed in sections 2.3.1 through 2.3.3.

2.3.1 Behaviourism

In this section, first the main characteristics of behaviourism will be explained. A typical design of a learning activity using behaviourist approach will then be explained and learning situations that suit behaviouristic approach best will be identified. Finally, the events that led to the search of alternative learning theories to behaviourism are explained.

According to Leonard (2002), behaviourism is the belief that instruction is achieved by observable, measurable, and controllable objectives set by the instructor and met by the learners who elicit a specific set of responses based upon a controlled set of stimuli.
Behaviourism does not concern itself with the learner’s mental states. Considered the “grandfather of behaviourism,” B.F. Skinner generated much of the experimental data that serves as the basis of behavioural learning theory (Roblyer, 1997). In behaviourism, the mind is viewed as a “black box” meaning that response to stimulus can be observed quantitatively, totally ignoring the possibility of thought processes occurring in the mind (Good and Brophy, 1990).

Chen and Hung (2003) illustrate how learning activities for a given instructional objective can be designed under different learning theories. The example they have used is as follows: Given two numbers (no greater than ten), students will be able to recall the product of two numbers without hesitation (less than one second). Their example focuses on how students memorise the multiplication table. Chen and Hung propose the following behaviourist design for the learning activity to achieve the learning objective: The teacher gives the students printouts of the multiplication table (stimulus). Then the teacher will move the students systematically from the easier to the more difficult tasks, for example, first focus on one’s and ten’s, then the ‘five’s or two’s, and subsequently the others. Students are tested on the multiplication table (response) everyday until they master it. Some reward system is set up to encourage to students to perform well at tests (reinforcement). According to Chen and Hung (2003), the behaviourist approach is most effective when there are absolutely no rules to follow or rely on or when the purpose is to memorise the rules and the only way to learning is through rote memorisation. Examples of such situations include memorising the number sequences, recalling names of objects and recognising alphabets. Usually, very little high-order thinking (e.g., compare and contrast, synthesis and problem-solving) from the student is required (Chen and Hung, 2003).

Bandura and Walters (1963) argued that an individual also could model behaviour by observing the behaviour of another person. This theory led to Bandura’s Social Cognitive Theory. According to Roblyer (1997), the mere emphasis on the observable outcomes or behavioural changes was also not acceptable to many educational psychologists. They were not agreeable to the treatment of human mind as a “black box” which ignored the possibility of thought processes occurring in the mind. The behaviourists’ view that stimulus-response
learning alone could form the basis for building higher-level skills too was not acceptable to them. As they focussed on capabilities such as rule learning and problem solving, they became more concerned with the internal process (those inside the brain) that went on during learning (Roblyer, 1997).

The research of cognitive theorists led to the development of Cognitivism.

2.3.2 Cognitivism

Under this section, the birth and the main characteristics of cognitivism will be explained. Then a typical design of a learning activity using cognitivist approach will be explained and the learning situations that suit cognitivist instructional design best are identified. Finally, the fundamental differences between objectivist learning theories (behaviourism and cognitivism) and constructivist learning theories are discussed and this serves as an introduction to the section on Constructivism.

According to Good and Brophy (1990), during the 1950s and 1960s, a group of researchers known as the cognitive theorists began to hypothesise explanations for learning that focus on the internal mental process people use in their effort to make sense of the world. Cognitive theorists while accepting some of the behaviouristic concepts, viewed learning as involving the acquisition or reorganisation of the cognitive structures through which humans process and store information (Good and Brophy, 1990). Roblyer (1997) state that the information-processing theorists were among the first and most influential of the cognitive theorists. They hypothesised processes inside the brain that allow human beings to learn and remember (Roblyer, 1997). Information-processing theorist, David Ausubel (1968) recommended that teachers could take the advantage of the “cognitive structures” around which information is organised in the brain by using “advance organizers” to bridge the gap between what the learner already knows and the new information.

Roblyer (1997) states that cognitivism is fundamentally based on the assumption that the human mind works like a computer when thinking and learning. It is assumed that the human
act of learning consists of three components analogous to the parts of a computing process: input variables (information to be learned), a “processing component” consisting of executive controls (such as attention and expectancies) working in conjunction with short-term and long-term memory, and output variables (outward indications that a process has taken place) (Roblyer, 1997). Leonard states that cognitivism focuses on the accurate transmission of knowledge of the objective reality of the world from a teacher (expert) to students. He elaborates that success is achieved when, at the end of the lesson, the students have the same mental construct of the objects being studied as that of the teacher. Cognitivism is considered a powerful force in delineating how humans think, learn, transmit information and solve problems (Leonard, 2002).

According to Roblyer (1997), Gagne built on the work of behavioural and information-processing theorists by translating principles from their learning theories into practical instructional strategies that teachers could employ with directed instruction. Gagne’s well-known three major contributions in this area were i) the events of instruction, ii) the types of learning, and iii) learning hierarchies (Gagne et al., 1992). Roblyer (1997) states that these and similar contributions by others are known as systematic instructional design or systems approaches to designing instructions. According to Dick (1992), the major principles of systematic instructional design have been derived from Skinnerian psychology and Gagne’s conditions of learning.

Chen and Hung (2003) also illustrated a design of learning activity of multiplication tables using a cognitivist approach. They propose the following cognitivist design for the learning activity to achieve the learning objective: The teacher will identify patterns, rules or principles first. From his own expert experience, the teacher will teach students the most effective/efficient way of memorising the table. These may include rules and patterns that help the students to memorise the multiplication table better. For example, the teacher could begin the lesson by directing students to observe the inter-changeability or associative relationship of two numbers (e.g., 9 X 6 = 54, 5+4 = 9). Every time a pattern is introduced, students will be asked to answer questions related to the pattern until they fully understand
what the pattern means and how to apply that pattern to their learning of the multiplication table.

According to Chen and Hung (2003), the cognitivist approach is best to provide when the domain of knowledge is too complex for students to explore and grapple independently. They also state the interplay between students' current level of understanding and the potential level of understanding with assistance from the more capable ones is an important factor for the teacher to decide whether or not to employ this approach.

According to Duffey and Jonassen (1992), both behaviourism and cognitivism fall in to the objectivist class of theories. They also state that objectivist cognitivist psychology is explicit about the independent existence of information and the acquisition of that information. Understanding is seen as being composed of a knowledge base in the form of an expert model. Constructivism, on the other hand, provides an alternative to this thinking. Constructivism, however, like objectivism, holds that that there is a real world that we experience. However, the argument is that meaning is imposed on the world by us, rather than existing in the world independently of us. According to constructivist view, there are many ways to structure the world, and there are many meanings or perspectives for any event or concept. Thus there is not a correct meaning that we are striving for (Duffey and Jonassen, 1992).

The alternative thinking about the existence of many meanings and perspective for any event or concept and that meaning is imposed on the world by us rather than its independent existence, led to the development of Constructivism.

2.3.3 Constructivism

Under this section, the main characteristics of constructivism will be explained. Then a typical design of a learning activity using constructivist approach will be explained and learning situations that suit constructivist instructional design best are identified.
Change from cognitivism to constructivism has been quite substantial as compared to the change from behaviourism to cognitivism as both are objective in nature. Behaviourism and cognitivism both support the practice of analysing a task and breaking it down to manageable chunks, establishing objectives, and measuring performance based on those objectives. Constructivism, on the other hand, promotes a more open-ended learning experience where the methods and results of learning are not easily measured and may not be the same for each learner.

According to Leonard (2002), constructivism is the belief that learners, having some prior knowledge and experience as a basis from which to test out their hypotheses, build their own set of content to solve a particular set of problems posed by the instructor. Constructivism is a learner-centric educational paradigm, in which content is constructed by the learners rather than by the instructor. Leonard (2002) also states that under constructivist learning paradigm, the instructor is no longer a primary intermediary and single conduit of knowledge between the learners and the learning experience. Perkins (1992) emphasises the “active learner” component of constructivism. He argues that the learner is an active processor of information but more importantly that the learner elaborates upon and interprets the information.

According to Roblyer (1997), one of the pre-eminent examples of constructivism commonly cited in the literature is Bruner’s Discovery Learning theory. Discovery learning theory is based on the assumption that learners are better positioned to remember concepts if they discover about them on their own (Roblyer, 1997). Leonard (2002) states that, on the other hand, under cognitivism, it is the instructor who prepares and delivers the instruction without leaving any room for learner discovery. However, Discovery Learning theory works on the assumption that the learners are mature self-motivated and experienced enough to actively participate in such learning style. The opposite of discovery learning occurs when the instructor does so much shaping and structuring of the content (as occurs in many learning theories under cognitivism) that little room is left for the learner’s own self-discoveries, errors, adjustments, and enhancements (Leonard, 2002).
Chen and Hung (2003) also illustrated the design of learning activity of multiplication tables using constructivist approach. They propose the following cognitivist design for the learning activity to achieve the learning objective: In contrast to cognitivist design of the learning activity, a constructivist teacher would expect the students to find and discover the patterns or rules of the multiplication table rather than being taught. One possible approach is to give students printouts of the multiplication table. The activity is then for students to discover patterns of the table by themselves. The teacher will guide students by asking questions. If the students cannot find the patterns, the teacher may further provide hints to the students. These hints serve as scaffolds in the initial stages and will eventually be removed once students have discovered the patterns. According to Chen and Hung (2003), the constructivist approach is best employed when the new knowledge to be learned is not too much beyond the student’s current level of capability. Most students with a little effort should be able to discover meanings of the topic. They also state that the teacher would not teach the rules or patterns directly. Rather, teacher’s role is to facilitate students’ discovery and to ask questions to steer their directions in explorations.

Now that each type of learning theory has been reviewed, it is appropriate to review their varying characteristics to determine their applicability to different learning situations.

2.3.4 Discussion about the three learning theories

It would be useful to compare the three theories first.

Chen and Hung (2003) provide a useful summary of the learning theories and their general orientations. This table can serve as an aid to designing learning activities under different approaches based on learning theories. Table 2.1 is an adapted version of Chen and Hung’s Summary of Theories of Learning table.
Table 2.1: Learning theories and their general orientations

<table>
<thead>
<tr>
<th>Learning Theory</th>
<th>General Orientations</th>
</tr>
</thead>
</table>
| Behaviourism    | • Stimulus and response  
|                 | • Students remember and respond. (Change in overt behaviour due to conditioning.)  
|                 | • Teachers present and provide for practice and feedback |
| Cognitivism     | • Information transmission and processing  
|                 | • Students remember strategies, rules, patterns  
|                 | • Teachers plan for cognitive learning strategies |
| Constructivism  | • Personal discovery of knowledge  
|                 | • Students discover relationships between concepts  
|                 | • Teachers provide instructional context and guide students to discover |

Cognitivism supports the use of models for use in the systems approach to instructional design. However, constructivism does not easily lend itself to the present systems approach to instructional design. Although Constructivism is not considered a prescriptive theory, Jonassen emphasises that it should provide more explicit guidelines for creating learning environments to support constructivist learning (Jonassen, on-line 1).

According to Jonassen (on-line 1), the difference between constructivist and objectivist (behaviourist and cognitivist), instructional design is that objective design has a predetermined outcome and intervenes in the learning process to map a pre-determined concept of reality into the learner’s mind, while constructivism maintains that because learning outcomes are not always predictable, instruction should foster, not control, learning. In this context, Jonassen looked at the commonalities among constructivist approaches to learning to suggest a “model” for designing constructivist learning environments (Jonassen, on-line1). Perkin (1992) states that while behaviourism and constructivism are very different theoretical perspectives, cognitivism shares some similarities with constructivism. He states that, for example, information-processing theorists (cognitivists) presented the computer model of the mind as an information processor. Constructivists added that this information processor must be seen as
not just shuffling data, but wielding it flexibly during learning – making hypotheses, testing tentative interpretations, and so on (Perkins, 1992).

Bednar et al. (1992) state that an eclectic approach (selecting ideas, styles, etc. from different sources) is clearly preferred by the field of instructional design. They argue that practitioners need best guidance possible for their design and development efforts, and the guidance should be sought from the widest array of research and theory on human learning and cognition. According to Bednar et al. (1992), those who advocate mixing techniques from different theoretical perspectives, point to the fact that the instructional strategies derived from one learning theory are often very similar to those derived from another learning theory even when theoretical explanations of those strategies may differ. The techniques that lead to instruction seem separable from their theoretical framework (Bednar et al., 1992). Also, Ertmer and Newby (1993), after having compared and contrasted the three learning theories, Behaviourism, Cognitivism, and Constructivism, do not advocate one single learning theory for use in instructional design. They matched the learning theories with the content to be learned. Jonassen (on-line 2) also stressed the importance of the level of learning (content) and the context in selecting an appropriate learning theory to be adopted.

According to Ertmer and Newby (1993), a behavioural approach can effectively facilitate mastery of the content of a profession (knowing what). On the other hand, cognitive strategies are useful in teaching problem-solving tactics where defined facts and rules are applied in unfamiliar situations (knowing how). Constructive strategies are specially suited to dealing with ill-defined problems through reflection-in-action (Ertmer and Newby, 1993).

Ertmer and Newby (1993) also tried to match the learning theories with the type of tasks to be learned. The tasks requiring a low degree of processing (e.g. basic paired associations, discriminations, rote memorisation) seem to be facilitated by strategies most frequently associated with a behavioural outlook (e.g. stimulus-response, contiguity of feedback/reinforcement). On the other hand, the tasks requiring an increased level of processing (e.g. classifications, rule or procedural executions) are primarily associated with strategies having a stronger cognitive emphasis (e.g. schematic organisation, analogical
reasoning, algorithmic problem solving). Finally, the tasks demanding high levels of processing (e.g. heuristic problem solving, personal selection and monitoring of cognitive strategies) are best learned with strategies advanced by the constructivist perspective (e.g. situated learning, cognitive apprenticeships, social negotiation) (Ertmer and Newby, 1993).

Wilkinson (1995) states that because of the divergent and subjective nature of constructive learning, it is easier for a designer to work from the systems, and thus the objective approach to instructional design. He states that it is not to say that classical instructional design techniques are better than constructive design, but it is easier, less time consuming and most likely less expensive to design within a "closed system" rather than an "open" one (Wilkinson, 1995).

Considering the type of tasks that most of the engineering curricula present to undergraduate students, which involve classifications, rules, procedures and the like, and the need to ensure that all learners achieve a more or less similar learning outcomes, it appears that the cognitive approach should be used as the primary approach for the majority of undergraduate engineering courses. This does not rule out the use of instructional strategies based on other learning theories where appropriate. There are also other reasons to support the selection of cognitivist approach over a constructivist approach, e.g., cost and time involved in designing the instructions.

Selection of an approach to teaching and learning (a learning theory) is only the first step towards designing instructions. Learning theories provide the general orientation for designing instructions. However, to design specific instructions, instructional designers need to follow certain guidelines. Because of the divergent and subjective nature of constructivist learning, instructional designers find it easier to work from systems and therefore they prefer cognitivist approach. In cognitivist approach, the instructional designers generally analyse the learning contexts and set goals. Individual tasks are broken down and learning objectives are developed. Evaluation is done by determining whether criteria for the objectives have been met. In this approach the designer decides what is important for the learner to know and attempts to transfer that knowledge to the learner. Guidelines for carrying out the above activities are
provided by various instructional design models which are primarily based on cognitivist leaning theories. Therefore, it is important to review the existing instructional design models to select an appropriate one for this study.

2.4 Instructional Design models

Under this section, existing instructional design models and their classifications will be reviewed. Different types of instructional design models will be compared and contrasted to determine their suitability for different learning situations.

Smith and Ragan (1999) state that the designers are engaged in three major activities in the process of instructional design: analysis, strategy development, and evaluation. These three activities are the essence of most instructional design models. Smith and Ragan (1999) also defines instructional design models as visualised depictions of instructional design process, emphasising main elements and their relationships.

There is a large number of instructional design models described in the literature but selection of one from them for a particular instructional setting is a challenging task. Edmonds et al. (1994) state that instructional design (ID) professionals typically employ instructional models that guide their practice. However, they say, it is not clear how a specific model is selected for an instructional situation. Andrews and Gordson (1980, in Edmonds et al., 1994) proposed a four-dimensional framework for comparing a sample of 40 instructional design models. The sample of 40 models was drawn based on systems design principles, comparing and categorising them according to four dimensions defined in the framework. The framework does not place any values on models and only tells how one model is different from another (Edmonds et al., 1994). However by early 1990’s, Andrews and Goodson’s framework needed to be replaced due to the changes that took place since its introduction. A need for a new framework which could assess the potential success of any instructional design model has emerged. Edmonds et al. (1994) introduced a new framework taking in to account the proliferation of variations in instructional design applications during the past period, the introduction of instructional design into new learning contexts, and the emergence of
alternative approaches to instructional design (Edmonds et al., 1994). The framework introduced by Edmonds and others is centred on four classifications: (1) types of orientation (prescriptive or descriptive), (2) type of knowledge (procedural or declarative), (3) required expertise (novice, intermediate or expert), and (4) theoretical origins (hard systems, soft systems or intuition) (Edmonds et al., 1994). This framework too was superseded by a recent survey of instructional design models conducted by Gustafson and Branch (2002). As Gustafson and Branch’s work is the most current classification (taxonomy) available, it is used for comparison of instructional design models in this study. Before proceeding to use the Gustafson and Branch’s work, it will be appropriate to review a few other issues related to instructional design models.

A comprehensive survey was conducted by Sullivan et al. (1993) to determine the opinions of the educational technology personnel about the future of their field. Strong agreements were shown by the respondents on some issues relating to instructional design models. Following were the related issues. The strongest agreement was with the statement “Improving existing models of instructional design is an important goal for educational technology”. Among other statements that showed strong agreement was the statement, “Improved models of instructional design will enable educational technologists to automate (by computer) much of the development of instructional programs”. These findings indicate the need for continuous improvement of the instructional design models and the potential of improved models to automate (computerise) development of instructional programs. However, this is beyond the scope of this study.

Going back to the topic of classifying instructional design models, Gustafson and Branch (2002) have conducted a survey of all the instructional design models and placed them into three categories using a taxonomy developed by Gustafson. The three categories are: classroom, product, and system. The placement of any model in a particular category was based on the assumptions made by its creator about the conditions under which development and delivery of instruction will occur (Gustafson and Branch, 2002).
Gustafson and Branch (2002) also explain that instructional design models visually communicate the associated processes to the stakeholders by illustrating the procedures that make the production of instruction possible. They also identify analyse, design, develop, implement, and evaluate (known as ADDIE process) as core elements in instructional design process and state that each element informs the other during the development and revision continues throughout the process, at least until the instruction is implemented.

According to Gustafson and Branch (2002), the first category in the taxonomy of instructional design models is classroom. Classroom ID models are primarily of interest to professional teachers who accept as a given that their role is to teach and that students require some form of instruction. Users of this category of ID models include elementary and secondary school teachers, community college and vocational school instructors, and university faculty.

The second category of ID models in Gustafson’s taxonomy is product. Gustafson and Branch (2002) explains that product development models typically assume the amount of product to be developed will be several hours or perhaps a few days, in duration. The amount of front-end analysis for product-oriented models may vary widely. Also, under product-development model, users may have no contact with the developers except during prototype tryout. However, in some rapid prototyping models, early and continuous interaction with users and/or clients is a central feature of the process. Product-oriented models focus on creating instructional products rather than more comprehensive instruction systems, like under system-oriented models – the third (last) category of ID models in Gustafson’s taxonomy.

The third and last category of models under Gustafson’s taxonomy is systems-oriented model. According to Gustafson and Branch (2002), systems-oriented models typically assume that a large amount of instruction, such as an entire course or entire curriculum, will be developed with substantial resources being made available to a team of highly trained developers. Assumptions vary as to whether original production or selection of materials will occur, but in many cases original development is specified. The amount of front-end analysis is usually high. Systems-oriented ID models usually begin with a data collection phase to determine the feasibility and desirability of developing an instructional solution to a “problem”.

After having reviewed the three categories of the ID models under Gustafson’s taxonomy, it became evident that the most appropriate category for developing instructional solutions to learning problems in any undergraduate course in engineering is system-oriented model.

After having selected the general category of an appropriate ID model, system-oriented model in this case, a specific ID model has to be identified for continuing this study further.

2.5 Selection of an ID model

In Gustafson and Branch’s (2002) survey, six ID models have been selected to represent the category of systems-oriented models. They are Inter-service Procedures for Instructional Systems Development; Gentry; Dorsey, Goodrum and Schwen; Diamond; Smith and Ragan; and Dick, Carey and Carey. Some of these models will be reviewed to ascertain their suitability for use in this study.

Inter-service Procedures for Instructional Systems Development (IPISD) is a joint effort of the United States military services. According to the Gustafson and Branch’s survey, IPISD is one of the most highly detailed ID process generally available. IPISD is designed specifically for military training and therefore is not useful in other contexts (Gustafson and Branch, 2002).

According to Gustafson and Branch (2002), most widely cited ID model is the one originally published by Walter Dick and Lou Carey to which they have now added James Carey. The Dick, Carey and Carey model has become the standard to which all other ID models are compared. This model reflects the fundamental design process used in many business, industry, government, and military settings. However, critics of this model state that it is too mechanistic and simplistic, and too linear and inflexible.

Gustafson and Branch (2002) states that the Smith and Ragan ID model is becoming increasingly popular with students and professionals in the field of instructional technology who are particularly interested in the cognitive psychology base of the ID process. Almost half of the procedures in this model address the design of instructional strategies. The Smith and
Ragan model reflects their philosophic belief that applying a systematic, problem-solving process can result in effective, learner-centred instruction. Gustafson and Branch (2002) emphasises that Smith and Ragan model is particularly strong in the area of developing specific instructional strategies, which is a common weakness of many other ID models. Dick (1996), the co-author of the text “The Systematic Design of Instruction” referred to Smith and Ragan’s text (and model) as a fine alternative to his own text and model.

Smith and Ragan’s model consists of three major activities, namely, analysis, strategy, and evaluation. It incorporates certain attributes which are not universally seen in other models. These attributes are inclusion of learning context analysis as a function in the design process, sequencing of test development, and the placement of revision within the formative evaluation process. The authors of the model also recognise the interwoven, non-linear nature of actual instructional design process (Smith and Ragan, 1999).

The researcher is convinced of the clarity, comprehensiveness, and ease of use of the Smith and Ragan model. The detailed procedures on the various steps of the instructional analysis phase and the clear descriptions about instructional strategies for different types of learning have been found to be quite useful in the instructional design process. Adoption of Gagne’s nine events of instruction in the development of different instructional strategies is extremely helpful in producing comprehensive and systematic instructions.

Considering the researcher’s own findings about the model, the Gustafson and Branch’s survey findings, and other references, Smith and Ragan’s ID model was selected as the basis for conducting further studies.

Based on the foregoing discussion and findings, it has become evident that there is a lack of pedagogical consideration in designing instructions in engineering education and therefore there is a need for a systematic approach to designing instruction. In the context of this study, it has also become clear that a cognitivist approach would be appropriate for designing instructions. The Smith and Ragan’s model is chosen as the instructional design model for this purpose.
3.1 Introduction

One of the observations that repeatedly concerned the researcher during his employment with the Open University of Sri Lanka (OUSL) was the poor performance in the fundamental engineering course of Strength of Materials. The Strength of Materials course is a core course in Civil and Mechanical Engineering disciplines and serves as a foundation for many advanced courses and design in these disciplines. The high importance of this course in an engineering curriculum and the actual poor performance in this course were confirmed by the subject matter expert and the head of Mechanical Engineering department at the OUSL. The researcher therefore decided to carry out investigations into the possible reasons for this poor performance in Strength of Materials and to find possible solutions to alleviate it.

In the preceding chapter on Literature Review it was also established that in the context of engineering education, generally there is a lack of pedagogical consideration in designing instructions despite the existence of tools or guidelines for incorporating such considerations. They include revised Bloom’s taxonomy (Anderson and Krathwohl, 2001) and Gagne’s (1992) five categories of human capabilities for classifying learning objectives. By following these tools or guidelines, Computer Aided Learning (CAL) appears to have the potential to provide flexibility and satisfy the needs of students with different learning styles. According to the literature, CAL has become a popular instructional solution for overcoming some learning problems, particularly with distance learners.

Therefore, it was decided that a pilot study be carried out first to find out the attitudes and perceptions of students about CAL as an approach of instruction. If students favour CAL, further explorations will be made to determine how best the identified performance problems can be addressed using a CAL approach.
Major results and findings of these exploratory studies are presented here in the following order.

1. The Pilot Study
2. Further Explorations

3.2 Pilot Study

The pilot study was conducted both at the University of Canterbury and the Open University of Sri Lanka. One part of the pilot study focused on the students’ use of existing CAL modules in Mechanics of Machines and Strength of Materials. The students who took part in this study were subsequently involved in semi-structured interviews. The purpose of these interviews was to find out the students’ attitude and the perceptions about using CAL to determine its acceptability as an approach to learning. The other part of the pilot study consisted of observations of students using a CAL module in Strength of Materials at the University of Canterbury. These observations, which were recorded on video, were to find out how students actually behave when using CAL. This was done to assess students’ enthusiasm about this instructional approach.

The following is a summary of the responses to interview questions of 15 participants, 8 from the University of Canterbury and 7 from the OUSL. These participants included young and mature male and female native and non-native speakers with different competency levels in academic subjects, English and computing. The interview questions are given in Appendix 3.1 (Canterbury) and Appendix 3.2 (OUSL). Also included in this summary are the observations made based on the video recordings of students using a CAL module.

Summary of major findings:

1. Graphics, animations, sound, immediate feedback, step-by-step explanations, brief and specific instructions, high interaction with the subject matter, ability to drill and practise were identified as the features of CAL that most participants liked.
Participants also liked to treat CAL as a supplement to the text books and not as an alternative.

2. More worked examples and exercises with varying complexity, additional help and explanations to suit different levels of students, access to different references within the CAL modules were mentioned as useful improvements to the existing CAL modules.

3. Almost all the participants reported that they are comfortable with using CAL in their studies and their confidence in the topics was considerably improved after using the CAL modules.

4. Prior computer knowledge had positive impact on attitudes towards the use of CAL modules in learning; however the lack of such prior knowledge was not regarded as a disadvantage by participants when they used CAL modules.

5. Almost all the participants reported that using CAL in studies is less stressful than studying from the textbooks, which are often difficult to read and understand.

6. Almost all the participants reported that they were enthusiastic and they showed high concentration and engagement when using CAL in their studies.

7. Majority of non-native English speakers reported that CAL modules helped them overcome English language difficulties.

The findings of the pilot study indicated that CAL is an acceptable and attractive approach to learning. The participants at both the universities expressed that they found the CAL modules useful and liked to use them in their studies. Furthermore, they liked to use CAL as a supplement to their traditional learning methods rather than as a substitute to it. Most of the non-native English speakers indicated that the use of CAL modules helped them overcome their English language difficulties.

The pilot study was conducted at both the University of Canterbury and the OUSL to find out the general attitudes and perceptions of engineering students towards use of CAL as an alternative approach in their learning. However, further explorations and the subsequent studies were conducted using the OUSL setting due to the expressed concerns about the
student performance there and the researcher’s motivation to find solutions to them due to his previous affiliation to the institution.

### 3.3 Further Explorations

Even though it has been found that generally the students do like to use CAL as an approach to learning, further explorations were necessary to verify whether there is actually a performance problem, and if so, how such a problem could be analysed and instructional solutions found. It was expected that the findings of these exploratory studies would provide sufficient basis for determining appropriate instructional solutions.

As the initial step in conducting further explorations, students’ learning performance was first analysed. If the performance was found to be satisfactory, further explorations would not be necessary but if the results of the analysis indicated a concern in performance, further investigations and analyses would be carried out to search for an appropriate instructional solution. As the student performance was found to unsatisfactory, further analyses were required. These analyses were carried out using the Smith and Ragan’s (1999) model for instructional analysis supplemented by an additional analysis introduced by the researcher.

Smith and Ragan’s model for instructional analysis consists of three components. Refer to Smith and Ragan’s model in the list below.

1. Learning Context
   a. Instructional needs
   b. Learning environment
2. Learners
3. Learning Task (Task Analysis)

Learning Context is subdivided into Instructional Needs and Learning Environment. Analysis of instructional needs is also known as needs analysis or needs assessment (Smith and Ragan, 1999). The purpose of the analysis of instructional needs or needs analysis is to determine
whether there are gaps between the desired learning outcomes and the actual achievement. If there are several gaps, they are prioritised based on appropriate criteria. Prioritised gaps are then reviewed to determine which ones of them are instructional needs and which are most appropriate for design and development of instruction. The analysis of the learning environment will provide information regarding the environment or “system” within which the instruction will be conducted and the learning undertaken. The second component in the instructional analysis is the analysis of the learners or the target audience. The analysis of learners is to determine the characteristics of the learners which have a bearing on the design of instructions. The last component of the instructional analysis is the analysis of the learning task and this will be discussed in Chapter 4.

Identification of the gaps in performance thereby the instructional needs is not sufficient to design instruction. According to Smith and Ragan (1999), it is the analysis of the learning task that transforms the instructional needs into a form that can be used for subsequent design of instruction. The analyses of the learning environment and the learners are expected to produce, a description of the system within which the learning is undertaken, and the characteristics of the learners, respectively to assist the designing of instruction. It was however felt that a detailed analysis of the various issues raised by different parties during the above analyses will be useful. This analysis is expected to produce a list of suggested instructional solutions that could be incorporated in the final design of instruction.

Therefore, the Smith and Ragan’s model was enhanced by adding a detailed analysis of the issues raised by the learners and the academics. The analysis involved review of the issues raised, from different perspectives, e.g., learners, academics and the researcher. The instructional solutions suggested as a result of these reviews are incorporated in the final design of instructions.

The analyses of the learning context and the learners were carried out as per the Smith and Ragan’s model. Data necessary for these analyses were gathered using various methods and instruments. As an enhancement to Smith and Ragan’s model, a detailed analysis of the various issues raised by the students and the academic staff were carried out to solicit a list of
suggested solutions to be designed. Overall findings from the above analyses were then reviewed to determine measures, that were most appropriate in designing instructional solutions, to the performance problem under study. The analysis of the learning task is discussed in Chapter 4.

**Learning Context and Learner analyses**

Different methods, instruments or records were used to gather necessary data for the analysis of the learning context and the learners. Instruments used are available in the Appendices 3.3 to 3.12.

**Data gathering**

Two questionnaires about the learning context and learner characteristics, one for the present students (Appendix 3.3) and another for the past students of the same course (Appendix 3.4), were administered.

Interviews were held with current students, the subject expert, experts in Education, Educational Technology and English, the head of the Mechanical Engineering department, the dean of Engineering Technology, and the Vice-Chancellor to find out the issues relating to the identified performance problem. Pre-set questions were used during these interviews while open discussions also ensued at the end of many interviews. Guiding questions used in the semi-structured interviews are presented in Appendices 3.5 through 3.12.

Two focus group discussions were held with groups of current students at the main campus and one of the main regional campuses to solicit views about the level of services provided by the university to them and the improvements that are necessary. A total of fourteen (14) students participated in these discussions. Questions posed to the students at the focus group discussions are listed in Appendix 3.13.
Six documents and records were used to gather necessary data for the analyses. They include student lab reports, tutor-marked assignments, continuous assessment tests, final examinations. Statistics regarding the student performances were obtained from the course coordinators and the Student Records.

Following table shows the various means used to gather data on different subcomponents of the analysis.

**Table 3.1: Different means used for data gathering under Instructional Analysis**

<table>
<thead>
<tr>
<th>Subcomponents</th>
<th>Questionnaires</th>
<th>Interviews</th>
<th>Focus groups</th>
<th>Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional needs</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learner profile</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Learner performance</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learner characteristics</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Learning environment</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The data gathered through various techniques or instruments such as questionnaires, interviews, review of past records, etc. were analysed. Most of the findings are triangulated as they are confirmed from more than one source. The following sections report major results and findings from these further explorations.

**Learning Context analysis**

The first step in learning context analysis is to find out whether there is a need for developing or revising instructions (instructional needs). Therefore, the researcher perceived poor performance in the Strength of Materials course needed to be verified to determine whether there are any instructional needs.
Instructional needs

The interviews with the related course coordinator and the head of Mechanical Engineering department confirmed the researcher’s observations about the poor student performance in the course. Both the course coordinator and the head of the department also stressed the relatively high importance of this course in the curriculum of both Civil and Mechanical Engineering programmes and expressed deep concern about continued poor performance in this important course. The following statistics on the student performance in the Strength of Materials course were obtained from the student records at the OUSL, which confirmed the researcher’s observations and the academics’ concern. Hence, the course of Strength of Materials was chosen for further investigation under this project.

Table 3.2 shows the past student performance on the Strength of Materials course.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of students sat</th>
<th>Number of students passed</th>
<th>Pass rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>58</td>
<td>30</td>
<td>52</td>
</tr>
<tr>
<td>2000</td>
<td>60</td>
<td>16</td>
<td>27</td>
</tr>
<tr>
<td>2001</td>
<td>80</td>
<td>18</td>
<td>23</td>
</tr>
<tr>
<td>2002</td>
<td>102</td>
<td>56</td>
<td>50</td>
</tr>
<tr>
<td>Overall</td>
<td>300</td>
<td>120</td>
<td>40</td>
</tr>
</tbody>
</table>

The OUSL’s Mechanical Engineering Department has a target pass rate of 60% and a minimum acceptable pass rate of 30% for the Strength of Materials course.

The student pass rate on this course has fluctuated from 23% to 52% during the period of 1999 to 2002 with an overall of 40%.

Also, it was observed that at least 50% of the students made more than one attempt to pass the final exam on Strength of Materials.
The existence of a gap between the expected and actual performance levels on this course is evident. This gap should be further analysed to determine specific instructional solutions to bridge it.

The students gave several reasons for their relatively poor performance in the subject. The main reason mentioned was the difficulty in understanding the study material. Students also mentioned that they experience major difficulties in dealing with the English language. Clearer explanations of theory and difficult terms, step-by-step derivation of equations and solution of examples, more worked examples and model exam questions were requested by the students. More face-to-face (F2F) sessions to explain theory, workout more examples and to clarify doubts were also requested by the students. Additional references on the subject were also in their wish list. These findings are consistent with that of the pilot study.

Various observations, reasons and solutions to address the existing learning problems were recommended by the academics and the administrators through their responses to the interview questions. There was consensus on the need to revise the study material to provide clear and concise explanations, worked examples and explanations of difficult words. Also effective use of limited F2F sessions was emphasised. Provision of CAL materials was suggested to supplement the print materials and to compensate for the limited tutor support and F2F sessions. It was made clear that the number of F2F sessions cannot be increased due to the limited resources available. It was also pointed out that those students who were employed already found it difficult to attend the currently scheduled F2F sessions due to their work commitments. The above circumstances in the given setting point to a need for providing improved instructions through CAL modules.

Once the instructional needs are established, the next step is the analysis of the learning environment.
Learning Environment

According to Smith and Ragan’s model, the analysis of the learning environment will provide information regarding the environment or “system” within which the instruction will be conducted and the learning is undertaken.

It was found that about 50% of the students mentioned that they study on campus and the rest said they do their studies at home or elsewhere. Only 26% of the students have access to computers outside the university campus. 70% of the students said they are satisfied with the computer facilities provided by the university.

Despite the relatively low access to computers outside the campus, it is expected that more and more students will gain access to computers as they become cheaper and the benefits of their use are recognised. Also, the interview with the Vice-Chancellor revealed that the OUSL’s policy towards the use of technology in education is positive and the ongoing infrastructure and facility enhancement projects will provide, among other things, a modern nation-wide distance education communication network and major upgrades of computer facilities. These changes in the learning environment will improve the student access to computers thus facilitating the use of CAL modules more easily.

These changes in the learning environment encouraged the use of CAL as an instructional solution as the access to computers by students is becoming less an issue.

The next component in the analysis, according to Smith and Ragan’s model, is the analysis of the learners.

Learner analysis

The learner analysis is the second component of the instructional analysis (Smith and Ragan, 1999). The learners are also known as the target audience. The analysis of learners will reveal the profile and the characteristics of the learners which have design implications.
Learner profile

About two thirds of the students who followed this course are enrolled on the main campus and the rest are enrolled at various regional centres located throughout the country. Also, about 50% of the students were over 24 years-old. Further, 56% of the students were employed full-time or part-time and 83% of the students said they have passed the English language as a subject at the General Certificate of Education (Ordinary Level) examination.

As majority of the students are enrolled at the main campus, any shortcomings in personal access to computers can be easily compensated by the relatively well equipped computer facilities available there. As regional campuses are also reasonably equipped with computers, use of CAL as an approach to learning is unlikely to act as a barrier to any students. Mature and employed students are likely to find CAL as an attractive alternative due to the flexibility it provides in terms of time and location of study. Passing English as a subject at the G.C.E. (O/L) examination indicates that the students have acquired a minimum level of competency to follow a course in English.

Learner characteristics

The students have rated themselves as follows in their levels of knowledge in different subjects (Table 3.3).

Table 3.3: Students’ perceptions about their abilities in different subjects and skills

<table>
<thead>
<tr>
<th>Knowledge/Skills</th>
<th>Excellent (%)</th>
<th>Very good (%)</th>
<th>Good (%)</th>
<th>Satisfactory (%)</th>
<th>Poor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics</td>
<td>26</td>
<td>44</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>4</td>
<td>65</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>English</td>
<td>14</td>
<td>36</td>
<td>41</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Computer skills</td>
<td>4</td>
<td>22</td>
<td>52</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Practical knowledge</td>
<td>4</td>
<td>4</td>
<td>39</td>
<td>44</td>
<td>9</td>
</tr>
</tbody>
</table>
Almost all the students mentioned that they are mostly visual learners and like to learn by seeing things. About 75% of the students indicated that they prefer to study in pairs or small groups. Almost all the students said that they are studying this program out of their own interest and not due to any parental pressure or the like. Over 90% of the students indicated that they want to pass this course with high grades and not with a minimum pass. When asked to indicate their preferred ways of learning, the most highly ranked way of learning was face-to-face sessions followed by peer discussions and audio/video/CAL, in preference order. This order of preference has a contradiction with the available learning environment indicating possible reasons for some of the problems. The entire programme is offered in the distance mode and still the students’ most preferred way of learning is through face-to-face sessions. This is a cause for dissatisfaction among students. Therefore, the instructions and their delivery need to be carefully designed by taking this disparity into account.

According to Smith and Ragan’s model, the information gathered up to this stage should be sufficient to move on task analysis. However, it was felt that an additional analysis of the suggested solutions will be useful in informing the decision making process later in the design stage. Therefore, an additional analysis of suggested solutions was conducted and the results are shown in the next section. This analysis, introduced by the researcher, is an enhancement to Smith and Ragan’s model.

Analysis of suggested solutions

The detailed results of the analysis of these issues which include issues/preferences indicated by the students, subject experts, the head of the department, and the dean of the faculty, experts in education and educational technology, and the vice-chancellor are presented in the Appendix 3.14. The analysis includes issues/preferences, interviewees’ suggestions, researcher’s views, and suggested solutions.

This analysis has produced a total of 76 suggested solutions of which 64 (84%) were instructional and 12 (16%) were non-instructional solutions (Appendix 3.14). Actions that require contributions from subject matter experts, instructional designers and other experts to
design or improve instructions or the way the teaching and learning is conducted were treated as instructional solutions. Any other actions that do not require such contributions and require only administrative efforts such as stocking extra reference books in the library are treated as non-instructional solutions. Of the instructional solutions, around 60% pointed to the development of a CAL module with tutorials and exercises and the remaining 40% suggested various other non computer-related actions to improve instructions.

Following are the prioritised issues grouped under two headings.

The issues have been prioritised based on the emphases indicated by the students and academics during the surveys. Issues that may be addressed by a CAL module have been listed first.

1) Improve basic study material to provide:

1. Clear and simple language
2. More interactions
3. More feedback
4. More worked examples
5. Means to visualise difficult concepts (graphics)
6. Additional media components to enable easy understanding of the subject content and improve English knowledge
7. Improved glossaries

2) Improve student support by providing:

1. Timely feedback
2. More tutor support and better trained tutors
3. Worked examples/model answers
4. Study guides
5. Training on study skills
6. Opportunities for group work
7. Effective face-to-face sessions or alternative arrangements
8. Learning resources to make students more independent
9. Additional support to pick up English language fluency

The proposed CAL module is expected to address at least 11 of the 16 (about 70%) prioritised issues listed above.

The analysis shown in Appendix 3.14 has been rearranged according to the prioritised issues and that is available in the Appendix 3.15.

The analysis so far indicates that a CAL module with tutorials and exercises for drill and practice with appropriate language level and feedbacks could be an appropriate solution to the given learning problems at the OUSL. However, the proposed solution raises the following questions. How should this CAL module be designed? Are there any models or guides to follow? Are there any special instructional strategies that would suit Computer Aided Learning? And, finally, how effective would such a CAL module be in addressing the given problem? Answers to these questions will be sought through instructional analysis, investigations, review of relevant literature, and design of tests and evaluations.

The next step in a typical instructional design process, after the analysis of the learning context and the learners, is the analysis of the learning task or task analysis (Smith and Ragan, 1999). Task analysis leads to the design of instruction. As a tool to enhance the task analysis (thereby the design) was searched, the Revised Bloom's Taxonomy (RBT) was found (Anderson and Krathwohl, 2001). The RBT was selected as the appropriate tool for the reasons explained in Chapter 4. As there have been no prior applications, to the best of the researcher's knowledge, the use of the RBT in task analysis is a totally new endeavour. However, to the researcher's knowledge, the usefulness and effectiveness of the RBT for task analysis has not yet been established. Therefore it was thought necessary to investigate this. Also, the researcher could also not find any work in the literature that shows a relationship between the type of
knowledge and the cognitive process associated with a given learning outcome, as classified by the RBT, and the instructional strategies used to achieve them. As the existence of such strategies could influence the design of instruction, it seemed logical to investigate into the possibility of such relationships between the instructional strategies and the types of knowledge and cognitive processes. Furthermore, it is also important to know how effective the use of the RBT is in the design of CAL module.

The above exploration and further analysis therefore led to the following three research questions which guide the current study.

*Research questions*

1. In what ways does the Revised Bloom’s Taxonomy inform Task Analysis?

2. What is the relationship between the type of learning outcome and the instructional strategies used to achieve that learning outcome?

3. What is the effectiveness of the computer-based instruction?

Methods employed to answer the above research questions and findings will be reported separately in Chapters 4, 5, and 6.
Chapter 4

Task Analysis

In this chapter, the instructional design process is briefly explained. Then the importance of task analysis in designing instructions and the relevance of the Revised Bloom’s Taxonomy (RBT) as a tool for task analysis is discussed. The application of the RBT in the task analysis is explained using the learning tasks of derivation and application of the flexure formula. The results of this application are then presented and discussed. Finally, the lessons learned from this application are explained and concluding remarks highlighting the limitations of the study and suggestions for future improvements are made.

This chapter addresses the first research question of this study:

“In what ways does the Revised Bloom’s Taxonomy inform Task Analysis?”

The contents of this chapter have been accepted for publication in the International Journal of Engineering Education (IJEE) as an article entitled “Opportunities and Challenges in Instructional Design for Teaching the Flexure Formula Using the Revised Bloom’s Taxonomy” (see Appendix 7.1). At the time of submitting this thesis the article was in press.

4.1 Introduction

A typical instructional design process includes five stages, namely, Analysis, Design, Development, Implementation and Evaluation, known as the ADDIE processes (Kruse, online). In general, each stage in the process provides outputs that serve as inputs for subsequent stages. However, there are situations where these five stages do not necessarily follow linearly. During analysis, instructional designers develop a clear understanding of the gaps between the desired and the actual learning outcomes. The design stage documents the content, exercises, and assessments including teaching and learning strategies. The
development stage deals with the actual creation of the learning materials while the implementation stage is concerned with the students’ actual learning experience. Finally, the evaluation stage looks into the effectiveness of the designed instruction.

According to Smith and Ragan (1999), there are three main components in the analysis stage: learning context analysis, learner analysis, and learning task analysis. The learning context analysis consists of two steps: identification of the gaps in the achievement of learning outcomes (needs assessment), and identification of the environment under which learning occurs (learning environment). The second component, the learner analysis, is concerned with the learner characteristics that may have implications for the design of instructions. The final part of the analysis, which is the focus of this chapter, is the learning task analysis. This deals with a detailed and hierarchical breakdown of the learning task to identify the underlying learning objectives and prerequisite knowledge. Combined results of the analysis of these three components provide a basis for designing instructional strategies. According to Marks (2002), although this analytical approach is well-established, there has been a general concern that insufficient time is spent in the analysis of the learning task prior to the design stage.

Based on the surveys and interviews of students and lecturers during the early stages of the instructional analysis (learning context and learner analyses), priority was given to the topic of bending stress calculation. The major reasons were the importance of this type of stress calculation in engineering design and the complexity of the derivations.

Once the topic was selected, the gaps between the desired and actual outcomes were identified as suggested in the model by Smith and Ragan (1999). Several issues which are believed to have contributed to these gaps were also identified. From the identified gaps, a list of goals that the learners need to achieve, and are currently unable to do was developed.

However, the list of goals was not in a form that could be readily used for developing the instructional modules. According to Smith and Ragan (1999), it is the task analysis that transforms goal statements into a form that may be used as a guide in designing instruction. The outcome of such a task analysis is a hierarchy of sub-goals. These sub-goals describe what
learners will be able to do or should know at the end of the instruction. The task analysis also identifies the prerequisite skills necessary to achieve such goals. For teaching the beam bending theory and applications, two hierarchies of sub-goals in the form of flow charts were developed; one for the derivation of the engineers beam bending theory and another for its application. In this chapter only the flowchart on the application of the beam bending theory is presented and discussed (Figure 4.1). The draft flowchart on the derivation of the flexure formula is available in Appendix 4.1. After some deliberation, it was decided to limit this study to the application of the beam bending formula.

4.2 The Revised Bloom's Taxonomy

The Bloom's Taxonomy is one of the popular tools used for task analysis. According to Jenkins and Arola (2001), the Bloom's Taxonomy helps educators to assess how much and how well the students have learned. The Revised Bloom's Taxonomy (RBT) allows classification in a two dimensional table form, based on the type of knowledge and the type of cognitive process involved in the learning task. Vable (2003) states that such classifications are likely to help the teachers in determining appropriate teaching techniques and grouping the learning tasks into separate modules, courses, etc. based on the type of knowledge and cognitive processes (skills). According to Anderson and Krathwohl (2001), the original Taxonomy of Educational Objectives (OBT) is a framework for classifying statements of what teachers expect or intend students to learn as a result of instruction. An example of such a statement is, "by the end of the lesson, students will be able to correctly answer multiplication questions using the times table for numbers up to 10, for at least 90% of the questions". In this study, it was decided to use the Revised Bloom's Taxonomy (RBT) developed by Anderson and Krathwohl (2001). Krathwohl (2002) states that similar to the OBT, the RBT is a framework for classifying the learning objectives that describe what students are expected to achieve as a result of instruction.
Prerequisites

Recall the definition of centroid

Recall First Moment of Area theorem

Recall the formulae for areas

Recall the definition of centroid

Recall the assumptions used in deriving Flexure Formula (Beam Bending Formula)

Are all the assumptions met?

Recall definition of Plane of Bending and axis of symmetry

Conclude the location of the neutral axis by visual examination, i.e., centre line

Conclude the position of neutral axis of overall section

Calculate the position of neutral axis of overall section

Calculate area for individual rectangular/circular sections

Does the overall section have an axis of symmetry perpendicular to the plane of bending?

Yes

No

Yes

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Figure 4.1: Task Analysis – Application of the Flexure Formula, continued
The original taxonomy included six major categories. They are: knowledge, comprehension, application, analysis, synthesis, and evaluation. Table 4.1 shows the structure of the original taxonomy. The action verbs such as recall, apply and calculate are classified in to one of the six different categories. For example, a learning objective may specify that, after the instruction a student should be able to translate a word problem in to a numerical one. Then the appropriate category for this action would be comprehension (Table 4.1). According to Krathwohl (2002), one assumption of the original Bloom’s taxonomy is that learning is hierarchical and is largely based on prerequisite skills and knowledge. For example, if a learning outcome is pitched at the comprehension level, the teacher must first cover activities at the knowledge level before proceeding to the intended comprehension level.

Krathwohl (2002) also suggests that the uni-dimensionality is a limitation of the OBT. That is, the learning objectives are generally classified using only one dimension, namely the action verb. The uni-dimensional taxonomy provides information sufficient only for a preliminary indication. For example, an objective that reads, "the students should be able to apply Hooke’s Law to simple one dimensional axial straining problems" would be classified on the basis of the action verb (in this case, apply) only. The noun, "Hooke's law", is not used for classification. In fact, the noun can also provide useful information. With this additional information, the instructional designers will have a broader basis for developing suitable instructional strategies.

In an attempt to address the above problems, Anderson and Krathwohl (2001) proposed a revision to the Bloom’s taxonomy. Table 4.2 shows the structure of the revised taxonomy. In revising the taxonomy all six cognitive process dimensions in this original taxonomy have been preserved, but three major changes have been made. Firstly, knowledge is classified as a second dimension and is divided into four categories. Secondly, the category synthesis in the original taxonomy has been renamed as create. Thirdly, the categories evaluation and synthesis (now renamed as create) have been swapped in their positions. This makes create the highest cognitive process in the revised taxonomy.
Table 4.1: Structure of the original taxonomy (Anderson and Krathwohl (2001))

<table>
<thead>
<tr>
<th>1.0 Knowledge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.10 Knowledge of specifics</td>
<td></td>
</tr>
<tr>
<td>1.11 Knowledge of terminology</td>
<td></td>
</tr>
<tr>
<td>1.12 Knowledge of specific facts</td>
<td></td>
</tr>
<tr>
<td>1.20 Knowledge of ways and means of dealing with specifics</td>
<td></td>
</tr>
<tr>
<td>1.21 Knowledge of conventions</td>
<td></td>
</tr>
<tr>
<td>1.22 Knowledge of trends and sequences</td>
<td></td>
</tr>
<tr>
<td>1.23 Knowledge of classifications and categories</td>
<td></td>
</tr>
<tr>
<td>1.24 Knowledge of criteria</td>
<td></td>
</tr>
<tr>
<td>1.25 Knowledge of methodology</td>
<td></td>
</tr>
<tr>
<td>1.30 Knowledge of universals and abstractions in a field</td>
<td></td>
</tr>
<tr>
<td>1.31 Knowledge of principles and generalisation</td>
<td></td>
</tr>
<tr>
<td>1.32 Knowledge of theories and structures</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.0 Comprehension</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Translation</td>
<td></td>
</tr>
<tr>
<td>2.2 Interpretation</td>
<td></td>
</tr>
<tr>
<td>2.3 Extrapolation</td>
<td></td>
</tr>
</tbody>
</table>

| 3.0 Application        |  |

<table>
<thead>
<tr>
<th>4.0 Analysis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Analysis of elements</td>
<td></td>
</tr>
<tr>
<td>4.2 Analysis of relationships</td>
<td></td>
</tr>
<tr>
<td>4.3 Analysis of organisational principles</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>5.0 Synthesis</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Production of a unique communication</td>
<td></td>
</tr>
<tr>
<td>5.2 Production of a plan, or proposed set of operations</td>
<td></td>
</tr>
<tr>
<td>5.3 Derivation of a set of abstract relations</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6.0 Evaluation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Evaluation in terms of internal evidence</td>
<td></td>
</tr>
<tr>
<td>6.2 Judgements in terms of external criteria</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2: Structure of the revised taxonomy (Anderson and Krathwohl (2001))

<table>
<thead>
<tr>
<th>Knowledge dimension</th>
<th>Cognitive process dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Factual Knowledge – The basic elements that students must know to be acquainted with a discipline to solve problems in it.</td>
<td>1.0 <strong>Remember</strong> - Retrieving relevant knowledge from long-term memory</td>
</tr>
<tr>
<td>Aa. Knowledge of terminology</td>
<td>1.1 <strong>Recognising</strong></td>
</tr>
<tr>
<td>Ab. Knowledge of specific details and elements</td>
<td>1.2 <strong>Recalling</strong></td>
</tr>
<tr>
<td>B. Conceptual Knowledge – The interrelationships among the basic elements within a larger structure that enable them to function together.</td>
<td>2.0 <strong>Understand</strong> - Determining the meaning of instructional messages, including oral, written, and graphic communication.</td>
</tr>
<tr>
<td>Ba. Knowledge of classifications and categories</td>
<td>2.1 <strong>Interpreting</strong></td>
</tr>
<tr>
<td>Bb. Knowledge of principles and generalisations</td>
<td>2.2 <strong>Exemplifying</strong></td>
</tr>
<tr>
<td>Bc. Knowledge of theories, models, and structures</td>
<td>2.3 <strong>Classifying</strong></td>
</tr>
<tr>
<td>C. Procedural Knowledge - how to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods.</td>
<td>2.4 <strong>Summarising</strong></td>
</tr>
<tr>
<td>Ca. Knowledge of subject-specific skills and algorithms</td>
<td>2.5 <strong>Inferring</strong></td>
</tr>
<tr>
<td>Cb. Knowledge of subject-specific techniques and methods</td>
<td>2.6 <strong>Comparing</strong></td>
</tr>
<tr>
<td>Cc. Knowledge of criteria for determining when to use appropriate procedures</td>
<td>2.7 <strong>Explaining</strong></td>
</tr>
<tr>
<td>D. Metacognitive Knowledge - Knowledge of cognition in general as well as awareness and knowledge of one's own cognition.</td>
<td>3.0 <strong>Apply</strong> - Carrying out or using a procedure in a given situation.</td>
</tr>
<tr>
<td>Da. Strategic knowledge</td>
<td>3.1 <strong>Executing</strong></td>
</tr>
<tr>
<td>Db. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge</td>
<td>3.2 <strong>Implementing</strong></td>
</tr>
<tr>
<td>Dc. Self-knowledge</td>
<td>4.0 <strong>Analyse</strong> - Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose.</td>
</tr>
<tr>
<td></td>
<td>4.1 <strong>Differentiating</strong></td>
</tr>
<tr>
<td></td>
<td>4.2 <strong>Organising</strong></td>
</tr>
<tr>
<td></td>
<td>4.3 <strong>Attributing</strong></td>
</tr>
<tr>
<td></td>
<td>5.0 <strong>Evaluate</strong> - Making judgements based on criteria and standards.</td>
</tr>
<tr>
<td></td>
<td>5.1 <strong>Checking</strong></td>
</tr>
<tr>
<td></td>
<td>5.2 <strong>Critiquing</strong></td>
</tr>
<tr>
<td></td>
<td>6.0 <strong>Create</strong> - Putting elements together to form a novel, coherent whole or make an original product.</td>
</tr>
<tr>
<td></td>
<td>6.1 <strong>Generating</strong></td>
</tr>
<tr>
<td></td>
<td>6.2 <strong>Planning</strong></td>
</tr>
<tr>
<td></td>
<td>6.3 <strong>Producing</strong></td>
</tr>
</tbody>
</table>
Since the revised Bloom's taxonomy allows identification of the type of knowledge and the cognitive process associated with a particular learning objective, it provides a broader basis for finding suitable instructional strategies. For example, in teaching an application of Hooke's law the cognitive process applicable is *apply* and the relevant knowledge category is *conceptual*.

Krathwohl (2002), through the RBT, encourages a lenient approach for classifying objectives. This gives flexibility in using the revised taxonomy in selecting action verbs and classifying objectives. The need to be flexible in determining learning objectives has been noted by others also. For example, Mager (1975) in his book entitled "Preparing Instructional Objectives" states that one needs not be constrained by a strict hierarchy. He suggests that objectives should be specified as the learning process naturally demands, without strict compliance to a hierarchy.

It should be noted that the RBT is not the only taxonomy used for classifying learning objectives. Gagne (1992), for example, has also developed a taxonomy for classifying learning objectives consisting of five categories of 'human capabilities'; *intellectual skills*, *cognitive strategies*, *verbal information*, *motor skills* and *attitudes*. The *intellectual skills* have been further subdivided into five different levels based on their complexity; *discriminations*, *concrete concepts*, *rules* and *defined concepts*, *higher-order rules*, and *problem solving*. The clearly defined cognitive process and knowledge categories and action verbs that are available in the RBT were found to be more suitable for the purpose of this particular task analysis. Therefore the RBT was selected.

To the researcher's knowledge, at the time of writing this thesis, existing literature has no information on any study that has applied the RBT to a task analysis. The question of whether the revised taxonomy will enhance the analysis of learning tasks in hand has remained, until now. As explained in chapters 6 and 7, the CAL module using the instructional strategies selected on the basis of the RBT based task analysis was found to have improved the student performance in the topic taught.
4.3 Task analysis of the Flexure Formula

As mentioned already, two flowcharts of the learning tasks, one for the derivation of the elastic beam bending formula in equation (1) and another for its application to some common types of structural beam sections have been developed.

\[ \sigma = \frac{-M_y}{I} \quad \text{...(1)} \]

Here, \( \sigma \) is the normal stress at distance \( y \) from the neutral axis of the beam, \( M \) is the bending moment and \( I \) is the second moment of area about the neutral axis which is the centroidal axis of the transverse cross section of the beam. At the time the students learn this formula, they are expected to be able to determine the bending moment in the beam for a given loading subject to any boundary conditions. They are also expected to know the meaning of the centroid and the second moment of area of a geometric shape and to be able to calculate these for some common shapes that are obtained by adding or subtracting rectangles and circles. Another expectation is that they know the meaning of stress, as intensity of induced force, but until this time they would have only learnt how to calculate the stress due to centric axial loading. These are the prerequisites. Learning the derivation of equation (1) is the first learning task. Once they learn this, and understand the assumptions and limitations of the theory, they would be expected to apply this to some common beam sections and determine the maximum values of stress. According to Jenkins and Arola (2001), understanding the assumptions on which a particular formula is based and knowing their limitations are important in determining if a given situation is an example or a non-example for using a particular method of solution. Several text books, lecture notes and computer programs that are currently available for teaching this course have been used in developing the flowcharts (Ilanko, 2003a and 2003b; Hibbeler, 2003).

Once the flowcharts were drafted, each task was classified according to the RBT. The charts were then verified by five other subject experts (validators), three from the University of Canterbury in New Zealand and two from the Open University of Sri Lanka. Four of the experts were academic staff and have taught this subject and one was a postgraduate teaching
assistant at the time of validation. Classification of some of the tasks required several rounds of discussion between the researcher and a subject expert.

4.4 Results

The final version of the validated chart for the application of the flexure formula is given in Figure 4.1. In general the validators agreed with the classification and the order of tasks in the flowcharts. The issues that needed clarification were discussed and were resolved until a consensus was reached. Some changes proposed by the validators were implemented; others were considered but not implemented for reasons that were explained to the validators concerned. The changes suggested and implemented include, revision of objective descriptions to include hollow sections (Objectives 12 and 14, Figure 4.1), rearrangement of connectors between objectives and revision of the dotted line which separates the main instruction from prerequisites (Objectives 15 and 16, Figure 4.1). A suggestion to include a worked example in parallel to the steps in the flowchart was not adopted as such details are relevant in the design stage but not in this analysis stage. An interesting question on classification was raised. That is, why some tasks were classified as conceptual instead of factual in the knowledge dimension. This is elaborated later.

The application flowchart was used to prepare the instruction design. It should be noted that the flowchart and the categories assigned to the objectives represent only one way for teaching the application of the flexure formula. There may be many other different ways that are equally appropriate based on the approach to analysis of the content and sequencing of learning objectives. It should also be noted that the flow chart presented in this study may or may not be appropriate for other contexts.

It is interesting to note that in the taxonomy table (Table 4.3), many of the cells are empty. This table sheds some light towards the design of the computer based modules. Decisions on issues such as whether teaching a particular task is best done by one strategy or another may depend on the type of knowledge and the type of cognitive process associated with each task. This means, it may be possible to use the same type of activity for Objectives 2, 3, 4, 5, 7, 10, 15 and 17 as they are all in the same cell in Table 4.3.
Table 4.3: Taxonomy table for the application of the flexure formula

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>A. Factual Knowledge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Conceptual Knowledge</td>
<td>Obj. 1</td>
<td>Obj. 2</td>
<td>Obj. 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obj. 9</td>
<td>Obj. 3</td>
<td>Obj. 8</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Obj. 4</td>
<td>Obj. 18</td>
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<tr>
<td></td>
<td></td>
<td>Obj. 5</td>
<td>Obj. 19</td>
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<td></td>
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<tr>
<td></td>
<td></td>
<td>Obj. 7</td>
<td></td>
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<td></td>
<td></td>
<td>Obj. 10</td>
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<td></td>
<td></td>
<td>Obj. 15</td>
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<tr>
<td></td>
<td></td>
<td>Obj. 17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Procedural Knowledge</td>
<td>Obj. 13</td>
<td>Obj. 11</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Obj. 21</td>
<td>Obj. 12</td>
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<td>Obj. 14</td>
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<td></td>
<td></td>
<td>Obj. 16</td>
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<td></td>
<td></td>
<td>Obj. 20</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>D. Metacognitive Knowledge</td>
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</tbody>
</table>

4.5 Discussion

The researcher is of the opinion that the lessons learned from conducting the task analysis using the RBT will be of use to other researchers and engineering lecturers. Some of the challenges that were encountered in the process of developing the flowcharts and the opportunities the RBT offers are described in the following sections.

The RBT versus the OBT

There are numerous sources in the literature for action verbs relating to the OBT (Bowen, online). Some of these verbs are now classified under different categories in the RBT from what they were in the OBT. It is worth noting that some action verbs are classified under more than one category in the OBT. Table 4.4 shows some examples.
Table 4.4: Action verbs and taxonomy categories

<table>
<thead>
<tr>
<th>Verb</th>
<th>Revised Taxonomy Category</th>
<th>Original Taxonomy Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify</td>
<td>Remember</td>
<td>Knowledge and Analysis</td>
</tr>
<tr>
<td>Infer</td>
<td>Understand</td>
<td>Comprehension and Analysis</td>
</tr>
<tr>
<td>Generalise</td>
<td>Understand</td>
<td>Apply and Synthesis</td>
</tr>
<tr>
<td>Illustrate</td>
<td>Understand</td>
<td>Comprehension and Analysis</td>
</tr>
<tr>
<td>Select</td>
<td>Analyse</td>
<td>Apply, Analyse and Evaluate</td>
</tr>
</tbody>
</table>

This situation can cause confusion in determining the appropriate cognitive process for a given learning objective, leading to confusions in the selection of appropriate strategies. In the task analysis for the application of the flexure formula (Figure 4.1), there is an objective (# 15) ‘To be able to infer whether the bending moment to be used in the formula is explicitly given in a usable form”. This objective could initially point to an exercise to identify some data from a given description. However it should be more cognitively demanding. It involves “drawing a logical conclusion from presented information”, according to the RBT. In this task, the student, from the given problem description needs to determine whether all the necessary information regarding bending moment is available. This type of cognitive process is described as infering in the RBT and is categorised under understand (Table 4.2). On the other hand, in the OBT, infering is categorised under both comprehension and analysis (Table 4.4) requiring additional effort in classification to avoid confusion.

The clear and concise descriptions of categories and cognitive processes and identification of typical action verbs under each subcategory in the RBT help categorise action verbs appropriately. This would reduce the chances of misclassification of action verbs. The descriptions in the RBT were found to be generally clear enough to make the identification of new action verbs easy. We suggest that a longer list of action verbs will be useful to avoid misclassification of action verbs due to subtle differences in their meaning.

In addition there is a need to be cautious in using verbs that are similar in their common usage. The descriptions for each cognitive process in the RBT were found to be useful to distinguish subtle differences between similar action verbs and place them in the correct cognitive process category. For example, in daily usage classify and distinguish may be taken to mean more or less the same. However in the RBT, classify means the action of determining that something
belongs to a certain category and is listed under understand, whereas distinguish means the action of discriminating relevant from irrelevant parts of presented material and is listed higher in the cognitive process hierarchy under analysis. These definitions lead to subsequent identification of suitable instructional strategies. In the same example above, an appropriate activity for classify would be for learners to look at a picture of an animal and indicate its respective animal family. On the other hand, requiring learners to read a passage describing the characteristics of different animals in order to recognise the characteristics of given animal families would be an example of the activity distinguish which comes under analysis.

During the early stages of the task analysis, it became clear that both the OBT and the RBT are useful in identifying some inappropriate classification. In initial attempts to assign a cognitive level to some objectives the indicated level appeared to be too high. For example, for some tasks that suggest checking or verification of certain conditions, the cognitive process was first thought to be checking which comes under the category of evaluate. This is the fifth in the six cognitive levels in the RBT. However the surrounding objectives in the hierarchy of objectives were all at a significantly lower level of remember. It was thought that in learning, it would be unusual for the student to skip several cognitive levels in one step, in this case from the 1st to the 5th. A closer look at the description of checking suggested that this action occurs when a student detects inconsistencies or fallacies within a process or product, determines whether a process or product has internal inconsistency, or detects the effectiveness of a procedure as it is being implemented (Mayer, 2002). Based on the above description, since the tasks on hand do not actually require such a high-level cognitive effort it was decided that they could not be described as checking for the classification purpose. Further analysis revealed an appropriate classification at the second level of the cognitive processes, understand. The cognitive process of exemplifying under the category of understand would closely represent the efforts of the tasks.

The minimisation of the difference between the cognitive levels of associated objectives will ensure that there will be no big jumps in cognitive effort between successive tasks. The descriptions of cognitive processes and representative action verbs provided in the RBT were
found to be useful in achieving this. The researcher believes that this may facilitate a smoother transition in students' learning process.

*Uni-* versus *two-dimensionality*

As explained earlier, the two dimensions of the RBT, knowledge and cognitive process, provide a broader basis for designing teaching and learning activities. The objectives analysed using the RBT can be translated into instructional strategies that are suitable from either the knowledge perspective or the cognitive process perspective.

Further studies on instructional strategies show that existing literature commonly use knowledge categories such as concepts, procedures, etc. to describe different instructional strategies (e.g. concept learning, procedure learning, etc.). However, closer scrutiny of these strategies reveals that they are really intended for achieving different learning outcomes associated with specific cognitive processes. This suggests that in many situations it may be easier to determine the related cognitive process (learning outcome) by identifying the knowledge type first. The RBT is more user-friendly in that it helps identify the knowledge type which in turn can help determine the learning outcome and thereby the appropriate instructional strategy.

The learning objectives identified in the present study were found to be confined to three categories: *remember, understand* and *apply* cognitive processes (Table 4.3). In the knowledge dimension, they are confined to *conceptual* and *procedural* knowledge. This limits our ability to draw conclusions related to other cognitive processes or knowledge types. It would be worthwhile conducting a study in a topic involving the remaining categories in the knowledge and cognitive process dimensions.

Interestingly, the findings from this study seem to suggest that the two dimensions of the RBT may not be totally independent. Certain observations can be made here. For example, all *procedural knowledge* objectives are associated with *understand* and *apply*. In fact in this particular module, they are all associated with *calculations* of different properties. Further,
most objectives of factual knowledge are associated with remember. In fact, without referring to the current study, it was challenging to think of examples for factual knowledge at a level other than remembering. These observations point to a possibility that the two dimensions of the RBT may not be totally independent. Based on these observations a table was developed showing apparent dependencies between types of knowledge and cognitive processes (see Table 4.5) which point to frequent association between the specific knowledge and cognitive categories. These findings support the existing literature.

Table 4.5: Knowledge Vs. Cognitive Process dependency

<table>
<thead>
<tr>
<th>Type of knowledge</th>
<th>Cognitive processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factual</td>
<td>Remember</td>
</tr>
<tr>
<td>Conceptual</td>
<td>Understand and Apply (e.g. principle learning)</td>
</tr>
<tr>
<td>Procedural</td>
<td>Understand and Apply</td>
</tr>
<tr>
<td>Metacognitive</td>
<td>Analyse, Evaluate, Create</td>
</tr>
</tbody>
</table>

The designer’s versus the learner’s point of view

Potential for misclassification is present in both knowledge and cognitive process dimensions. This can be particularly challenging in situations where an instructional designer’s point of view on a particular knowledge may differ from that of the students. During the validation process, questions were raised about the knowledge and cognitive process category assigned to some of the objectives. Examples included questions on whether a task should be categorized as conceptual or factual in the knowledge dimension, and evaluate or analyse in the cognitive process dimension.

Furthermore, the fact that most of the knowledge categories assigned in the task analyses are either conceptual or procedural was noted by a validator. This led to the question whether some knowledge must be based on facts and whether conceptual knowledge, after having been used by someone for considerable time, could become factual knowledge. For example, can Hooke’s law be regarded as factual knowledge instead of conceptual? This led to some discussion on the interpretation of the term factual knowledge. After some debate, a decision was made that this knowledge would not be seen as factual from the students’ point of view.
and therefore the knowledge type for this particular objective should remain as conceptual. The lesson learned from this process is that whenever there is a dilemma in choosing a particular type of knowledge or cognitive process, the decision should be based on the students' viewpoint.

### 4.6 Concluding remarks

The Revised Bloom's Taxonomy has been used to carry out a task analysis for teaching bending stress calculations. Based on this a flowchart of the learning objectives for teaching the application of the flexure formula has been developed. The chart shows the knowledge and cognitive process associated with each learning objective and the necessary prerequisites. This provides an overview of all the enabling objectives leading to the accomplishment of the main learning objective.

The above flowchart and the related taxonomy table were used in selecting appropriate instructional strategies for designing instructions in the CAL module. The taxonomy classifications were also used to formulate a draft framework for selection of instructional strategies to aid the instructional design process. These and other related issues are discussed in Chapter 5 (Design and Development).

The effectiveness of the CAL module that incorporated instructional strategies based on the RBT classifications was evaluated. While the evaluation produced positive results it would not be possible to attribute them solely to the use of RBT. The details of the evaluation exercise are described in Chapter 6 (Evaluation).

Based on the experience in this study, the suitability of the RBT in contrast with the OBT was discussed. Both versions of the Taxonomy were found to be useful in identifying appropriate classifications. Compared to the OBT, the RBT was found to provide clearer descriptions of the cognitive process, permitting easier identification of new action verbs. In addition, identification of the knowledge dimension was found to facilitate the selection of appropriate
instructional strategies. The results obtained from this particular task analysis point to a possibility that the two dimensions in the RBT may not be totally independent.

Some combinations of the cognitive process and knowledge categories are absent in the taxonomy table of this particular study. Future studies may focus on topics that are likely to result in objectives associated with higher cognitive process and metacognitive knowledge in order to examine the suitability of other aspects of the RBT for task analysis.
Chapter 5

Design and Development

5.1 Introduction

In this chapter, first a general overview of instructional strategies is made. Then the events of instruction that need to be followed to achieve different learning outcomes and their associated instructional strategies are reviewed. The variations in instructional strategies according to the types of learning are reviewed to ascertain their effect on designing instruction. Then the implementation of selected instructional strategies for different types of learning in a computer-based environment is illustrated. Finally, other important design considerations that are relevant to the development of the CAL module are discussed.

This chapter addresses the second research question of this study:

“What is the relationship between the type of learning outcome and the instructional strategies used to achieve that learning outcome?”

It is useful to have an overview of the instructional strategies before proceeding to discuss the issues relating to design of instructions.

5.2 Instructional strategies

5.2.1 Overview

There are various definitions of instructional strategies in the literature. Gropper (1973) defines instructional strategies as prescriptive rules for designing instructional events which create appropriate learning experiences required for the mastery of each of the various types of behavioural objectives. Further, Briggs (1977) defines instructional strategy as (a) determining
the sequencing of instruction for each objective, and (b) designing the instructional events (teaching steps) to be employed. Rothwell and Kazanas (2004) state that in the most general sense, an instructional strategy is perhaps best understood as an overall plan governing instructional content (what will be taught?) and process (how will it be taught?). Further, Smith and Ragan (1999) state that instructional strategies are about what particular content will be included, how that content will be presented, and how instruction containing such content will be sequenced. The above definitions in general appear to emphasise three aspects of instruction; the content, how it is presented, and how it is sequenced. However, most of the definitions except the Smith and Ragan's appear to emphasise only two of the three aspects. For example, Briggs' definition emphasises the sequence and content while Rothwell and Kazanas' definition emphasises the content and the presentation. On the other hand, Smith and Ragan's definition appears to emphasise all three aspects: content, presentation, and sequence. This researcher adopted Smith and Ragan's definition of instructional strategies, and the concepts underlying this definition have been used as the basis for developing instructions under this study.

In further review of literature, Rothwell and Kazanas (2004) state that instructional strategy should grow out of an analysis of the work tasks that learners are being instructed to perform and from the corresponding performance objectives established to achieve those desired results. They also state that the type of learners and learning environment associated with the learning task are also important factors in selecting or developing an instructional strategy. These factors are similar to the three components of the instructional analysis described by Smith and Ragan (1999).

According to Romiszowski (1981), any instructional strategy is also seen as a translation of a philosophical or theoretical position regarding instruction into a statement of the way in which instruction should be carried out in specific circumstances. On the other hand, Gagne et al. (1992) relate the instructional strategies to events of instruction that are used to facilitate planned learning experiences. Also, Gropper (1973) in his description of instructional strategies, emphasises the importance of sequencing instructional events. These point to two main approaches in dealing with instructional strategies; i) an approach based on philosophical views, and ii) another approach based on instructional events.
The first approach: Romiszowski (1981) describes two theoretical positions about learning and instructing that seem to represent major anchor points on a philosophical continuum of instructional strategies. Some instructional designers believe that all learning can be described best as resulting from a process of reception. This view leads to expositive instructional strategies. But others believe that all learning is best described as resulting from a process of learner discovery. This view leads to experiential instructional strategies. The difference between the two types of strategies can be illustrated as follows. In the case of teaching a concept, an expositive strategy would be to present and explain the definition of the concept before presenting the examples that represent the concept. Alternatively, an experiential strategy would be to first present the examples of the concept and then make the learners induce the generality of the concept. While expositive and discovery instructional strategies constitute more or less opposite anchor points on a continuum, there are many points in between (Romiszowski, 1981). According to Smith and Ragan (1999), neither approach is better than the other, but in a particular situation, one maybe more appropriate than the other depending upon the context, the learners, and the learning task. From personal teaching experience, and from the experience of other teachers' comments, this researcher also believes that a flexible approach that allows the instructional designer to choose appropriate strategies from either approach depending on the situation. As discussed in detail in Chapter 3, the three factors, context, learners, and the learning task are the three constituent components of instructional analysis. Hence, it is reasonable to expect that the results of instructional analysis could be useful in selecting the most appropriate type of strategies, discovery or expository. For the undergraduate engineering courses taught at the OUSL, considering the high anxiety associated with learners (learners) and the limited time and teacher resources available to attain the required learning outcomes (context), the use of expositive instructional strategies (reception) appears most suitable. However, this should not preclude the use of discovery type strategies where possible. The practicality of using discovery type strategies in distance learning is also another issue to be considered. Smith and Ragan’s (1999) graphical representation of “The balance of generative (discovery) and supplantive (expositive) strategies” also suggests that expositive instructional strategy may be more appropriate for the present study.
The second approach: This is based on the events of instruction and the conditions of learning. Instructional strategy is rooted in assumptions about what does-or should- happen during any planned learning experience and about what type of learning the instruction is intended to facilitate (Gagne et al., 1992). Gagne's nine events of instruction, which serve as the basis for this approach of formulating instructional strategies, will be discussed later in this chapter.

The two ways of thinking about instructional strategies as discussed above are complementary to each other and in the view of this researcher they are both useful. The events of instruction form the sequence and the structure of instruction. On the other hand, the philosophical view about instructions, that is, which approach, expositive or discovery, will address how the events of instruction are implemented. Smith and Ragan (1999) using their expanded events of instruction (adapted from Gagne's nine events of instruction) clearly explain how each event of instruction changes, based on the type of philosophical approach used, i.e. expositive or discovery. Smith and Ragan (1999) indicate that selecting one approach or a combination of the two approaches for designing instructions is a critical decision that the instructional designer has to make.

Sequencing is an important aspect of instruction (Gagne et al., 1992; Gropper, 1973), which is carried out using what is known as the events of instruction.

5.2.2 Events of instruction

The events of instruction are designed to make it possible for learners to proceed from where they are at present to the achievement of the desired learning outcomes. Events of instruction generally arrange the external conditions of learning in such a way to ensure that learning occurs. There are different schemes of events of instruction designed to achieve learning outcomes from lessons. Typically, within a selected scheme, the events of instruction apply to all types of lessons regardless of their intended outcomes. However, there are some events of instruction whose associated instructional strategies can be varied to achieve different types of learning outcomes (Gagne et al., 1992) such as concepts and procedures.
There are many schemes for describing the events of instruction, also sometimes known as teaching steps. One example is Pucel’s (1989) eight instructional events. However, more widely known than these eight steps are the nine key instructional events (events of instruction) identified by Gagne et al. (1992), listed below:

1. Gain attention of the learner
2. Informing the learner of the objective
3. Stimulating recall of prerequisite learning
4. Presenting the stimulus material
5. Providing learning guidance
6. Eliciting the performance
7. Providing feedback about performance correctness
8. Assessing the performance
9. Enhancing retention and transfer

According to Gagne et al. (1992), the desired learning outcomes also influence the choice of instructional strategy. For example, learners should not be asked to acquire verbal information in precisely the same way that they are led to develop a cognitive strategy, intellectual skills, motor skills, or new attitudes. They also elaborate that learning experiences are of different kinds, and a different instructional strategy is appropriate for each kind.

Ragan (2004) states that it is helpful to first look at the type of learning associated with the overall learning goal to determine the appropriate instructional strategy. Once the overall instructional strategy is determined based on the type of learning, events of instruction are designed.

According to Gagne (1970), instructional planning is vastly simplified by assigning learning objectives to five major categories (taxonomy) of human capabilities. The categories are intellectual skills, cognitive strategies, verbal information, motor skills, and attitudes. These categories are formed because each leads to a different class of human performance. Within each of these five categories, regardless of the subject matter of instruction, the same qualities of performance apply. The intellectual skills are grouped into five levels of complexity:
discriminations, concrete concepts, rules and defined concepts, higher-order rules, and problem solving. Gagne et al. (1992) state that the category of intellectual skills provides the best structural model for instructional design.

The instruction must take into account a whole set of factors that influence learning, and that collectively may be called the conditions of learning (Gagne, 1970). Some of these conditions pertain to the stimuli that are external to the learner. Others are internal conditions, to be sought within the individual learner. They are states of mind that the learner brings to the learning tasks; in other words, they are previously learned capabilities of the individual learner. These internal capabilities are a highly important set of factors for ensuring effective learning (Gagne et al., 1992).

The appropriate instructional strategy for each event depends on the desired results. Therefore, an instruction aimed at helping learners acquire a particular human capability (e.g. verbal information or develop intellectual skills, etc.) requires its own appropriate strategy within the planned learning experience. However, in the case of some instructional events such as gaining attention (event 1), the particular strategy employed to bring about the event does not have to be different for each type of learning objective. Most common strategies used for gaining attention are actions such as showing something on the blackboard or projector screen, asking questions from the class, demonstrating how something works, etc. These strategies can be readily used for any type of learning. However, according to Gagne et al. (1992), there are four events that need to be specific to each type of learning objective. They are the following events: event 3, stimulating recall of prerequisite learning; event 4, presenting the stimulus material; event 5, providing learning guidance; event 6, eliciting the performance (Gagne et al., 1992). Smith and Ragan (1999) have developed what they call expanded events of instruction. The expanded events of instruction consist of fifteen events which are based on Gagne’s nine events of instruction. Smith and Ragan (1999) have placed these fifteen events into four groups, namely, introduction, body, conclusion, and assessment. In the expanded events of instruction (see the list below), the Gagne’s four events of instruction (3, 4, 5 and 6), mentioned above, are represented by five events under the body of instruction.
Listed below are the Expanded Events of Instruction (Smith and Ragan (1999)). Examples of their implementation within the CAL module are given in pages 74 through 84 (section 5.3).

1. Gain attention to lesson
2. Inform learner of instructional purpose
3. Stimulate learner's attention
4. Provide overview
5. Stimulate recall of prior knowledge
6. Present information and examples
7. Focus attention
8. Guide or prompt use of learning strategies
9. Elicit response
10. Provide feedback
11. Provide summary and review
12. Enhance transfer
13. Provide remotivation and closure
14. Conduct assessment
15. Provide feedback and remediation

Review of the types of instructional strategies available in the literature reveals that most of them are based on types of learning similar to Gagne's five categories of human capabilities (Gagne et al., 1992; Smith and Ragan, 1999). Although these instructional strategies are named based on the types of learning (e.g. concept learning), there seems to be a cognitive process associated with each of these strategies. Each strategy targets to achieve that cognitive process as its ultimate learning outcome (e.g. understand cognitive process for concept learning). This association between the type of learning (knowledge) and the cognitive process has been noted by the researcher and is explained in Chapter 4 (Table 4.5).

Now that a considerable amount of discussion has been made about the instructional strategies and the events of instruction, it would be opportune to look at some actual examples. As mentioned above, there are three important aspects of an instructional strategy; i) what to learn (content), ii) how to present, and iii) instructional sequence. Table 5.1 shows examples of a
few instructional strategies analysed in respect of the above three aspects. Instructional events referred to in the table are based on Gagne’s nine events of instruction, listed above.

### Table 5.1: Analysis of instructional strategies

<table>
<thead>
<tr>
<th>Instructional strategy</th>
<th>What to learn</th>
<th>How to present</th>
<th>Instructional sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Present the stimulus material (best example/prototype or definition)</td>
<td>Given a set of objects, classify the ones with an axis of symmetry as symmetrical objects</td>
<td>Present a clear example of an object which has an axis of symmetry, on the blackboard or computer screen. Also, present a written definition of symmetry.</td>
<td>This strategy (‘presenting the stimulus material’) should be preceded by a strategy ‘to stimulate recall of prerequisite knowledge’. In this case, prerequisite knowledge may be the concept of ‘axis.’ The succeeding strategy would be ‘to provide learning guidance’.</td>
</tr>
<tr>
<td>2. Stimulate recall prerequisite knowledge (review component concepts)</td>
<td>Given the stress that an elastic material is subjected to, calculate the corresponding strain that material undergoes (Hooke’s law).</td>
<td>Ask students to recall what is ‘stress’ and ‘strain’. Alternatively, students may be assisted in recalling by getting them to answer a multiple choice question where the correct definition (equation) is one of the answers. If the responses are incorrect, provide feedback to lead the learners to the correct answer.</td>
<td>This strategy (‘stimulate recall of prerequisite knowledge’) should be preceded by a strategy ‘to inform the learner of the objective of the lesson/task’. The objective of this lesson/task is for the learners to be able to calculate stresses and strains using Hooke’s law. The succeeding strategy would be ‘to present the stimulus material’.</td>
</tr>
</tbody>
</table>
| 3. Present the stimulus material (explain how to determine if the procedure is required or relevant) | Given a symmetrical beam that is subjected to pure bending, calculate the normal stress it undergoes using the flexure formula. | Present examples and nonexamples for applying the flexure formula. Provide practice questions for identifying examples and nonexamples. Give feedback. | This strategy (‘presenting the stimulus material’) should be preceded by a strategy ‘to stimulate recall of prerequisite knowledge’. In this case, prerequisite knowledge may be the concepts of ‘pure bending’ and ‘axial loading’. The succeeding strategy would be to ‘provide learning guidance’.
It was mentioned earlier that some strategies used to achieve certain events of instruction are common to many types of learning and some are specific to a given type of learning. This led to the study of how the strategies used to achieve these specific events of instruction vary according to the type of learning. Also, questions such as whether certain strategies are common to some types of learning and whether some strategies used in cognitively less demanding types of learning (e.g. concept learning) are also included in strategies used in more cognitively demanding types of learning (e.g. procedure learning) were also considered in this study. Further, investigations were carried out to determine how different strategies used to achieve certain events of instruction (and ultimately the intended learning outcome) can be implemented in a computer-based instruction. This has resulted in a draft framework that could be used to facilitate the development of computer based instruction for achieving different learning outcomes identified through a task analysis conducted using the Revised Bloom’s Taxonomy (RBT). The development of this framework is explained in the following sections.

5.2.3 The RBT classifications and instructional strategies

According to Lovell-Troy (1989), there are well over hundred instructional strategies available in the literature for use by teachers. He states that their use by teachers is however limited due to two reasons: i) lack of an easily remembered model for making instructional decisions, and ii) lack of organisation of the plethora of existing instructional strategies. In this study, the instructional strategies developed by Smith and Ragan (1999) are adopted and used. These strategies are organised under the fifteen instructional events in the expanded events of instruction.

As discussed in Chapter 4, the task analysis carried out (using the RBT) on the application of the flexure formula produced the taxonomy table depicted in Table 4.3. As noted already, the learning objectives derived from the task analysis occupy only cells B1-B3 and C2-C3 in the taxonomy table. In this thesis, it was decided to focus on B2, B3, and C3 cells as a considerable proportion of the objectives have clustered in them. The objectives in cells B2, B3, and C3 can be treated as examples of concept learning, principle learning, and procedure
learning, respectively, as explained by Smith and Ragan (1999). In Gagne's definition of levels of complexity in intellectual skills, these objectives fall under concepts (concrete and defined) and rules (Gagne, et al., 1992).

According to the researcher's view, concepts, principles, and procedures can be viewed as follows: Concepts are grouping of ideas or things into categories for ease of reference. Each time one has to refer to the ideas or things grouped this way it can be done by referring to the name given to that group or category rather than describing all the individual components in the group (e.g. triangle, symmetry, etc.). “Ideas or things” may include objects, symbols or events. For example, force is a concept. Different types of forces such as axial forces and lateral forces are grouped under the concept of force. All the different types of forces in the group (concept of force) share common features, such as having common units of measure or having the potential to make the objects they (different types of forces) are applied to, move, accelerate or deform. A group of concepts can also form another concept. For example, a grouping of the concepts force and moment can result in another concept called action. A common feature that brings both force and moment under one overall concept of action is that they both have the potential to make the objects that they are applied to, move, deform or accelerate. On the other hand, principles prescribe relationship between two or more concepts. Relationship between stress and strain (two individual concepts) can be explained using the principle called Hooke's law. Procedure is generally a set of steps or an algorithm prescribed to obtain a certain output or product. The steps involved in calculating the second moment of area about the neutral axis of a composite beam form a procedure.

Concept learning, principle learning and procedure learning are three types of learning commonly associated with teaching. Smith and Ragan (1999), within their range of various instructional strategies, have presented separate instructional strategies for concept learning, principle learning and procedure learning. The same authors, in their review of Gagne's types of learning outcomes under intellectual skills, have identified principle learning as one of the learning outcomes along with other outcomes such as concept learning, procedure learning, problem solving, cognitive strategies, etc. Merrill (1983) has described the learning tasks in terms of two dimensions; one dimension is content and the other is performance. He identified four types of content, namely, facts, concepts, principles, and procedures. Merrill also
introduced three levels of performance as outcomes for the four types of content identified by him. These levels are remember, use and find. The original Bloom’s taxonomy also identified three main categories of knowledge (content) and it has listed principles as one of the subcategories of knowledge. From the above, it can be seen that principle learning has been commonly recognised as a separate type of learning in the literature. However, the revised Bloom’s taxonomy (RBT) which also introduced two dimensions to define a learning objective, namely, type of knowledge and cognitive process, has not considered principles as a separate type of knowledge. In fact in the RBT, principles have been classified under conceptual knowledge.

Based on the researcher’s experience, the presence of a separate knowledge type for principles would have made the classification of learning objectives using the RBT easier. Learning objectives associated with principles such as theorems, laws, etc. do not strictly fit into either conceptual or procedural type of knowledge. Classifying these as concepts fails to recognise the presence of the relationship between the concepts that defines the principle, an essential feature of principle knowledge. There is also a major difference between procedures and principles. Some instructional strategies for teaching procedures emphasise the presence of intermediate steps in a procedure which may be absent in teaching a principle. However, it was found that after classifying the principles as conceptual knowledge, associated with the cognitive process of application in the RBT’s taxonomy table appropriate instructional strategies could be chosen. These would essentially be those strategies relating principle learning such as the ones developed by Smith and Ragan (1999). This observation was communicated to Anderson (2005) and Krathwohl (2005) who are members of the committee of authors that developed the RBT. They would like to avoid any revisions to the RBT unless proposals for such revisions are supported by a larger community of researchers. However, they do not have objections for modifying the taxonomy table to include an additional category for principle knowledge in its use to facilitate better communication in specific applications. The researcher however felt that it is important to make this point known.

Appendix 5.1 shows the events of instruction for the above three types of learning. The events shown there are limited to those instructions belonging to the “body” of instruction in Smith and Ragan’s expanded events of instruction. Other events of instruction belonging to
introduction, conclusion, and assessment are not considered here as it is the events of instructions belonging to the body of instructions that are considered to be more specific to individual types of learning than the others. The body of instruction includes the following events of instruction: recall prior knowledge, process information, focus attention, employ learning strategies, practice, and provide feedback. Appendix 5.1 also shows twenty nine (29) strategies used for different events of instructions under different types of learning, e.g. concept learning, principle learning, and procedure learning. B2, B3, and C3 refer to the cell addresses in the taxonomy table (Table 4.3). Review of the contents in Appendix 5.1 indicates that the strategies in cognitively more demanding types of learning such as procedure learning tend to encompass the strategies of cognitively less demanding types of learning such as concept learning (e.g. strategies B2.1 to B2.4 and B3.1). This is consistent with the literature (Gagne, et al., 1992). Both principles and procedures in Smith and Ragan’s model appear to be included in Gagne’s category of rules.

It may be seen from Appendix 5.1 that instructional strategies relating to recall prior knowledge (event of instruction) are generally common among the three types of learning. However, the differences in strategies start to emerge from the event of instruction for process information. The learners would encounter the material they are about to learn, first under this event. It is observed that the remaining strategies such as focus attention, employ learning strategies, and practice are all related to the event of process information.

Before proceeding to compare the related instructional strategies, it is important to be able to understand the types of knowledge and cognitive processes involved in the three types of learning. Table 5.2 shows a comparison of the three types of learning with types of knowledge and cognitive processes.

<table>
<thead>
<tr>
<th>Type of Learning</th>
<th>Type of Knowledge</th>
<th>Cognitive Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concept learning</td>
<td>Conceptual</td>
<td>Understand</td>
</tr>
<tr>
<td>Principle learning</td>
<td>Conceptual</td>
<td>Apply</td>
</tr>
<tr>
<td>Procedure learning</td>
<td>Procedural</td>
<td>Apply</td>
</tr>
</tbody>
</table>
It is interesting to note that both concept learning and principle learning share a common type of knowledge (conceptual) but have different cognitive processes, understand and apply, respectively. On the other hand, principle learning and procedure learning are associated with different types of knowledge (conceptual and procedural knowledge, respectively) but they both share the same cognitive process, apply. It is observed that instructional strategies for concept learning emphasise understanding while the instructional strategies for both principle and procedure learning emphasise application. This can be seen from the underlined phrases in the general description of strategies in the first row of Table 5.3 which provides a general description and a range of instructional strategies for different types of learning. The strategies listed are for the event of instruction for process information. These and other strategies for other events of instruction are given in a larger table in Appendix 5.1.

It can also be seen from the Table 5.3 that there are variations in instructional strategies for principle learning and procedure learning although they share the same cognitive process of application. This variation is evidently from the different types of knowledge involved, conceptual and procedural. Therefore, it can be deduced that the instructional strategies are primarily based on the cognitive process associated with the learning objective. However, the type of knowledge also has an influence on specific details of the strategies.

Implementation of some of these strategies is illustrated in the next section using actual examples from the design of the CAL module. Some other important issues relating to the design of the CAL module such as the structure of the module, navigation, screen layouts and storyboards also are discussed briefly in another succeeding section.
<table>
<thead>
<tr>
<th>Events of Instruction / Type of Learning</th>
<th>Concept Learning (B2: Concept/Understand)</th>
<th>Principle Learning (B3: Concept/Apply)</th>
<th>Procedure Learning (C3: Procedure/Apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process information</td>
<td>Expose to best example and/or definition; emphasise criterial attributes; consider matched examples and nonexamples; present concept in range of settings with diversity of nonrelevant attributes.</td>
<td>Present/induct relationship; state in principle form; demonstrate application</td>
<td>Simplify complex procedures, situations that require procedures, steps in procedure, order of steps, how to evaluate correctness of application. May elaborate over several iterations.</td>
</tr>
<tr>
<td>(B2.5) Present best example/prototype or definition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B2.6) emphasise criterial attributes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B2.7) present matched examples and nonexamples</td>
<td></td>
<td></td>
<td>(B2.7) Explain how to determine if the procedure is required by using matched examples and nonexamples</td>
</tr>
<tr>
<td>(B2.8) present concept in a range of settings with diversity of nonrelevant attributes.</td>
<td></td>
<td>(B3.1) Present the relationship with a statement</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(B3.2) present the application of principle with examples</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(B2.5) present best example of application of principle.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>(C3.2) Explain/demonstrate how to complete the steps in the procedure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(C3.3) provide opportunity to practise each step sequentially</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(C3.4) Elaborate importance of each step to facilitate remembering the steps in the procedure</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(C3.5) Explain how to check appropriateness of a completed procedure.</td>
<td></td>
</tr>
</tbody>
</table>
5.3 Development

This section is divided into two; one about the implementation of selected instructional strategies in the actual design of the CAL module and the other about some other important issues relating to the overall design of the CAL module.

5.3.1 Implementation of instructional strategies

In actual practice, good teachers and instructional designers use the instructional strategies selectively. They sometimes combine several strategies together or do not make use of some strategies at all based on their judgement of the given learning situation. If the instructional designer or teacher is aware that certain skills and knowledge already exist among the learners, use of some strategies will be reduced or abandoned altogether.

The following sections illustrate how some of the selected instructional strategies were implemented in the CAL module. Illustrations are arranged according to the type of learning. Examples of the implementation of instructional strategies for concept learning are illustrated first.

Concept learning

Following are some instructional strategies used for process information under concept learning:

- Present best example/prototype or definition (B2.5)
- Present nonexamples (B2.7)

The concept to be learned in this example is axis of symmetry, which is a useful concept in locating the neutral axis of symmetrical shapes. The concept of symmetry is not part of the present instruction on application of the flexure formula and in the task analysis it is identified as a required prerequisite knowledge. The example of symmetry is used for the purpose of illustrating how concepts can be taught using a CAL module.
Figure 5.1 shows a screen shot from the CAL module. This screen shows how the learning of the concept of symmetry is facilitated using examples (B2.5). The text in the main display panel (top-left panel) refers to axis of symmetry. Clicking of underlined (hypertext) text brings up the examples in the feedback panel (top-right panel) as shown in the Figure 5.1. Clicking the 'play' button on the screen will start an optional voice explanation on the concept of symmetry.

The CAL module’s hyperlinked explanation of “axis of symmetry” is particularly useful for learners as they could refresh their memories about this prerequisite knowledge, if they wish, while reviewing the main topic, without having to look for additional sources outside the main lesson. This would minimise their distraction from the main lesson and allow them to spend their learning time effectively. The optional voice explanation is also expected to provide the learners with additional information on the topic and support in improving their English knowledge. The users of the CAL module have commented positively about the availability of different options (hypertext, voice, graphics, etc.) from a single screen and stated that it helped them learn better and faster.
2.2 Locate the Neutral Axis
We will now deal with step 2.

To locate the neutral axis it is good to first find out whether the overall cross-section of the beam has an **axis of symmetry** perpendicular to the plane of bending. If so, the neutral axis will be the centreline of the section.

Let us take an example of a rectangular beam.

The above cross-section has an axis of symmetry perpendicular to the plane of bending.

* Click PLAY/STOP button to turn on/off the audio.
* Click highlighted words for more explanation.

**Figure 5.1:** Concept learning (*present examples* - strategy B2.5)

Figure 5.2 below shows a screen which presents different shapes which are not symmetrical. They are nonexamples of symmetry. In the text on the screen there is a prompt to the user. In case the user wants to know why a particular shape is not an example of symmetry, he or she can click on the shape to bring up an explanation on the feedback panel on the right indicating why the shape is not considered symmetrical. Figure 5.2 shows the explanation provided by the CAL module when the first shape on the left of the screen has been clicked. This screen shows the implementation of instructional strategy B2.7, *present nonexamples*. The availability of such explanations through the CAL module helps learners clarify any doubts that they may have, and this is an important need identified during the instructional analysis, i.e. the need of the distance learners to be able to clarify doubts promptly. Clicking the ‘play’ button on the screen will start an optional voice explanation why the shapes on the screen are not examples of symmetry.
2.5 Locate the Neutral Axis

The following sections do not have an axis of symmetry perpendicular to the plane of bending.

Top and bottom flanges have different thicknesses. Therefore, there could be no axis of symmetry perpendicular to the plane of bending.

Do you know why? Click a section to see the reason.

* Click PLAY/STOP button to turn on/off the audio.

Figure 5.2: Concept learning (present nonexamples - strategy B2.7)

In the following section, a few examples of the implementation of instructional strategies relating to principle learning are illustrated.

**Principle learning**

Following are some strategies used for *process information* under principle learning:

- Present the relationship with a statement (B3.1)
- Present the application of the principle with examples (B3.2)

The principle to be learned in this example is the First Moment of Area theorem, which is used to locate the centroid of a beam. The location of the centroid is an important step in the calculation of flexural stresses in beams. Figure 5.3 shows a screen shot where the relationship
established in the First Moment of Area theorem is presented (B3.1). Text, equations and graphics are used to present the theorem (principle).

Here is the summary of the First Moment of Area theorem.

The total first moment of area about any arbitrary datum = total area x distance to the centroid

\[ \int y \, dA = \bar{y}A \]

\[ \bar{y} = \frac{\int_A y \, dA}{A} = \frac{\int_A y \, dA}{A} \quad (1) \]

Figure 5.3: Principle learning (present the relationship with a statement - strategy B3.1)

Figure 5.4 below shows a screen shot where an example of the application of the First Moment of Area theorem is presented (B3.2). Learning principles is about understanding and applying concepts while concept learning is about understanding concepts. Therefore, the strategy of giving examples of application to teach a principle is a distinctive strategy of principle learning.
Let us locate the neutral axis of the ‘I’ beam shown here.

Using equation (3),

\[
y = \frac{\sum A_i y_i}{\sum A_i}
\]

\[
y = \frac{(200 \times 40) \left(25 + 100 + 40/2\right) + (100 \times 30) \left(25 + 100/2\right) + (200 \times 25) \left(25/2\right)}{\left[(200 \times 40) + (100 \times 30) + (200 \times 25)\right]}
\]

\[
= \frac{(1160000) + (225000) + (62500)}{8000 + 3000 + 5000}
\]

\[
= \frac{1447500}{16000} = 90.47 \text{ mm}
\]

In the following section, a few examples of the implementation of instructional strategies relating to procedure learning are illustrated.

**Procedure learning**

Following are some strategies used for *process information* under procedure learning:

- Explain how to determine if the procedure is required by using matched examples and nonexamples (B2.7) – This is a common strategy and was also used under concept learning.
- Explain/demonstrate how to complete the steps in the procedure (C3.2) – This strategy may also be used under other types of learning, e.g., principle learning.
Provide opportunity to practise each step sequentially (C3.3) – This is a strategy specific to procedure learning.

Elaborate importance of each step to facilitate remembering the steps in the procedure (C3.4) – This is a strategy specific to procedure learning.

Explain how to check appropriateness of a completed procedure (C3.5) – This strategy may also be used under other types of learning, e.g., principle learning.

The procedure to be learned in this example is the application of the Flexure Formula, which is the overall objective of the CAL module. The entire CAL module has been designed and developed as a procedure learning exercise. Within the CAL module there are also individual procedures that are taught (e.g., application of Second Moment of Area theorem, application of Parallel Axis theorem, etc.).

Most of the strategies for process information under procedure learning are different from those for other types of learning such as concept or principle learning. Both principle learning and procedure learning are associated with the cognitive process of application. However, the differences in instructional strategies in the two types of learning may be attributable to the distinct features associated with the procedure learning include: i) provision of opportunity to practice each step in the procedure sequentially, and ii) elaboration of importance of each step to facilitate remembering the steps in the procedure.

Implementation of some of the strategies relating to procedure learning is illustrated below using examples of the developed CAL module.

Figure 5.5 shows a list of steps that are used in studying the application of the flexure formula procedure. This is a demonstration of the importance of the steps (sequence) in the procedure (C3.4). The first step is checking the appropriateness of the flexure formula (B2.7), which could be common to other types of learning as well. Clicking the underlined link takes the learner to the details of the step on how to check the appropriateness. Details are not presented here.
We are going to study the application of the flexure formula. This procedure consists of four steps. They are:

Step 1. Check the appropriateness of the formula.
Step 2. Locate the neutral axis.
Step 3. Obtain the second moment of area about the neutral axis.
Step 4. Apply the flexure formula.

Let us start with the first step now.

Figure 5.5: Procedure learning (Elaborate importance of each step – strategy C3.4)

Figure 5.6 below shows an exercise given to the learners to check one of the conditions that needs to be met in applying the flexure formula. Learners interact with the CAL module by dragging the labels to the appropriate objects. The text on the top-left panel shows the feedback given by the CAL module for a correct learner response. The user is presented with diagrams of two beams, i.e. one that undergoes pure bending and another that is subjected to a bending moment and an axial force. The user is asked to indicate which one of the two beams is an example and which one is a nonexample for applying the flexure formula, by dragging the respective labels ('example' and 'nonexample') to the diagrams. The user is given a feedback depending on the nature of the answer. If the answer is wrong the CAL module will provide a feedback saying why it is wrong. If the answer is correct, a motivational feedback is given with an explanation why it is correct. This will help the learner to know the correct answer even if the user response was guess work. The teaching point emphasised here is that the flexure formula is applied to the beams with pure bending only. This type of interaction with the content and the context-sensitive feedbacks are likely to help the users learn better.
Let us do a little exercise.

Example

Non-Example

Drag the label 'example' or 'non-example' to the above objects to confirm whether they are examples or non-examples for applying flexure formula.

* Click PLAY/STOP button to turn on/off the audio.

Figure 5.6: Procedure learning (*determine if the procedure is required or relevant* — strategy B2.7)

Only some strategies of procedure learning are illustrated. Figures 5.7 and 5.8 show an interactive exercise provided for learners to practise a step in the procedure. In Figure 5.7, the feedback given for incorrect learner input is shown on the top-right panel, which gives learner a choice of a hint or correct answer. Figure 5.8 shows the feedback which the CAL module provided when the 'hint' button was clicked. These two figures are related to strategy C3.3, which is about providing opportunity to practise steps in the procedure. The acceptance of text input, its evaluation, and provision of context-sensitive feedback to the learners is done by the CAL module. These would provide the learners at the OUSL with much desired help they have requested during the needs analysis. The learners emphasised that they need more feedback and help in solving problems. The two-stepped feedback, hint and complete answer, also gives the learners opportunity to reattempt the question before reading the correct answer.
The foregoing sections illustrate how various strategies under different types of learning are implemented in a CAL environment. The strategies illustrated are from the process information event in Smith and Ragan's expanded events of instruction.

As previously mentioned, Smith and Ragan's expanded events of instruction consists of four major parts; introduction, body, conclusion, and assessment. Of these four parts, assessment is not considered in this study. However, introduction and conclusion are included in the developed CAL module. So far in this chapter, strategies relating to the body of instruction
were discussed. It is opportune to briefly look at the instructional strategies used under introduction and conclusion of the CAL module as well.

The introduction part of the expanded events of instruction includes the following instructional events: i) Gain attention, ii) Inform learner of instructional purpose, iii) Stimulate learner's attention, and iv) Provide overview. Appendix 5.2 contains the text that was narrated along with a series of animations and pictures to achieve the above mentioned instructional events. These narrations and animations were intended to gain learner's attention, stimulate learner's attention, and inform learner of the instructional purpose.

Appendix 5.3 illustrates the implementation of instructional strategies relating to the instructional events under conclusion part of the instruction. The relevant instructional events are: i) Provide summary and review, ii) Enhance transfer, and iii) Provide remotivation and closure.

It could be seen from the foregoing sections that various strategies are used to implement different events of instruction under different types of learning. This points to a need for a framework to assist selection of strategies based different events of instruction and types of learning.

It is hoped that the draft framework of strategies for different events of instruction under different types of learning (Appendix 5.1) developed under this study would serve as a useful reference for selecting appropriate instructional strategies to design instructions to suit different learning situations, either print- or computer- based. This is likely to help the instructional designers in their work. This draft framework covers only the instructional events within the 'body' of instruction as defined in Smith and Ragan's (1999) expanded events of instruction and this also is limited only to concept learning, principle learning, and procedure learning. Therefore, further improvements to this draft framework are necessary to include more instructional events and types of learning.
In addition to the use of appropriate instructional strategies, several other considerations needed to be made in the design and development of the CAL module. These considerations are explained in the next section.

5.3.2 Other important design considerations

Authoring tool

Selection of a suitable authoring tool was one of the important decisions that had to be made. The availability of the original software and the programming skills within the department where this research was conducted prompted the selection of Authorware™, a product of Macromedia, as the main authoring tool for the CAL module. Box (2001), referring to a study done by others on various authoring tools available for computer-aided instruction, states that Authorware is highly appropriate for the production of teaching programs due to its ease of use, flow-chart-based design and ready ability to modularise products.

Overall structure of the CAL module

A chart (Figure 5.9) that shows the integration of the different parts of the CAL module was developed. This was found to be very useful in the development of the CAL module and helped ensuring easy navigation within the module.
Screen design

Design of a screen layout that is simple, consistent, attractive, effective, and easy to use was recognised. The following considerations were used in finalising the screen layout for the CAL module. The final layout was arrived at after several iterations.

i) Clarity
ii) Consistency
iii) Meaningfulness
iv) Ease of use
v) Hardware considerations (e.g. screen resolution)
vi) Software considerations (e.g. availability of default navigational buttons)
vii) Needs of the instruction (e.g. need to give frequent feedbacks, need to play/stop audio clips)

The screen layout was designed in such a way that there are designated areas on the screen for specific types of information. This type of layout is expected to be easy to learn and use. The
effectiveness of the screen layouts, navigations, etc. was tested using learnability tests. Results of such tests carried out on this CAL module are presented and discussed in Chapter 6 (Evaluation). As shown if Figure 5.10, the white panel in the top-left part of the screen is the main display panel and is meant to carry the important parts of the lesson. According to Galitz (1993), eyeball fixation studies indicate that in looking at displays of information, usually one’s eyes move first to the upper left centre of the display. Accordingly, the location of the main display is most appropriate. Specific locations (panels) are designated for instructions on the use of the CAL module (pale cyan instruction panel), any feedbacks the CAL module provides (yellow feedback panel) and control panel (for navigation). Panels are colour coded for easy recognition and consistency. For example, feedbacks always appear in yellow background. However, when there is no necessity for a feedback panel based on the content being explained on the screen, the space allocated for the feedback panel is merged with the main display panel to provide a larger space for text and graphics under the main display panel. In general, simplicity, clarity, and understandability were given high consideration in the design of screen layouts.

Figure 5.10: Different panels in screen layout
Appearance

The researcher was aware of the importance of visually pleasing composition of screens. The pleasing screens appear to engage the users in the learning process better. Galitz (1993) states that a lack of visually pleasing composition is disorienting, obscures the intent and meaning, slows one down, and confuses. There are many features that contribute to a visually pleasing screen. Balance, proportion, and density are some of the aspects that were considered in designing a suitable visual environment. In the presentation of learning materials, it was attempted to balance the content within the screen and to maintain a balance between the text and graphics, where applicable. The density on the screen, i.e. how much text or graphics are on one screen, was also closely monitored. Where possible, the content was broken into chunks and presented in successive screens. Rules of thumb were used for the number of text lines, number of words per line, the total number of words per screen, etc. to maintain a desirable level of density. The font size was also a factor in this effort.

It was found expedient to prepare the text and graphics separately using a word-processing software and then to import to Authorware. This saved programming time. However, there were occasional difficulties relating to editing and clarity of imported text and graphics in Authorware.

Navigation

The structure of the CAL module discussed above served as the basis for designing the navigation within the CAL module. The buttons in the control panel provided the basic navigation within and between sections. The main menu and sub-menus in the module provide access to different sections. Also the menu bar on top of each screen provided alternative means to access various parts of the CAL module. Also the hyperlinked section titles at beginning and end of sections provide access to relevant sections without having to go through the main and submenus. The tutorial on 'How to use this module' is intended to help the initial users and others.
Readability of instructional text

Considering the poor English language proficiency of the learners at the OUSL, as identified in the instructional analysis, special consideration was given in developing the instructions. Simple words, short sentences, short paragraphs, limited text per screen, etc. were used to improve the readability of instructional text. Randomly, selected texts were subjected to readability tests using a standard word processing software. Where the readability scores were not favourable, text was revised to improve its readability index.

Audio clips

Access to optional audio clips was included in both the main display panel and feedback panel where an audio clip was provided. These audio clips provide additional explanation to the contents displayed on the screen. The provision to make the use of audio clips optional is based on the necessity to give the users the opportunity to decide when to use the audio facility and when to switch it off. It was observed during the pilot study that some students, particularly the ones with English language difficulties, are very enthusiastic about the use of audio clips. Inclusion of the audio facility in the CAL module is based on the findings of the needs analysis conducted at the beginning of this study.

Storyboards

Over 300 storyboards were prepared for the entire CAL module. A special format was developed for use by the researcher who developed the storyboards and the developers (Dr. S. Ilanko, Senior Lecturer at the University of Canterbury and Namal Surangika, programmer at The e-Drive Ltd., Sri Lanka) who used the storyboards for programming the CAL module using Authorware and Flash. Most of the storyboards were hand-written. On some occasions to save the time of the developer, certain storyboards were prepared using word processing software so that the developer could copy the relevant content, particularly the graphics, on to the authoring tool directly. Appendix 5.4 shows a blank storyboard format used in the development of the CAL module. To a large extent the storyboard resembles the standard screen layout used in the module. In addition, the storyboard has provision for screen ID
number, objective number (from the task analysis) being explained, page (screen) number within the selected objective, and the event of instruction being handled under the selected objective (e.g. introduction, process information, practice, etc.). This additional information on the storyboard helps the instructional designer to track the objectives identified in the task analysis and to ensure that all the instructional events necessary for the objective are also detailed. The developers also found these detailed storyboards useful as they could work independently of the instructional designer to a great extent by relying on the information on the storyboards. Appendices 5.5 and 5.6 show two storyboards used in the development of the CAL module.

Development (programming)

The entire CAL module except for a small section on practice questions and animated introduction at the beginning of the module was developed by Dr. S. Ilanko using Authorware. The other sections were developed using Flash by Namal Surangika. This section of the module was integrated into the main program using executable Flash files called from the main Authorware programme. A few existing CAL packages available at the Mechanical Engineering department of the University of Canterbury were also linked to the newly developed CAL module to provide the users with access to certain prerequisite knowledge (which are not part of the instruction developed under this study) and additional exercises.

A summary of the researcher's major experiences during the design and development process is presented in the following section as “Lessons learned”.

5.4 Lessons learned

The RBT classification and the event of instruction determine the design of learning activities. Initially, the type of knowledge, whether it is conceptual or procedural, etc., helps the selection of the overall group of instructional strategies that suits the type of knowledge (e.g. conceptual learning, procedure learning, etc.) because the instructional strategies are referred to by the knowledge type. Then the individual event of instruction, whether it is process information (present stimulus material), provide learning guidance, or provide feedback, etc., influences the selection of specific instructional strategies that are ultimately used to
implement the learning activities. During the design of learning activities, the availability of a sequence to follow (the list of instructional events) facilitates the instructional designer's work and ensures that the instruction is complete and is free of gaps. Instruction thus developed is likely to assist the achievement of the desired learning outcome better.

Task analysis helps identify and include prerequisite knowledge in design. The availability of a completed task analysis, which identifies the necessary prerequisite knowledge in addition to the enabling learning objectives of the main learning goal, helps include access to prerequisite knowledge from the main instruction for those users who wish to recall them to refresh their memories. This way the user is provided with all the information on the main instruction as well as the prerequisite knowledge in a single CAL module.

The type of learning content influences the structure of the CAL module. The type of content to be taught has an influence on the way the instruction is organised. In the present study, the entire instruction is about learning a procedure. It was found convenient to structure the CAL module according to the steps involved in the procedure. In the instructional strategies associated with learning procedures, the need to emphasise the sequence of steps, elaborate the importance of individual steps, etc. are highlighted. A structure based on the steps of the procedure therefore is useful in achieving the overall learning goal of application of the flexure formula.

Standardised screen layouts help organise content conveniently. The availability of specific space on the screen for different types of content such as lesson material, feedback, instructions, etc. makes design of screens convenient. This influences the amount of lesson material that can be included in a screen and makes the designer 'chunk' information.

Storyboards help communication between designer and developer, and expedite development. Storyboards developed for each screen with screen ID numbers, contents, instructions, feedback and branching information served as an effective means of communication between the designer and developer. This helped the developer work independently necessitating only very little communication with the designer which was limited to clarifying doubts. Although a large number of storyboards (over 300) had to be developed for this module, the clarity and
speed with which the development was carried out justified the effort. Storyboards were initially hand-written but later some of them were converted to electronic form to expedite development as the storyboards in such form could be simply copied and pasted on to the authoring tool. However, in some occasions, difficulties were encountered when the content (particularly the graphics) had to be altered once they have been imported into the authoring tool.

Standardised feedback methods expedite development and provide consistency within the module. The way the feedback is provided for user inputs can be standardised. The developers can prepare shells to suit the types of feedback and determine appropriate navigation paths if there are a few standard methods of providing feedback. The developers can then customise these to suit the contents in each occasion. This expedites development. One or more types of feedback mechanisms can be made available. For example, one simple way to provide a feedback would be to tell the user whether his or her answer is correct or wrong with reasons, and give an opportunity to retry. A more sophisticated way of giving feedback would be to give i) a motivational message to the user if the answer is correct, possibly with an explanation why it is correct (this will make the user know the right answer if the user answer was due to guess work) and ii) if the answer is wrong, give the opportunity to retry with additional options of a 'hint' and 'correct answer'. If the types of such feedback options are decided before hand, the developers can expedite their development work by developing and using shells as mentioned above.

5.5 Summary

The foregoing sections of this chapter can be summarised as follows:

The results of task analysis conducted using Revised Bloom’s Taxonomy are useful in classifying learning objectives and thereby selecting instructional strategies for designing instruction.

The instructional strategies are primarily associated with the type of learning outcome (cognitive process). However, the nature of content to be learned (type of knowledge) also has an influence on the instructional strategies.
This study has resulted in a comprehensive methodology for designing computer-based instructions by using the results of a task analysis conducted using the Revised Bloom’s Taxonomy, selecting appropriate instructional strategies based on Smith and Ragan’s expanded events of instruction, and incorporating user needs identified through a needs analysis.

The tabulation of instructional strategies for different events of instructions under different types of learning (Appendix 5.1), compiled by the researcher using Smith and Ragan’s descriptions of different instructional strategies, can serve as a useful draft framework for designing instructions, both print- and computer-based. This framework is in its initial stages and needs to be developed further by incorporating other instructional events and types of learning.

The researcher’s experience suggests that an additional type of knowledge for principles in the Revised Bloom’s Taxonomy will help the classification of learning objectives with such type of knowledge, and the selection of appropriate instructional strategies more conveniently. However, a decision to reclassify should only be made after studying other combinations of knowledge and cognitive processes.
Chapter 6

Evaluation

6.1 Introduction

In this chapter the results of the evaluation of the computer aided learning (CAL) module will be presented and discussed. The CAL module was prepared based on a task analysis conducted using the revised Bloom's taxonomy (RBT). Its effectiveness in improving the student performance in the application of the flexure formula and its capability in addressing the identified user needs were evaluated. The module's interface was also subjected to a usability evaluation to ascertain its learnability and the user satisfaction.

This chapter is devoted to the third research question of this study:

"What is the effectiveness of the computer-based instruction module?"

It is important to establish the objectives of evaluation, review existing methods of evaluation, and select and design a suitable procedure to ascertain its effectiveness and usability.

6.1.1 Objectives of evaluation

The usual purpose of an evaluation is to determine whether the designed instruction has achieved its intended objective, which often is improvement of student performance. Typically, the intention of an evaluation is to improve the instruction based on the findings of that evaluation. Stufflebeam and Shinkfield (1985) state that the most important purpose of evaluation is not to prove but to improve. They also argue that one cannot be sure that the goals one pursues are worthy unless they can match the needs of the people they are intended to serve.
The importance of determining the worth and merits of instruction or training programs in relation to their intended goals is emphasised in Stufflebeam and Shinkfield’s (1985) definition of evaluation. They defined evaluation as the process of delineating, obtaining, and providing descriptive and judgemental information about the worth and merit of some object’s goals, design, implementation, and impacts in order to guide decision making, serve needs for accountability, and promote understanding of the involved phenomena.

Usually, the evaluation of instructional materials is done in two stages; during development and after development. These evaluations are called formative and summative evaluations, respectively. Formative evaluations provide feedback to the instructional designer to make improvements to the instruction while it is still under development. On the other hand, summative evaluations are conducted after the instruction has been developed and implemented. The findings of summative evaluations will provide information about the effectiveness of the instruction in achieving the intended learning goals. As this study is concerned with ascertaining the effectiveness of the completed computer aided learning module (product) in achieving the learning goals associated with application of the flexure formula, only summative evaluation will be considered.

There are different levels and aspects of evaluation which are worthy of consideration prior to designing an evaluation.

### 6.1.2 Aspects of evaluation

Three aspects of evaluation are briefly introduced. Kirkpatrick (1994) identified four levels of evaluation. They are: reaction, learning, behaviour, and results. Reaction measures the participant (learner)’s response to the activity in the form of impressions about the relevance of the activity (instruction) in enabling them to fulfil the duties of their jobs (to perform a learning task). Learning evaluation measures increased level of achievement of the content and skills intended by the activity (learning task). On the other hand, behaviour evaluation measures change in behaviour or attitude as a result of using the knowledge and skills of the activity transferred to the job over a period of time (using the knowledge and skills gained by
learning the task). Finally, results evaluation measures the impact on the business (educational program) in the form of return on investment (ROI) from the activity.

Stufflebeam and Shinkfield (1985) introduced four evaluation types, namely, context, input, process, and product. This model is commonly referred to as the CIPP model. Context evaluation answers the following questions: What needs were addressed, how pervasive and important were they, and to what extent were the project's objectives reflective of assessed needs? According to CIPP model, input evaluation is expected to find answers to the following questions: What procedural, staffing, and budgeting plans were adopted to address the needs, what alternatives were considered, why was it chosen over them, and to what extent was it a reasonable, potentially successful, and cost-effective proposal for meeting the assessed needs? Furthermore, process evaluation answers the following questions: To what extent was the project plan implemented, and if it was modified, how and for what reasons was it modified? Finally, product evaluation answers the following questions: What results – positive and negative as well as intended and unintended – were observed, how did the various stakeholders judge the worth and merit of the outcomes, and to what extent were the needs of the target population met? (Stufflebeam and Shinkfield, 1985).

Comparison of Stufflebeam's CIPP model and Kirkpatrick's model reveals that the former is a more comprehensive model for evaluation. CIPP model's product evaluation appears to cover the full scope of Kirkpatrick's model. However, considering the scope of this study, it is practical only to conduct the first two levels of Kirkpatrick's model of evaluation, i.e. evaluation of reaction and learning. Evaluation of reaction is the same as measuring customer satisfaction. Instruments such as questionnaires can be used to measure student satisfaction of an instructional product. Evaluation of learning can be done by using various tests to measure acquisition of knowledge and skills. This is generally the scope covered by Kirkpatrick's product evaluation.

There are other aspects to evaluate in CAL modules. Usability is another important aspect of a CAL module that is commonly evaluated.
Nielsen (1993) introduced the term "usability" for measuring the effectiveness of another aspect of computer-based instruction. "Usability" is one part of the overall evaluation of "usefulness" of a computer-based instruction, according to Nielsen (1993). The other part of the "usefulness" evaluation is that of the "utility". Nielsen defines "utility" as the question of whether functionality of the system in principle can do what is needed. This is basically the measurement of the effectiveness of the instruction in achieving its intended objectives. On the other hand, according to Nielsen (1993), "usability" is the question of how well the users can use the functionality (what it is designed for) of the system. Nielsen (1993) subdivides the usability evaluation into five subcategories (attributes). They are learnability (easy to learn), efficiency (easy to use), memorability (easy to remember), errors (few errors), and satisfaction (subjectivity pleasing). Learnability, according to Nielsen (1993), maintains that the system should be easy to learn so that the user can rapidly start getting some work done with the system. This means that the system's user interface should be easy to understand and the users are able to manoeuvre within the system without difficulty so that they can get on with learning the content productively. On the other hand, satisfaction, according to Nielsen (1993), refers to how pleasant it is to use the system. Learnability and satisfaction attributes appear more relevant to the current CAL module and are included in the design of evaluation. Also, it is important to evaluate user perceptions about the capability of the CAL module to meet the user needs as identified in the original instructional analysis.

Stufflebeam's product evaluation and generally Kirkpatrick's entire model of evaluation fall into the category of "usefulness" evaluation according to Nielsen's definition of different types of evaluations. The evaluations of learnability and satisfaction are "usability" evaluations in Nielson's definition. Stufflebeam's and Kirkpatrick's models do not specifically address usability evaluations. Nielson's model is particularly useful when the solution involves computers. Based on the above review, it was found appropriate to conduct the following evaluations of the CAL module:

a) Evaluation of CAL module for its effectiveness in achieving improvement in learner performance ("utility" evaluation)

b) Evaluation of learnability of the user-interface (a "usability" evaluation)
c) Evaluation of user satisfaction about the CAL module (a "usability" evaluation)

d) Evaluation of user feedbacks about the CAL module’s capability in meeting user needs.

Appropriate experiments and survey instruments for conducting the above evaluations need to be designed. Also, the methods of conducting the experiments and surveys need to be developed. These activities are explained in the next section.

6.2 Methodology

In this section, the methodology used for carrying out the above four evaluations is explained. Table 6.1 shows the methods and/or instruments used in conducting the above evaluations. The details of the various aspects of the evaluation are described in the following paragraphs.

**Table 6.1: Aspects of evaluations and methods/instruments used**

<table>
<thead>
<tr>
<th>Aspect of evaluation</th>
<th>Pre-test</th>
<th>Post-test</th>
<th>Learnability test</th>
<th>Questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Effectiveness</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Learnability</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. User satisfaction</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>4. User feedbacks</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Effectiveness (Utility) evaluation*

Evaluation of the effectiveness was done through a pre-test and a post-test. Both pre-test (Appendix 6.1) and post-test (Appendix 6.5) were similar in format except the questions included therein were different. Each test consisted of three questions relating to the calculation of flexural stresses in symmetrical beams due to pure bending. This was the overall learning objective covered in the CAL module. The pre- and post-tests were designed for a duration of 30 minutes each. Marking schemes for each test were designed in consultation with a subject matter expert.
Table 6.2 represents the design of the evaluation used for measuring the effectiveness of the CAL module.

**Table 6.2: Design of evaluation for measuring effectiveness of CAL module**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-test</th>
<th>Treatment</th>
<th>Post-test</th>
<th>Final exam</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimental</strong></td>
<td>O₁</td>
<td>X</td>
<td>O₂</td>
<td>O₃</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>O₁</td>
<td>-</td>
<td>-</td>
<td>O₃</td>
</tr>
</tbody>
</table>

Legend: O₁, O₂, and O₃ – Observations  X – treatment (use of CAL module)

A pre-test consisting of three questions (Appendix 6.1) was administered to 76 students. The duration of the test was 30 minutes. The pre-test was conducted in two sessions in mid November 2004. The participants were asked to write their answers in the space provided in the question paper and all scripts were collected for marking. The participants were not allowed to take the question papers away.

Invitations to take part in the use of the developed CAL module (treatment) and the post-test were sent to all the students who were enrolled (91) on the course. The invitees were requested to fill-in an attendance confirmation form. A total of 38 (42%) of the invitees responded. Of those responded, 58% of them agreed to participate. Due to low turnout in the first and second sections held in mid January 2005, because of the tsunami disaster on 26th December 2004, an additional session was also arranged in the end of January 2005. Telephone contacts and follow-ups were made between the sessions to improve the attendance at the three sessions.

At the three sessions, which were held in the OUSL’s main computer lab, participants were provided with individual computers with the CAL module already installed. They were also provided with headphone sets to be able to listen to the audio clips in the CAL module. The participants were given as much time as they liked to use the CAL module before they were given the post-test.
At the first session, five participants were given the learnability test. This was done before the participants were allowed to use the CAL module. In the learnability test, the participants were given two screen shots (Appendices 6.2 and 6.3) and were asked to predict functions of certain components on the computer screen or identify components on the computer screen that would execute a function mentioned. The participants’ responses were gathered through the special forms developed for the purpose (Appendix 6.4).

The post-test (Appendix 6.5) was equivalent (but not the same) to the pre-test. The duration of the test was also 30 minutes. Both tests were first drafted by the researcher based on the past examination questions on the topic from the OUSL and the University of Canterbury. These questions were reviewed and moderated by subject matter experts at both universities before including in the pre- and post-test. As the two tests were conducted more than two months apart and the fact that the participants were not allowed to take any question papers away from the test site, the chances of participants remembering the questions were remote.

All participants of the post-test were given a questionnaire (Appendix 6.6) to answer after the post-test. The questionnaire was designed to receive feedback from the participants about their overall satisfaction and other perceptions about the capability of the CAL module.

Both pre-test and post-test answer scripts were marked using a marking scheme, agreed to by an academic who teaches the related course. Answer scripts of only 16 post-test participants could be used in the evaluation as the remaining 3 (out of the total of 19) participants had not taken the pre-test and therefore a comparison with pre-test performance was not possible. The corresponding 16 pre-test answer scripts (of the same participants in the post-test) were also marked to make the comparison of the marks of the two tests possible. Additionally, another randomly selected 16 answer scripts from the remaining unmarked pre-test answer scripts were marked. These 16 randomly selected scripts serves as the control group for the evaluation.

When marking both pre-test and post-test answer scripts (16 each), the level of mastery of related learning objectives as identified in the task analysis and classified using the revised
Bloom's taxonomy (RBT) was recorded. Mastery of learning objectives were classified as "achieved", "partially achieved", and "not achieved".

**Learnability evaluation**

The following instruments were used for learnability evaluation. Two screen shots were obtained from two representative screens of the CAL module. Fourteen objects such as buttons, menus, hyperlinks, etc. were marked on these two screen shots. A form (Appendix 6.4) consisting of thirteen questions, mainly of multi-choice type, was developed to obtain user responses. The questions were on identifying or predicting about functions of various objects on the computer screen. The purpose of identification questions is whether the users are able to self-teach how to use the package without instruction. For prediction questions, they are to evaluate whether the graphical representation of various objects signals to users their respective functions. Two examples of the questions used in the learnability evaluation are shown in Figures 6.1 and 6.2. The two screen shots that were used in the learnability test are shown in Appendices 6.2 and 6.3.

**Question:** Suppose, you have finished with the current page and would like to move to next page, which object will you click?

**Answer:**

![Figure 6.1: Learnability evaluation question (identification)](image)

**Question:** What do you think will happen if you click the button number 2 (main menu)?

**Tick your answer:**

- [ ] It will take me out of the program altogether
- [ ] It will take me to a page that allows me to go to different parts of the program
- [ ] It will take me to a new topic called "main menu"
- [ ] It will take me to the next section

![Figure 6.2: Learnability evaluation question (prediction)](image)
User satisfaction & user needs

A questionnaire was developed for receiving responses on user satisfaction and user feedbacks and comments about the CAL module (Appendix 6.6). The questionnaire includes a section on participants’ biographical information, a section with ten different statements, and a section for giving free comments and feedbacks on the CAL module. The ten statements covered areas of overall user satisfaction and user impressions about the CAL module’s capability in meeting identified user needs. The participants’ responses are to be given on a Likert-style scale where, 1 = strongly disagree, and 5 = strongly agree.

Following sections will explain the designs of various evaluation exercises carried out under this study.

The results of the evaluations exercises carried out according to the above methodology are presented in the following section.

6.3 Results and discussion

In this section, the results of the four evaluations conducted under this study are presented and discussed.

Due to unfortunate circumstances relating to the Indian Ocean tsunami that affected Sri Lanka (where this evaluation was conducted) in late December 2004 and associated disruption of the normal lives of millions of people of the country, it was not possible to carry out some of the evaluation exercises completely according to the plan. The pre-test was conducted in November 2004, prior to the natural disaster, and it was attended by 76 participants, which was 85% of the total batch. The treatment, post-test, usability test, and the questionnaire to measure student perceptions were administered in late/mid January 2005 as originally scheduled. Invitations to participate in the above activities were sent to all those enrolled on the course. As almost all the pre-test participants indicated their willingness to participate in the treatment and post-test (by ticking a box at the bottom of their answer scripts), at least a
50% turnout was expected for the treatment and post-test. Despite holding an additional session and various telephone communications and follow-ups with prospective participants, only 19 participants attended treatment, post-test, and usability test, and answered the student perception questionnaire. Of these 19 participants, only 16 had attended the pre-test. The tests that were planned to measure performance of experimental and control groups at the final exam of the course were not conducted as the exam had to be rescheduled by several months due to the natural disaster and the results of such tests would not arrive in time for inclusion in this study. Results of the various evaluations are discussed in the following sections.

### 6.3.1 Evaluation of effectiveness

The *t*-test carried out using the pre-test scores of the 16 participants each from the experimental group and the control group returned a *p* value larger than 0.05 indicating that the mean scores of the two groups are not significantly different. In other words, the experimental group may be regarded as a fair representation of the total group of participants who took the pre-test, and the performance levels of the experimental group and the control group are comparable at the pre-test level.

Further, the analysis of the pre- and post-test scores of the experimental group produced the following results (Table 6.3).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean score</td>
<td>26</td>
<td>70</td>
</tr>
<tr>
<td>Standard deviation (σ)</td>
<td>34.6</td>
<td>27</td>
</tr>
<tr>
<td>Pass rate</td>
<td>25%</td>
<td>81%</td>
</tr>
<tr>
<td><em>p</em> (<em>t</em>-test)</td>
<td>&lt; 0.0001</td>
<td></td>
</tr>
</tbody>
</table>

The results of *t*-test indicate a significant improvement in the performance of students from the pre-test to the post-test. The improvement in mean scores from 26 to 70 is also major as
according to OUSL's grading scales in which this corresponds to an improvement from a “fail” grade to a high “B” grade. Also, pass rate in the tests has improved from 25% to 81%. This again is a major improvement from “unsatisfactory” level to an “excellent” level according to OUSL classification of course pass rates. The Mechanical Engineering Department’s target pass rate for this course is 60%. Therefore, the pass rate at the post-test represents a much improved rate than targeted. The comparison of standard deviations (\( \sigma \)) of the scores of pre- and post-tests, 34.6 and 27.0, respectively, also shows a decrease in dispersion of scores around the mean score of the post-test. This indicates a reduction in the variation of student performances within the sample, which is also a positive sign. The positive changes in mean scores, pass rates, and reduced standard deviations of post-test scores reconfirm the findings of the \( t \)-test, i.e., the existence of a highly significant improvement \((p < 0.001)\) in the student performance between the two tests. However, the results were not compared against the control group due to the disaster. Even though there still exist possibilities that the improvement may due to other factors, the result is promising and the researcher is confident that the improvement is a genuine reflection of the effectiveness of the designed CAL. For example, one other possible cause for such an improvement is the students' revision of the associated lesson materials as part of their ongoing preparation for the final exam. However, such revision is unlikely to produce a pass rate as high as 81%. The usual pass rate for this course has been around 40%. On the other hand, the positive feedbacks (Table 6.5) received from the post-test participants appear to indicate that they have benefited from the CAL module in achieving the learning objective. Therefore, the above findings seem to suggest that the developed CAL module has primarily contributed towards the significant improvement in performing the tasks associated with the overall learning objective.

In addition to the analysis of the performance in the overall stress calculation exercise, similar \( t \)-tests were carried out on the marks of individual questions in the pre- and post-tests (Appendices 6.1 and 6.5). The \( t \)-test results \((p \text{ value})\) for questions 1, 2 and 3 were all less than 0.01. This also indicates a highly significant improvement in performance in all three questions.
Although the performance on all three post-test questions showed highly significant improvement over the pre-test questions, the level of mastery of enabling objectives (objectives that serve as prerequisites in achieving the overall objective) under different questions varied. Table 6.4 shows the levels of mastery of enabling objectives achieved at pre- and post-tests. Mastery level represents the proportion of students who fully acquired the knowledge and skills associated with a particular objective. Partial achievement (mastery) of learning objectives is treated as “not achieved” (not mastered).

It can be noted from Table 6.4 that mastery levels of all the objectives have improved after treatment in general. Higher improvement levels are achieved with objectives with recall cognitive process. This improvement is associated with both conceptual and procedural types of knowledge. However, the mastery levels associated with objectives 5, 6, and 7 are 50% or less at post-test level. These objectives are associated with procedural knowledge, and understand and apply cognitive processes. The relatively low mastery levels may be attributable to the more complex nature of the type of knowledge and the higher level of cognitive effort associated. The RBT does not stipulate that its four types of knowledge, namely, factual, conceptual, procedural, and metacognitive, are in an order of increasing complexity. However, review of respective descriptions of the four types of knowledge given by Krathwohl (2002) indicates that they appear to be in such an order, moving from factual knowledge to metacognitive knowledge. On the cognitive processes, Krathwohl (2002) states that the six categories, remember, understand, apply, analyse, evaluate, and create are on a scale from simple to complex. This means remember being less complex than understand, which is less complex than apply, and so on. It is observed that more complex or more cognitively demanding cognitive processes incorporate some or all less cognitively demanding cognitive processes that appear below them in the hierarchy. This is consistent with the literature. Mayer (2002) elaborates that cognitive process which is associated with applying a procedure to an unfamiliar task (similar to what is involved with calculation of flexural stresses in beams) has to rely on understanding of the problem and procedure first before proceeding with actual application of procedure. Lovell-Troy (1989) states that application problems should be viewed as a two-step process, i.e., understand followed by apply. With the foregoing discussion, it may be deduced that the developed CAL module has helped mastery
of all the associated learning objectives but with different degrees of success, i.e. the higher the complexity of the learning objective in terms of type of knowledge and cognitive process, the more difficult to master them.

**Table 6.4: Mastery levels of objectives at pre- and post- tests**

<table>
<thead>
<tr>
<th>Objective</th>
<th>RBT Classification</th>
<th>Mastery Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Pre-test</td>
</tr>
<tr>
<td>1. Recall the flexure formula</td>
<td>C1 Procedural Knowledge/Recall</td>
<td>38</td>
</tr>
<tr>
<td>2. Recall first moment of area theorem</td>
<td>B1 Conceptual Knowledge/Recall</td>
<td>50</td>
</tr>
<tr>
<td>3. Calculate neutral axis using first moment of area theorem</td>
<td>B3 Conceptual Knowledge/Application</td>
<td>50</td>
</tr>
<tr>
<td>4. Recall second moment of area theorem</td>
<td>C1 Procedural Knowledge/Recall</td>
<td>25</td>
</tr>
<tr>
<td>5. Calculate second moment of area of beam around its neutral axis</td>
<td>C3 Procedural Knowledge/Application</td>
<td>13</td>
</tr>
<tr>
<td>6. Interpret values of stresses</td>
<td>C2 Procedural Knowledge/Understand</td>
<td>6</td>
</tr>
<tr>
<td>7. Calculate stresses using flexure formula</td>
<td>C3 Procedural Knowledge/Application</td>
<td>13</td>
</tr>
</tbody>
</table>

The questionnaire that was administered immediately after the post-test produced following average ratings (Table 6.5).
Table 6.5: User feedback ratings

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I found the language used in the CAL module simple and clear</td>
<td>4.6</td>
</tr>
<tr>
<td>2. I found the interactions and feedback in the CAL module helpful in</td>
<td></td>
</tr>
<tr>
<td>clarifying doubts about the topic</td>
<td>4.4</td>
</tr>
<tr>
<td>3. I found the examples in the CAL module helpful in clarifying</td>
<td></td>
</tr>
<tr>
<td>doubts about the topic</td>
<td>4.4</td>
</tr>
<tr>
<td>4. I found the graphics in the CAL module helpful in understanding</td>
<td>4.5</td>
</tr>
<tr>
<td>concepts better</td>
<td></td>
</tr>
<tr>
<td>5. I found the voice explanation (audio) helpful in understanding the</td>
<td>4.2</td>
</tr>
<tr>
<td>topic better</td>
<td></td>
</tr>
<tr>
<td>6. I found the voice explanations in the CAL module helpful in overcoming</td>
<td>3.5</td>
</tr>
<tr>
<td>language (English) difficulties</td>
<td></td>
</tr>
<tr>
<td>7. I found the translations available in the CAL module helpful in</td>
<td>3.9</td>
</tr>
<tr>
<td>overcoming language (English) difficulties</td>
<td></td>
</tr>
<tr>
<td>8. For this particular module, I prefer CAL tutorials over human tutor</td>
<td>4.2</td>
</tr>
<tr>
<td>support</td>
<td></td>
</tr>
</tbody>
</table>

The first eight statements are related to the prioritised learner issues that were identified during the instructional analysis (Chapter 3). Most of the issues that were feasible to be addressed through a computer-based solution were incorporated in the design of the CAL module. Interestingly, the participants have shown strong agreement with statements relating to the prioritised learner issues, with an overall average of 4.2. This indicates the capability of the CAL module in addressing the identified learner issues. Also, the user feedbacks and comments from the questionnaire, summarised in Table 6.6, reinforce the participants’ positive impression about the CAL modules’ ability to meet the identified user needs. The need for clear and simple instructions was one of the highest priorities of the students. This need was highly important in view of the students’ English language difficulties. The participants have rated the clarity and simplicity of the language in instruction at 4.6, which is a very high level of satisfaction. Box (2001) also stated that CAL modules can help students with English language problems as they could study the learning materials at their own pace. The availability of optional audio explanations and translations also appear to have contributed to compensate for the English language difficulties thereby enabling better understanding of the content (statements 6 and 7 in Table 6.5). In turn this may have contributed towards improvement in learner performance. The user needs for more interactions, feedback and
worked examples also have been well satisfied (statements 2 and 3). Also, the prioritised need for graphical presentations has been satisfied (statement 4).

Table 6.6: Prioritised issues and participant comments

<table>
<thead>
<tr>
<th>Prioritised issues</th>
<th>Participant comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear and simple language</td>
<td>o “Simple explanation the theoretical background”</td>
</tr>
<tr>
<td></td>
<td>o “I like the language used in CAL module. Because it is simple and easy to understand.”</td>
</tr>
<tr>
<td>More interactions, feedback and worked examples</td>
<td>o “The way examples given, explanations”</td>
</tr>
<tr>
<td></td>
<td>o “The answers checking and models for practising”</td>
</tr>
<tr>
<td></td>
<td>o “I like to practice model question”</td>
</tr>
<tr>
<td>Means to visualise difficult concepts</td>
<td>o “Graphical presentations, step by step learning method”</td>
</tr>
<tr>
<td>(graphics)</td>
<td>o “The graphs for explain, …”</td>
</tr>
</tbody>
</table>

6.3.2 Usability evaluation

The questionnaire that was administered immediately after the post-test returned following results on user satisfaction (Table 6.7).

Table 6.7: User satisfaction rating

<table>
<thead>
<tr>
<th>Statement</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am satisfied with the CAL learning experience</td>
<td>4.5</td>
</tr>
<tr>
<td>2. I like to use more of this type of CAL modules in my studies</td>
<td>4.7</td>
</tr>
</tbody>
</table>

The high rating of 4.5 of user satisfaction in the use of the CAL module is encouraging. This may be because the participants were able to receive most of the support they were looking for in an instruction of this nature. The participants' high satisfaction in the use of the CAL module is further demonstrated by the expression of their desire to use the CAL in other courses with a very high rating of 4.7. Use of computer as an approach to learning appears to
have become attractive. There seem to be no hesitation in using them. The participants' keenness to use computers for studies was also observed during the treatment. This is encouraging as the majority of distance learner issues need to be addressed using computers.

Another part of the usability evaluation was to determine the effectiveness of the user-interface (learnability) of the CAL module. The results produced by the learnability test are shown in Table 6.8.

Of the thirteen predictions or identifications the learnability participants were asked to make from the user-interface of the CAL module, 9 were totally correct. On one question, 75% of the responses were correct. Relatively low performance on this question may be attributable to the presence of another reasonably acceptable answer (prediction) in the multiple choices given as possible answers, which one participant has selected as correct answer (reasonable conjecture). On three remaining questions, 50% of the responses were correct. However, lower performance in two of these three questions may be due to minor confusion caused by the test instrument itself. On the other question of these three, lower performance can be again attributable to the presence of another reasonably acceptable answer (prediction) in the related multi-choice answers, similar to the first low performance (75%) question explained above. This means the results of the learnability test are generally positive (overall accuracy of 86.5%) and the participants did not have any major problems in learning the user-interface of the CAL module. In other words, the users of the CAL module can easily determine or accurately predict what each component on the user interface can do. Such understanding of the interface will allow the users to get on with the main content efficiently. Note that the low number of learnability evaluators (4) is acknowledged. Nielsen (1993) recommends five evaluators as a reasonable number and three evaluators as the minimum for usability evaluations in general. Also in this study five evaluators were used initially but one evaluator's input had to be discarded due to incompleteness.
Table 6.8: Learnability test results

<table>
<thead>
<tr>
<th>Question number</th>
<th>Correct responses</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>9</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>13</td>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>Average</td>
<td>3.5</td>
<td>86.5</td>
</tr>
</tbody>
</table>

While the students did not indicate any features that they did not like, they suggested the following improvements to the CAL module (Table 6.9):

Table 6.9: Participant comments for improving the CAL module

<table>
<thead>
<tr>
<th>Recommended improvement</th>
<th>Participant comments</th>
</tr>
</thead>
</table>
| Expand scope            | o “Exercises for other type of cross sections”  
o “Using more examples, some difficult ones, prepare another CAL modules for other sections at Strength of Material”. |
| Improve graphics        | o “Please redraw some diagrams”                  |
| Improve sound           | o “Sometimes the voice is not continuous”        |
| Improve navigation      | o “If we need go to next page we must click mouse. But I have another key on the keyboard.” |
These suggestions do not indicate any serious shortcomings and may be implemented in any future design.

6.4 Summary

The above discussion can be summarised as follows:

1. The results indicate that the use of the CAL module has resulted in a very significant performance improvement in calculating flexural stresses in symmetrical beams under pure bending.

2. The mastery of enabling objectives as a result of the instruction varies according to their complexity. The more complex the type of knowledge and the more cognitively demanding the cognitive process involved, the harder it is to master a learning objective.

3. The design of the CAL module has met most of the user needs identified in the instructional analysis.

4. The use of simple and clear language, audio explanations, and translations of difficult English words in the CAL module has helped the learners overcome English language difficulties.

5. The overall user satisfaction with the CAL module is high.

6. The user interface design of the CAL module is satisfactory.

The significant improvement in the student performance may have been primarily due to: a) the instructional design based on a task analysis carried out using the RBT which enabled the selection of appropriate instructional strategies and systematic presentation of the learning content, and b) the addressing of the major issues identified in the instructional analysis.
Particularly, the features in the instructional design to address the issues such as the clarity of instructions, the English language difficulties, prompt feedback and opportunity to drill and practice may have resulted in improved learning. The availability of voice explanations also may have been another contributory factor in improved learning as all participants used this facility, which was optional.

There may have been other factors that contributed to this improvement such as the novelty of computer aided learning to many of the participants. The enthusiasm and keenness with which the participants used the CAL module were clearly visible during the treatment. This too may have been a contributory factor. The appropriately designed user-interface may have also contributed to the overall learning as the participants could carry on with the learning task without having to waste time in figuring out which components of the screen to use for what. Also, the users' experience that most of their needs have been addressed point to an increased motivation which may have helped them to concentrate on learning.

Although it is difficult to establish the relative influence of the various factors listed above, from the results of the evaluations and the user comments and feedbacks, it appears that it was the use of suitable instructional strategies identified by using the RBT based objectives, and the design of the CAL module based on the needs analysis that contributed most towards the significant improvement in student performance.

Based on the success of the CAL module developed under this study, it is suggested that the OUSL students’ performance on other topics of the same course and other selected courses may be improved through the use of CAL modules developed using a process similar to the one used in the present study. This also satisfies the requests made by the students to provide more CAL modules to support their studies, at different stages of this study.
Chapter 7

Conclusions

In this chapter, a summary of the findings of the present study together with its limitations are presented. Some suggestions for future studies are also proposed. The chapter ends with some overall concluding remarks.

7.1 Summary of findings

*Taxonomy helps classification of objectives.* It was found that the two dimensions provided in the Revised Bloom's Taxonomy (RBT) help to classify the learning objectives. The action verbs provided in the RBT help to determine the type of cognitive process associated with the learning outcomes.

*Two dimensions in objectives are associated.* The two dimensions of learning objectives appear to be associated with each other. There appears to be an association between the types of knowledge and the cognitive processes. However, this association was found to be useful in the classification of learning objectives.

*Classification of objectives helps selection of instructional strategies.* The types of knowledge and the cognitive processes (two dimensions) associated with the learning objectives facilitate selection of appropriate instructional strategies that enable achievement of the learning outcomes targeted for those objectives. The instructional strategies are primarily associated with the type of learning outcome (cognitive process). However, the nature of content to be learned (type of knowledge) also has an influence on the instructional strategies. Some instructional strategies are specific to the type of learning objective while the others are common to all types of learning objectives.
Higher cognitive tasks encompass lower cognitive tasks. The instructional strategies associated with higher levels of cognitive effort encompass many instructional strategies of lower levels of cognitive effort in addition to their own specific strategies. These findings support the existing literature.

A separate type of knowledge for principles is useful. It is thought, an additional type of knowledge for principles in the Revised Bloom's Taxonomy will help classification of learning objectives with such type of knowledge and selection of appropriate instructional strategies more conveniently. However, a decision to reclassify should only be made after studying other combinations of knowledge and cognitive processes.

The designed CAL is effective in improving student performance significantly. The use of the CAL module appears to have resulted in a highly significant performance improvement in calculating the flexural stresses in symmetrical beams under pure bending. This performance improvement may be attributable to the use of instructional strategies, selected based on the RBT classification, and the fulfilment of the learner needs identified through the instructional analysis in the design of the instruction.

Complexity of objectives affects mastery. The more complex the type of knowledge and the more cognitively demanding the cognitive process involved, the harder it is to master a learning objective.

The designed CAL module addresses most user needs. The designed CAL module addresses many learner needs successfully by incorporating designs features such as interactions, feedbacks, hypertext, translations, graphics, audio, etc.

The designed user interface yields high user satisfaction. High user satisfaction with CAL modules is attained through appropriate design of user interface and by addressing user needs in the design of the instruction. The developed CAL module has met most of the user needs.
The OUSL has a model to follow in CAL module development. As the CAL module developed in this study addressed a typical performance problem at the OUSL and has produced highly significant results, the process and tools used in this study may serve as a guide to future development of CAL modules at the OUSL.

Framework of strategies aids instructional design. The tabulation of instructional strategies for different events of instructions under different types of learning (Appendix 5.1), compiled by the researcher using Smith and Ragan’s descriptions of different instructional strategies, could serve as a useful draft framework for designing print- or computer-based instructions, both print- and computer-based. This framework is in its initial stages of development and needs to be developed by including a wider range of instructional events and types of learning.

The methods and instruments developed in this study serve as examples for instructional design. The methodology, instruments, and approaches used in this study for instructional analysis (analyses of learning context, learner, and learning task) and relating the findings of the instructional analysis to the design of instruction may serve as useful guides for the instructional designers in designing instructions. Insufficient effort spent on the design of instructions is a major concern among the engineering educators as highlighted in Chapter 2. The availability of the instruments and methods presented here is expected to motivate the designers to devote more time in the actual design, thus addressing the above concern.

A draft framework for the selection of instructional strategies offer potential for further research and development in instructional design. The RBT classification of objectives and ability to select instructional strategies for them using the draft framework of strategies help develop effective instructions.

7.2 Limitation and future studies

Lack of control group limits generalisation of results. Relatively low turnout at the post-test and the absence of a control group (both due to tsunami disaster) to compare results with the experimental group is a limitation of this study.
Improve the draft framework for selection of instructional strategies. The draft framework proposed for selecting instructional strategies is limited in scope to selected knowledge and cognitive process categories. Even in the selected categories, the strategies for discovery learning have not been explored well. It would be beneficial to improve the draft framework developed under this study by incorporating more instructional events and types of learning to enable instructional designers to select appropriate instructional strategies for learning objectives identified through task analyses carried out using the RBT. It is proposed that this draft framework be published and made widely accessible to researchers and teachers, through the web, to facilitate a speedy development. A group of interested researchers could take the initiative, with sponsorship from an organisation or a journal such as Computer Applications in Engineering Education or International Journal of Engineering Education.

More complex contents need to be analysed. It would be useful to conduct studies with topics involving more complex types of knowledge and more cognitively demanding tasks (e.g. metacognitive knowledge and analysis, evaluation, and create cognitive processes) to examine their dependencies in task analysis conducted using the RBT.

Develop assessment scheme for topics in Mechanics of Materials, based on the RBT. The researcher is of the opinion that it would be beneficial to develop model assessment questions based on the RBT classifications for use as reference by teachers in their regular work. This may help ensure evaluation of achievement of learning objectives at appropriate cognitive level.

Prepare a pool of computer-based strategies. It would be beneficial if examples were prepared for the selection of suitable computer-based strategies (e.g. drag and drop, multiple-choice questions, hypertext, simulations, etc.) to implement the instructional strategies selected from the general framework of strategies.

Study effectiveness of instructional strategies. It is of interest to carry out studies to evaluate the contributions of instructional strategies, selected based on the RBT classification, towards
effectiveness of the CAL modules. This could help to identify areas that could benefit by fine-tuning of the instructional strategies.

*Study methods to improve mastery of objectives.* It is of interest to see how the ‘partially achieved’ status of objectives can be converted to ‘full achievement (mastery)’ through the use of the CAL module.

*More action verbs are needed.* It would be useful to conduct future studies to prepare a longer list of action verbs under some cognitive process categories in the RBT to avoid misclassification of action verbs due to subtle differences in their meaning.

### 7.3 Concluding remarks

This study has successfully addressed the learning performance problem at the OUSL, which it was set up to solve. The instructional design which incorporated strategies selected based on task analyses carried out using the Revised Bloom’s Taxonomy has resulted in highly significant improvements in learner performance. Fulfilment of most of the user needs through the design of the CAL module and its appropriately designed user-interface have resulted in high user satisfaction. This study has also resulted in a comprehensive methodology for designing computer-based instruction through appropriate classification of objectives, selection of instruction strategies, and incorporation of user needs. The draft framework for the selection instructional strategies developed in this study provides potential for future research and development in instructional design. The OUSL now has a tested model for development of CAL modules for addressing learning performance problems. The instruments and methodology used in this study can serve as a guide for future development of CAL modules. The availability of these instruments and methodology is expected to motivate the academics to devote more time in the actual design, thus addressing the concern about insufficient time and effort spent on the design of instructions in engineering.
References


Bates, A.W., (1997). The impact of technological change on open and distance learning, *Distance Education, Melbourne, 18* (1)


Hurst, Fred (2001), *The death of distance learning?* EDUCASE quarterly Number 3 2001


Krathwohl, D. R. (2005), Private communication dated 08/05/2005.


Appendix 3.1

Semi-structured student interview questions – University of Canterbury

1. What is it like to work with CAL module compared to using text books?
2. What features did you like most?
3. What features didn’t you like in the CAL module?
4. What additional features would be useful for CAL module?
5. Do you feel more confident in the topic after using the CAL module?
6. Are you comfortable with using computers for education in general?
7. Do you feel that your prior computer knowledge has affected your acceptance of CAL as a way of learning?
8. Do you think the use of CAL would help you better perform in the topic?
9. Does the immediate feedback provided by CAL module help your learning and increase your motivation to learn?
10. How does this kind of CAL module compare with teacher assisted tutorials?
11. Would you like to have more CAL modules on different topics?
12. Do you feel less stressed when studying with a CAL module?
13. How enthusiastic are you about using CAL modules in your studies?
14. Do you like your assessments also conducted using computers?
15. Any general comments?
Appendix 3.2

Semi-structured student interview questions – Open University of Sri Lanka (OUSL)

1. What is it like to work with CAL module compared to using text books?
2. What features did you like most?
3. What features didn’t you like in the CAL module?
4. What additional features would be useful for CAL module?
5. Do you find working on CAL module more interesting than working with textbooks?
6. Do you feel more confident in the topic after using the CAL module?
7. Are you comfortable with using computers for education in general?
8. How does this kind of CAL module compare with teacher assisted tutorials?
9. Would you like to have more CAL modules on different topics?
10. Do you feel less stressed when studying with a CAL module?
11. Do you like your assessments also conducted using computers?
12. How far, according to your opinion, can CAL modules help you resolving your existing learning problems?
13. Any general comments
### Personal Data

Please let us know a little bit about yourself:

- **Your Registration No.** [ ] Your Regional Centre: [ ] (optional)

- **Your age group:**
  - [ ] 18-24
  - [ ] 25-29
  - [ ] 30-34
  - [ ] 35-44
  - [ ] 45-54
  - [ ] Over 55

- **Sex:**
  - [ ] Male
  - [ ] Female

- **Marital Status:**
  - [ ] Single
  - [ ] Married

- **What is your current level of achievement in English?**
  - **G.C.E. (O/L) Grade, if any:**
    - [ ]
  - **OUSL Course (highest) Code** [ ] **Grade** [ ]

- **At what academic level did you join OUSL?**
  - [ ] Level 1
  - [ ] Level 2
  - [ ] Level 3

- **Your employment status:**
  - [ ] Employment full-time
  - [ ] Employed part-time
  - [ ] Not employed
Instructional Needs

1. How well are you familiar with the objectives of individual lessons (sessions) and units you have studied so far (which say that at the end of lesson/course you should be able to do certain activities)?

- [ ] Not at all
- [ ] Somewhat
- [ ] Reasonably well
- [ ] Very well
- [ ] Extremely well

2. According to your own opinion, how well are you achieving these objectives at present?

- [ ] Not satisfactory
- [ ] Somewhat satisfactory
- [ ] Satisfactory
- [ ] Very satisfactory
- [ ] Extremely satisfactory

3. Are you confident that you have already got the necessary preparation (prior knowledge) to follow this course?

- [ ] Not confident
- [ ] Somewhat confident
- [ ] Confident
- [ ] Very confident
- [ ] Extremely confident

4. According to you, are the instructions (study materials, lab classes, day schools, etc.) on this course delivered efficiently?

**Study materials**

- [ ] Not efficiently
- [ ] Somewhat efficiently
- [ ] Efficiently
- [ ] Very efficiently
- [ ] Extremely efficiently

**Lab classes**

- [ ] Not efficiently
- [ ] Somewhat efficiently
- [ ] Efficiently
- [ ] Very efficiently
- [ ] Extremely efficiently
Appendix 3.3
Day schools

[Not efficiently] [Somewhat efficiently] [Efficiently] [Very efficiently] [Extremely efficiently]

Part II

Learning Environment

5. Where do you normally study?

[At home] [On campus] [Uni/Library] [Elsewhere] 

Please specify: _______________________

6. How often do you use the following facilities in your studies?

Library

[Not at all] [Somewhat] [Frequently] [Very frequently] [Daily]

Audio/Visual facilities

[Not at all] [Somewhat] [Frequently] [Very frequently] [Daily]

Computers

[Not at all] [Somewhat] [Frequently] [Very frequently] [Daily]
Appendix 3.3

Other facilities (please specify) ____________________________________________________________

☐ ☐ ☐ ☐ ☐
Not at all Somewhat Frequently Very frequently Daily

7. Do you have access to a computer outside the university, for use in your studies?

☐ ☐
Yes No

8. How much are you satisfied with the following facilities provided by the university?

Library

☐ ☐ ☐ ☐ ☐
Not at all relatively satisfied Somewhat satisfied Reasonably satisfied Very satisfied Extremely satisfied

Audio/Visual facilities

☐ ☐ ☐ ☐ ☐
Not at all satisfied Somewhat satisfied Reasonably satisfied Very satisfied Extremely satisfied

Computers

☐ ☐ ☐ ☐ ☐
Not at all satisfied Somewhat satisfied Reasonably satisfied Very satisfied Extremely satisfied

9. What other facilities or arrangements do you wish to have to help your studies? Please list.

_____________________________________________________________________________________
_____________________________________________________________________________________
Appendix 3.3

Part III

Learner Characteristics

10. How do you rate yourself against the level of skills required to follow this course?

Mathematics

- Poor
- Satisfactory
- Good
- Very good
- Excellent

Science

- Poor
- Satisfactory
- Good
- Very good
- Excellent

English

- Poor
- Satisfactory
- Good
- Very good
- Excellent

Computer Skills

- Poor
- Satisfactory
- Good
- Very good
- Excellent

Hands-on (practical) experience relating to the subject

- Poor
- Satisfactory
- Good
- Very good
- Excellent

11. What is your preferred learning style?

Visual learner – prefers to learn things through graphs, pictures, etc. Also, learns best by looking at the teacher while in class. Likes class discussions and taking detailed notes.
Appendix 3.3

**Auditory learner** – prefers to learn things through listening, reading aloud, talking to oneself about important points, reading through the notes, etc.

**Haptic learner** – prefers not to sit still in one place, likes to move around the room. Likes music and television be in the background while studying.

12. How do you prefer to do your studies in relationship with others?

I prefer to study:

- [ ] Alone
- [ ] In pairs
- [ ] In small groups
- [ ] In large groups
- [ ] With tutor

13. What is your own assessment about your general health that would affect your studies?

- [ ] Poor
- [ ] Satisfactory
- [ ] Good
- [ ] Very good
- [ ] Excellent

14. Do you have any health or other related conditions that affect your studies such as listening, reading, etc.? Please state briefly the condition.

15. What are the main reasons for following this programme? Tick the relevant reasons.

- [ ] Parents forced me to do it
- [ ] Want to become a degree holder
- [ ] Want to become an engineer
- [ ] Want to find a well-paying job
- [ ] Want to improve on my present career
- [ ] Not selected for conventional university
- [ ] There was nothing else to do
- [ ] Other (Please specify)
Appendix 3.3

16. Do you think that the course **MEX 3231: Strength of Materials I** is important in studying the Engineering Programme?

- [ ] Not important
- [ ] A little important
- [ ] Important
- [ ] Very important
- [ ] Extremely important

17. Do you want to obtain a higher grade (A or B) or are you satisfied with a simple (C) for this course at the end of the year?

- [ ] Want a higher grade
- [ ] Happy with a simple pass

18. What additional media (in addition to printed material) do you like to use in your studies? (e.g. audio tapes, video tapes, computer-based learning materials, face-to-face discussions with tutor, group discussions with other students, etc.). Please list them in the order of importance to you (1 – most important)?

1. __________________________
2. __________________________
3. __________________________
4. __________________________
5. __________________________
6. __________________________

19. How important are the peers (co-course mates) for you in carrying out your studies.

- [ ] Not important
- [ ] A little important
- [ ] Important
- [ ] Very important
- [ ] Extremely important

20. Do you think that you have already developed the study skills (efficient ways to study) necessary to follow this course successfully or do you need advice and assistance to develop such skills?

- [ ] I already have the necessary study skills
- [ ] I need assistance to develop study skills

21. What do you think about the subject content and associated workload of this course for the given credit rating (1/3)?
Appendix 3.3

Too much for the given credit rating
Too little for the given credit rating
Just about right for the given credit rating

22. How well are you satisfied with the services provided by the (Mechanical Engineering) Department, in studying this course?

[ ] Not satisfied  [ ] A little satisfied  [ ] Satisfied  [ ] Very satisfied  [ ] Extremely satisfied

23. How well are you satisfied (in general) with the services provided by the University, in carrying out your studies?

[ ] Not satisfied  [ ] A little satisfied  [ ] Satisfied  [ ] Very satisfied  [ ] Extremely satisfied

Please return the filled questionnaire to: Course Co-ordinator – MEX 3231, Mechanical Engineering Department, Open University of Sri Lanka, Nawala, Nugegoda.

Thank You

Request:

If you like to further participate in this research project, please give your personal details. Your contribution to this project is highly appreciated.

Name: ________________________________

Address: ________________________________

Tel. No. ________________________________ email: ________________________________
Appendix 3.4

THE OPEN UNIVERSITY OF SRI LANKA
SURVEY OF PAST STUDENTS
MEX 3231: STRENGTH OF MATERIALS I
July 2002

QUESTIONNAIRE

Note:
You can answer most of the questions in this questionnaire by ticking the relevant boxes. However, there are few other questions where you are requested to write short answers. In answering these questions, please be very free and open to provide us with your real feelings and opinions.

Personal Data

Please let us know a little bit about yourself:

♦ Your Registration No. ____________ Your Regional Centre: ________________
   (optional)

♦ Your age group:
   18-24 ☐ 25-29 ☐ 30-34 ☐ 35-44 ☐ 45-54 ☐ Over 55 ☐

♦ Sex: Male ☐ Female ☐

♦ Martial Status: Single ☐ Married ☐

♦ Which academic year did you pass the MEX 3231: Strength of Materials I in?
   Academic year: ____________

♦ What is the grade you received for the above course (A, B, C, etc.)? ____________

♦ How many attempts did you make before passing the above course?
   Just one attempt ☐ Two attempts ☐ More than two attempts ☐

♦ Your employment status:
   Employment full-time ☐ Employed part-time ☐ Not employed ☐
Part I

Instructional Needs

1. How well are you familiar with the objectives of the course: Strength of Materials I (which say that at the end of lesson/course you should be able to do certain activities)?

- Not at all
- Somewhat
- Reasonably well
- Very well
- Extremely well

2. According to your own opinion, how well did you achieve these objectives?

- Not satisfactory
- Somewhat satisfactory
- Satisfactory
- Very satisfactory
- Extremely satisfactory

3. Are you confident that you have already gained necessary prior knowledge through MEX 3231: Strength of Materials – I to successfully follow the course, MEX 5232: Strength of Materials – II?

- Not at all satisfied
- Somewhat satisfied
- Satisfied
- Very satisfied
- Extremely satisfied

4. According to you, are the instructions (study materials, lab classes, day schools, etc.) on Strength of Materials – I delivered efficiently?

**Study materials**

- Not efficiently delivered
- Somewhat efficiently delivered
- Efficiently delivered
- Very efficiently delivered
- Extremely efficiently delivered

**Lab classes**

- Not efficiently delivered
- Somewhat efficiently delivered
- Efficiently delivered
- Very efficiently delivered
- Extremely efficiently delivered
Appendix 3.4

Day schools

<table>
<thead>
<tr>
<th></th>
<th>Not efficiently</th>
<th>Somewhat efficiently</th>
<th>Efficiently</th>
<th>Very efficiently</th>
<th>Extremely efficiently</th>
</tr>
</thead>
</table>

5. What were the difficulties or shortcomings that you experienced while studying the course, *Strength of Materials – I*? Please list them with any suggestions that you may have for improvement of the delivery of the course.

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Part II

Learning Environment

6. Where do you normally study?

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<tbody>
<tr>
<td></td>
<td>At home</td>
<td>On campus</td>
<td>Uni.Library</td>
<td>Elsewhere</td>
<td></td>
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Please specify: __________________

7. How well were you satisfied with the following facilities provided by the university in following the *Strength of Materials – I*?

Library

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<tr>
<td></td>
<td>Not at all</td>
<td>Somewhat</td>
<td>Frequently</td>
<td>Very frequently</td>
<td>Daily</td>
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</table>

### Audio/Visual facilities

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<th>Not at all</th>
<th>Somewhat</th>
<th>Frequently</th>
<th>Very frequently</th>
<th>Daily</th>
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</thead>
</table>

### Computers

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<tr>
<th>Not at all</th>
<th>Somewhat</th>
<th>Frequently</th>
<th>Very frequently</th>
<th>Daily</th>
</tr>
</thead>
</table>

### Other facilities (please specify)

- [ ] Not at all
- [ ] Somewhat
- [ ] Frequently
- [ ] Very frequently
- [ ] Daily

---

8. Do you have access to a computer outside the university, for use in your studies?

- [ ] Yes
- [ ] No

9. What other facilities or arrangements do you wish to have to help your studies? Please list.

- [ ]
- [ ]
- [ ]
## Learner Characteristics

10. How do you rate yourself against the level of skills required to follow this course?

### Mathematics

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<th>Poor</th>
<th>Satisfactory</th>
<th>Good</th>
<th>Very good</th>
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### Science

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### English

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<th>Good</th>
<th>Very good</th>
<th>Excellent</th>
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### Computer Skills

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<th>Poor</th>
<th>Satisfactory</th>
<th>Good</th>
<th>Very good</th>
<th>Excellent</th>
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### Hands-on (practical) experience relating to the subject

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<th>Poor</th>
<th>Satisfactory</th>
<th>Good</th>
<th>Very good</th>
<th>Excellent</th>
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</table>

11. What is your preferred learning style?

**Visual learner** – prefers to learn things through graphs, pictures, etc. Also, learns best by looking at the teacher while in class. Likes class discussions and taking detailed notes.
Appendix 3.4

Auditory learner – prefers to learn things through listening, reading aloud, talking to oneself about important points, reading through the notes, etc.

Haptic learner – prefers not to sit still in one place, likes to move around the room. Likes music and television be in the background while studying.

12. How do you prefer to do your studies in relationship with others?

I prefer to study:

☐ ☐ ☐ ☐ ☐ ☐

 Alone  In pairs  In small groups  In large groups  With tutor

13. Do you think that the course MEX 3231: Strength of Materials I is important in studying the Engineering Programme?

☐ ☐ ☐ ☐ ☐ ☐

Not important  A little important  Important  Very important  Extremely important

14. Do you want to obtain a higher grade (A or B) or are you satisfied with a simple (C) for this course at the end of the year?

Want a higher grade ☐

Happy with a simple pass ☐

15. What additional media (in addition to printed material) do you like to use in your studies? (e.g. audio tapes, video tapes, computer-based learning materials, face-to-face discussions with tutor, group discussions with other students, etc.). Please list them in the order of importance to you (1 – most important)?

1. __________________________ 4. __________________________

2. __________________________ 5. __________________________

3. __________________________ 6. __________________________
Appendix 3.4

16. Do you think that you have already developed the study skills (efficient ways to study) necessary to follow this course successfully or do you need advice and assistance to develop such skills?

I already have the necessary study skills

I need assistance to develop study skills

17. What do you think about the subject content and associated workload of this course for the given credit rating (1/3)?

Too much for the given credit rating

Too little for the given credit rating

Just about right for the given credit rating

18. How well are you satisfied with the services provided by the (Mechanical Engineering) Department, in studying this course?

Not satisfied
A little satisfied
Satisfied
Very satisfied
Extremely satisfied

19. How well are you satisfied (in general) with the services provided by the University, in carrying out your studies?

Not satisfied
A little satisfied
Satisfied
Very satisfied
Extremely satisfied
Appendix 3.4
Please return the filled questionnaire to: **Course Coordinator – MEX 5232, Mechanical Engineering Department, Open University of Sri Lanka, Nawala, Nugegoda.**

**Thank You**

**Request:**

If you like to further participate in this research project, please give your personal details. Your contribution to this project is highly appreciated.

Name: 

Address: 

Tel. No. ............................... email: __________________________

---------------------------
Appendix 3.5

Semi-structured Interview Questions – Current Students

1. How do you feel about your own achievements in this course as compared to the course objectives?
2. What language difficulties do you experience in studying this course?
3. What other difficulties do you experience in studying this course?
4. Do you experience any difficulties in studying this course due to your present maths knowledge?
5. Do you experience any difficulties in studying this course due to your present practical knowledge relating to the subject? Which way does it affect your studies?
6. You have asked for more face-to-face contact sessions and what do you want to achieve from them? How do you want them organised?
7. Are there any alternative methods or ways that you can suggest to achieve what you want from face-to-face contact sessions?
8. You have asked for group discussions and how can they help you study better? How do you want them organised?
9. You have asked for more worked examples, answers to self-assessment questions, model answers, etc. and how are they going to help you?
10. Do you think computers can help you study better? Which way could they help you?
11. Are you satisfied with the computer facilities provided by the university?
12. What improvements do you want done to the library services to help your studies better?
13. Which way do you want audio and video facilities to help your studies?
14. What are your views about Continuous Assessment Tests? How can they be improved to help you study better?
15. What are your views about Tutor-Marked Assignments? How can they be improved to help you study better?
16. How do you feel about the way laboratory classes are conducted? What can be done to improve?
17. How do you feel about the overall time you spend in studying this course? What do you spend most of your time on? How many hours do you spend per lesson on average?
18. Are you targeting for a higher grade (A or B) at the end of this course or satisfied with a simple pass (C)?
19. Do you lack any study skills required to follow this course? If so, what kind of assistance do you need to gain such skills?
Appendix 3.6

Semi-structured Interview Questions - Subject Expert

1. What are the learning goals set for this course?
2. How well do you think the identified learning goals are being achieved?
3. Can you suggest some evidence or method for verifying the actual achievement of the learning goals?
4. In your opinion, what are the gaps between what is achieved and what should be achieved?
5. What do you think are the reasons for this gap?
6. Which ones of these gaps should be addressed on a priority basis? Why do you give priority to them?
7. In your opinion, what would be the best way to bridge the identified gaps?
8. What is the level of experience of the lecturers/tutors with the subject content, learners and teaching in general?
9. How does this course fit into the existing curricula? Is the philosophy or strategy adopted for the delivery of this course any different from other courses?
10. What are the facilities available to the students learning this course? Labs, computers, etc.
11. What are the characteristics of the class? (number of students. The distribution of students throughout different centers country-wide, differences in maturity, accessibility of facilities at centers)
12. What are the characteristics of the delivery system that this course is subject to?
13. How do you feel about the course and the students’ achievements?
14. Are the lecturers/tutors happy with the way the course is delivered?
Appendix 3.7

Semi-structured Interview Questions - Expert in Education

1. What is your general opinion about the achievements (of learning goals) by OUSL students in general and Engineering students in particular?

2. In your opinion, what are the gaps between what is achieved and what should be achieved?

3. What do you think are the reasons for these gaps?

4. Which ones of these gaps should be addressed on a priority basis? Why do you give priority to them?

5. In your opinion, what would be the best way to bridge the identified gaps?

6. Are there any typical characteristics of Engineering students that you have observed, which are different from other students and need attention?

7. Per survey findings of this project, students ask for more day schools, group discussions, etc. How can the University fulfill these requests? Are there any alternatives?

8. What is your assessment of the students’ English knowledge? How does this affect their learning? What can be done to improve the situation?

9. What is your assessment about the study skills of students? What skills do they lack? What are the priorities and how can we help them?

10. Any other points that, in your opinion, would be useful in designing instructions

11. Any other issues that OUSL students are faced with that hinder their studies?
Appendix 3.8

Semi-structured Interview Questions – Expert in Educational technology

1. What is your general opinion about the achievements (of learning goals) by OUSL students in general?

2. In your opinion, what are the gaps between what is achieved and what should be achieved?

3. What do you think are the reasons for these gaps?

4. Which ones of these gaps should be addressed on a priority basis? Why do you give priority to them?

5. In your opinion, what would be the best way to bridge the identified gaps?

6. Are there any typical characteristics of OUSL students that you have observed?

7. Per survey findings of this project, students ask for more day schools, group discussions, etc. How can the University fulfill these requests? Are there any alternatives?

8. What is your assessment of the students’ English knowledge? How does this affect their learning? What can be done to improve the situation?

9. What is your view about use of Computer-Based Tutorials by students in their studies?

10. What is your assessment about the study skills of students? What skills do they lack? What are the priorities and how can we help them?

11. Any other points that, in your opinion, would be useful in designing instructions

12. Any other issues that OUSL students are faced with that hinder their studies?
Appendix 3.9

Semi-structured Interview Questions – Expert in English

1. What is your general opinion about the achievements of English language goals by Engineering students?

2. In your opinion, what are the gaps between what is achieved and what should be achieved?

3. What do you think are the reasons for these gaps?

4. Which ones of these gaps should be addressed on a priority basis? Why do you give priority to them?

5. In your opinion, what would be the best way to bridge the identified gaps?

6. Are there any typical characteristics of Engineering students that you have observed, which are different from other students and need attention?

7. How do the performance of Engineering students compare with that of other students (Science and Humanities)?

8. How does the standard of English (of Engineering students) change during the programme?

9. According to your opinion, how does the students’ English knowledge impact their learning? What can be done to improve their learning?

10. What can students do themselves to improve the situation?

11. What can the academics (both subject and English) do to improve the situation?

12. What changes do you suggest for incorporation in new study materials, to mitigate the identified problems?

13. Students indicate that they spend a large portion of their study time in understanding the text, difficult words, etc. What do you suggest to improve this situation?

14. In addition to printed material, what else can be used to improve the situation?

15. Any other points that, in your opinion, would be useful in improving the learning process?
Appendix 3.10

Semi-structured Interview Questions – Head of Department

1. What is your general assessment about the achievement of learning goals by Mechanical Engineering / Engineering students?

2. In your opinion, what are the gaps between what is achieved and what should be achieved?

3. What do you think are the reasons for this gap?

4. Which ones of these gaps should be addressed on a priority basis? Why do you give priority to them?

5. In your opinion, what would be the best way to bridge the identified gaps?

6. What are the facilities available to the students learning this course? Labs, computers, etc.

7. What are the prospects of any new facilities that would be made available to the students in the near future, to improve their studies?

8. What are the characteristics of the students? (number of students. The distribution of students throughout different centers country-wide, differences in maturity, accessibility of facilities at centers)

9. What are your views of the delivery system that this course is subject to?

10. Per survey findings of this project, students ask for more day schools, group discussions, etc. How can the University fulfill these requests? Are there any alternatives?

11. What is your assessment of the students’ English knowledge? How does this affect their learning? What can be done to improve the situation?

12. Any other comments that would be useful in designing instructions to help students overcome their learning problems?
Appendix 3.11

Semi-structured Interview Questions – Dean of the Faculty

1. What is your general assessment about the achievement of learning goals by Mechanical Engineering/Engineering students?

2. In your opinion, what are the gaps between what is achieved and what should be achieved?

3. What do you think are the reasons for this gap?

4. Which ones of these gaps should be addressed on a priority basis? Why do you give priority to them?

5. In your opinion, what would be the best way to bridge the identified gaps?

6. What are the facilities available to the students learning this course? Labs, computers, etc.

7. What are the prospects of any new facilities that would be made available to the students in the near future, to improve their studies?

8. What are the characteristics of the students? (number of students. The distribution of students throughout different centers country-wide, differences in maturity, accessibility of facilities at centers)

9. What are your views of the delivery system that this course is subject to?

10. Per survey findings of this project, students ask for more day schools, group discussions, etc. How can the University fulfill these requests? Are there any alternatives?

11. What is your assessment of the students’ English knowledge? How does this affect their learning? What can be done to improve the situation?

12. Any other comments that would be useful in designing instructions to help students overcome their learning problems?
Appendix 3.12

Semi-structured Interview Questions – Vice Chancellor

1. What are the current vision and the major policies envisaged for the Open University of Sri Lanka.

2. What do you think are the major issues confronting the present OUSL students?

3. What are the major improvements or facilities that are to be acquired in the short and mid term.

4. What are the positive impacts that these improvements/facilities would bring about to the university in general and to the issues that the students are currently faced with?

5. What are your views about the role of the instructional design in delivering courses at a distance? How do you think this area can be improved for the benefit of students? Are there any policies and/or plans targeted for this?

6. What are your views about how Technology can help students in improving their learning process?
Focus Group Discussion Questions

Brainstorming session

1. What are the difficulties you encounter in studying this course?, and

2. What do you suggest to overcome these difficulties and to improve your learning and performance?

Group discussion

1. How do you feel about your own achievements in the course as compared to the course objectives?

2. What “language difficulties” do you experience in studying this course?

3. What other difficulties do you experience in studying this course?

4. Do you experience any difficulties in studying this course due to your present math knowledge?

5. Do you experience any difficulties in studying this course due to your present practical knowledge relating to the subject? Which way does this affect your studies?

6. You have asked for more face-to-face contact sessions (day schools, etc.). What do you want to achieve from them? How do you want them organized?

7. Are there any alternative methods or ways that you can suggest to achieve what you want from face-to-face contact sessions?
Focus Group Discussion Questions

Group discussion, continued

8. You have asked for Group Discussions. How can they help you study better? How do you want them organized?

9. You have asked for more worked examples, answers to self-assessment questions, model answers, etc. How are they going to help you?

10. Do you think computers can help you study better? Which way could they help you?

11. Are you satisfied with the computer facilities provided by the university?

12. What are your views about how Technology can help students in improving their learning process?

13. Which way do you want audio and video facilities to help your studies?

14. What are your views about Continuous Assessment Tests (CAT)? How can they be improved to help you study better?

15. How do you feel about the overall time you spend in studying this course? What do you spend most your time on?

16. Are you targeting for a higher grade (A or B) at the end of this course or satisfied with a simple pass (C)?

17. Do you lack any study skills required to follow this course? If so, what kind of assistance do you need to gain such skills?
## Appendix 3.14

### Analysis of Needs Analysis Findings

<table>
<thead>
<tr>
<th>Issues / preferences</th>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students</td>
<td></td>
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<tr>
<td>Experience difficulties in understanding the study material</td>
<td>• More theory explained at Face-to-Face (FTF) sessions</td>
<td>• There are limited slots for FTF sessions. The majority of staff recommend that these slots be used for computing problems</td>
<td>• Use interactive CAL (tutorials) to supplement print in explaining basic concepts well (I)</td>
</tr>
<tr>
<td></td>
<td>• Discussion of difficult problems in FTF sessions</td>
<td>• Once theory is well explained using CAL (tutorials), time can be devoted to solve difficult problems at FTF sessions. CAL (drill and practice) can provide more exercises and opportunity for those who cannot attend FTF sessions</td>
<td>• Use FTF sessions to solve difficult problems</td>
</tr>
<tr>
<td></td>
<td>• Additional references</td>
<td>• Given the low language fluency of students at this stage, it would be desirable to provide materials which are tailor-made for this</td>
<td>• Use interactive CAL (tutorials) as a supplementary learning resource/reference (I)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Recommend and stock</td>
<td></td>
</tr>
<tr>
<td>Issues / preferences</td>
<td>Interviewees’ suggestions</td>
<td>Researcher’s views</td>
<td>Potential solutions</td>
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<tr>
<td></td>
<td>Model exam papers</td>
<td>course (suited for distance learning)</td>
<td>relevant text books in the library (NI)</td>
</tr>
<tr>
<td></td>
<td>Worked examples and answers to past questions</td>
<td>Students can access the copies of past papers in the library Include problems/examples of exam-complexity in the CAL (drill and practice) Provide worked examples similar to exam questions and answers to past exam questions Include problems/examples of exam-complexity in the CAL (drill and practice)</td>
<td>Ensure all past exam papers are held in the libraries (NI). Use interactive CAL (drill and practice) to provide exam-type questions (I) Place exam-type questions and answers, and answers to actual past questions in the library (I) Use interactive CAL (drill and practice) to provide exam-type questions (I)</td>
</tr>
<tr>
<td></td>
<td>Opportunity to workout more problems</td>
<td>Provide a range of questions with answers (not workings) under each topic for students work out individually, in groups or with tutor support Include a range of questions under each topic in interactive CAL (drill and practice). Revise existing print material using information</td>
<td>Place typical questions and answers in the library (I) Use interactive CAL (drill and practice) to provide typical questions (I)</td>
</tr>
<tr>
<td></td>
<td>Clear explanation of equations and more detailed</td>
<td></td>
<td>Update existing print material (I)</td>
</tr>
<tr>
<td>Issues / preferences</td>
<td>Interviewees’ suggestions</td>
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<tr>
<td></td>
<td>steps in derivation and examples</td>
<td>from task analysis</td>
<td>• Use interactive CAL (tutorial) to provide step-by-step explanations using task analysis results (I)</td>
</tr>
<tr>
<td></td>
<td>• Audio/video/CAL to supplement study material</td>
<td>• Include in CAL (tutorial). Use task analysis (prerequisite analysis)</td>
<td>• Produce audio tapes that explain print material to students (I)</td>
</tr>
<tr>
<td></td>
<td>• Course guide to assist students in organising their studies</td>
<td>• Audio tapes can be produced as a cheap and quick solution. Most interviewees (staff) recommended this as learners will have the opportunity to listen and this is expected to help the students improve their English</td>
<td>• Use interactive CAL (tutorial) with multimedia to supplement print material (I)</td>
</tr>
<tr>
<td></td>
<td>• More PCs to do coursework and access Internet</td>
<td>• It may be economical and logistically convenient to incorporate all media in one platform, i.e. a CAL (tutorial) using multimedia</td>
<td>• Prepare a course guide and issue it with study material (I).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Prepare a course guide and issue it with study material</td>
<td>• Incorporate study guide in CAL (tutorial) (I).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• CAL (tutorial) can also incorporate a study guide</td>
<td>• Upgrade PCs and related infrastructure (NI).</td>
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<tr>
<td></td>
<td></td>
<td>• With the new ADB-funded project, facilities are to be</td>
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</tbody>
</table>

*Appendix 3.14*
### Appendix 3.14

<table>
<thead>
<tr>
<th>Issues / preferences</th>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Preferences</td>
<td></td>
<td>upgraded. This will also improve computer access for students to use CAL</td>
<td>• Arrange factory visit (I).</td>
</tr>
<tr>
<td></td>
<td>• Factory visits to gain practical knowledge</td>
<td>• Although the factory visits will be the best way for students to receive first hand information, distance learners may not have time to attend these visits. A video or simulation incorporated in CAL could be a preferred alternative.</td>
<td>• Use CAL (video and/or simulation) to inform students about real-life applications (I).</td>
</tr>
<tr>
<td></td>
<td>• More opportunity for peer discussions</td>
<td>• Providing physical facilities such as discussion rooms, etc. is not a problem. There should be material to conduct discussion on. Interactive/self-assessment questions in print material or CAL (tutorial and drill and practice) can be used for peer discussion.</td>
<td>• Incorporate interactive/self-assessment questions to facilitate peer discussions (I).</td>
</tr>
<tr>
<td></td>
<td>• Training in study skills</td>
<td></td>
<td>• Design interactive CAL (tutorial and drill and practice) to promote peer discussion (I).</td>
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<td></td>
<td></td>
<td></td>
<td>• Conduct seminars in study skills (NI).</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>• Add glossaries to print material (I).</td>
</tr>
<tr>
<td>Experience difficulties in reading and understanding English</td>
<td>• Explanation of difficult terms</td>
<td>• Include glossary with explanations in English and local languages</td>
<td>• Incorporate in CAL (tutorials) glossaries with multi-language</td>
</tr>
<tr>
<td>Issues / preferences</td>
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<tr>
<td>Limited opportunities to clarify doubts</td>
<td>• Prefer to listen than to read</td>
<td>• Audio can help students overcome some of the language-related difficulties.</td>
<td>explanations. (Explanations may come as screen tips without having to visit a separate page) (I).</td>
</tr>
<tr>
<td>Subject Expert</td>
<td></td>
<td></td>
<td>• Issue audiotapes with print material (I).</td>
</tr>
<tr>
<td>Subject matter is not explained clearly enough</td>
<td>• More tutor support</td>
<td>• with limited tutor resources and limited FTF sessions, CAL could fill in the gap.</td>
<td>• Use CAL (tutorial and drill and practice) to compensate for lack of tutor support (I).</td>
</tr>
<tr>
<td></td>
<td>• Improve study material to be more student-friendly</td>
<td>• Print material can be revised using existing guidelines and task analysis results</td>
<td>• Revise print material (I).</td>
</tr>
<tr>
<td></td>
<td>• Provide audio, video, CD facilities to supplement study material</td>
<td>• CAL (tutorial) could incorporate revised text as well as media components. Task analysis results can be used to improve clarity of material.</td>
<td>• Use CAL (tutorial) with multimedia and task analysis input to improve clarity of learning material (I).</td>
</tr>
<tr>
<td>Issues / preferences</td>
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<tr>
<td>Not enough problems are solved</td>
<td>• Need to provide more opportunities to solve problems</td>
<td>• Place typical questions and answers in the library (I)</td>
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<td></td>
<td>• Provide a guide with worked examples</td>
<td>• Prepare and issue a study guide with print material (I).</td>
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<tr>
<td></td>
<td>• Encourage group work</td>
<td>• Provide interactive and self-assessment questions to provide basis for group work (I).</td>
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<tr>
<td>Lack skills in solving problems</td>
<td></td>
<td>• Use interactive CAL (tutorial and drill and practice) to encourage</td>
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<td></td>
<td></td>
<td>active interaction with content as individual and group learners. Study guide</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>also can be incorporated (I)</td>
<td></td>
</tr>
<tr>
<td>Students do not read additional</td>
<td>• This may be due to language difficulties. Tailor-made text and</td>
<td>• Use interactive CAL (tutorial) to encourage students to use it as a reference</td>
<td></td>
</tr>
<tr>
<td>references</td>
<td>other learning resources using simple language may change the situation</td>
<td>additional to print material (I).</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of distance learning skills</td>
<td>• Provide training in related study skills</td>
<td>• The university should provide training on these skills</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Conduct seminars in study skills (NI).</td>
</tr>
<tr>
<td>Issues / preferences</td>
<td>Interviewees' suggestions</td>
<td>Researcher's views</td>
<td>Potential solutions (Instructional (I) / non-instructional (NI))</td>
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</tbody>
</table>
| Reluctant to speak English fearing making mistakes | • Need to give special support in English  
• Provide audio tapes on lesson materials | • English department should work in collaboration with Engineering department to assist students in upgrading their English knowledge  
• Audio in tapes or as part of CAL (tutorial) multimedia can help | • Launch/enhance programmes to teach English through the engineering subjects (I).  
• Use CAL (tutorial) to solve part of the language-related problems (I). |
| Quality of temporary tutors is poor | • Train tutors | • Training tutors in a traditional way is not feasible as they are mostly hired on temporary basis. A well-designed CAL can be used to train temporary tutors as well. On hiring, they can be required to go through the CAL (tutorial and drill and practice). After being familiar with the CAL, tutors will be better equipped to assist the learners. | • Use CAL (tutorial and drill and practice) to train temporary tutors (I). |

**Head of Department**

| Fail to understand the basic concepts well | • Provide visual aids to help understand difficult engineering concepts  
• Need to provide resources | • CAL (tutorial, simulations, and drill and practice) with multimedia can be used to meet this. CAL can serve as | • Use CAL (tutorial, simulations, and drill and practice) with multimedia to help students understand |
<table>
<thead>
<tr>
<th>Issues / preferences</th>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
</table>
| Poor in application of theory in solving problems | to compensate for the lack of FTF sessions  
  • Provide a mix of media products to supplement print material | a supplementary resource. Task analysis results can be used to present fundamental concepts better (step-by-step) | basic concepts better (I). |
| Poor standard of English | • Develop habit of problem solving  
  • Encourage student-centred learning  
  • Use available FTF sessions to solve problems rather than to lecture theory. | • Provide worked examples, and problems to work on  
  • Provide CAL (drill and practice) to work independently or as groups  
  • Use CAL or worked examples, and problems to provide training in solving problems. | • Issue worked examples, and unresolved problems along with print materials (I).  
  • Provide CAL (drill and practice) for students to work individually, in groups and to be used in FTF sessions (I). |
| Poor standard of English | • Provide additional language support as learners are moving from their mother tongue to English  
  • Help improve English through the subject they study  
  • Encourage use of English even with mistakes initially | • English and Mechanical Engineering Departments need to work together to come up with an overall programme to address this problem | • Launch/enhance programmes to teach English through the engineering subjects (I). |
### Potential solutions (Instructional (I) / non-instructional (NI))

<table>
<thead>
<tr>
<th>Issues / preferences</th>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions</th>
</tr>
</thead>
</table>
| The way the study material is written is not suitable for distance learning | • Use media to mitigate the language problem  
• Provide opportunity to listen to lesson materials (students prefer this as it involves less efforts by them than to read) | • Use of CAL (tutorial) with multimedia can provide opportunities for learners to receive the subject matter through different media, meeting varied learner preferences including opportunity to listen. | • Use CAL (tutorial) with multimedia to alleviate the problem with poor English (I). |
| | | • Revise/simplify the language in study material | • Revise the existing print material on the subject using OUSL guidelines (I). |
| | | • This can be achieved through revision of existing study material using university guidelines for developing study materials in print. However, this has been a very slow process at OUSL.  
• Alternatively, through CAL (tutorial and drill and practice) with appropriate use of language and interactions to suit distance learners. | • Use CAL (tutorial and drill and practice) with appropriate language and feedback could help distance learners (I). |
<p>| Dean of the Faculty | | | |
| Poor quality of study material written many years ago | • Improve study material in terms of language, more | • This can be addressed by revising existing print | • Revise the existing print material on the subject |</p>
<table>
<thead>
<tr>
<th>Issues / preferences</th>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor assimilation of subject content</td>
<td>interactions, examples, etc.</td>
<td>material using OUSL guidelines</td>
<td>using OUSL guidelines (I).</td>
</tr>
<tr>
<td></td>
<td>• Senior academics to spend more time on lesson development</td>
<td>• Alternatively, CAL (tutorial) with appropriate academic and pedagogic input</td>
<td>• Use CAL (tutorial) with appropriate pedagogic input could help learners assimilate subject better (I).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(instructional analysis) can help students assimilate subject better.</td>
<td></td>
</tr>
<tr>
<td>Poor language skills – major deficiency</td>
<td></td>
<td>Launch/enhance programmes to teach English through the engineering subjects (I).</td>
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<tr>
<td></td>
<td></td>
<td>Use CAL (tutorial) with multimedia to alleviate the problem with poor English (I).</td>
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<tr>
<td>Poor student commitment</td>
<td></td>
<td>Revise the existing print material on the subject using OUSL guidelines (I).</td>
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<tr>
<td></td>
<td>• Surveys show that students are keen to learn. However the language difficulties,</td>
<td>• Use CAL (tutorial and drill and practice) with appropriate media components and instant feedback could</td>
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<td></td>
<td>unfriendly study material, poor tutor support, etc., are likely to affect student</td>
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<td></td>
<td>progress resulting in low morale perceived as low commitment. Among other measures</td>
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<tr>
<td></td>
<td>CAL (tutorial and drill and practice) with instant feedback could</td>
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<tr>
<td>Issues / preferences</td>
<td>Interviewees’ suggestions</td>
<td>Researcher’s views</td>
<td>Potential solutions (Instructional (I) / non-instructional (NI))</td>
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<tr>
<td>Poor study planning by students</td>
<td></td>
<td>• Students need to be trained in academic study skills on how to plan their time and get best use of it.</td>
<td>• Conduct seminars in study skills (NI).</td>
</tr>
<tr>
<td>Non-timely issuance of assignments</td>
<td>• Issue study material on time</td>
<td>• Academics in-charge need to be held responsible for timely issuance of assignments</td>
<td>• Issue course assignments according to published schedule (NI).</td>
</tr>
<tr>
<td>Delayed feedback to students</td>
<td>• Provide prompt feedback</td>
<td>• Prompt feedback is a very vital component in distance learning, which helps students to know how they progress. Academics need to ensure timely feedback is given on assignments submitted by students. • CAL (tutorial and drill and practice) with feedback could fill in some of the gaps left by the delayed feedback on assignments</td>
<td>• Return marked assignments with model answers and appropriate feedback within specified time frame (I). • CAL (tutorial and drill and practice) with built-in interactions could provide useful feedback to students (I).</td>
</tr>
<tr>
<td>Students experiencing difficulties in getting tutor support</td>
<td>• Make lecturers more accessible through more FTF sessions, by phone and email.</td>
<td>• More FTF sessions are unlikely to be allowed due to the nature of distance learning. The present</td>
<td>• Improve availability and accessibility of lecturers/tutors through proper procedures and</td>
</tr>
<tr>
<td>Issues / preferences</td>
<td>Interviewees’ suggestions</td>
<td>Researcher’s views</td>
<td>Potential solutions (Instructional (I) / non-instructional (NI))</td>
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</tr>
<tr>
<td><strong>Expert in Education</strong></td>
<td></td>
<td>infrastructure problems and limited access to computers by students make tutor support less accessible.</td>
<td>scheduling (NI).</td>
</tr>
</tbody>
</table>
| Study material not self-explanatory and not written for the distance learner | • Improve study materials using easy language, glossaries, more interactions, examples, etc  
• Provide additional supplementary materials  
• Provide at least audiotape with simple explanations (students like to learn by listening)  
• Provide audio, video, interactive CDs as additional learning resources, as applicable. This will help the student to become independent | Part of these suggestions can be achieved through revision of existing study material using university guidelines for developing study materials in print. However, this has been a very slow process at OUSL.  
• Alternatively, through CAL (tutorial and drill and practice) with multimedia and appropriate use of language these suggestions can be met | • CAL (tutorial and drill and practice) with built-in interactions/feedback could provide a limited alternative to tutor support (I).  
• Revise the existing print material on the subject using OUSL guidelines (I).  
• Use CAL (tutorial and drill and practice) with multimedia and appropriate language to make the content easier to understand and students more independent (I). |
<table>
<thead>
<tr>
<th>Issues / preferences</th>
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<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of time to devote to studies</td>
<td>• Provide training in study skills</td>
<td>• This is a typical problem for employed distance learners. They need to be helped to use the available time effectively. Properly designed CAL can help the students to use their time more effectively</td>
<td>• Use tailor-made CAL (tutorial and drill and practice) with appropriate feedback, etc. to help students to use their time effectively (I).</td>
</tr>
<tr>
<td>Lack of study skills</td>
<td>• Encourage group learning</td>
<td>Interactive/self-assessment questions in print material or CAL (tutorial and drill and practice) can be used for peer discussion.</td>
<td>• Incorporate interactive/self-assessment questions to facilitate peer discussions (I). • Design interactive CAL (tutorial and drill and practice) to promote peer discussion (I).</td>
</tr>
<tr>
<td>Lack of orientation in distance learning</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Lack of support from the Uni. (student support)</td>
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<td></td>
</tr>
<tr>
<td>Expert in Education Technology</td>
<td>• Provide training in study skills</td>
<td></td>
<td>• Conduct seminars in study skills (NI).</td>
</tr>
<tr>
<td>Employed students find it difficult to cope up with studies due to lack of time</td>
<td>• Provide multimedia-based resources to help those who could not attend day</td>
<td></td>
<td>• Use tailor-made CAL (tutorial and drill and practice) with appropriate</td>
</tr>
<tr>
<td>Issues / preferences</td>
<td>Interviewees’ suggestions</td>
<td>Researcher’s views</td>
<td>Potential solutions</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>Students prefer teacher-centred learning, they lack independence</td>
<td>- Provide multimedia-based learning resources to help students become less dependent on teachers</td>
<td></td>
<td>• Use CAL (tutorial and drill and practice) with multimedia and appropriate language to make the content easier to understand and students more independent (I).</td>
</tr>
<tr>
<td>Students rather like theory to be explained in the day school than working out problems</td>
<td></td>
<td></td>
<td>• The time available during FTF sessions is not sufficient to cover any theory in depth. Most of the interviewed academics and even the Vice-Chancellor recommend that FTF sessions be used to work out difficult problems rather than to lecture. The students ask more theory to be explained in FTF sessions as they find difficult to understand theory from the print material. Improved lesson materials in print, and CAL (tutorials) could</td>
</tr>
</tbody>
</table>
### Appendix 3.14

<table>
<thead>
<tr>
<th>Issues / preferences</th>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Do not work out enough problems/exercises</strong>&lt;br&gt;<strong>Weak in application of knowledge but can recall theory with relative ease.</strong></td>
<td>• Provide tutor support to improve application of knowledge by working more problems, etc.&lt;br&gt;• Modify study material to include more problems/interactions&lt;br&gt;• Provide worked examples and more problems to work on&lt;br&gt;• Encourage group work during day schools and through assignments/coursework&lt;br&gt;• Hire part-time tutors to support students</td>
<td>• Provision of worked examples and more problems to work on will facilitate tutors’ work and can support group work as students can jointly solve the problems. Assignments too can be set to encourage group work</td>
<td>• Issue to students along with print materials a set of worked examples and problems to work on&lt;br&gt;• Set assignments that will require students to work in groups&lt;br&gt;• Use CAL (drill and practice) with feedback to encourage problem solving and to compensate for low tutor support.</td>
</tr>
<tr>
<td><strong>Weak in presenting knowledge</strong></td>
<td>• Provide guidance to improve presentation of knowledge</td>
<td>• This option may not be feasible due to funding constraints</td>
<td></td>
</tr>
<tr>
<td><strong>Poor English knowledge affects learning</strong></td>
<td>• Incorporate elements in instructions to help students improve their English.</td>
<td></td>
<td>• Conduct seminars on Presentation Skills (NI).&lt;br&gt;• Revise print materials in collaboration with English department to enable</td>
</tr>
</tbody>
</table>
## Issues / preferences

<table>
<thead>
<tr>
<th>Interviewees’ suggestions</th>
<th>Researcher’s views</th>
<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provide multimedia resources to help students improve their English</td>
<td></td>
<td>students to improve their English while studying the subject (I).</td>
</tr>
<tr>
<td>• Give training in reading skills</td>
<td></td>
<td>• Use CAL (tutorial) with multimedia to help students study the subject from media other than text (audio is preferred over text) (I).</td>
</tr>
</tbody>
</table>

### Vice-Chancellor’s remarks to identified problems

<table>
<thead>
<tr>
<th>Students find difficult to comprehend study material</th>
<th></th>
<th>These comments have been used in coming up with the potential solutions above.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Provide glossaries with explanations in local language</td>
<td></td>
<td>• Use CAL (tutorial) with multimedia to help students study the subject from media other than text (audio is preferred over text) (I).</td>
</tr>
<tr>
<td>• Use available guides to develop student-friendly material</td>
<td></td>
<td>• Conduct seminars on Study Skills (NI).</td>
</tr>
<tr>
<td>• Build interactive activities, questions, etc. to engage the students with subject content</td>
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<table>
<thead>
<tr>
<th>Face-to-Face sessions</th>
<th></th>
<th>These comments have been used in coming up with the potential solutions above.</th>
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</thead>
<tbody>
<tr>
<td>• Being a distance education institution OUSL cannot increase FTF sessions indefinitely</td>
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</table>

These comments have been used in coming up with the potential solutions above.
<table>
<thead>
<tr>
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<th>Potential solutions (Instructional (I) / non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/V facilities</td>
<td>• Need to use existing FTF hours to help students best. Convert day schools to workshops</td>
<td>These comments have been used in coming up with the potential solutions above.</td>
<td></td>
</tr>
<tr>
<td>Practical experience</td>
<td>• Incorporate activities that require students to use audio/video facilities</td>
<td>These comments have been used in coming up with the potential solutions above.</td>
<td></td>
</tr>
<tr>
<td>Students are used to rote learning</td>
<td>• This is a cultural issue and is a result of the national schooling system • Add more practicals/projects to instruction</td>
<td>These comments have been used in coming up with the potential solutions above.</td>
<td></td>
</tr>
<tr>
<td>Peer discussions</td>
<td>• Students are free to have peer discussions on campus • Students can use interactive questions in study material to conduct peer discussions (but many study materials do not have interactive questions at present)</td>
<td>These comments have been used in coming up with the potential solutions above.</td>
<td></td>
</tr>
<tr>
<td>Use of Technology</td>
<td>• The university is to receive the following facilities in the near future through an ADB-funded project:</td>
<td>The OUSL’s attitude towards new technology and plans to acquire them in the near future support the solutions suggesting the use of CAL to</td>
<td></td>
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</table>
### Issues / preferences

<table>
<thead>
<tr>
<th>Interviewees’ suggestions</th>
<th>Reseacher’s views</th>
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</tr>
</thead>
</table>
| - Nation-wide network connecting all OUSL centres country-wide  
- Upgraded labs/computer equipment  
- Staff training  
- Overall infrastructure improvement  
- Video conferencing  
- Training of academic staff on production of interactive multi-media courseware and on e-Learning.  
- University wants to train its staff in advance to be ready for incoming new technology | solve many instructional problems discussed above. | - |
## Appendix 3.15

### Analysis of Prioritised Needs

<table>
<thead>
<tr>
<th>Prioritised Needs</th>
<th>Relevant Learner Background</th>
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<th>Potential Solutions (Instructional (I)/ non-instructional (NI))</th>
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</thead>
<tbody>
<tr>
<td>1. Improve basic study material to provide:</td>
<td></td>
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<tr>
<td>o Clear and simple language in study material</td>
<td>• 50% of students say they possess below average (satisfactory or poor) English knowledge</td>
<td>Students: As they find difficult to understand existing study material, students request more theory explained, difficult problems discussed, and clear explanations of equations and derivations given at Face-to-Face (FTF) sessions. Also, they request additional references to clarify doubts. Academics: Academics and administrators agree that the existing study material needs to be revised to make it more suitable for distance learning and student-friendly. Also, they suggest providing additional audio, video and CAL facilities to supplement study material in print. The Dean wants senior academics to spend more time on lesson improvement/ development. Researcher’s views: All parties agree that the study material needs to be revised to make them clearer, simpler and more distance learner friendly. The students’ request to explain more theory, equations, derivations, etc. at FTF</td>
<td>• Revise the existing print material on the subject using OUSL guidelines (I). • Recommend and stock relevant text books in the library (NI) • Use interactive CAL (tutorials) with learner friendly language and multimedia components to supplement print material (I).</td>
</tr>
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</table>
### Prioritised Needs

<table>
<thead>
<tr>
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<th>Potential Solutions (Instructional (I)/ non-instructional (NI))</th>
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<tbody>
<tr>
<td>More interactions</td>
<td>• The students are generally weak in understanding important theoretical concepts and are still weaker in applying theory into solving problems. Students: Students request opportunities to workout problems and clarify doubts, more worked examples and model exam papers, answers to past questions, opportunities for peer discussions on study material and problems. Academics: Academics agree on the need to provide more opportunities to solve problems, provide worked examples and to develop habits of problem solving. Academics also would like to encourage group work by students and reduce their dependence on teachers. Also, the academics want to</td>
<td>• Place typical questions and answers in the library (I) • Provide interactive and self-assessment questions along with print material to help students</td>
<td></td>
</tr>
<tr>
<td>More worked examples</td>
<td></td>
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<td></td>
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<tr>
<td>More feedback</td>
<td></td>
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<td></td>
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<tr>
<td>Prioritised Needs</td>
<td>Relevant Learner Background</td>
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<td>Potential Solutions (Instructional (I)/ non-instructional (NI))</td>
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<tr>
<td>Students’ learning method preferences:</td>
<td>76% students like to work in pairs or small groups</td>
<td>use FTF sessions for problem solving rather than for lecturing theory.</td>
<td>apply themselves to subject matter and to provide basis for group work (I).</td>
</tr>
<tr>
<td>Students’ learning method preferences:</td>
<td>Students' learning method preferences: 1) Face-to-face, 2) Peer Discussions, 3) Audio/Video/CAL</td>
<td>Researcher’s views: Providing worked examples, model exams, problems to workout, etc would help students to apply themselves to the subject. These materials could be used to encourage peer discussions, which could eventually help reduce dependence on teachers. Peer discussions are the second most preferred learning method of students after FTF sessions. Peer discussions are also a highly recommended learning method for distance learners. Availability of these materials will also facilitate effective discussion at FTF sessions.</td>
<td>Provide CAL (tutorial and drill and practice) for students to work individually, in groups and to be used in FTF sessions (I).</td>
</tr>
<tr>
<td>Improved glossaries</td>
<td>50% of students say they possess below average (satisfactory or poor) English knowledge</td>
<td>Students: Students experience difficulties in understanding many words in the text and request explanations of difficult words. Academics: Academics suggest that glossaries with explanations in local languages be provided with study material</td>
<td>Add glossaries with local language explanations to print material (I). Incorporate in CAL (tutorials) glossaries with multi-language explanations.</td>
</tr>
<tr>
<td>Prioritised Needs</td>
<td>Relevant Learner Background</td>
<td>Related Interviewees’ Comments/ Researcher’s views</td>
<td>Potential Solutions (Instructional (I)/ non-instructional (NI))</td>
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</tr>
<tr>
<td>Means to visualise difficult concepts</td>
<td>- The students are generally weak in understanding important theoretical concepts and are still weaker in applying theory into solving problems</td>
<td>Students: Students request more theory explained at FTF sessions. Academics: Academics find that students do not understand basic theoretical concepts well, based on student performance on their submissions, tests, exams, etc. Researcher’s views: The researcher too found this situation to be true while analysing student performance on Continuous Assessment Tests and Final Exams. During the Needs Analysis, the researcher was approached by students to explain basic concepts such as sign conventions, etc., which were not clear to the students from the printed material. Use of graphics, animations, simulations, etc. could help students visualise various theoretical concepts, which are otherwise difficult to explain using text. As the majority of students are visual learners this action will suit them well.</td>
<td>Use interactive CAL (tutorials with animations, simulations, etc.) to supplement print material (I).</td>
</tr>
<tr>
<td>Additional media components to</td>
<td>- More than 50% students say they</td>
<td>Students: Students experience many problems in reading and understanding English; difficult words, pronunciation</td>
<td>Improve print materials with</td>
</tr>
<tr>
<td>Prioritised Needs</td>
<td>Relevant Learner Background</td>
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<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>enable easy understanding of the subject content and improve English knowledge</td>
<td>have below average (satisfactory or poor) English knowledge and practical knowledge</td>
<td>problems, unclear statements, limited opportunity to listen to the spoken language, etc. Students say they prefer to listen rather than to read.</td>
<td>simplified language, glossaries and supplement it with audiotapes in collaboration with English Dept. (I).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Academics: Academics agree that students have a poor standard of English. This is a major factor in poor student performance. The academics also agree that the subject matter is not explained clearly enough in the print material. They suggest the use of different media to mitigate the language problems. The use of audio tapes to explain lessons is recommended by many academics as this would give students an opportunity to listen to the teacher’s voice and to study the material using more senses (seeing and hearing). Listening is expected to have a favourable impact on improving English standard of students. The academics are of the view that English could be taught better through the subject (Strength of Materials, in this case) than English per se. The academics also recommend training in reading skills for students.</td>
<td>• Use interactive CAL (tutorials with multimedia) to supplement print material (I).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Researcher’s views: The poor standard of English is accepted as one of the major causes for low performance of students. Improving the language of the text, addition of glossaries, and multimedia to support the lesson materials could lead to improved learning. It is believed that the extensive multi-sensory capabilities (seeing, hearing, etc.)</td>
<td>• Conduct training on reading skills together with other study skills (NI).</td>
</tr>
</tbody>
</table>
### Prioritised Needs

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<tr>
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<tbody>
<tr>
<td>and over learning through multiple presentations and examples of the same concept by using CAL with multimedia would result in better learning. Training to improve reading skills needs to be conducted.</td>
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</table>

**2. Improve student support by providing:**

- **Timely feedback on student submissions**
  - 50-75% students become eligible to sit the final exam based on continuous assessment marks
  - 20-50% pass the final exam

**Students:** Students always request more FTF sessions. In addition to having lectures on theory, the students want the FTF sessions to clarify doubts that arise when they are engaged with study material. Employed students who are unable to come to scheduled FTF sessions, request contacts through phone, email, and post. Students request timely feedback on their submissions during the academic year.

**Academics:** While agreeing on the importance of timely feedback, the academics accept the delays and poor quality of feedback. Access to lecturers and tutors through phone, email and post does not work satisfactorily.

**Researcher’s views:** Timely and quality feedback is considered as one of the cornerstones of successful distance learning. This is important to students as they have only very limited face-to-face sessions with their tutors. The feedback is the only way students could know how they are performing. The timeliness and the quality of feedback have a lot to be desired. The quality of feedback is subject to improvement.

**Potential Solutions**

- Improve availability and accessibility of lecturers/tutors through proper procedures and scheduling (NI).
- Return marked assignments with model answers and appropriate feedback within specified time frame (I).
- CAL (tutorial and drill and practice) with built-in...
### Prioritised Needs

<table>
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<tr>
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</thead>
</table>
| **Tutor support**           | Students’ most preferred learning method is Face-to-Face contact with tutor. Around 30% of students study on campus regularly. | Improve availability and accessibility of lecturers/tutors through proper procedures and scheduling (NI).  
  - CAL (tutorial and drill and practice) with built-in interactions/feedback could provide a limited alternative to tutor support (I). |

Students: Students want more face-to-face contacts with tutors. Students want tutors to clarify the doubts in lesson materials and help them in solving problems. Academics: Academics agree that students need to be given tutorial support. They are also aware that at present tutor support is not properly provided. The non-availability of tutors when students call on, infrastructure problems (e.g., telephone) and limited access to computers by students (for email) contribute to this problem.  

Researcher’s views: While the access to existing tutors need to be improved, additional FTF sessions are unlikely to be approved. This (FTF sessions) is due to two reasons: i) non-availability of funds to hire additional tutors, and ii) the university policy of not to increase FTF hours as it could disadvantage the employed students who find it difficult to attend scheduled FTF sessions due to their job commitments. Many of these issues can be addressed by using CAL (tutorial, drill and practice) with appropriate interactions could provide useful feedback to students (I).
<table>
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<tr>
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</tr>
</thead>
</table>
| o Worked examples/model answers | • The students are generally weak in understanding important theoretical concepts and weaker in their application to problem solving  
• 76% of students like to work in pairs or small groups | Students: Students request opportunities to work out problems, they want worked examples, model exam questions, etc. They also like to work in pairs or small groups in doing their studies.  
Academics: Academics complain that students do not solve enough problems on their own to gain experience in applying theory into practice. This results in poor performance at tests and exams and their preparation as engineers. The academics want to encourage students in developing problem-solving habits.  
Researcher’s views: Poor problem solving skills were evident through the review of students’ answer scripts as well as marks obtained at different tests and exams. Students need some additional support and guidance to get on with problem solving such as worked examples and feedback/clarifications when they are actually solving problems. Provision of worked examples, guidelines and occasional tutor support could address this problem. Students’ preference to work as pairs or small teams could | • Place exam-type questions and answers, and answers to actual past questions in the library (I)  
• Incorporate interactive/self-assessment questions in print material to facilitate peer discussions (I)  
• Use interactive CAL (drill and practice) to provide exam-type questions, self-assessment questions to |
# Appendix 3.15

<table>
<thead>
<tr>
<th>Prioritised Needs</th>
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<tbody>
<tr>
<td>o Study guides</td>
<td>About 50% of students are recent school leavers</td>
<td>Students: Students request guides to help them organise their studies within the course. Academics: Academics observe that students generally do not plan their work properly. The academics agree that students need to be given more guidance to help them organise their studies. Researcher’s views: Students following this course are newcomers to distance learning. They have come out of a schooling system, which is very much teacher-centred. These students are affected adversely on two counts. First count: Any traditional university education will require school leavers to make big adjustments involving their learning styles, responsibility for their decisions, organising their studies, meeting deadlines, etc. This itself is a major adjustment especially in the early years of the university studies. On the second count, they are studying in distance mode, which do not provide much FTF sessions. This is a much bigger adjustment. Under these conditions, students need a lot of guidance and support for adjustment. The existing university instructions for writing new study materials include some guidelines to help students organise their work and information on how the course and</td>
<td>promote peer discussion (I)</td>
</tr>
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be used to achieve the desired results.
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<tr>
<th>Prioritised Needs</th>
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</thead>
</table>
| Training on study skills | • About 50% of students are recent school leavers  
• All students are new comers to distance learning  
• All students believe in the importance of the course  
• 91% of students want to pass the course with good grades | • Students: 83% of students say they need training in study skills.  
Academics: Academics say that students lack study skills necessary for distance learning, cannot effectively plan their studies, and show low commitment towards studies. Academics recommend that students be given training on study skills.  
Researcher’s views: Given the inexperience in studying at a distance, students need to be helped to acquire skills necessary to study in the new mode. Based on their responses to questionnaires, students are aware of the importance of the course in studying engineering and would like to gain good grades in it. This shows some keenness and enthusiasm on the part of the students. Lack of commitment observed by some academics may be attributed to their inability to cope up with the new learning mode due to lack of necessary skills. Students need to be given training on study skills as they start the programme of studies. | • Conduct seminars in study skills (NI). |

assessments are organised, etc. However, the conversion of existing study material into new format has become a very slow process. Study guides need to be prepared and issued along with print material. These guides could be incorporated in CAL (tutorial) as well.
### Prioritised Needs | Relevant Learner Background | Related Interviewees’ Comments/ Researcher’s views | Potential Solutions (Instructional (I)/ non-instructional (NI))
--- | --- | --- | ---
**Opportunities for group work**<br>76% of students like to work in pairs or small groups<br>95% of students value peer support | Students: A large majority of students would like to work in pairs or small groups. They request more opportunities for peer discussions.<br>Academics: Academics recommend group work and peer discussions. This they say could compensate for limited tutor support available. Academics also recommend design of coursework, assignments, and FTF sessions to encourage group work.<br>Researcher’s views: It is beneficial to design instruction, activities, assignments, etc. to encourage group work. Peer discussions are always encouraged under distance learning to compensate for the limited FTF sessions and to allow students to discuss, understand and solve problems. The researcher has observed frequent group discussions among students and informal lectures by senior students. The course material should incorporate various interactions, self-assessment questions, worked examples, model answers, etc. to provide basis for conducting group work. | Issue to students along with print materials a set of worked examples and problems to work on<br>Set assignments that will require students to work in groups<br>Use CAL (drill and practice) with feedback to encourage problem solving and to compensate for low tutor support.

**Effective Face-to-Face sessions or alternative arrangements**<br>Face-to-Face sessions are the most preferred learning method | Students: Students most preferred method of learning is FTF sessions. Students want more FTF sessions than what is presently available. They want to use these sessions for explaining theory. | Revise print material to include simpler language, interactive/self-
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<tr>
<td>of students</td>
<td>Academics: Academics want to use the available FTF sessions for problem solving and group work rather than for teaching theory. The university policy does not allow any extra FTF sessions. By adding more FTF sessions, the students who are unable to attend FTF sessions due to work and other constraints are likely to be disadvantaged. <strong>Researcher’s views:</strong> The attendance at FTF sessions is very poor and becomes worse towards the end of the academic year. This is paradoxical. On one hand, students ask for more FTFs but on the other hand, they do not attend the ones that are available. When they are at FTF sessions, they mostly listen and do not ask any question from the lecturer. The reason given by students for poor attendance at FTF session is that they want detailed coverage of theory at FTF sessions and the lecturers are unable to do that due to limited time. So the students are disappointed and not attending FTF sessions. The reason given for not asking questions at FTF sessions is that students have not been able to understand (engage with) the subject matter properly and are therefore not in a position to ask questions. Revision of study material to make them easy to understand and include in them more interactions, worked examples, self-assessment questions, etc. could help students to understand theory better before coming to FTF sessions. Then they could clarify specific theory and assessment questions, etc. to facilitate better understanding, peer discussions, and effective use of available FTF sessions (I).</td>
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<td></td>
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<td></td>
<td>• Use interactive CAL (tutorial and drill and practice) with feedback to provide interactive/self-assessment questions to facilitate better understanding, peer discussions, and effective use of available FTF sessions (I).</td>
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</thead>
</table>
| Learning resources to make students more independent | - Face-to-Face sessions are the most preferred learning method of students  
- 76% of students like to work in pairs or small groups  
- 95% of students values peer support | Students: Students are used to a teacher-centred learning culture. They request more FTF sessions. Also prefer to work in pairs or small groups.  
Academics: Academics note that teacher-centred learning culture is a carry-over from the schooling system and it is not compatible with distance learning. They are of the view that instructions, activities, assignments, projects, etc. should be designed in such a way that students work independently of teachers by themselves or in groups.  
Researcher’s views: Easy-to-understand study material combined with worked examples, interactive/self-assessment questions, assignments/projects that require group work could make students learn in a more collaborative and independent (of teacher) manner. This could be achieved from CAL (tutorial and drill and practice) as well. | Revise print material to include simpler language, interactive/self-assessment questions, etc. to facilitate better understanding, peer discussions, and independence (I).  
Use interactive CAL (tutorial and drill and practice) with feedback to provide interactive/self-assessment questions to facilitate better |
<table>
<thead>
<tr>
<th>Prioritised Needs</th>
<th>Relevant Learner Background</th>
<th>Related Interviewees’ Comments/ Researcher’s views</th>
<th>Potential Solutions (Instructional (I)/ non-instructional (NI))</th>
</tr>
</thead>
</table>
| o Additional support to gain English language fluency | - 50% of students say their English knowledge is just satisfactory or poor  
- Pass rate in the course is only 10%-40% | Students: Students have enormous difficulties with the English language. They ask for simpler language, explanation of difficult words, audio/video to help them understand study material better. Students indicate that they prefer to listen rather than to read.  
Academics: Academics have identified the English language issue as one of the major problems that students face. Academics say that students need to be given special support in this regard. Many academics are of the view that audio tapes on study material can help students a great deal in understanding and improving English as they would get a chance to listen to teacher’s voice as compared to only reading of study materials. Academics are also of the view that it is preferable to teach English using the course they study rather than teaching English per se. They also recommend the use of multimedia to improve students’ English standard.  
Researcher’s views: Low English standard is considered a major contributory factor towards poor academic performance. The Mechanical Engineering department | - Initiate close collaboration between English Language and Mechanical Engineering departments in design and delivery of course material to improve the English language situation (I).  
- Provide audiotapes to supplement print material (I).  
- Use interactive multimedia CAL (tutorial) with understanding, peer discussions, and independence (I) |
### Prioritised Needs

<table>
<thead>
<tr>
<th>Prioritised Needs</th>
<th>Relevant Learner Background</th>
<th>Related Interviewees' Comments/ Researcher's views</th>
<th>Potential Solutions (Instructional (I)/ non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Train tutors</td>
<td>n/a</td>
<td><em>The students are generally weak in understanding important theoretical concepts and are still weaker in applying theory into solving problems</em> &lt;br&gt; <em>Pass rate in the course is only 10% -40%</em></td>
<td><em>Use CAL (tutorial and drill and practice) to train temporary tutors to make them more effective (I).</em> &lt;br&gt; <em>Use of same CAL (tutorial and drill and practice) by students will help them clarify most of the doubts by themselves thereby reducing</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Students: Students are concerned about limited opportunities available to clarify doubts. They want more tutor support. Students in the regions request visiting tutors to clarify their doubts. &lt;br&gt; Academics: Some academics are not happy with the quality of the tutors and recommend tutor training. &lt;br&gt; Researcher's views: Provision of additional tutors is not feasible due to limitation of funds. Most of the tutors are temporary employees. The availability of tutors for consultation by students is not properly organised. Students cannot contact the tutors by phone or email due to infrastructure deficiencies and because such practice is not yet institutionalised. Training tutors (who are mostly temporary employees) needs to work closely with the English department in solving this major problem. Input from language experts needs to be sought in designing and delivering course material. Multimedia also can help students improve English (along with subject knowledge) as the students will be able deal with study material from different perspectives. Observations made during the exploratory stage of this project also confirm that students with English language difficulties prefer presentations of study material through different media such as text, audio and video.</td>
<td>special design input from language perspective (I).</td>
</tr>
</tbody>
</table>
### Prioritised Needs

<table>
<thead>
<tr>
<th>Prioritised Needs</th>
<th>Relevant Learner Background</th>
<th>Related Interviewees’ Comments/ Researcher’s views</th>
<th>Potential Solutions (Instructional (I)/ non-instructional (NI))</th>
</tr>
</thead>
<tbody>
<tr>
<td>temporary employees) in a formal way is not feasible. CAL (tutorial) developed for students or a modified version of it could be given to the tutors for self-training. Once the tutors have gone through these tutorials they will be better equipped to assist the students.</td>
<td></td>
<td>dependence on tutors (I).</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4.1

Task Analysis - Derivation of the Flexure Formula

Prerequisites

BX1
Recall the assumptions used in deriving Flexure Formula

BX1
Recall definition of neutral axis

BX1
Recall that stress on an object with no transverse load can be represented in a 2-D view

BX3
Use the assumption that sectional dimensions of the beam are small compared to span and deflection due to shearing is negligible.

BX3
Use the assumption that transverse sections of beam remain plane during bending if the assumption stated above is maintained.

BX3
Use the assumption that deflections due to bending are small

BX2
Represent deformed lines as circular segments (arcs)

BX1
Recall definition of pure bending

BX1
Recall geometric property of representing length of a circular arc through radius of the arc (r) and associated angle (θ)
Appendix 4.1

Prerequisites

BX 1
Recall definition of strain

BX 2
Conclude linear relationship between strain and distance of segment from Neutral Axis (N.A.).

CX 3
Draw 2-D view of an infinitesimal deformed element on the longitudinal plane of the beam

CX 3
Develop an expression for deformed length of a segment located at a distance from neutral axis using arc length

CX 3
Develop an expression for the length of neutral axis using arc length

CX 3
Develop an expression for strain using expressions obtained above

BX 1
Recall relationship between arc length, radius and angle

Prerequisites
Appendix 4.1

Prerequisites

B X 1
Recall Hooke's Law

C X 3
Apply integration for linear function

Apply Hooke's Law to strain/distance (from N.A.) relationship

Apply stress/force relationship to the previously obtained relationship

Apply integration to obtain expression for net force

Apply conditions under which pure bending occurs (no axial force)

Reorganise the expression for force taking constants outside integral sign and deduce that first moment of area about the neutral axis is zero

Conclude neutral axis passes through centroid

Prerequisites

B X 1
Recall relationship between stress and force

B X 1
Recall definition of pure bending

B X 1
Recall first moment of area theorem
Recall definition of moment

Recall sign convention for stress and bending moment

Recall second moment of area

Develop an expression for moment applied to an infinitesimal area in section

Apply sign convention for bending moment

Develop an expression for total moment by integrating moment of infinitesimal element

Reorganise the expression for total moment taking constants outside the integral sign

Rewrite expression for moment by substituting value for second moment of area

Rewrite expression for stress substituting value for E from expression for M in previous step, to arrive at Flexure Formula

Apply Integration

Recall expression for stress (σ) obtained previously
Appendix 5.1

Types of learning, events of instruction, and instructional strategies

<table>
<thead>
<tr>
<th>Events of Instruction / Type of Learning</th>
<th>Concept Learning (B2: Concept/Understand)</th>
<th>Principle Learning (B3: Concept/Apply)</th>
<th>Procedure Learning (C3: Procedure/Apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall knowledge</td>
<td>Review concepts constituting critical attributes of concept; use techniques such as informal questioning, formal pretest, advanced organizer, or analogy.</td>
<td>Review component concepts</td>
<td>Review component concepts, sub-procedures, or related principle.</td>
</tr>
<tr>
<td>Process information</td>
<td>Expose to best example and/or definition; emphasise criterial attributes; consider matched examples and nonexamples; present concept in range of settings with diversity of nonrelevant attributes.</td>
<td>Present/induct relationship; state in principle form; demonstrate application</td>
<td>Simplify complex procedures, situations that require procedures, steps in procedure, order of steps, how to evaluate correctness of application. May elaborate over several iterations.</td>
</tr>
<tr>
<td></td>
<td>(B2.1) informal questioning</td>
<td>(B3.1) Review/Verify ability to apply the concepts</td>
<td>(C3.1) Verify ability to apply simple procedures that form part of the new procedure being learned.</td>
</tr>
<tr>
<td></td>
<td>(B2.2) formal pre-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B2.3) advance organizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B2.4) analogy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B2.5) Present best example/prototype or definition</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(B2.6) emphasise criterial attributes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix 5.1

<table>
<thead>
<tr>
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<th>Concept Learning (B2: Concept/Understand)</th>
<th>Principle Learning (B3: Concept/Apply)</th>
<th>Procedure Learning (C3: Procedure/Apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B2.7) present matched examples and nonexamples</td>
<td>(B2.7) Explain how to determine if the procedure is required by using matched examples and nonexamples</td>
<td>(B3.1) Present the relationship with a statement</td>
<td>(B2.8) present concept in range of settings with diversity of nonrelevant attributes.</td>
</tr>
<tr>
<td>(B2.7) present matched examples and nonexamples</td>
<td>(B2.8) present concept in range of settings with diversity of nonrelevant attributes.</td>
<td>(B3.1) Present the relationship with a statement</td>
<td></td>
</tr>
<tr>
<td>(B2.8) present concept in range of settings with diversity of nonrelevant attributes.</td>
<td>(B3.1) Present the relationship with a statement</td>
<td>(B3.2) present the application of principle with examples</td>
<td></td>
</tr>
<tr>
<td>(B2.8) present concept in range of settings with diversity of nonrelevant attributes.</td>
<td>(B3.2) present the application of principle with examples</td>
<td>(B2.5) present best example of application of principle.</td>
<td></td>
</tr>
<tr>
<td>Focus attention</td>
<td>Identify critical characteristics of situations requiring procedure, key cues to transitioning between steps, keywords for each step, cues for correct completion of procedure.</td>
<td>Note the direction and size in change of one variable when another variable(s) changes</td>
<td></td>
</tr>
<tr>
<td>Focus attention</td>
<td>Isolate criterial attributes in examples with highlighting such as boldface type, colour, or a simplified drawing.</td>
<td>Note the direction and size in change of one variable when another variable(s) changes</td>
<td></td>
</tr>
<tr>
<td>Events of Instruction / Type of Learning</td>
<td>Concept Learning (B2: Concept/Understand)</td>
<td>Principle Learning (B3: Concept/Apply)</td>
<td>Procedure Learning (C3: Procedure/Apply)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>------------------------------------------</td>
<td>--------------------------------------</td>
<td>----------------------------------------</td>
</tr>
<tr>
<td>(B2.6) Isolate/highlight important (criterial) attributes using boldface type or colour</td>
<td>(B3.3) Explain the way one variable changes in response to a change in another variable</td>
<td>(B2.7) Identify critical conditions that require procedure</td>
<td></td>
</tr>
<tr>
<td>(B2.9) Isolate/highlight criterial attributes using simplified drawings</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C3.5) Explain how to verify correct completion of procedure</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C3.6) Highlight key cues that characterise the steps</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(C3.7) Identify/present keywords for each step</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employ learning strategies</td>
<td>Generate concept maps, analogies, mnemonics, or images.</td>
<td>Make a mnemonic rule statement, diagram of relationship</td>
<td>Use job aid, mnemonic for order of steps.</td>
</tr>
<tr>
<td>(B2.4) Explain analogies</td>
<td>(B2.10) Generate concept maps</td>
<td>(B2.10) Generate diagrams of relationship</td>
<td></td>
</tr>
<tr>
<td>(B2.10) Generate concept maps</td>
<td>(B2.10) Generate diagrams of relationship</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B2.11) Develop mnemonics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B2.12) Use images</td>
<td></td>
<td>(C3.8) Use job aid/check list</td>
<td></td>
</tr>
</tbody>
</table>
## Appendix 5.1

<table>
<thead>
<tr>
<th>Events of Instruction / Type of Learning</th>
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<th>Principle Learning (B3: Concept/Apply)</th>
<th>Procedure Learning (C3: Procedure/Apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Practice</strong></td>
<td>Identify examples from previously unencountered instances, which range in difficulty and settings; explain categorisations; generate examples.</td>
<td>Predict, explain, control changes in concept(s) based on change of another; recognise situations where rule applies; determine whether rule correctly applied.</td>
<td>Identify situations requiring procedure, order of steps, completion of steps, correct completion of procedure.</td>
</tr>
<tr>
<td>(B2.13) Identify new situations representing concept</td>
<td>(B3.4) Predict, explain, control changes in variables based on changes in another</td>
<td>(B2.7) Recognise situations where rule applies</td>
<td></td>
</tr>
<tr>
<td>(B2.14) Explain categorisations based on attributes of concept</td>
<td>(B3.5) Determine whether rule has been applied correctly</td>
<td>(C3.2) Describe order of steps</td>
<td></td>
</tr>
<tr>
<td>(B2.15) Generate new examples representing concept</td>
<td>(C3.3) Completion of steps</td>
<td>(B3.5) Correct completion of procedure</td>
<td></td>
</tr>
<tr>
<td><strong>Provide feedback</strong></td>
<td>Provide feedback that contains attribute isolation</td>
<td>Obtain information on whether rule applicable, outcome of application</td>
<td>Correct answer with explanation, checklist or rating scale</td>
</tr>
</tbody>
</table>
### Appendix 5.1

<table>
<thead>
<tr>
<th>Events of Instruction / Type of Learning</th>
<th>Concept Learning (B2: Concept/Understand)</th>
<th>Principle Learning (B3: Concept/Apply)</th>
<th>Procedure Learning (C3: Procedure/Apply)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(B2.6) Provide feedback emphasising criterial attributes</td>
<td>(B2.7) Provide feedback on applicability of the rule (principle)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(B3.5) Provide feedback on accuracy of application of rule</td>
<td>(B3.5) Explain shortcomings in the answers and correct them</td>
<td></td>
<td>(C3.9) Compare answers with checklist or rating scale</td>
</tr>
</tbody>
</table>

Shaded cells indicate that related strategies are used elsewhere in the table with minor variations in description.
Welcome to the computer-aided learning module on application of flexure formula.

Flexure formula, which we are going to study in this module, will allow us to calculate stresses in beams due to pure bending.

As you know, we study the application of flexure formula as a part of the Strength of Materials course. The Strength of Materials course is aimed at understanding the effects of external loads such as bending moments and resulting internal forces in structural components or machine elements.

Knowledge of Strength of Materials and related advanced courses help you design buildings, bridges, machine tools etc. Here are some examples of where such knowledge has been used.

However, all designs are not successful. As you can see, there are situations where designs fail due to poor design or other reasons.

The animation you now see is of the famous 5939-foot-long Tacoma Narrows Bridge in United States - moments before it collapsed due to 42-mile-per-hour wind storm on November 7, 1940.

So as prospective mechanical or civil engineers you have a very important role in designing safe structures and machines. Studying application of flexure formula is an important step in that direction.

Figure : Text of narration used under the “introduction” part of the CAL module
Appendix 5.3

Strategies used in Conclusion

With this we have now effectively covered the entire procedure of application of flexure formulas. As we have already noticed, the entire procedure is broken down into four distance steps. They are:

Step 1: Check the appropriateness of the flexure formula

Step 2: Locate the neutral axis

Step 3: Obtain the second moment of area about the N.A.

Step 4: Apply the flexure formula

Figure: Conclusion (provide summary and review)

6.3 Conclusions

With this knowledge, you should be able to:

1. Calculate stresses due to a bending moment in beams of various sections used in engineering practice.

2. Determine whether the calculated stresses are tensile or compressive.

What you have just learnt is one of the most fundamental topics in strength of materials, also known as mechanics of materials.

Figure: Conclusion (provide summary and motivation)
The understanding of this fundamental topic will help us study the higher level courses in Strength of Materials (Mechanics of Materials) and courses such as Structural Analysis.

To gain more experience in solving problems using the flexure formula, please attempt the separate exercise modules provided as part of this computer-aided learning module (CAL). One has pre-designed numerical problems for you to try. The other enables you to create your own problems and solve them. You may want to try the pre-designed problems first and then try the user-generated problems. Please go to the practice menu page and select the exercise module you want.

* Click the highlighted text to go to the practice menu.

Figure: Conclusion (provide review and enhance transfer)
## Appendix 5.4

**Storyboard template**

<table>
<thead>
<tr>
<th>Screen ID:</th>
<th>Objective no.</th>
<th>Page ___ of ___</th>
<th>Event:</th>
</tr>
</thead>
</table>

**Main Content**

**Feedback**

**Instructions**

---

**Main Menu**
Appendix 5.5

Sample Storyboard

Screen ID: S2/52
Objective no. 6
Page 1 of 10
Event: Elicit performance/Give feedback

Main Content

Let us have some quick practice.

Calculate the total area of the following cross section and enter the answer in the space provided.

120 mm

20 mm

150 mm

30 mm

15 mm

Instructions:
Click 'Skip practice' to skip the practice and go to next section
Appendix 5.5

Main Content

Let us have some quick practice. (Same as S2/52)

Calculate the total area of the following cross section and enter the answer in the space provided.

120 mm

20 mm

150 mm

30 mm

15 mm

Feedback

(For incorrect response)

Sorry! Try again.

If you need help, click following buttons.

Instructions:

Click 'Skip practice' to skip the practice and go to next section

(Same as S2/52)
Main Content

Let us have some quick practice.

Calculate the total area of the following cross section and enter the answer in the space provided.

120 mm

20 mm

150 mm

30 mm

15 mm

Answer

Erase user input

Skip Practice

Go to next section

(Same as S2/52)

Feedback

Hint

Total area = $A_1 + A_2 + A_3$

= $bd_1 + wh + bd_2$

Now try again.

Instructions:
Click ‘Skip practice’ to skip the practice and go to next section

(Same as S2/52)
Appendix 6.1

THE OPEN UNIVERSITY OF SRI LANKA
FACULTY OF ENGINEERING TECHNOLOGY

PRE-TEST ON APPLICATION OF FLEXURE FORMULA

NOVEMBER 2004

Duration: 30 minutes

Answer all questions

Answers should be written within the space allocated in this question paper.

Registration No.

1. Find the neutral axis (N. A.) of the T-beam having dimensions as shown in the figure below. (25 %)
Appendix 6.1

2. Determine the second moment of area of the above beam section about its neutral axis.
   (50 \%)
Appendix 6.1

3. If the above T-beam section is subjected to a positive bending moment of 2500 Nm, find the stresses at the top and bottom of the beam section. State whether the stresses are tensile or compressive. (25 %)

Do you like to use the Computer-Aided Learning module (computer-based tutorial) on the Application of Flexure formula? YES □ NO □
Appendix 6.2

Learnability Test Screen - 1

The flexure formula is expressed as follows:

\[ \sigma = \frac{M y}{I} \]

where

- \( \sigma \) (sigma) - normal stress
- \( M \) - bending moment
- \( I \) - second moment of area about the neutral axis
- \( y \) - distance from the neutral axis

Note: It is important to follow a sign convention when applying the above formula.

* Click PLAY/STOP button to turn on/off the audio.
* Click highlighted words for more explanation.
Appendix 6.3

Learnability Test Screen – 2

0.3 Introduction

The flexure formula is expressed as follows:

\[ \sigma = \frac{My}{I} \]

where

\( \sigma \) (sigma) - **normal stress**
\( M \) - bending moment
\( I \) - **second moment of area** about the **neutral axis**
\( y \) - distance from the **neutral axis**

Note: It is important to follow a **sign convention** when applying the above formula.

**Normal Stress**
Also called direct stress = intensity of induced normal force (perpendicular to the plane on which it is acting).
For a bar under centric axial force, 
\[ \sigma = \frac{F}{A} \]
Appendix 6.4

Computer-Aided Learning Module on Flexure Formula

Learnability Test

January 2005

The screen shots (Figure 1 (Appendix 6.2) and Figure 2 (Appendix 6.3)) are given to you with this are part of the Computer-Aided Learning (CAL) module on Application of Flexure Formula.

The screens have several buttons, links (hypertext) and highlighted words to help users interact with the module.

You are requested to indicate your choice of buttons, links or highlighted words for executing tasks described below. Please use the numbers assigned to different buttons, links, etc. to indicate your choice, if applicable.

Refer to Figure 1 (Appendix 6.2):

1. What do you think will happen if you click the button number 9?

Tick your answer:

- [ ] It will play a video on flexure formula
- [ ] It will play an audio explanation on flexure formula
- [ ] It will play an animation on flexure formula
- [ ] It will play an audio explanation in Tamil and Sinhala

2. What do you think will happen if you click the button number 8?

Tick your answer:

- [ ] It will stop playing a video on flexure formula
- [ ] It will stop playing an animation on flexure formula
- [ ] It will stop playing an audio explanation on flexure formula
- [ ] It will stop playing an audio explanation in Tamil and Sinhala
3. What do you think will happen if you click the blue underlined text “neutral axis”?

Tick your answer:

☐ It will play an audio on “neutral axis”

☐ It will do nothing

☐ It will give Sinhala and Tamil translations of word “neutral axis”

☐ It will produce additional explanation on “neutral axis”.

4. What do you think will happen if you click the button number 2 (main menu)?

Tick your answer:

☐ It will take me out of the program altogether

☐ It will take me to a page that allows me to go to different parts of the program

☐ It will take me to a new topic called “main menu”

☐ It will take me to the next section

5. Suppose, you want to choose the language for translations, which object will you click?

Answer: ☐

6. Suppose, you have finished with the current page and would like to move to next page, which object will you click?

Answer: ☐

7. Suppose, you would like to go back to the previous page to verify, which object will you click?

Answer: ☐
8. Suppose, you have finished with the current topic of the CAL module and would like to move to the next topic, which object will you click?
Answer: 

9. Suppose, you would like to go back to the previous topic, which object will you click?
Answer: 

10. Suppose, you would like to go back to the beginning of the current topic, which object will you click?
Answer: 

Refer to Figure 2 (Appendix 6.3):
While you are in Figure 1, if you click the highlighted text “normal stress”, additional explanation about “normal stress” will appear in the yellow area and the screen will look like what is shown in Figure 2.

11. What do you think will happen if you take the mouse over the red word “induced” in the yellow area?
Tick your answer:

- [ ] It will play an audio about the word “induced”
- [ ] It will give explanation on the word “induced”
- [ ] It will display a translation of the word “induced”
- [ ] It will do nothing

12. Suppose, you have read the explanation in the yellow area on ‘Normal Stress’ and would like to listen to an audio explanation relating to that, which object will you click?
Answer: 

13. If you want to exit the program immediately, which object(s) will you click?

Tick your answer:

☐ Object number 2

☐ Object number 11

☐ Object number 12

☐ Object number 13
1. Find the neutral axis (N. A.) of the T-beam having dimensions as shown in the figure below. (25 %)

![Diagram of a T-beam with dimensions 250 mm, 50 mm, 150 mm, and 60 mm]
Appendix 6.5

2. Determine the second moment of area of the above beam section about its neutral axis. (50 %)
Appendix 6.5

3. If the above T-beam section is subjected to a positive bending moment of 3000 Nm, find the stresses at the top and bottom of the beam section. State whether the stresses are tensile or compressive. (25 %)
Appendix 6.6

Computer-Aided Learning Module on Flexure Formula

User-Satisfaction Questionnaire

January 2005

The purpose of this questionnaire is to help us gain understanding about how you feel about the CAL module you have just used. Your responses to the questions and comments will assist us in doing that.

We will use this information only for the purpose of this research and the information you provide will be treated as strictly confidential.

Thank you for your cooperation.

Your Registration number: ______________________

Your Age group:
18-24 [ ] 25-29 [ ] 30-34 [ ] 35-44 [ ] 45-54 [ ] Over 55 [ ]

Your Regional Centre:
Colombo [ ] Other [ ] (Please specify)

Sex:
Male [ ] Female [ ]

Mode of study:
Full-time [ ] Part-time [ ]

Work status:
Full-time [ ] Part-time [ ] Not working [ ]
Appendix 6.6

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neither disagree nor agree</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I found the language used in the CAL module simple and clear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I found the interactions and feedback in the CAL module helpful in clarifying doubts about the topic</td>
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<td>3. I found the examples in the CAL module helpful in clarifying doubts about the topic</td>
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<tr>
<td>4. I found the graphics in the CAL module helpful in understanding concepts better</td>
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<td>5. I found the voice explanation (audio) helpful in understanding the topic better</td>
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<tr>
<td>6. I found the voice explanations in the CAL module helpful in overcoming language (English) difficulties</td>
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<td>7. I found the translations available in the CAL module helpful in overcoming language (English) difficulties</td>
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<td>8. For this particular module, I prefer CAL tutorials over human tutor support</td>
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<td>9. I am satisfied with the CAL learning experience</td>
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<tr>
<td>10. I like to use more of this type of CAL modules in my studies</td>
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<td>11. I liked the following features (in this CAL module) most. Please list.</td>
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</table>
### Appendix 6.6

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<table>
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</thead>
<tbody>
<tr>
<td>12. I did <strong>not</strong> like the following features (in this CAL module). Please list.</td>
<td></td>
</tr>
<tr>
<td>13. I would like to propose the following changes to this CAL module. Please list</td>
<td></td>
</tr>
<tr>
<td>14. Any other suggestions?</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 7.1

Opportunities and Challenges in Instructional Design for Teaching Flexure Formula Using Revised Bloom’s Taxonomy

Gamini A. K. Padmaperuma, Sinniah Ilanko, Der-Thanq Chen
University of Canterbury, New Zealand

Abstract

The purpose of this article is to show how the Revised Bloom’s Taxonomy has been used in designing an instruction module in an analytical course in engineering for distance learning. Identification of the type of knowledge and cognitive process associated with each task is found to be useful in informing the selection of appropriate instructional strategies. Using bending stress calculation as a sample case study, potential opportunities and challenges facing the instructor are discussed. Problems associated with the original taxonomy and the enabling features in the revised taxonomy for more informed analyses are also described.

Background: Search for a teaching strategy

Mechanics of Materials is a core course in many engineering disciplines. It is an analytical course requiring good mathematical skills and understanding of abstract concepts making it particularly unpalatable and difficult for those learning this at distance. Continued poor student performance in a first course in Mechanics of Materials has been a concern for those who teach this course at the Open University of Sri Lanka (OUSL). While the students follow this course in English, their medium of instruction at school is in the vernacular. They often find this transition in the medium of instruction challenging, and it is particularly so in the technical courses due to their lack of exposure to technical vocabulary. Inadequate preparation in English of students entering the first year of university studies in Engineering is a concern of other non-English speaking countries as well [1].

The student performance in this course is comparatively low among the courses at the same level with a failure rate of more than 50% in the period between 1999 and 2002. This has motivated us to undertake research to formulate a suitable strategy for improving the learning of such analytical courses through distance.

General Approach

In order to understand the various steps taken in the course of this research, it is worth outlining the general procedures employed. A typical instructional design process includes five stages, namely, Analysis, Design, Development, Implementation and Evaluation, known as the ADDIE processes [2]. In general, each stage in the process provides outputs that serve as inputs for subsequent stages. However, there are situations where these five stages do not necessarily follow sequentially. During analysis, instructional designers develop a clear understanding of the gaps between the desired and the actual learning outcomes. The design stage documents the content, exercises, and
assessments including teaching and learning strategies. The development stage deals with the actual creation of the learning materials while the implementation stage is concerned with the students’ actual learning experience. Finally, the evaluation stage looks into the effectiveness of the designed instruction.

According to Smith, there are three main components in this stage: learning context analysis, learner analysis, and learning task analysis [3]. The learning context analysis consists of two steps: identification of the gaps in the achievement of learning outcomes (needs assessment), and identification of the environment under which learning occurs (learning environment). The second component, the learner analysis, is concerned with the learner characteristics that may have implications on the design of instructions. The final part of analysis, which is the focus of this paper, is the learning task analysis. This deals with a detailed and hierarchical breakdown of the learning task to identify the underlying learning objectives and prerequisite knowledge. Combined results of the analysis of these three components provide a basis for designing instructional strategies. Although this analytical approach is well-established, there has been a general concern that insufficient time is spent in the analysis of the learning task prior to the design stage [4]. Our study has now reached the end of the analysis stage. This paper focuses on the analysis of the learning task. The early stages of the analysis will be stated only briefly.

A needs assessment at the Open University of Sri Lanka (OUSL) was conducted through surveys and interviews of students and lecturers. As a result, priority was given to the topic of bending stress calculation. The major reasons are the importance of this type of stress calculation in engineering design and the complexity of the derivations.

Once the topic was selected, the gaps between the desired and actual outcomes were identified as suggested in the model by Smith and Ragan [3]. Several issues which are believed to have contributed to these gaps were also identified. These findings are currently being used in the selection and design of appropriate instructional strategies. From the identified gaps, a list of goals that the learners need to achieve, and are currently unable to do was developed.

However, the list of goals was not in a form that could be readily used for developing instruction modules. It is the Task Analysis that transforms goal statements into a form that may be used as a guide in designing instruction [3]. The outcome of such task analysis is a hierarchy of sub-goals. These sub-goals describe what learners will be able to do or should know at the end of instruction. The task analysis also identifies the prerequisite skills necessary to achieve such goals. For teaching the beam bending theory and applications, two hierarchies of sub-goals in the form of flow charts were developed; one for the derivation of the engineers beam bending theory and another for its application. For the purpose of this paper only the flowchart on application of the beam bending theory has been used (Figure 1).

Task Analysis Tool: The Revised Bloom's Taxonomy
Appendix 7.1

The Bloom’s Taxonomy is one of the popular tools used for task analysis. It helps educators to assess how much and how well the students have learned [5]. Revised Bloom’s Taxonomy (RBT) allows classification in a two dimensional table form, based on the type of knowledge and the type of cognitive process involved in the learning task. Such classifications are likely to help the teachers in determining appropriate teaching techniques and grouping the learning tasks into separate modules, courses, etc. based on the type of knowledge and cognitive processes (skills) associated [6]. The original Taxonomy of Educational Objectives (OBT) is a framework for classifying statements of what teachers expect or intend students to learn as a result of instruction [7]. An example of such a statement is, “by the end of the lesson, students will be able to correctly answer multiplication questions using the times table for numbers up to 10, for at least 90% of the questions.” In the present research, we have decided to use the Revised Bloom’s Taxonomy (RBT) developed by Anderson, et al. [7]. Similar to the OBT, the RBT is a framework for classifying the learning objectives that describe what students are expected to achieve as a result of instruction [8].

The original taxonomy included six major categories. They are: knowledge, comprehension, application, analysis, synthesis, and evaluation. Table 1 shows the structure of the original taxonomy. The action verbs such as recall, apply and calculate are classified into one of the six different categories. For example, a learning objective may specify that, after the instruction a student should be able to translate a word problem into a numerical one. Then the appropriate category for this action would be comprehension (Table 1). According to Krathwohl, one assumption of the original Bloom’s taxonomy is that learning is hierarchical and is largely based on prerequisite skills and knowledge [8]. For example, if a learning outcome is pitched at the comprehension level, the teacher must first cover activities at the knowledge level before proceeding to the intended comprehension level.

Krathwohl also suggests that the uni-dimensionality is a limitation of the OBT [8]. That is, the learning objectives are generally classified using only one dimension, namely the action verb. The uni-dimensional taxonomy provides information sufficient only for a preliminary indication. For example, an objective that reads, "The students should be able to apply Hooke’s Law to simple one dimensional axial straining problems" would be classified on the basis of the action verb (in this case, apply) only. The noun, "Hooke’s law", is not used for classification. In fact, the noun can also provide useful information. With this additional information, the instructional designers will have a broader basis for developing suitable instructional strategies.

In an attempt to address the above problems, Anderson and Krathwohl proposed a revision to the Bloom’s taxonomy [8]. Table 2 shows the structure of the revised taxonomy. In revising the taxonomy all six cognitive process dimensions in the original taxonomy have been preserved, but three major changes have been made. Firstly, knowledge is classified as a second dimension and is divided into four categories. Secondly, the category synthesis in the original taxonomy has been renamed as create. Thirdly, the categories evaluation and synthesis (now renamed as create) have been
swapped in their positions. This makes create the highest cognitive process in the revised taxonomy.

Since the revised Bloom’s taxonomy allows identification of the type of knowledge and the cognitive process associated with a particular learning objective, it provides a broader basis for finding suitable instructional strategies. For example, in teaching an application of Hooke’s law the cognitive process applicable is apply and the relevant knowledge category is conceptual.

Krathwohl, through the RBT, encourages a lenient approach for classifying objectives [8]. This gives flexibility in using the revised taxonomy in selecting action verbs and classifying objectives. The need to be flexible in determining learning objectives has been noted by others also. For example, Mager in his book entitled “Preparing Instructional Objectives” states that one needs not be constrained by a strict hierarchy [9]. He suggests that objectives should be specified as the learning process naturally demands, without strict compliance to a hierarchy [9].

It should be noted that the RBT is not the only taxonomy used for classifying learning objectives. Gagne, for example, has also developed a taxonomy for classifying learning objectives consisting of five categories of ‘human capabilities’; intellectual skills, cognitive strategies, verbal information, motor skills and attitudes. The intellectual skills have been further subdivided into four different levels based on their complexity; discriminations, concrete concepts, rules and defined concepts, and higher order rules-problem solving [10]. The clearly defined cognitive process and knowledge categories and action verbs that are available in the RBT were found to be more suitable for the purpose of this particular task analysis. Therefore the RBT was selected.

To our knowledge, existing literature has no information on any study that has applied the RBT to a task analysis. The question of whether the revised taxonomy will enhance the analysis of learning tasks in hand remains to be answered. It is hoped that some observations reported from the current study will help establish its appropriateness and suitability or otherwise.

Task Analysis for Flexure Formula

Two flowcharts of the learning tasks, one for the derivation of the elastic beam bending formula in equation (1) and another for its application to some common types of structural beam sections have been developed.

\[ \sigma = -\frac{My}{I} \]  \hspace{1cm} (1)

Here, \( \sigma \) is the normal stress at distance \( y \) from the neutral axis of the beam, \( M \) is the bending moment, \( I \) is the second moment of area about the neutral axis which is the centroidal axis of the transverse cross section of the beam. At the time the students learn this formula, they are expected to be able to determine the bending moment in the beam for a given loading subject to any boundary conditions. They are also expected to know
the meaning of the centroid and second moment of area of a geometric shape and to be able to calculate these for some common shapes that are obtained by adding or subtracting rectangles and circles. Another expectation is that they know the meaning of stress, as intensity of induced force, but until this time they would have only learnt how to calculate the stress due to centric axial loading. These are the prerequisites. Learning the derivation of equation (1) is the first learning task. Once they learn this, and understand the assumptions and limitations of the theory, they would be expected to apply this to some common beam sections and determine the maximum values of stress. Understanding the assumptions on which a particular formula is based and knowing their limitations are important in determining if a given situation is an example or a non-example for using a particular method of solution [5]. Several text books, lecture notes and computer programs that are currently available for teaching this course have been used in developing the flowcharts [11-13].

Once the flowcharts were drafted, each task was categorized according to the RBT. The charts were then verified by five other subject experts (validators), three from the University of Canterbury in New Zealand and two from the Open University of Sri Lanka. Four of the experts were academic staff and have taught this subject and one was a postgraduate teaching assistant at the time of validation. Classification of some of the tasks required several rounds of discussion between the researcher and a subject expert.

Results

The final version of the validated chart for the application of the flexure formula is given in Figure 1. In general the validators agreed with the classification and the order of tasks in the flowcharts. The issues that needed clarification were discussed and were resolved until a consensus was reached. Some changes proposed by the validators were implemented; others were considered but not implemented for reasons that were explained to the validators concerned. The changes suggested and implemented include, revision of objective descriptions to include hollow sections (Objectives 12 and 14, Figure 1), rearrangement of connectors between objectives and revision of the dotted line which separates the main instruction from prerequisites (Objectives 15 and 16, Figure 1). A suggestion to include a worked example in parallel to the steps in the flowchart was not adopted as such details are relevant in the design stage and not in this analysis stage. An interesting question on classification was raised. That is, why some tasks were classified as conceptual instead of factual in the knowledge dimension. This is elaborated later.

The application flowchart is now being used to prepare an instruction design. Since the needs analysis indicated that a computer based teaching module is likely to be the most feasible way to teach this course at distance, research is currently in progress to select appropriate strategies for each type of task using an interactive multi-media program.

It should be noted here that the flowchart and the categories assigned to the objectives represent only one way for teaching the application of the flexure formula. There may be many other different ways that are equally appropriate. For example, it is possible that some of the objectives may be expanded into smaller components. Conversely, it is also
possible to merge some of the objectives to form some major objectives. In fact, the entire flow chart could be considered as application of the flexure formula which is an instance of procedural knowledge. We anticipate some revisions to the flow chart in Figure 1 may be carried out during the design of a computer based instruction module or after its implementation. It should also be noted that the flow chart presented in this study may or may not be appropriate for other contexts.

It is interesting to note that in the taxonomy table (Table 3), many of the cells are empty. This table sheds some light towards the design of the computer based modules. Decisions on issues such as whether teaching a particular task is best done by one strategy or another may depend on the type of knowledge and the type of cognitive process associated with each task. This means, it may be possible to use the same type of activity for Objectives 2, 3, 4, 5, 7, 10, 15 and 17 as they are all in the same cell in Table 3.

Discussion

We are of the opinion that the lessons learned from conducting the task analysis using the RBT will be of use to other researchers and engineering lecturers. Some of the challenges that were encountered in the process of developing the flowcharts and the opportunities the RBT offers are described in the following sections.

RBT versus OBT

There are numerous sources in the literature for action verbs relating to the OBT [14]. Some of these verbs are now classified under different categories in the RBT from what it was in the OBT. It is worth noting that some action verbs are classified under more than one category in the OBT. Table 4 shows some examples.

This situation can cause confusion in determining the appropriate cognitive process for a given learning objective, leading to confusions in the selection of appropriate strategies. In the task analysis for the application of the flexure formula (Figure 1), there is an objective (# 15) “To be able to infer whether the bending moment to be used in the formula is explicitly given in a usable form”. This objective could initially point to an exercise to identify some data from a given description. However it should be more cognitively demanding. It involves “drawing a logical conclusion from presented information”, according to the RBT. In this task, the student, from the given problem description needs to determine whether all the necessary information regarding bending moment is available. This type of cognitive process is described as inferring in the RBT and is categorised under understand (Table 2). On the other hand, in the OBT, inferring is categorised under both comprehension and analysis (Table 4) requiring additional effort in classification to avoid confusion.

The clear and concise descriptions of categories and cognitive processes and identification of typical action verbs under each subcategory in the RBT help categorise action verbs appropriately. This would reduce the chances of misclassification of action
Appendix 7.1

verbs. The descriptions in the RBT were found to be generally clear enough to make the identification of new action verbs easy. We suggest that a longer list of action verbs will be useful to avoid misclassification of action verbs due to subtle differences in their meaning.

In addition there is a need to be cautious in using verbs that are similar in their common usage. The descriptions for each cognitive process in the RBT were found to be useful to distinguish subtle differences between similar action verbs and place them in the corrective cognitive process category. For example, in our daily usage classify and distinguish may be taken to mean more or less the same. However in the RBT, classify means the action of determining that something belongs to a certain category and is listed under understand, whereas distinguish means the action of discriminating relevant from irrelevant parts of presented material and is listed higher in the cognitive process hierarchy under analysis. These definitions lead to subsequent identification of suitable instructional strategies. In the same example above, an appropriate activity for classify would be for learners to look at a picture of an animal and indicate its respective animal family. On the other hand, requiring learners to read a passage describing the characteristics of different animals in order to recognise the characteristics of given animal families would be an example of the activity distinguish which comes under analysis.

During the early stages of the task analysis, it became clear that both the OBT and the RBT are useful in identifying some inappropriate classification. In initial attempts to assign a cognitive level to some objectives the indicated level appeared to be too high. For example, some tasks that suggest checking or verification of certain conditions, the cognitive process was first thought to be checking which comes under the category of evaluate. This is the fifth in the six cognitive levels in the RBT. However the surrounding objectives in the hierarchy of objectives were all at a significantly lower level of remember. It was thought that in learning, it would be unusual for the student to skip several cognitive levels in one step, in this case from the 1st to the 5th. A closer look at the description of checking suggested that this action occurs when a student detects inconsistencies or fallacies within a process or product, determines whether a process or product has internal inconsistency, or detects the effectiveness of a procedure as it is being implemented [15]. Based on the above description, since the tasks on hand do not actually require such a high-level cognitive effort it was decided that they could not be described as checking for classification purpose. Further analysis revealed an appropriate classification at the second level of the cognitive processes, understand. The cognitive process of exemplifying under the category of understand would closely represent the efforts of the tasks.

The minimisation of the difference between the cognitive levels of associated objectives will ensure that there will be no big jumps in cognitive effort between successive tasks. The descriptions of cognitive processes and representative action verbs provided in the RBT were found to be useful in achieving this. This is likely to facilitate a smoother transition in students' learning process.
Appendix 7.1

Uni- versus two-dimensionality

As explained earlier, the two dimensions of the RBT, knowledge and cognitive process, provide a broader basis for designing teaching and learning activities. The objectives analysed using the RBT can be translated into instructional strategies that are suitable from either the knowledge perspective or the cognitive process perspective.

Further studies on instructional strategies show that existing literature commonly use knowledge categories such as concepts, procedures, etc. to describe different instructional strategies (e.g. concept learning, procedure learning, etc.). However, closer scrutiny of these strategies reveals that they are really intended for achieving different learning outcomes associated with specific cognitive processes. This suggests that in many situations it may be easier to determine the related cognitive process (learning outcome) by identifying the knowledge type first. The RBT is more user-friendly in that it helps identify the knowledge type which in turn can help determine the learning outcome and thereby the appropriate instructional strategy.

The learning objectives identified in the present study were found to be confined to three categories: remember, understand and apply cognitive processes (Table 3). In the knowledge dimension, they are confined to conceptual and procedural knowledge. This limits our ability to draw conclusions related to other cognitive processes or knowledge types. It would be worthwhile conducting a study in a topic involving the remaining categories in the knowledge and cognitive process dimensions.

Interestingly, the findings from this study seem to suggest that the two dimensions of the RBT may not be totally independent. Certain observations can be made here. For example, all procedural knowledge objectives are associated with understand and apply. In fact in this particular module, they are all associated with calculations of different properties. Further, most objectives of factual knowledge are associated with remember. In fact, without referring to the current study, it was challenging to think of examples for factual knowledge at a level other than remembering. These observations point to a possibility that the two dimensions of the RBT may not be totally independent. Based on these observations we developed a table showing apparent dependencies between types of knowledge and cognitive processes (see Table 5) which point to frequent association between the specific knowledge and cognitive categories. These dependencies could be limited to our study only. Future studies may show whether this is also the case in other subject areas.

The Designer’s versus the Learner’s Point of View

Potential for misclassification is present in both knowledge and cognitive process dimensions. This can be particularly challenging in situations where an instructional designer’s point of view on a particular knowledge may differ from that of the students.
Appendix 7.1

During the validation process, questions were raised about the knowledge and cognitive process category assigned to some of the objectives. Examples included questions on whether a task should be categorized as conceptual or factual in the knowledge dimension, and evaluate or analyse in the cognitive process dimension.

Furthermore, the fact that most of the knowledge categories assigned in the task analyses are either conceptual or procedural was noted by a validator. This led to the question whether some knowledge must be based on facts and whether conceptual knowledge, after having been used by someone for considerable time, could become factual knowledge. For example, can Hooke’s law be regarded as factual knowledge instead of conceptual? This led to some discussion on the interpretation of the term factual knowledge. After some debate, a decision was made that this knowledge would not be seen as factual from the students’ point of view and we maintain that the knowledge type for this particular objective should remain as conceptual. The lesson learned from this process is that whenever there is a dilemma in choosing a particular type of knowledge or cognitive process, the decision should be based on the students’ viewpoint.

Concluding Remarks

The Revised Bloom’s Taxonomy has been used to carry out a task analysis for teaching bending stress calculations. Based on this a flowchart of the learning objectives for teaching the application of flexure formula has been developed. The chart shows the knowledge and cognitive process associated with each learning objective and the necessary prerequisites. This provides an overview of all the enabling objectives leading to the accomplishment of the main learning objective. Further work is in progress to identify the appropriate instructional strategies for achieving learning objectives based on the cognitive process and knowledge dimensions in the Revised Bloom’s taxonomy.

Based on the experience in this study, the suitability of the RBT in contrast with the OBT was discussed. Both versions of the Taxonomy were found to be useful in identifying appropriate classifications. Compared to the OBT, the RBT was found to provide clearer descriptions of the cognitive process, permitting easier identification of new action verbs. In addition, identification of the knowledge dimension was found to facilitate the selection of appropriate instructional strategies. The results obtained from this particular task analysis point to a possibility that the two dimensions in the RBT may not be totally independent.

Some combinations of the cognitive process and knowledge categories are absent in the taxonomy table of this particular study. Future studies may focus on topics that are likely to result in objectives associated with higher cognitive process and metacognitive knowledge in order to examine the suitability of other aspects of the RBT for task analysis.
Appendix 7.1

References


Appendix 7.1


Appendix 7.1

Figure 1: Application of Flexure Formula

Prerequisites

Recall the assumptions used in deriving Flexure Formula (Beam Bending Formula)

Are all the assumptions met?

Yes

No

Is the beam undergoing Pure Bending, and the effect of shear force, if any, is minor?

Yes

No

Conclude that this problem cannot be solved using Flexure Formula (Use another method).

Does the overall section have an axis of symmetry perpendicular to the plane of bending?

Yes

No

Conclude the location of the neutral axis by visual examination, i.e., centre line

Calculate the position of neutral axis of overall section

Recognise the various rectangular and/or circular sections that make up the overall section

Yes

No

Recall the definition of centroid

Recall the definition of Plane of Bending and axis of symmetry

Recall definition of Pure Bending

Recall the formulae for areas

Recall the definition of centroid

Recall First Moment of Area theorem
Appendix 7.1

Prerequisites

- Recall Second Moment of Area theorem
- Recall definition of bending moment
- Apply selected sign convention for bending moment
- Calculate second moment of area for individual rectangular/circular sections (including hollow sections)
- Calculate second moment of area for the total section (including hollow sections) around neutral axis
- Interpret the problem description to get magnitude and sign of bending moment
- Use an appropriate sign convention
- Recall sign convention for stress and bending moment
- Recall Flexure Formula
- Recall sign convention for stress

Steps

1. Interpret formula to suit given situation
2. Does the overall section have more than one single rectangular or circular section?
3. Yes: Calculate the second moment of area around section's centroidal axis
4. Yes: Calculate second moment of area for individual rectangular/circular sections (including hollow sections)
5. Yes: Calculate second moment of area for the total section (including hollow sections) around neutral axis
6. No: Is the bending moment applied to the section given in the problem description?
7. No: Recall definition of bending moment
8. Yes: Interpret the problem description to get magnitude and sign of bending moment
9. Use an appropriate sign convention
10. Recall sign convention for stress and bending moment

Calculations

11. Calculate the second moment of area around section's centroidal axis
12. Interpret formula to suit given situation
13. Yes: Calculate the second moment of area for individual rectangular/circular sections (including hollow sections)
14. Yes: Interpret formula to suit given situation
15. No: Is the bending moment applied to the section given in the problem description?
16. Yes: Calculate bending moment and assign appropriate sign, using given data
17. Yes: Interpret the problem description to get magnitude and sign of bending moment
18. Yes: Use an appropriate sign convention
19. Yes: Calculate the distance to the top and bottom of section from the neutral axis, with appropriate signs
20. Yes: Apply values obtained for moment, second moment of area and distance from N.A. into Flexure Formula
21. No: Recall Second Moment of Area formula
22. No: Recall Parallel Axis formula
23. No: Recall Flexure Formula
24. No: Recall sign convention for stress
25. No: Recall sign convention for stress and bending moment

Diagram

- C X 2: Interpret formula to suit given situation
- C X 3: Calculate the second moment of area around section's centroidal axis
- C X 3: Calculate second moment of area for individual rectangular/circular sections (including hollow sections)
- C X 3: Interpret formula to suit given situation
- C X 3: Calculate second moment of area for the total section (including hollow sections) around neutral axis
- B X 2: Does the overall section have more than one single rectangular or circular section?
- B X 2: Is the bending moment applied to the section given in the problem description?
- B X 1: Recall definition of bending moment
- C X 1: Recall Second Moment of Area theorem
- B X 3: Apply selected sign convention for bending moment
- C X 3: Calculate second moment of area for individual rectangular/circular sections (including hollow sections)
- C X 3: Calculate second moment of area for the total section (including hollow sections) around neutral axis
- B X 1: Recall sign convention for stress and bending moment
- B X 1: Recall sign convention for stress
- C X 1: Recall Parallel Axis formula

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Table 1: Structure of the original taxonomy

<table>
<thead>
<tr>
<th>Category</th>
<th>Subcategory</th>
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<tbody>
<tr>
<td>1.0 Knowledge</td>
<td>1.10 Knowledge of specifics</td>
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<td></td>
<td>1.11 Knowledge of terminology</td>
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<tr>
<td></td>
<td>1.12 Knowledge of specific facts</td>
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<tr>
<td></td>
<td>1.20 Knowledge of ways and means of dealing with specifics</td>
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<tr>
<td></td>
<td>1.21 Knowledge of conventions</td>
</tr>
<tr>
<td></td>
<td>1.22 Knowledge of trends and sequences</td>
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<td></td>
<td>1.23 Knowledge of classifications and categories</td>
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<td>1.24 Knowledge of criteria</td>
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<td>1.25 Knowledge of methodology</td>
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<td></td>
<td>1.30 Knowledge of universals and abstractions in a field</td>
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<td></td>
<td>1.31 Knowledge of principles and generalisation</td>
</tr>
<tr>
<td></td>
<td>1.32 Knowledge of theories and structures</td>
</tr>
<tr>
<td>2.0 Comprehension</td>
<td>2.1 Translation</td>
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<td></td>
<td>2.2 Interpretation</td>
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<tr>
<td></td>
<td>2.3 Extrapolation</td>
</tr>
<tr>
<td>3.0 Application</td>
<td></td>
</tr>
<tr>
<td>4.0 Analysis</td>
<td>4.1 Analysis of elements</td>
</tr>
<tr>
<td></td>
<td>4.2 Analysis of relationships</td>
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<tr>
<td></td>
<td>4.3 Analysis of organisational principles</td>
</tr>
<tr>
<td>5.0 Synthesis</td>
<td>5.1 Production of a unique communication</td>
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<tr>
<td></td>
<td>5.2 Production of a plan, or proposed set of operations</td>
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<td></td>
<td>5.3 Derivation of a set of abstract relations</td>
</tr>
<tr>
<td>6.0 Evaluation</td>
<td>6.1 Evaluation in terms of internal evidence</td>
</tr>
<tr>
<td></td>
<td>6.2 Judgements in terms of external criteria</td>
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</tbody>
</table>
Appendix 7.1

<table>
<thead>
<tr>
<th>Knowledge dimension</th>
<th>Cognitive process dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Factual Knowledge – The basic elements that students must know to be acquainted</td>
<td></td>
</tr>
<tr>
<td>with a discipline to solve problems in it.</td>
<td>1.0 <strong>Remember</strong> - Retrieving relevant knowledge from long-term memory</td>
</tr>
<tr>
<td>Aa. Knowledge of terminology</td>
<td>1.1 <strong>Recognising</strong></td>
</tr>
<tr>
<td>Ab. Knowledge of specific details and elements</td>
<td>1.2 <strong>Recalling</strong></td>
</tr>
<tr>
<td>B. Conceptual Knowledge – The interrelationships among the basic elements within</td>
<td>2.0 <strong>Understand</strong> - Determining the meaning of instructional messages, including oral,</td>
</tr>
<tr>
<td>a larger structure that enable them to function together.</td>
<td>written, and graphic communication.</td>
</tr>
<tr>
<td>Ba. Knowledge of classifications and categories</td>
<td>2.1 <strong>Interpreting</strong></td>
</tr>
<tr>
<td>Bb. Knowledge of principles and generalisations</td>
<td>2.2 <strong>Exemplifying</strong></td>
</tr>
<tr>
<td>Bc. Knowledge of theories, models, and structures</td>
<td>2.3 <strong>Classifying</strong></td>
</tr>
<tr>
<td>C. Procedural Knowledge - how to do something; methods of inquiry, and criteria for</td>
<td>2.4 <strong>Summarising</strong></td>
</tr>
<tr>
<td>using skills, algorithms, techniques, and methods.</td>
<td>2.5 <strong>Inferring</strong></td>
</tr>
<tr>
<td>Ca. Knowledge of subject-specific skills and algorithms</td>
<td>2.6 <strong>Comparing</strong></td>
</tr>
<tr>
<td>Cb. Knowledge of subject-specific techniques and methods</td>
<td>2.7 <strong>Explaining</strong></td>
</tr>
<tr>
<td>Cc. Knowledge of criteria for determining when to use appropriate procedures</td>
<td></td>
</tr>
<tr>
<td>D. Metacognitive Knowledge - Knowledge of cognition in general as well as awareness</td>
<td></td>
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<tr>
<td>and knowledge of one's own cognition.</td>
<td></td>
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<tr>
<td>Da. Strategic knowledge</td>
<td></td>
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<tr>
<td>Db. Knowledge about cognitive tasks, including appropriate contextual and conditional</td>
<td></td>
</tr>
<tr>
<td>knowledge</td>
<td></td>
</tr>
<tr>
<td>Dc. Self-knowledge</td>
<td></td>
</tr>
<tr>
<td><strong>Table 2: Structure of revised taxonomy</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 3: Taxonomy table for application of flexure formula

<table>
<thead>
<tr>
<th></th>
<th>Remember</th>
<th>Understand</th>
<th>Apply</th>
<th>Analyse</th>
<th>Evaluate</th>
<th>Create</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factual Knowledge</strong></td>
<td>Obj. 1</td>
<td>Obj. 2</td>
<td>Obj. 6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obj. 9</td>
<td>Obj. 3</td>
<td>Obj. 8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obj. 4</td>
<td>Obj. 18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Obj. 5</td>
<td>Obj. 19</td>
<td></td>
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<td></td>
<td></td>
<td>Obj. 7</td>
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<td>Obj. 10</td>
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<tr>
<td></td>
<td></td>
<td>Obj. 15</td>
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<tr>
<td></td>
<td></td>
<td>Obj. 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Conceptual Knowledge</strong></td>
<td>Obj. 13</td>
<td>Obj. 11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Obj. 21</td>
<td>Obj. 12</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Obj. 14</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Obj. 16</td>
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<tr>
<td></td>
<td></td>
<td>Obj. 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Procedural Knowledge</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Metacognitive Knowledge</strong></td>
<td></td>
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</tr>
</tbody>
</table>
Appendix 7.1

Table 4: Action verbs and taxonomy categories

<table>
<thead>
<tr>
<th>Verb</th>
<th>Revised Taxonomy Category</th>
<th>Original Taxonomy Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify</td>
<td>Remember</td>
<td>Knowledge and Analysis</td>
</tr>
<tr>
<td>Infer</td>
<td>Understand</td>
<td>Comprehension and Analysis</td>
</tr>
<tr>
<td>Generalise</td>
<td>Understand</td>
<td>Apply and Synthesis</td>
</tr>
<tr>
<td>Illustrate</td>
<td>Understand</td>
<td>Comprehension and Analysis</td>
</tr>
<tr>
<td>Select</td>
<td>Analyse</td>
<td>Apply, Analyse and Evaluate</td>
</tr>
</tbody>
</table>
Appendix 7.1

Table 5: Knowledge Vs. Cognitive Process dependency

<table>
<thead>
<tr>
<th>Type of knowledge</th>
<th>Cognitive processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factual</td>
<td>Remember</td>
</tr>
<tr>
<td>Conceptual</td>
<td>Understand and Apply (e.g. principle learning)</td>
</tr>
<tr>
<td>Procedural</td>
<td>Understand and Apply</td>
</tr>
<tr>
<td>Metacognitive</td>
<td>Analyse, Evaluate, Create</td>
</tr>
</tbody>
</table>
Appendix 7.1

Biographical information

**Gamini Padmaperuma** is a PhD candidate at the University of Canterbury. He has a M.Sc (honours) degree in Mechanical Engineering from the Moscow PFU university, and a M.Tech in Production Engineering from the Brunel University, UK. He is a chartered professional engineer and has been a Senior Lecturer in Mechanical Engineering at the Open University of Sri Lanka. His research interests are in instructional design, computer-based tutoring systems and engineering management.

**Sinniah Ilanko** is a Senior Lecturer in Mechanical Engineering at the University of Canterbury. He has Bachelors and Masters Degrees in Civil Engineering from the University of Manchester, and a PhD from the University of Western Ontario. His major research activities are in Vibration and Stability of Structures and Numerical Analysis, but he also has an interest in Engineering Education. He was recently appointed as an Editorial Adviser to the Journal of Sound and Vibration.

**Der-Thanq Chen** is a Senior Lecturer in the University Centre for Teaching and Learning at the University of Canterbury. He currently leads the e-learning initiatives at the University and lectures courses in instructional design and interactive multimedia design. His areas of research interest include online learning communities and the design of constructivist learning environments.