SOME PSYCHOLOGICAL THEORIES IN ENGINEERING EDUCATION

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What is it that makes the student experience in engineering so challenging? Although it is accepted that the applied nature of any science is likely to be a critical test of understanding concepts, it is particularly true in regard to training engineers, where elements of the key sciences are interwoven with mathematics and management studies. This integration of disciplines is needed to provide a framework for professional practice so that, for example, an engineer's insight into process design embraces not only an overall understanding of scientific feasibility but also the economic, safety, and controllability issues.

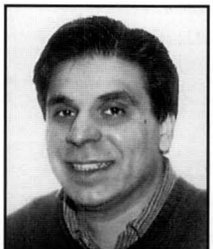
So, what constitutes effective training in undergrduate engineering? It is easy to provide disparate courses covering an identified curriculum, but effective training can be judged only through students' overall mapping of the course and ultimately the holistic knowledge schema drawn by the students. It is not then surprising that psychological and biological principles in memory and cognition should provide some basis in the design, delivery, and evaluation of a course; see, for example, the discussions of Haile[1] on the educational implications of brain structure and function. While the issue is complicated by individual student motivation for learning, by using some of the basic psychological principles that describe learning and motivation, some common practices for good teaching can be demonstrated.

To the experienced lecturer, such practice may be either second nature or common sense, but the underlying psychological principles may not be apparent. Of course, the literature in chemical engineering has been rather thorough in describing good teaching methods, such as student-centered, cooperative, and problem-based learning (see the following section). But when a psychological background to memory and learning is understood, these teaching methodologies can be better evaluated and applied by the new teacher, or indeed even by a teacher who adheres to the traditionalist teaching approach. In the following sections, a brief overview of these principles is given and some exemplary teaching practices in engineering education highlighted.

MEMORY AND LEARNING

Through the centuries, human perception of the nature of the mind has been constantly redefined to reflect the beliefs, social norms, and even the fashions of the time. But recently, the dominating perception has changed from one of a spiritual entity to one with an analogy to computer operation. This new perception may be most satisfying to engineers in that it implies an underlying scientific basis for memory and learning as well as a logical and structured organization of the human mind. For example, we can readily relate our own thinking to recent developments in computer systems, such as parallel processing, neural networks, and the interactive separation of working and long-term memory facilities.

One such popular model of human memory is the multistore (or modal) model of Atkinson and Shiffrin,[2] a description of which will be given later in this paper. But the impor-



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tance of memory, and indeed why psychologists consider its study so critical in understanding human development and behavior, will be addressed first.

Why Memory?

The importance of memory can be realized through its relation to three generic concepts[3] that underpin Western psychology: associationism, constructivism, and rationalism. Associationism involves relating responses (R) to stimuli (S), which may be unconditioned, such as a reflex jerk to pain, or conditioned, such as emotional anxiety in anticipation of pain or, indeed, a new learning challenge. The latter leads to learning through the reinforcement of certain responses. The conditioned behavior may have originated from a previously encoded negative S-R set, but adapted to relate to different, and perhaps abstract (non-obvious), stimuli. Such learning is also referred to as operant learning, *i.e.,* behavior that is a consequence of reinforcement by pleasant or unpleasant experiences rather than distinct stimuli.

Encoded memories of conditioned or unconditioned S-R sets are obviously important in governing many everyday actions and form the basis of the behavioral approaches to learning. But, while some simple forms of animal life rely solely on behavioral associations, humans are also led through rational conduct. That is, we have the capacity to logically argue the pros and cons of a situation and to make connections with, or extrapolations from, previous knowledge. Such rationalization could, for example, overcome any inherent S-R sets through conscious recognition and re-evaluation of S-R related behavior, so that in effect there is continual development of existing knowledge.

This then reflects a constructivist view of learning; it is an important basis of cognitive learning, *i.e.,* use of reasoning, planning, and problem solving to advance understanding. In constructivist theories, learning is viewed as more than adapted S-R behavior; it is also a synergetic assemblage of cognitive operations, with perception and perceptual experiences postulated to be derived from data systems within the memory banks of the brain (see the discussion by Haile[1] on the biological nature of such learning). An implication of the constructivist view is that how well we learn will be dependent on our existing knowledge, *i.e.,* effective integration of new material will rely on connections or mappings to existing knowledge. Thus, memory, whether in implicit (automatic or associated) or episodic form, is a requisite for learning and development and will govern our responses, or even feelings, toward daily occurrences.

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Although it is clear that cognitive development can only proceed from a knowledge base, at any particular stage of development *self-concept* will also arise from this base. In other words, human perception of self is related to knowledge of the specific physical and social environment and the students' perception of their standing within this context. In this sense, issues of low self-esteem (where self-perception falls short of sought-perception) arise from the memories and thoughts of the individual. For example, poor self-concept may be closely related to an overly negative recollection of past experiences, which may in turn be indicative of a depressive state. Such depression, in turn, is likely to be closely associated with anxiety disorders.[4] Anxiety, depression, or low self-esteem will, of course, influence student motivation for learning, and may also dictate the approach to learning, as will be discussed below.

These issues must therefore be given due importance in an educational context. Enhancement of student self-esteem will be considered in a future paper, but the humanistic approach of Carl Rogers[5] may be particularly relevant here.[6] For example, some specific qualities of the teacher that are likely to promote high student self-esteem include

- *Non-judgmental acceptance of the student*
- *Genuineness; i.e., being a real person rather than wearing a professional mask*
- *Empathy; i.e., understanding and appreciating the student's feelings; understanding the feelings behind a student's words*
- *High teacher self-esteem in the teaching itself*

These qualities in a teacher are likely to promote a trusting and communicative learning environment and a positive teaching ethos. Some of these attributes have also been identified in chemical engineering education literature, *e.g.,* the influence of positive expectations of the lecturer on student learning[7] and "showing concern for the students as persons."[8] It is interesting to note that in the psychotherapeutic treatment of depression or anxiety, one approach has involved the conscious recognition and reinterpretation of past memories, which are deemed to be inhibiting psychological development (*i.e.,* psychoanalytical methods), whereas other methods have concentrated on changes in behavior or thought to alleviate negative associations (*i.e.,* cognitive-behavioral methods). In both cases, reevaluation of memories plays an important role in therapeutic treatment.

The Modeling of Memory

As mentioned above, the multi-store model of Atkinson-Shiffrin[2] has analogies to computer processing. Memory is modeled as three storage blocks. The first is a high-capacity sensory buffer in which the parallel input of visual, auditory, and haptic (pertaining to the skin senses) information is retained. The lifetime of such information is very short, but enables the individual, for example, to perceive continuous vision from discrete but frequent images. Attended information is fed to a short-term store (STS), whereas unattended information (such as background noise) is lost. In other words, attention to sensory input results in information transfer from the sensory buffer to STS memory.

Information in STS memory has been demonstrated to have a relatively short lifetime of approximately 30 seconds, unless a deliberate attempt is made to retain it. The capacity of STS is also small, in which typically 5 to 9 items of information, such as numbers, names, or grouped items, can be retained.[9] STS provides time for evaluation and processing information before the information is appropriately encoded into the long-term store (LTS).

In contrast with STS, LTS has a large storage capacity, but with substantial limitations in the rate of input and retrieval. The rehearsal of information within STS, or effective connection or relation to existing LTS memory, will result in effective information transfer. While the structural features of the memory store are considered as fixed, the control processes governing, say, attention, rehearsal, coding, and retrieval can be learned and are flexible and variable across individuals.

Evidence for short-term and long-term store modes arises from experimental observations in learning as well as from neuropsychological experiences.[9] For example, free recall of memories appears to consist of separate short- and long-term components, and information coding within STS and LTS memory appears to be of a different nature. Neuropsychological evidence from brain-damaged patients also shows that STS and LTS memory can be separately impaired, physically indicating there are two separate banks of memory.

Other clinical observations (in which, for example, problems in short-term memory do not necessarily result in long-term learning problems) have led to memory theories involving a multicomponent STS and even unstructured short-term and long-term memory processing. Likewise, previously held views of distinct coding methods within the STS and LTS is now recognized as an oversimplification of the storage processes. Nevertheless, the simple multi-store model does yield some practical insight into learning, as will be discussed below. One notable extension of the simple multi-store model involves the postulation of *working* memory, in which the STS plays an important role in cognitive activities by relating external information with recalled information from the LTS.

Approaches to Learning

Given the above description of memory, the relationship between memory and learning can be considered and approaches to effective student learning proposed. In general terms, effective learning can be described as

- *The encoding of information from STS memory into existing knowledge schema within LTS memory*
- *The effective use or recall of information within LTS memory*

TABLE 1
Principles of Behavioral, Cognitive, and Social Learning[10]

	Behavioral	Cognitive	Social
Bases	• associationism • conditioning to a stimulus • operant learning through reinforcement	• reasoning, thinking, problem solving, planning • use of a body of knowledge (schema) for understanding • assimilation of new information into existing schema, i.e., construct understanding	• learning through interaction • learning by guidance of skilled teacher or peer to help internalization of thinking "tools"
Implications	• small (simple) operant learning tasks to build up learning (i.e., gradual conditioning) • students need to master an operant task prior to moving to a more complicated task • behavioral interactionism possible, e.g., through manipulation of the learning environment	• leads to meaningful rather than rote learning • need to take into account existing student ideas and concepts • activating prior knowledge will expedite learning • student may make inferences (correct or otherwise) to fit new knowledge into an existing schema • helpful to use knowledge anchors or bridges using analogies • helpful to use topic maps for lessons, courses, and curricula	• facilitator or peers to emphasize connections, incite motivation, or structure task solution • teachers act as models and learning "scaffolds"

- *The abstraction or processing of this knowledge in postulating new understanding*

The above definitions encompass the common student conceptions of learning,[10,11] namely, a quantitative increase in knowledge, memorizing, acquiring facts and methods for subsequent use, the abstraction of meaning, an interpretative process for understanding reality, and developing as a person. In considering how learning is achieved, the two general processes mentioned above are applicable, *i.e.,* behavioral and cognitive learning.

A third process is attributed to social learning, which pertains to the influences of the peer-group or the teacher-student relationship, and encompasses the ideas of Vygotsky[25] on the socio-cultural influences on cognitive development. In Table 1, key concepts and implications of these three processes are summarized. Although of continued debate, cognitive and social learning are generally viewed as most relevant to educational psychology. For some recent perspectives on the behaviorist and cognitivist (constructivist) approaches to learning, the articles of Wheldall and Glynn[12] and Glasersfeld[13] are recommended.

While the dominance of a learning process may be situation dependent (and perhaps individual and maturation dependent), it is not too surprising that several cross-process mechanisms can be active during a learning situation. For example, the first time a student is asked to derive a material balance for a chemical reactor, the approach may rely on cognitive processes that relate past knowledge to the current problem, planning a solution methodology, and interacting with the lecturer for guidance from the base knowledge to the new desired knowledge. Effective retention of this learned material may rely on the STS rehearsal of an underlying principle, such as *mass in - mass out = mass reacted + mass accumulated,* as well as connections to existing LTS components, such as definitions of mass flux or the rate of reaction. Of course, problems in learning can arise at any process point, and the efficacy of the learning will strongly depend on student motivation. Motivation does not necessarily refer to the eagerness of a student in tackling a new learning challenge, but defines the actual drivers for learning. Biggs and Moore[14] for example, suggest four categories of motivation:

- ***Instrumental*** • such as reward and punishment extrinsic to the task; *e.g.,* fear of failure due to financial or parental implications
- ***Social*** • the desire to please peers and lecturers
- ***Achievement*** • a concern for the self to enhance position relative to others
- ***Intrinsic*** • an interest in the activity itself; *e.g.,* curiosity-driven learning

In other theories of student motivation, specific orientations to learning are suggested. For example, these may include task orientation, where students concentrate on learning and gain pleasure from the progress in their learning (intrinsic and achievement motivation), ego-orientation, where students are more concerned about their performance relative to others (social motivation), and work-avoidance orientation, where students gain comfort from doing as little work as possible. The third orientation could possibly arise from some inherent (perhaps unconscious) and extrinsic factor.

This paper [presents] an overview of psychological bases in student learning and [shows] them to be complex interactions of social, cognitive, and motivational issues, with possible underlying behavioral traits.

Whatever the student motivation may be, it is likely to influence the learning approach. Indeed, most lecturers are familiar with the concepts of deep and surface approaches to learning, and there is evidence to suggest that a student's intention to learn can govern the particular approach. The student's conception of learning will also be of importance to the approach, however. For example, students who believe that learning involves a quantitative increase in knowledge will pay more attention to memorizing text than to the intended content of the learning material. On the other hand, students who adopt a deep approach to learning are likely to view learning as an interpretative process for understanding.[11]

Closely related to motivational issues, the concept of locus of control (LC) has also been proposed in explaining deep and surface approaches.[14] The LC defines the students' perception as to how their learning is controlled. At one extreme, students perceive themselves as being controlled by external events (instrumental and social motivation), whereas at the other extreme, the perception is one of internal control of events (achievement and intrinsic motivation). Deep learning is likely to be favored by an internal locus and surface learning by an external locus.

Even with a favorable learning locus, however, external factors can lead to a surface approach in learning. For example, surface learning could be promoted by assessment criteria that are heavily biased toward factual reiteration, or by poor enthusiasm by a lecturer; for students who are socially motivated, either would signal a lack of importance for deep understanding.[15] An overview of the interrelations of the above mentioned concepts of memory, motivation, and learning is illustrated in Figure 1. Although the figure is based on the multi-store model mentioned above, the features of motivation and student approach are incorporated to emphasize the student, teacher, and organizational influences on learning.

Although some insight into student learning and motivation can be gained through the various theoretical and research contributions in the literature, what is it that makes individuals amenable to certain types of education and not others? Earlier in this article, the difficulty of engineering education was attributed to its multi-subject and applied nature. So the question could be rephrased as: What are the underlying aspects of applied and cross-subject work that favor certain types of learning styles? Here, issues of *cognitive styles* arise, *i.e.,* a student's habitual mode of perceiving, thinking, and problem-solving, or the characteristic style in which the cognitive tasks are approached or handled.

Several distinct cognitive styles have been identified by researchers and are typically defined through polar dimensions such as serialist-holistic, convergent-divergent, field dependent-field independent, reflective-impulsive, and leveling-sharpening.[16] Specific consideration will be given here to the convergent-divergent and holistic-serialist styles since they have the most obvious implications in engineering education and practice.

The convergent-divergent style considers students to have a preference for problems that either have a well-defined solution (convergent problems) or that are open-ended with several possible solutions (divergent problems). Convergent thinkers are likely to be attracted to courses in mathematics and the physical sciences, even early in their education, whereas divergent thinkers are likely to pursue studies in the arts or in the social or biological sciences.

Engineering undergraduates are thus expected to be convergent thinkers, and this is perhaps reinforced by elements of the coursework and the exam-based assessment. Often, however, the actual integration of various convergent-type procedures for, say, engineering design, is carried out with limited physical or chemical data, as well as loose or very general design specifications. Many engineering undergraduates do find it difficult to tackle such problems, and will typically narrow the decision-space, often using superficial criteria to converge on a solution. Thus, successful engineering education requires some training in divergent thinking so as to enable a flexible (creative) approach to knowledge application.

The second relevant cognitive style considers a student to have a preference for either overall (holistic) or step-by-step (serial) learning. Holistic learning arises when connections are sought to previous knowledge and other subject matter in order to attain comprehensive understanding (deep learning). In serialist learning, the student learns the details of specific operations and procedures of the subject field and makes use of serial strategies to logically connect these operations in addressing a problem.

Of course, many *versatile* learners will adopt both holistic and serialist styles as and when needed. In the context of engineering, a versatile style is necessary, but there is often a student tendency to adopt a serialist approach whereby a convergent style can be exercised at each task stage. Although such a tendency may be adequate for some problems, the outcome can be rather deterministic and therefore possibly lacking in an awareness of global issues. As for the case of

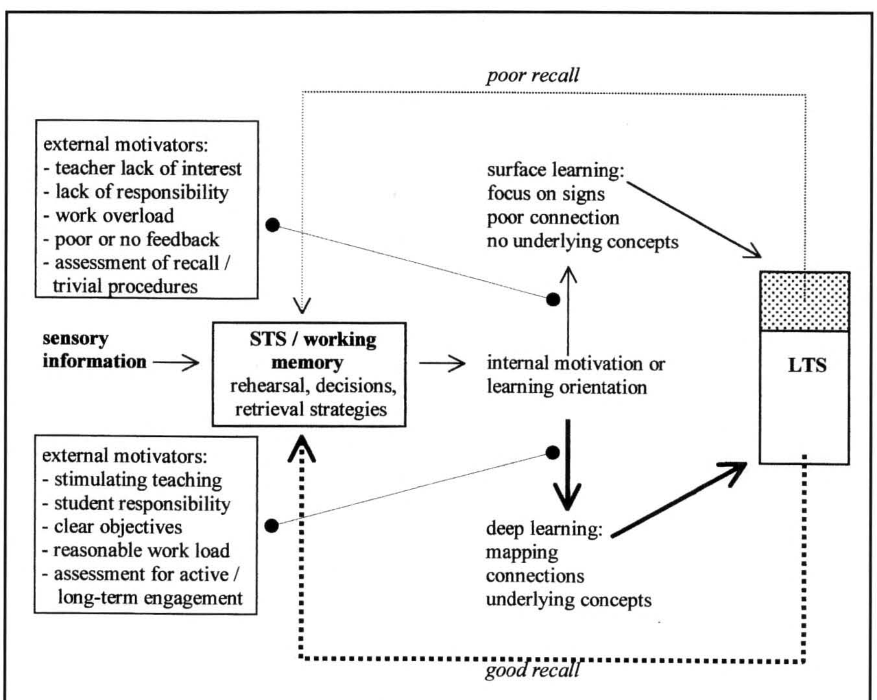

Figure 1. *Overview of memory, motivation, and learning, incorporating the multi-store model of Atkinson and Shiffrin.*[2]

divergent thinking, a student awareness of holistic approaches to learning is needed. Finally, it is interesting to note that a holistic and divergent approach is likely to lead to a student commitment for the critical evaluation of material as well as the appreciation of multiple viewpoints. Thus, such an approach is consistent with the higher levels of attainment of *Perry's Model of Intellectual Development* as described by Felder.[17]

Finally, learning styles that reflect the particular abilities of the student should also be appreciated. For example, Gardner[18] postulates the theory of multiple intelligences that include linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, and inter- and intra-personal intelligences. An educational implication here is that different students may learn in different ways, with some, for example, preferring visual material such as charts, graphs, and illustrations, and others preferring auditory material such as listening to an articulate lecturer, participating in class discussions, or using mnemonics to aid memory.

APPLICATIONS TO ENGINEERING EDUCATION

The above discussions on the theories and issues of student learning demonstrate the complexity of the process. Aspects of student motivation, self-concept, perceived locus of control, and cognitive styles, as well as differences in the knowledge schema of individuals, suggests that the learning experience should be student-centered. While it is easy to relate to the multitude of ideas on learning, practical implementations for effective learning may not be so obvious.

The approach in the following sections will be to summarize some key principles from the above discussions and highlight teaching practices that can promote favorable learning situations. Many of the recommendations arise from the teaching experiences gained within the Department of Chemical Engineering and Chemical Technology at Imperial College. Some reference to the literature in chemical engineering is also given to further illustrate the consistency of good teaching practice with the psychological arguments presented above.

While several of the recommendations below imply a conventional lecture-based teaching approach, it is important to recognize that formal lectures themselves have been identified as having a negative influence on deep learning.[19] Nevertheless, Giralt, *et al.*,[20] describe several factors that exist in the current higher-education climate that favor the lecture-based approach, such as the significant effort and time needed by the teaching staff to implement, for example, student-centered teaching strategies, appropriate staff motivation when ultimate promotional benefits may be perceived to be attained through research rather than teaching efforts, and the logistics of alternative (*e.g.*, small-group) teaching arrangements when student-to-staff ratios are relatively high. Even so, there is scope for improvement on traditional lecture styles, and indeed to complement existing lecture-based learning through pragmatic programs.

Cognitive Aspects

Students should be encouraged to develop cognitive skills and effective cognitive learning should be facilitated.

- The knowledge base and concepts held by individual students require adequate assessment, particularly in the foundation years of study. Prior-knowledge questionnaires should be supported by review classes before the introduction of new material. This is especially true for mathematics courses because of the wide variation in school-level mathematics curricula among national and international students. Assumed prior knowledge should also be clearly indicated to students for each lecture course, and if necessary, students should be provided with adequate time and references to prepare for the course.

  The use of graded problem sheets soon after the start of a course could be used to test the students' basic understanding of assumed concepts, such as the meaning of equilibria and kinetics in reaction engineering or mass conservation in process analysis. The teaching of courses by lecturers who have a similar background and focus as the students is also beneficial, such as the teaching of numerical methods and physical chemistry by relevant engineering staff. Similarly, managerial courses should be placed in the context of engineering by means of industrial case studies.

  For all courses, an element of feedback is required to enable students to evaluate acquired concepts. Where possible, detailed feedback on examinations could be given and compulsory post-exam tutorials arranged for students who do not achieve a minimum standard. Likewise, supplied with an outline solution set, all students could be asked to re-answer unsatisfactory examination questions, irrespective of their overall exam mark. Such a procedure may help to alleviate the carryover of misconceptions and ensure adequate background knowledge for follow-on courses.

  As a direct means of prior knowledge assessment, Felder and Brent[21] also suggest that lecturers new to a subject could ask students to anonymously compile lists on what is known about the course content as well as any specific questions they may have about the course.

- Students should be made aware of connections within and between lecture courses. Where possible, material should be related to practical knowledge through use of analogies or physical (visual) models. Furthermore, students should be given opportunities to infer connections through project work and cross-subject examinations. For example, within a particular course, a coursework element that integrates intended learning outcomes is beneficial. On a wider scale, yearly *mastery* exams that assess general (integrative) and essential engineering knowledge are useful, as are final-year projects in, for example, overall plant, process, or equipment design. Students could also be asked on occasion to draw *concept-maps* to link knowledge and skills attained among different courses.[8] Particular care is needed in modular degree programs to ensure course coherency and an effective student perception of course connectivity.

- Projects or learning tasks requiring a holistic and/or a divergent approach could be supplemented by workshops or tutorials that highlight subject inter-relationships and the need for an *open-structure* solution approach. For example, a design exercise could be preceded by a session that enables students to explore the complexities involved in defining a successful design and perhaps emphasize the iterative rather than the linear (serial) approach that is needed.

  Solution methodologies can sometimes be devised by working backward from the design specifications so as to generate an expanding, branched outline of pertinent issues, highlighting any interrelationships between them. Particularly relevant here are the creative problem-solving modules in engineering design described by Mackenzie, *et al.*,[22] *e.g.*, problem-statement definition techniques, brainstorming, and potential-problem analysis. In addition to core engineering courses, students should be encouraged to attend courses or to carry out activities that have a natural element of creativity and divergence, such as creative writing, art, and philosophy.

- For courses of particular conceptual difficulty, greater effort is needed on course design and delivery for demonstrating physical relevance. In such cases, problem-based learning, where theory is developed during the course of the problem solution, may be particularly useful. Problem-based learning here is congruent with the definition of Woods,[8] where the student learns because of a need to solve a real problem, as in the cases of design projects and interpretating laboratory results. Problems with real-world connections are likely to incite student interest.[21] Also of benefit is dividing some general courses, such as thermodynamics or engineering mathematics, and integrating the relevant components into practical or applied course material.

  Where possible, visual imagery may be particularly beneficial in illustrating underlying theory or concepts. For example, the McCabe-Thiele diagram for teaching distillation-column design (where the memory of the *staircase* effectively activates memories of material balances and VLE relationships) has proven effective for generations of students.[7] Such graphical and analytical methods should be sought where possible, particularly in foundation or introductory courses.

Social Aspects

Social learning should be encouraged through opportunities of peer learning and guided participation.

- Students should have opportunities to demonstrate their own understanding to peers and to discuss underlying issues of course material. This could be through student-led seminars and small-group tutorials.
- Students should have opportunity to share and apply understanding. The use of design projects throughout the degree program, as well as group-based laboratories, pilot plants, or field work, are of particular value. Another interesting approach, described by Newell,[23] involves peer-review of undergraduate laboratory reports for improving the oral and written communication skills of both the reviewer and the reviewee. But in any approach, care is needed to avoid undue student competition, which could otherwise cause student anxiety. Furthermore, effective student work groups are generally characterized by strong interpersonal interactions within the group and with the teaching staff.[7] Team development workshops, or *away-days*, as well as dedicated team facilitation by teaching staff, are likely to help promote an effective team approach to group work.
- Teaching staff (lecturers and postgraduate demonstrators) should have appropriate training in group supervision so as to act as effective learning scaffolds and bridges. This can be achieved through guided experiential programs and dedicated support groups on teaching.[24] The teachers themselves need to be of high self-esteem in their teaching and to demonstrate a genuine care (empathy) for the students.

Motivational and Behavioral Aspects

Appropriate mechanisms should be in place to address student personal developmental and motivational issues. Inherent behavioral characteristics that are inhibiting favorable motivation for learning should be recognized and addressed.

- Personal (non-academic) tutorials should be frequent and should promote adequate recognition of, and guidance on, counseling matters. This can be achieved through close collaboration with an appropriately trained senior tutor or a college-based counselor.

- To promote self-development and positive motivational drives, students should be made aware of individual and social psychology principles. This could be achieved indirectly through courses on industrial and organizational psychology, or through field courses in team development. Alternatively, to prevent increasing the students' workload, programs in these areas could be incorporated into existing personal tutorial systems. Such efforts may be helpful in promoting meta-learning strategies among the students.[20]

  In order to discourage a surface approach to learning, as well as instrumental motivations, overwork should be avoided and assessment criteria clearly defined; see also the discussions of Felder and Brent[21] on *active learning vs. covering the syllabus.* Likewise, to maintain the favorable stance of an internal-locus of control, student responsibility and choice should be made apparent. Students should be made aware of core areas for examination in a course and the expected level of competency demonstrated by examples. A choice of areas for student specialization should also be indicated and evaluated through an option-based component in the exam and/or a coursework element.
- It should be recognized that students in tutorial and project groups of mixed or similar academic ability are still likely to vary widely in their motivational drive. Here, careful academic counseling to illustrate individual components on the group dynamics, and to guide the peer learning of poorly motivated individuals, may be beneficial. In practice, academic supervisors and counselors could work together on some key group-based projects during the foundation years of study. This could also offer an opportunity to observe students for inherent or inhibiting behavioral traits that may be indicative of, for example, social phobia or anxiety.

CONCLUSIONS

This paper has presented an overview of psychological bases in student learning and has shown them to be complex interactions of social, cognitive, and motivational issues, with possible underlying behavioral traits. Most established and successful courses in engineering have, in many ways, successfully addressed cognitive and social learning issues through design and problem-based learning. But greater recognition is needed on the constructivist view of education in assessing prior knowledge and concepts and integrating course components.

Issues concerning student motivation, cognitive style and personal development require attention that has, to date, only been addressed superficially through inappropriately trained personal tutors or a facile (non-proactive) college counseling service. Improvements can also be made in controlling the peer learning environment through, for example, detailed consideration of the technical and social qualities of the individuals. Indeed, there may be an educational benefit in having mixed motivational groups that are carefully monitored and facilitated by an experienced supervisor, or on occasion, by academic and counseling supervisors.

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