Engineering Education

Research and Development in Curriculum and Instruction

John Heywood

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To Dick Culver, Sandy Courter, Karl Smith, John Sharp, and Eddie Gould
whose help and encouragement sustained me in the completion of this study

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FOREWORD

Those of us who regularly attend the Frontiers in Education conference (jointly sponsored by the Education Research and Methods division of the American Society for Engineering Education, the IEEE Education Society, and the IEEE Computer Society) have benefited for years from John Heywood's wisdom. With the publication of this volume, the culmination of many years of hard work, others will similarly benefit. In my opinion, this is a vitally important contribution to engineering education literature, which comes at a most propitious time. Engineering education research is gaining respect as the field becomes increasingly scholarly and adopts more stringent standards. For example, the *Journal of Engineering Education* has declared its mission to serve as an archival record of scholarly research in engineering education. Other signs of the increasing importance of engineering education research include the establishment of schools of engineering education at Purdue University and Virginia Polytechnic and State University, the proliferation of centers for engineering education in universities, the NSF-sponsored Center for the Advancement of Engineering Education (CAEE) headquartered at the University of Washington, and the founding of the Center for the Advancement of Scholarship on Engineering Education (CASEE) at the National Academy of Engineering.

John Heywood's review is an excellent complement to all of these efforts. It is an impressive compendium of the research and practice related to curriculum, instruction, and leadership in engineering education over the past forty years. I am convinced that only Professor Heywood, with his encyclopedic knowledge and astounding memory, could have accomplished such a feat. While each of us who works in engineering education will no doubt quibble about a favorite study that has been omitted, the volume as a whole provides an excellent overview of several decades of theory and practice. An especially attractive feature is its international focus. John Heywood's review will be an excellent general resource, but will be a "must" for any serious engineering education researcher. It will also be invaluable as a resource for graduate-level courses on teaching engineering.

All of us who are interested in providing the best education possible for our engineering students owe John Heywood a debt of gratitude for this important and timely book. It is a strong contribution to the field.

BARBARA OLDS
Professor of Liberal Arts and International Studies
Colorado School of Mines
ASEE Board of Directors 2002–2004
Chair, Educational Research and Methods (ERM) Division, ASEE 1999–2001

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PREFACE

Historically the Education Research and Methods Division (ERM) of the American Society for Engineering Education (ASEE) has provided leadership in research and innovation in teaching engineering. Five or so years ago the Division began to review its role and to look to the future. This book arose out of these discussions.

As part of my contribution to the debate, as a result of discussions with the group, I produced a paper on the need for instructional leadership in engineering education. It was used as a background paper for a seminar organized by the ERM Division at the Kansas City Frontiers in Education Conference (AD 2000), and it was published in the conference proceedings.

When I revised and extended this paper I replaced the term *instructional leader* with that of *curriculum leader.* This extended version of the paper was used as a background report for the Forum on Engineering Education Leadership that resulted from the Kansas City seminar.

Dick Culver, in his introduction to the Forum, used Astin's recently published definition of leadership to focus on the purposes of the Forum. He summarized it as follows:

"Leadership involves fostering change, implies intentionality, is inherently value-based, is by definition a group process, and thus depends on collaboration"[1]

Or, to put it in the way of the *New Shorter Oxford Dictionary* (1993) it is the *ability "to lead or influence."* Culver took the view that this necessarily involved change, thus by definition a leader is a change agent.

Culver argued that while there was a substantial body of research that supported the need for new approaches to teaching in higher education, this knowledge remained the preserve of educational researchers and a few dedicated teachers. The first objective of this book is to make the knowledge accumulated from research and innovation in the curriculum and instruction in engineering education more generally available.

He quoted from John T. Bruer's *The Minds Journey. From Novice to Expert* to support his case. *"Teaching methods based on research in cognitive science are the educational equivalents of polio vaccine and penicillin. Yet few outside the educational research community are aware of these breakthroughs or understand the research that makes them possible."*

This is the case worldwide, irrespective of the drive in some countries to evaluate university teaching. If evaluations are done by peers, then it is the case of the ignorant (I do not mean to deprecate) leading the ignorant, and such assessments are often carried out within a very limited notion of what constitutes good or effective teaching.

Teachers in higher education are accountable, if only to their profession. If they believe they are an expert profession, then they have obligation not only to ensure that beginning teachers have an adequate training but to be aware of the pedagogical knowledge that is available to inform the curriculum process.

But there is another argument. It stems from the fact that teachers in higher education value research in their own subjects. It is, therefore, surprising that the notion that teaching and learning should be informed by research has not pervaded the teaching profession in higher education. Patricia Cross has argued that teaching will not become a respectable activity until teachers treat their classrooms as laboratories for research.[2]

To encourage the development of this idea, Tom Angelo and Patricia Cross worked with teachers to develop and evaluate 50 techniques of classroom assessment. They are intended to help *"individual college teachers obtain useful feedback on what, how much and how well their students are learning. Faculty can then use this information to refocus their teaching to help students make their learning more efficient and more effective."*[3]

Another approach is to learn through more formal research into one's classroom practices, and even more generally into other dimensions of the curriculum process. Among others, Patricia Cross and Mimi Steadman as well as this writer have illustrated how this can be done.[4] There are several examples of such research in recent publications of the *Proceedings of the ASEE Annual Conferences* and the *Proceedings of the Frontiers in Education* conferences. Some provide major contributions to educational knowledge. While the first objective of this study is to provide an illustrative review of research and development in engineering education since 1960; the second objective is with the examples given to encourage the practice of classroom assessment and research.

Classroom assessment and classroom research require different levels of expertise. In the case of classroom assessment, teachers need not be necessarily exposed to a formal course of training since learning about learning is accomplished through the implementation of classroom assessment techniques. It is a level 1 of teaching expertise.

Classroom research requires more knowledge before one can begin. This might be related to a specialist topic (e.g., cooperative learning, student ratings), or it may be of a more general kind (e.g. the redesign of a curriculum). In either case the teacher(s) may require help from educational specialists, and there are examples of such collaboration in the recent literature of engineering education. These teachers acquire a level 2 of expertise and leadership. The third

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[1] Astin, A.W., Astin, H. S., and others (2001). *Leadership Reconsidered: Engaging Higher Education in Social Change.* W. K. Kellog Foundation, Battele Creek, MI.

[2] Cross, K. P. (1986) A proposal to improve teaching. *AAHE* (American Association for Higher Education) *Bulletin*. September. Pp 9-15.

[3] Angelo, T and. Cross, K. P. *Classroom Assessment.* Jossey Bass, San Francisco

[4] Cross, K. P. and M. Steadman (1996). Classroom Research. Jossey Bass, San Francisco.

objective is therefore to promote the idea of curriculum leadership. That is the idea that in departments and schools there will be persons who can be consulted about classroom assessment and research and are acknowledged as such.

Leading implies following. To the extent that we set ourselves goals, and to the extent that we set about obtaining those goals, we both lead and follow. In this sense, every individual is a leader, even at the level 1 of teaching expertise. Because this is the case, each individual has within him or herself the attributes of leadership. What distinguishes one person from another as a leader is the use to which they put the attributes of leadership in the varying situations in which they find themselves.[5] To acknowledge the findings of educational research and not to do anything about them is a neglect of professional responsibility. It is also a denial of the professional's responsibility to lead. Transformational leadership is required to create an environment in which teaching is valued as much as research.

Those faculty members who, in an ethos that values research above teaching, spend time on classroom assessment strategies are leading themselves, and by example, others. If they try to persuade others that such activities are worthwhile and lead to better practice, they are leading in the traditional understanding of leadership. The same is true of classroom research, the second level of expertise.

More generally, part of the role of the professional teacher is to lead beginning teachers into the pedagogy of higher education. In Ralph Tyler's words, they have the goal of *"helping practitioners who want to improve the curriculum of the schools* (engineering departments) *in which they work."*[6]

There will be those who have acquired the capability to do this at the first level of expertise. There will be others who can do it at the second level of expertise. Those who take on these leadership roles can help create a climate of cultural change from the bottom up. By themselves such activities cannot be expected to maintain cultural change since they are often due to the initiatives of individuals. In any event, those individuals also need support from the top, and this means that those at the top will have to have an understanding of the professional pedagogy. While they may wish to act as curriculum leaders themselves, given the scope of the knowledge required, there would seem to be the need to recognize a faculty, school, or departmental position of curriculum leader whose promotion prospects are not diminished because of the task. This is a third level of curriculum leadership.[7] A fourth level of leadership is involved in the external politics that determine the program.

Philip Jackson's summary of Joseph Schwab's view of the role of the curriculum specialist is as good a description of the role of a curriculum leader in any context as there is.[8] It read as follows,

- Skillful use of the rhetoric of persuasion (which includes knowing how to elicit participation in small group settings and person to person encounters). (*The first stage of curriculum leadership).*
- Experience in deliberation (*and causing people to deliberate at greater levels than they have before).*
- Ability to read learned journals and the habit of doing so.
- Ability to guide colleagues to the use of the journals, *and to encourage them to believe that their classrooms are laboratories for valid research.*
- Knowledge of curricular practices (*their design and improvement*).
- Knowledge of the behavioral sciences which contribute to the guidance of educational *policy and* practice (*e.g., branches of psychology and sociology).*
- *Knowledge of the humanities which contribute to the guidance of educational policy and practice* (*e.g., philosophy).*
- "nodding", and *sometimes detailed* acquaintance with some of the academic fields from which other *engineering* subjects are drawn.

There are difficulties with this list as with all lists. My comments are shown in italics. The first item would pre-suppose that the person is a propagandist for a particular model, but the real need is that all professional teachers should have defensible theories of learning, and sociology for it is in these domains of knowledge where the aims of education reside. This implies that professional teachers and curriculum leaders in particular should have a training that is at least in scope similar to a good quality course of training provided for graduates who wish to teach in high school.

Discussion of the idea of training university teachers is no longer anathema. In the United Kingdom the Government wishes to make the training of new teachers in higher education compulsory. Thus, an Institute for Teaching and Learning (ILT) has been established by legislation and university teachers are encouraged to become members. Some universities require all newly appointed teachers to take certificate courses accredited by the Institute for Teaching and Learning.[9]

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[5] Taken from Heywood, J. (1989). *Learning, Adaptability and Change*. Paul Chapman (Sage), London.

[6] Ralph Tyler is quoted thus by P. W. Jackson (1992). Conceptions of the curriculum and curriculum specialists. In P. W. Jackson (ed). *Handbook of Research on Curriculum*. American Educational Research Association. Macmillan, New York.

[7] Culver has suggested that the level 0 person be called a lecturer, the level 1 a practitioner, the level 2 a researcher and level 3 a leader.

[8] *Ibid* P. W. Jackson (1992)

[9] The ILT has been subsumed into a Higher Education Academy.

Cropley, writing from an Australian perspective, considered *"that, unless the requirements for faculty to have a formal teaching qualification become mandated, improvements in the quality of teaching and learning at universities will remain elusive and fractured. If universities wish to be competitive in the future and if they seek to have a reputation for quality, then the compulsory accreditation of teaching in higher education, both generally, and in education specifically, is a proactive step that is unequivocal about the commitment to that change."*[10] Governance of this kind could have a profound influence on the how, what, and why of accreditation.

Prior to that, both in Australia and the United Kingdom there had been a considerable amount of training, generally in the form of short courses, and a substantial amount of research had created a basic pedagogy of higher education. There have also been substantive contributions to this research effort in Canada and the United States.[11]

As in the rest of the world many short courses are on offer in North America, and many of these are provided for the induction of new teachers. Some courses are provided that offer credits. One or two universities are providing mentoring programs.[12]

Within engineering some 20 or so centers for engineering education and professional development have been created at universities in the United States. Several are of long standing. They are engaged in major research and faculty development. Some offer courses with credits for persons in doctoral programs who are graduate teaching assistants.[13] The National Academy of Engineering has now established a Center for the Advancement of Scholarship on Engineering Education. It seeks to *"enhance faculty awareness of challenges, opportunities, and standards for the conduct, evaluation and communication of research on engineering education. Reduce barriers to faculty engagement in such research, and speed the transition of education research results."*[14]

Worldwide, since the early 1960s, there has, been an increasing flow of papers in the engineering education journals and conferences. They number around 10,000 since 1964. There are at least 1500 articles that a tutor of students in a post-graduate education course would consider provide a framework for the discussion of pedagogical principles. The first purpose of this book is to examine that collection of papers from the perspective of the curriculum process. The second purpose is to have in mind the need for professional teachers, especially those who would lead the curriculum, to acquire defensible theories of learning, philosophy, sociology, and history as they apply to the process of curriculum improvement and evaluation.

Dr. Sandra Courter of the University of Wisconsin-Madison agreed to ask the students in two of her courses for TA's on Teaching and Learning in Engineering to evaluate the 14 chapters that had been written by asking them to critique them and give short papers about them in class. Some major changes were made as a result of these seminars.

Encouraged by these 20 or so TA's, and taking into account their advice as well as that of the aforementioned and other colleagues, I continue with the task. My purpose is to provide a resource for engineering educators working at each of these levels of expertise. It is based on the wide range of knowledge available in the literature of engineering education. I draw attention to its limitations, and where appropriate I point out relevant work in other fields of knowledge. It is comparable with the level of knowledge required by graduate trainees for teaching in high schools. While the language of the book may be challenging at times, and on occasion all too brief, it is hoped that the organization of this material within a single text will provide a substantial resource for those who wish to lead. This means that the more challenging chapters, so the TA's told us, come in the first part. Since the text is intended as a resource reader, each chapter is relatively self contained, and may be read independently of the others.

Doubtless some will argue that I should have included articles that are not included and excluded some that are. I shall have achieved my purpose if it is agreed that I have given the flavor of a field and the debates within it, together with sufficient information to guide further reading. For this reason I have tried to draw out examples issues from the authors themselves.

The report was concluded during a period when it was evident that an explosion in the number of reports on the evaluation of on-line learning in all its many forms had begun.[15] On-line learning is opening up many possibilities for inter-university collaboration in an international framework.[16] But, the first reports suggest that the same principles of learning that were established from traditional contexts for learning will apply. They also suggest that it is possible to establish effective communities of learning in the on-line contest.

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[10]Cropley, D. H. (2003). A case for compulsory teaching accreditation of engineering faculty. *IEEE Transactions on Education,* 46, (4), 460 – 463.

[11]For summary of much of this work especially in engineering see Stice, J., Felder, R.M., Woods, D. R., and A. Rugarcia (2000). The Future of Engineering Education 1V. Learning how to teach. *Chemical Engineering Education*, 34, (2), 118-127.

[12] *Ibid,*

[13] For example the Engineering Learning Center at the University of Madison-Wisconsin where some of the evaluation of this text was done. Descriptions of the work of some of these centres were given at the ERM division breakfast at the 2001 annual conference of ASEE.

[14] Fortenberry, N. L. (2003). Work-in-progress: Designing a support system for research on engineering education. *Proceedings Frontiers in Education Conference*, 3, S1A-p12.

[15] For example Ellis, T (2004). Animating to build higher cognitive understanding: a model for studying multimedia effectiveness' in education. *Journal of Engineering Education*, 93, (1), 59–64.

[16] See, for example J. Hamilton-Jones and T. Svane (2003). Developing research using reflective diaries. *Proceedings Frontiers in Education Conference*, 1, T3A-14 to 19.

For convenience the text is divided into four main parts. The first is about aims and objectives and their screening. It is about the curriculum process and how the foundation subjects of education (History, Philosophy, Psychology, and Sociology) are used to determine the aims and objectives of the curriculum and the internal structure that integrates assessment, content, teaching, and learning. Part II is about the curriculum *per se*, and it considers content organization, trends, and change. Chapter 7 is about change and the problems of changing the curriculum. This is followed by a chapter (8) on interdisciplinary and integrated study and a chapter on project and problem based models of the curriculum. Part III focuses on problem solving, creativity, and design. For convenience, in spite of some overlap between them, each of these concepts is dealt with in a separate chapter. Part IV focuses on teaching, assessment, and evaluation. Following on from the chapter on design in the previous section, this part begins with a chapter (13) on the lecture, cooperative learning, and teamwork. This is followed by a discussion of other approaches to teaching including case studies, PSI, laboratory work, and electronic assisted learning, a term that is meant to be all embracing (Chapter 14). Various definitions of the meaning of assessment are given, and the value of the traditional distinction between assessment and design is highlighted (Chapter 15). Chapter 17 draws together the lessons learnt from research, development, and experience for attrition and retention. The study concludes with a brief epilogue on the future of engineering education.

It is not expected that readers will approach this text linearly. Even though it contains its own logic each chapter may be treated as free standing, although inevitably there will be relationships with material in other chapters, some of which have been cross-referenced. This approach means that some overlaps are unavoidable.

Many of the activities and innovations referred to in this text are due to individuals apparently working on their own. Because nothing further has been reported about them, it is not known if they have continued with or stopped the innovation. For this reason the past tense is used throughout the text. In addition to the opening summaries, italics have been used for quotations.

JOHN HEYWOOD

Dublin, Ireland
August 2005

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I am particularly grateful to Sandra Courter for her patience. The structure owes much to her wisdom and insight. Her students, to whom I am most grateful, also provided me with many insights. John Cowan's criticisms were of great value, as were those of Sheri Sheppard, Don Evans, Sharon Fellows, John Sharp, Jim Stice, Karl Smith, Norman Fortenberry, and Charles Yokomoto. The origins of this work lie in many discussions with Dick Culver, and without his encouragement I would never have embarked on or continued with the task.

Over the forty year period of this study I was involved as team leader in several major projects into the education of engineers and technologists in the UK I also supervised post-graduates undertaking research in engineering education topics. These activities gave me the grounding in the literature that formed the background for the review. But one's understanding is influenced by the colleagues with whom one worked and they merit a specific thank you. I thank therefore, George Carter and Deryk Kelly with whom I conducted a 15 year longitudinal evaluation (action research) of an engineering science curriculum. To Michael Youngman, Bob Oxtoby, and the late Denis Monk with whom I developed new methods for deriving objectives for the training of engineers and technologists. To John Sharp and Jim Freeman for allowing me to collaborate with them in developing approaches to course evaluation, and to my postgraduates for their many insights especially Sam Lee, Joe Moon and Paul McElwee. In the area of school technology I thank Michael Murray, Glyn Price and Stan Owen. Finally to John Cowan with whom I regularly debated these issues

I am very grateful to Ed Gould of the University of Salford who prepared the camera copy and to his wife Margaret who provided the cover piece. Emma Balfe and Mary Weafer of the University of Dublin (Trinity College) who have provided me with much secretarial assistance over the years for which I am very grateful.

More than anyone, I am grateful to my wife Pauline, who had to put up with the four year day and night struggle to produce this work.

No acknowledgment would be complete without a thank you to all the authors whose work I have read, and whose contributions gave me so much pleasure. I regret that the scale of the exercise prevented me from drawing attention to many other studies that merited mention. The principal sources of reference were *Engineering Education subsequently The Journal of Engineering Educatio;, Engineering Science and Education Journal; The European Journal of Engineering Education; The IEEE Transaction on Education; The International Journal of Applied Engineering Education,* subsequently the *International Journal of Engineering Education; The International Journal of Technology and Design Education; The International Journal of Electrical Engineering Education;* the *Bulletin of Mechanical Engineering Education,* subsequently the *International Journal of Mechanical Engineering Education; and Research in Science and Technological Education.* These were scrutinised from 1966 or from their inception.

Other journals consulted included *ASEE Annual Conference Proceedings; Assessment and Evaluation in Higher Education; Chartered Mechanical Engineer; Chemical Engineering Education; IEE Proceedings; Journal of Technology Education; Nature; Physics Education; and Studies in Higher Education.*

By far the most number of citations come from the *Proceedings of the ASEE/IEEE Frontiers in Education Conferences*, and in very many respects this study is a tribute to the members of the ERM Division of ASEE, and the IEEE Education and Computer Societies. These proceedings were scrutinized from 1973.

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PART I: AIMS AND OBJECTIVES (OUTCOMES) AND THEIR SCREENING

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Chapter 1: Curriculum Design, Implementation and Evaluation

Summary

This Chapter begins with a definition of the curriculum. The curriculum is always subject to minor changes as teachers take up the prevailing ideas and respond to technological change. Sometimes it is necessary to formalize these changes. Formalization has to take into account the mission, aims and objectives of the institution in which the department resides. Engineering departments are also subject to the requirements of their profession. Change is often caused by external factors. It often demands substantial changes in the culture of the organizational unit responsible for delivering the curriculum.

A theoretical model of the curriculum process derived from a proposal by Tyler is discussed. Since Tyler's proposal the terminology has become very confused. An example of the application of the model to the problem of curriculum overload is discussed.

It is noted that there are many variations of this model but, the implications of all these models for the role of the teacher and the institution are similar. Taking into account any professional requirements, the role of the teacher is to determine (a) the aims and objectives (outcomes) of the course (program) to be given, (b) the best methods of achieving those aims and objectives (outcomes), (c) the sequence of learning and instruction, and,, if as a result of (b) and (c) they have been achieved. Traditionally the last process has been called evaluation. A distinction is made between the assessment of student learning and evaluation. Evaluation embraces the assessment of student learning. It would detect mismatches between the formal learning environment and the experiences of students in that environment achieving desired outcomes. It would also include the evaluation of teaching performance, the continuing appraisal of goals in response to sociotechnical change, and the attention to the core values of the course (program).

The Chapter concludes that the determination of aims and objectives (outcomes) is an important but difficult process that involves their screening using the philosophy, sociology, and psychology of education.

1. The Curriculum

In order to understand the curriculum process, it is necessary to offer a definition of the curriculum. Here, it is taken to be *the formal mechanism through which intended educational aims are achieved.* Since educational aims are achieved through learning, the curriculum process is described by those factors that bring about learning. Thus, both learning and instruction are central to the curriculum process. *Informal* changes may be made to the curriculum by teachers without the formal assent of the accrediting agency, and often are. Teachers may leave out or add to the material, or change the way in which it is taught and assessed by them. In technological subjects, teachers' often have to make changes to the content. Rather like automobiles the curriculum is subject to a continuing process of minor change. But these changes, which while from the teachers' perspective provide for continuous quality improvement, do not form the *formal* perspective that is the subject of quality assurance. Every now and again the accumulation of these changes makes necessary a major review of the curriculum and some departments do this irrespective of external pressures. More often than not it is external agencies that cause such a review, as for example those caused by ABET (Accreditation Board for Engineering and Technology) in the United States and SARTOR in the United Kingdom (Brown, 1998). Other agencies can intervene and influence the professional organizations in one way or another may, for example, the NSF (National Science Foundation) sponsored coalitions in the United States and the United Kingdom Employment Department's Enterprise in Higher Education Initiative. Sometimes the demands of professional organizations require substantial changes in the approach to the curriculum that have a bearing on how the curriculum is taught. Moreover, these changes may require a substantial change in the culture of the department or unit that has to initiate change. Bringing about change is not an easy exercise as a recent step by step study by Walkington (2002) shows. Those who would bring about change have to have an understanding of the system and the culture that they wish to change (i.e. its external and internal dynamics). While this Chapter is concerned with a general explanation of the curriculum process, a more detailed study of the curriculum and change is left to Chapter 7, understanding of the curriculum process requires an understanding of institutional structures, practices and procedures. It is with these that the Chapter begins.

1.1. The Curriculum, the Institution, and Accountability

For its delivery the curriculum is dependent upon teachers who function within some kind of unit that gives coherence to the subject being taught. More often than not, the unit is a department. Where, however, the subject is interdisciplinary, then it may be a team. For its delivery the curriculum is dependent on cohesion among the members of the team, and if there are tensions between team members learning may be impeded. There can, for example, be conflicts of interest between the subject areas for time within courses. *"My subject requires this amount of time!"* This is not to say that conflicts among the members of departments are avoided. Far from it! Such conflicts can be about the utilization of scarce resources, particularly if there is a shortage of teachers. Shortages of teachers will more often than not be due to decisions taken at a higher level, that is, the School (College, Faculty), the institution, and/or government. Hidden agendas play a powerful role in advancing or preventing change.

The institution has aims and objectives that it wishes to achieve, and to some extent their achievement will depend on the exchanges that it has with its external and internal environments. A diagram of some of the interactions it has to make is shown in Figure 1.1. It is considerably simplified.

It will be evident that if the taxpayer is unwilling to increase funding, or at least believed by the legislators not to be willing to pay, then the achievement of institutional goals may be hampered. One consequence is likely to be a cost-cutting exercise and since the most expensive item on any campus is person power, teachers may not be replaced when they leave. The making of such cuts, in the face of internal opposition, is a formidable exercise, and for some departments it may mean having to lose an elective, reduce the teaching in certain subjects, or find other ways to teach them (e.g., Midwinter, 2000).

The diagram also shows how the structures of an organization are not only affected by the social system but influence the practices and procedures that the institution develops to respond exchanges with its external environment. Because higher education institutions are slow to change, change is often forced on them from the outside. For example, the belief in the value of computer-assisted learning, probably backed up by a belief that it will reduce the number of teachers, can lead legislators to vote extensive funds for that purpose across the university. Teachers who might not have considered using computer-assisted learning find that they have to use it whether they like it or not. Perhaps, in the United Kingdom the biggest imposition from the outside during the last 20 years was the demand for greater and greater accountability. It demanded the utilization of one of the two most scarce resources in a university, time (Williams, 2002; Midwinter, 2000)[1]T.

The world wide demand for accountability has meant that institutions have had to put in place mechanisms and structures for quality assurance at all levels of the institution. Given that quality assurance is the degree to which these aims and objectives are achieved, then everyone in the institution has to be seen to be contributing to that goal. While engineering is not exempt from these conditions, it has like all professional subjects, its professional requirements to meet, and in institutional debates about funding it will use those requirements to try and protect its resources. ("If you insist on that, then we will not be able to meet the educational requirements of the profession.") Thus, one of the factors that worries engineering departments, is the supply of students. As engineering departments have found in the United Kingdom, if they do not have sufficient students they will be closed. For this reason, much attention is paid to mission statements. Aims and goals for such statements both at the institutional and professional levels are important for the marketing of the institution. They are also the criteria against which their performance can be judged.

[1] See Chapter 15 for a detailed discussion of the mechanisms for evaluation (quality) assurance in the United Kingdom.

1.2. Mission Statements, Aims and Goals

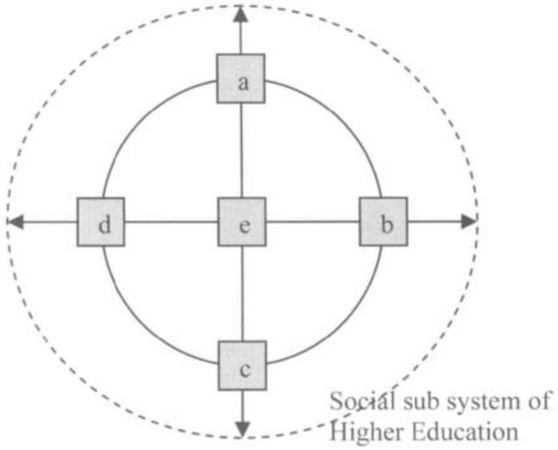
Unfortunately, there is no agreed terminology about the use of these terms. They are often used interchangeably (Heywood, 2000; Yokomoto and Bostwick, 1999). Even the term *objective* may be used instead of aim or goal. Those who use them seem to be agreed that they are fairly general and to be used to focus on where an institution or a department should go (or be going). One of the reasons for seeking a sharper focus was that many of the statements of aims became a pious list of platitudes that academics used when they had to defend what they did. In fact they had no means of judging whether, what they did was achieving the goals they believed in. Therefore, if we were to establish what academics achieved in their teaching, it would be necessary to have some criteria against which the performance of students could be judged. These criteria have to be derived from the aims that the institution has.

1.2.1. The Importance of Mission Statements

A mission statement should be the emotional hook on which an institution hangs its clothing. Because mission statements lacked substance they came to be disregarded by both faculty and students. The linkage between them and the reality of the institution was broken. Sometimes they were expressions of hope about how students would develop. But such hopes, as for example, those shown in Exhibit 1.1, did not necessarily find an appropriate response in the curriculum. Yet as Knight pointed out, aims that are related to attitudes are important (private communication). Unlike the examination objectives related to the knowledge and abilities to be tested, not all of these attitudes can be directly measured. They can, however, be detected in the way students tackle problems based on both syllabus content and the way they behave in coursework, as for example, in teamwork. As Nichols (1991) wrote *"Instead of 'assuming' their accomplishments, institutions are being challenged to demonstrate their overall effectiveness through assessment of departmental program outcomes and objectives linked closely to the institution's statement of purpose. This requirement changes the mission statement of purpose from a shelf-document with little practical use to the basis for institutional action and that is what it was intended to be"*(p,13).

But, as Swaim and Moretti (1991) commented, programs too have missions. When they argued the case for a more limited B.S. degree, they said that it was important to identify the mission of each level of education (i.e., B.S./M.S.), and once that had been done, curriculum questions can be addressed. In a short paper in Chemical Engineering Education Rugarcia et al, (2000) demonstrated this point in the first of six papers that considered the future of engineering education.

Nichols (1991) went on to argue that most mission statements are not substantial enough to provide a basis for institutional effectiveness. They will have to be to be expanded considerably and a *"working relationship between the revised statement of purpose and the intended outcomes and objectives at departmental and programme levels, must be established"* (p,13).



a = Aims and objectives b = Resources
c = Evaluation accountability
d = Practice and procedures e = Structures

Figure 1.1: A model of the institutional evaluation process within a sub system of higher education

He called for an expanded statement of institutional purpose. His examples, which also described linkages for various programs, listed what are sometimes called aims or goals, and, in the case of the linkages, broad outcomes or non-behavioural objectives. These lists of goals should provide statements against which the achievement of institutional goals can be measured.

1.2.2. The Importance of Aims

The trouble is that like all movements there was a danger of throwing the baby out with the bath water. In this case, the move to "objectivity", as this increasing focus on aims was called, carried with it the danger that it removed the emotional props that supported academics in their everyday work (Heywood, 1977). The language of higher education is a language of aims and goals, not a language of objectives and outcomes, however important they may be. It is a language of broad terminology about motivation, interest, intelligence, critical thought, willingness to learn, and in engineering-analytical thought and problem solving. It is a mix of cognitive and affective. Some aims are more tangible from a measurement perspective than others. The role of objectives and outcomes is in the interpretation of aims into practice, and that practice involves the way that students learn. Therefore, discussion of aims is important and several seminal texts continue to be relevant.[2] Such aims have to generate a dynamic for change or renewal or both, and take into account that learning in higher education is a complex process (Knight, 2001).

1.3. The Mission of Engineering Education

Like all systems, engineering education has to adjust, albeit slowly, to changes in the socioeconomic system in which it functions. Periodically it reviews its mission and goals, and sometimes such reviews are government inspired. In the past, American Society for Engineering Education (ASEE) has commissioned substantial reports into aspects of engineering education's future, as, for example, the Grinter Report (1955), see also ASEE 1968 (a, b). In the United Kingdom, the government sponsored an enquiry into engineering that resulted in the Finniston Report (1980), and many recent major developments in engineering education in the United Kingdom find their stimulus in that report. At the present time, in the United States, the current state of engineering education is the subject of an enquiry by the Carnegie Foundation (Sheppard, 2001).

Grayson (1978) summarized the goals proposed by the Grinter Committee as follows: The first, the technical goal, *"was the preparation of the student to perform analysis and creative design, or construction, production or operation where a full knowledge of the analysis and design of the structure, machine or process is essential."*

The second, the social goal:, *"was to develop an understanding of the evolution of Society and of the impact of technology on it, an acquaintance with an appreciation of the heritage of other cultural fields, and the development of a personal philosophy, which will ensure satisfaction in the pursuit of a productive life, and a sense of moral and ethical values consistent with the career of a professional engineer."*

The authors of ABET 2000 would surely claim that their aims are no different, and they might have pointed out that although the Grinter Committee had profound effects on the development of engineering education in the United States, there was still a long way to go to achieve perfection.

How to achieve the second goal is still a matter of controversy (Haws, 2001).

In Great Britain the cultural formation of engineers arises from a somewhat different tradition in which industry was expected to play a key part, even if for the most part it did not.[3] The Finniston Committee wrote that, *"we lay special emphasis on the role of employers in structuring and supervising the experience gained by young engineers in their first years work, which are in many ways the most critical in the*

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[2] For example Newman's *Idea of a University* especially in that he interpreted his idea in the practical reality of establishing the catholic University of Dublin (Culler, 1955; McGrath, 1962), and Whitehead's *The Aims of Education and Other Essays* in which, among other things, the science and mathematics curriculum is discussed.

[3] See Heywood (1969). See also Finniston (1980) paragraph 4.23, p 85.

package." (i.e., the formation of engineers). *"The academic years should seek best to develop in students the analytical and scientific foundations on which they will build their practical skills and also to prepare them to begin synthesizing and applying what they have learnt from the time they enter employment".* (Finniston, 1980, p, 77).

This is in contrast to the Grinter report where an important component of the education of an engineer was in creative design. The only mention of a government report on engineering design (Feilden, 1963) that made recommendations about engineering design education in the Finniston Report comes as a footnote to a section on market trends for manufacturing economies! [4]

(i)	The recognition of the need for a method which is organized, careful and intellectually honest in respect of experimental observation.
(ii)	The acceptance of the need to consider the parallel social and economic bases of engineering.
(iii)	An awareness of the need to derive the more particular relationships from basic concepts.
(iv)	An awareness of the advantage of seeking parallels in other fields to relate one kind of phenomenon to another.
(v)	An awareness of the advantage of attempting to reduce a social, economic or situation to a simple system.
(vi)	The recognition of the fact that it may be necessary to exercise judgment as well as reason when dealing with a problem.
(vii)	The recognition that a perfect answer to a problem may not exist, and that the best available answer must be sought.
(viii)	The recognition of the fact that not all the information necessary to tackle a problem may be available, and that some information which is available may not be relevant.
(ix)	The acceptance of the fact that more than one way of thinking exists, and that different ways may be more appropriate to different problems or different stages of the same problem.
(x)	The recognition of the fact that the required exactness of a calculation may vary from case to case (for example from a preliminary quick order of magnitude estimate to a precise forecast of performance).

Exhibit 1.1. The attitudes and interests that it was hoped students studying engineering science at the Advanced level of the General Certificate of Education would acquire. (*From Notes for the Guidance of Schools for Engineering Science at the Advanced level of the General Certificate of Education.* Joint Matriculation Board, Manchester)

The cultural press on institutions is considerable, and it is very difficult for them to stand aside from this culture and examine the inevitable contradictions through which practice is mediated. The same is true of departments and their teachers. Nevertheless, outside influences such as changing technology are forcing departments to make changes, and it seems from the engineering literature that research and new practices are having an impact on the curriculum process. Demands for accountability by legislators and especially by professional organizations are causing the curriculum to be reviewed at site level (Programme assessment (United States); subject review (United Kingdom)[5]. Such requirements provide the opportunity for fundamental curriculum change if the educational community is versed in the curriculum process and in the philosophical, psychological, and sociological foundations upon which it is based.

1.4. The Curriculum Process in Theory

A variety of models of the curriculum process have been proposed. There are many similarities between them. The models shown in Figures 1.2 to 1.5 have their origins in the work of Tyler (1949). Figures 1.2, 1.3, and 1.4 are characterized by the fact that they incorporate the syllabus (list of content). But the models shown in Figures 1.2 and 1.3 fail to take into account the entering characteristics of the learner. These are the characteristics that indicate the learner's potential to learn within the particular context to be faced.

There is really no adequate way to demonstrate the complexity of the curriculum process in either its static or dynamic form. Indeed Culver (private communication) has told the author that he prefers Figure 1.3 to the model in Figure 1.4 that attempted to demonstrate both the static (design) and dynamic (implementation) nature of the curriculum. An American model due to Cronbach (Figure.1.5) had to be adapted for use in the United Kingdom because, at the time, it omitted a component for assessment. This would no longer be the case in engineering education in the United States, because the ABET criteria are now focused on outcomes and their assessment. But it would still be necessary to distinguish between program and student learning assessment.

Kerns et al, (1998) described the six-step approach to the medical curriculum shown in Figure 1.6.

[4] Finniston (1980, p 17).

[5] The statement from the Finniston Committee arises from the fact that until the 1970's the major route for the education and training of engineers was by part-time study at a technical college while working in industry (see Payne, 1960). The Finniston report compared the system of education and training for engineers in Great Britain with the systems in France, Germany, Japan and the United States and came to the conclusion that these systems were "generally superior" to the British. *"This deficiency to a large extent reflects the relatively restricted and narrow British conception of engineering as a branch of applied science, which militates against an effective marriage between theory and application. The British system does not give students sufficient grounding in the technical, human and financial considerations nor does it adequately encourage the development of the wider skills and outlook required of engineers within the engineering dimension. In consequence employers have often taken the attitude that few engineers are properly equipped to take on broader managerial responsibilities and have employed them instead as providers of technical services, thereby closing the vicious circle"* (p 91). In arriving at this statement the Committee was greatly influenced by the view that there was no dichotomy between theory and practice in Germany because *" the philosophy of Technik which places everything taught firmly in the context of economic performance"* (p90).
The point to be made here is that while engineering courses have been extended to take into account these other considerations there is little evidence that the attitudes of engineering educators have changed. Moreover, there is nothing in the introductory statement of what the academic years should aim to do, that could be said to generate any dynamic that would lead to change.

The six steps are problem identification; and general needs assessment; needs assessment of targeted learners; goals and objectives; educational strategies; mplementation; and evaluation and feedback. Another model, due to Cowan and Harding (1986), that had its origins in engineering, is shown in Figure 1.7.

These models have many similarities with one developed by Grayson (1978) for engineering education. This is shown in Figure 1.8. Like the model in Figure 1.5 it is presented, for convenience, as a linear flow. But like the author of the models in Figures 1.3 and 1.4, Grayson recognised that the curriculum process is a complex ctivity. *"Each stage involves an iterative procedure, the output of which is evaluated before being used as part of the input to the next stage".* This approach differs from that of the author of Figures 1.3 and 1.4, who used, as indicated above, a separate model to show the institutional processes at work in designing the curriculum (Figure 1.1). Grayson combined these in the one model.

Grayson pointed out that *"curricula may be organized at two levels. The first approach may be at a broad or macro level, in which decisions are made about the type of courses to be offered, the amount of time to be devoted to each, the way they will be arranged over the program and so forth. Second, the particular content elements and learning activities can be selected and organized to optimize the knowledge gained by the student. This latter approach usually deals with materials within and the relationship between courses and can be based on certain principles of teaching and learning and of curriculum design. The two types of organization may be compared to the adjustment made in tuning a mechanism or an instrument: first gross adjustments are made, and then fine-tuning is carried out."*

Fine-tuning applies to groups of courses as a whole, and is similar to the process implicit in the model in Figure 1.4. Like that model, it requires the application of learning theory. Both models recognize that there is no single theory of learning, and for that reason it is incumbent on a teacher to adopt a defensible theory of learning. Over and above that, it will be argued that teachers should also have a defensible epistemology. While Grayson is one of a few engineers who in the 1960's and 1970's recognized that knowledge of human learning was such that it was no longer possible to concentrate on what the students should know without taking into account how they learn. He evidently saw the latter as part of fine-tuning. In the models in Figures 1.4 and 1.5, it has equal precedence with all the other elements, and it is the iterative interplay with them that makes curriculum design a complex activity. Figure 1.5 is intended to not only illustrate the complexity of the model but also its dynamic nature. In present day language the model is not static and something that is returned to every now and again but something that is continually done.

Shor and Robson (2000) took much the same kind of approach as Grayson to the continuous improvement required by ABET. They pointed out that in the traditional system the student's achievement in relation to outcomes *"is not used to adjust the sequence or nature of the student's educational experiences".* There is no feedback in the system. However, if there is feedback in the system the process is adjusted to ensure that the output matches the desired output. Clearly, this has implications for both design of assessment and the design of instruction.

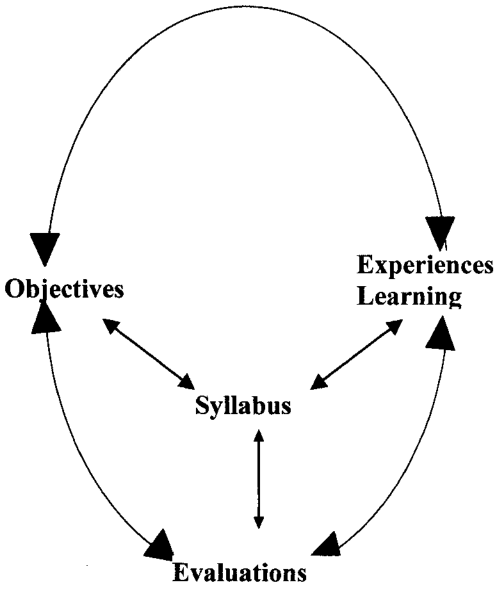

Figure 1.2. The syllabus as the result of the curriculum development and evaluation process. (Reprinted from *Assessment in Mathematics* (PEEP, 1976))

The first implication of the application of these models for the curriculum process, and thus for curriculum design, is that instruction should be designed to achieve specified aims and objectives and that different methods of instruction are more likely to obtain some objectives than others.

As indicated, the models in the illustrations have their origins in the work of Tyler, whose book *The Basic Principles of Curriculum and Instruction* has been described by Jackson (1992) as the Bible of the curriculum.[6] Tyler took the designer away from listing content in the first instance. He proposed that the curriculum designer had to begin, not by listing content,

[6] Tyler was not the first educationalist to believe that the curriculum should be defined by objectives. Bobbitt (1924) devised a model that was in many respects similar to Tyler's. It is of interest to engineers because he derived his objectives from human experience. As described by Jackson (1992) Bobbitt's first step was to analyze the broad range of human experience into major fields. (In the case of this text engineering would be a major field). The second step was to take these fields, one after the other, and analyze them into their specific activities. For example, in respect of engineering see Meuwese (1969) and Youngman et al (1978). *"One starts with rather large activities and breaks them up into smaller ones. This process is to continue until the curriculum makers have found the quite specific activities that are to be performed".* In the activities once discovered one can see the objectives of education (Jackson, 1992).

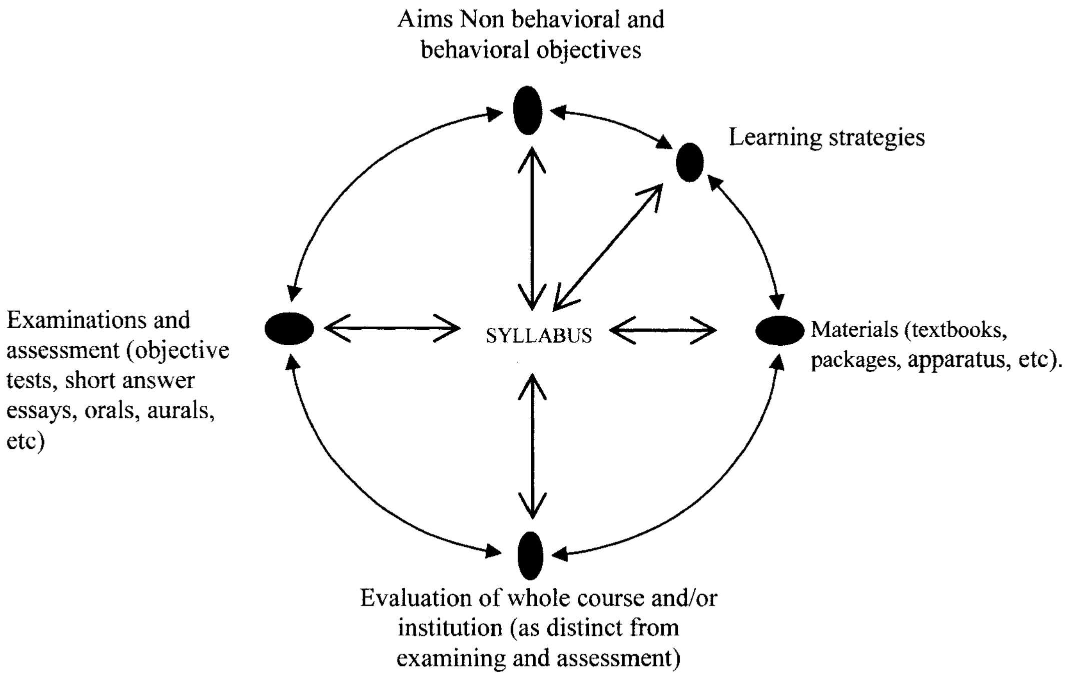

Figure 1.3. A development of the model in Figure 1.2 to show more fully the assessment curriculum instruction process.

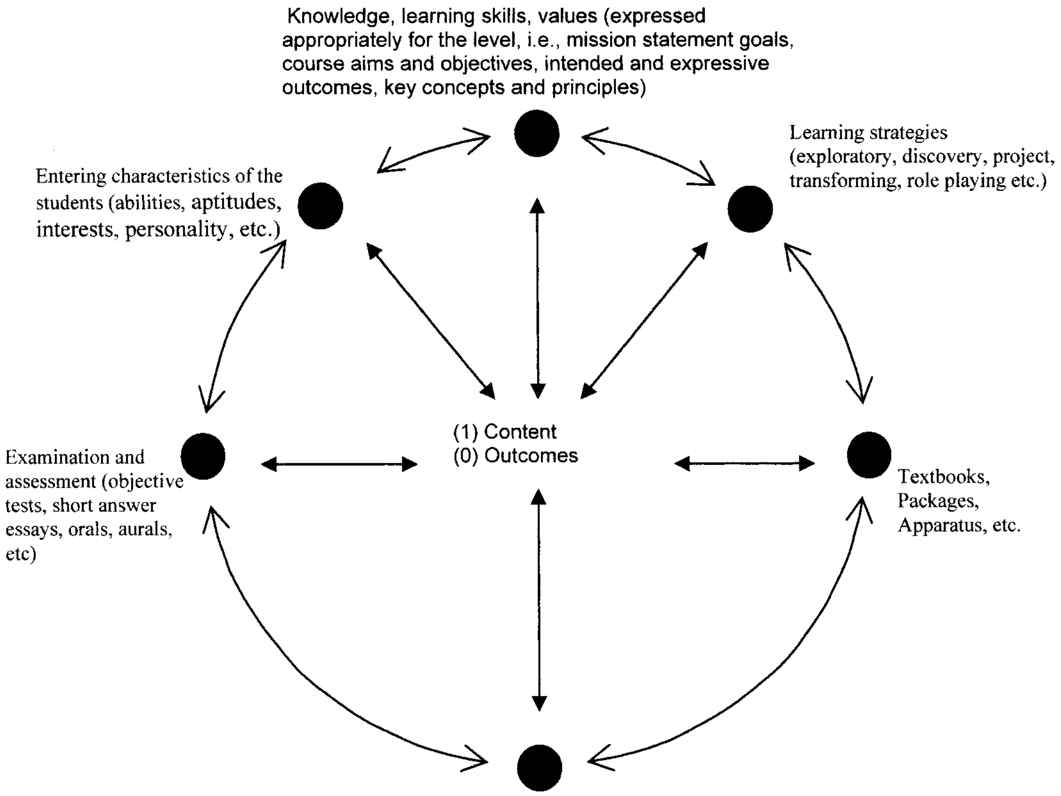

Figure 1.4. A development of Figure 1.3 to show the dynamic nature of the process. A model of the assessment, curriculum, learning, teaching process (1) The first phase in which the structure of the syllabus content is derived and (2) how the intended learning outcomes are a function of a complex interaction between all the parameters and allowing that there will also be unintended outcomes. The original model in *Enterprise Learning and Its Assessment in Higher Education* (Technical Report No. 20, Employment Department, Sheffield) referred only to the design of the syllabus while indicating that evaluation took care of the dynamic nature of the model. Professor Georgine Loacker of Alverno College suggested that this dynamism would be better expressed if the model also recorded the outcomes of the on going activity in the centre

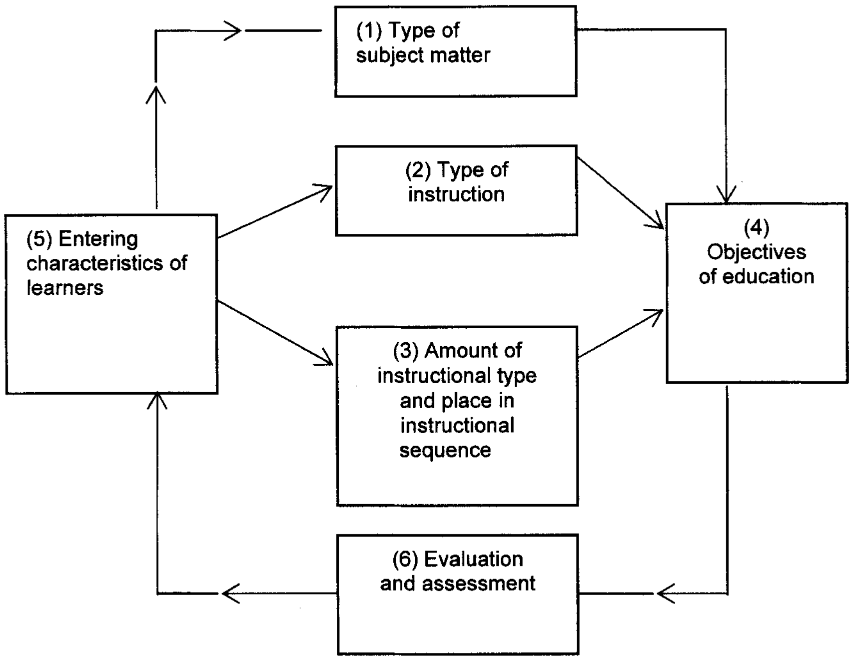

Figure 1.5 Theoretical generalization about the nature of instruction. (Shulman's, 1970, generalization of Cronbach's view of the nature of instruction). Block 6 has been added by this writer. Examples of the variables given by Shulman, (1) content of subject defined in task terms; (2) expository discovery (degree of guidance), inductive, deductive; (3) number of minutes or hours of instruction, position in sequence of instructional types; (4) products, processes, attitudes, self-perception; (5) prior knowledge, aptitude, cognitive style, values; (6) knowledge, comprehension, problem solving skills, etc.

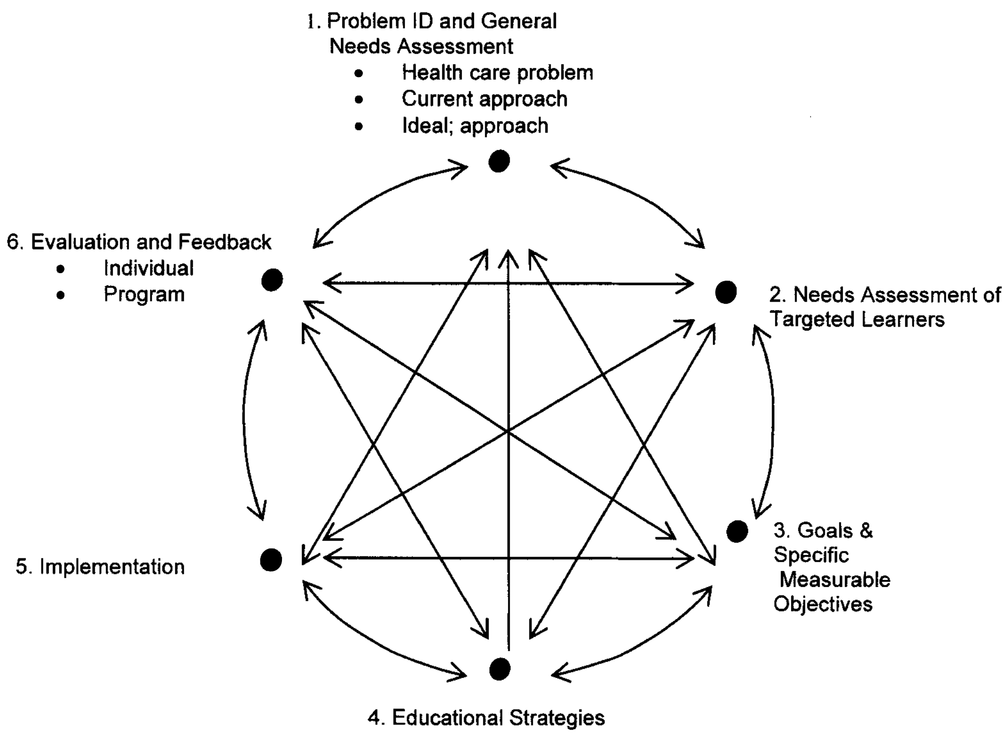

Figure 1.6. A six step approach to curriculum design for medical education (Kewrns, D. E., Thomas, P. A., Howard, D. M and E. B. Bass (1998). *Curriculum Development for Medical Education. A Six-Step Approach*. Reproduced by kind permission The Johns Hopkins University Press.)

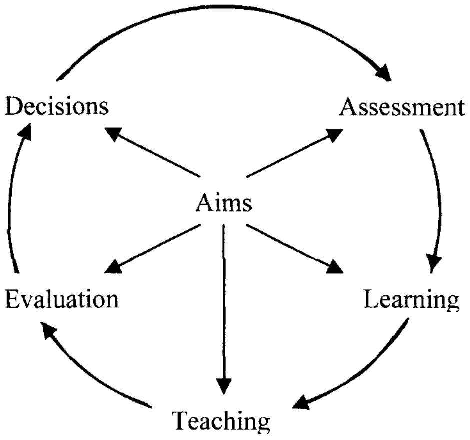

Figure 1.7. A model of the curriculum due to Cowan and Harding (1986). (Reproduced with the permission of J. Cowan)

but by declaring the aims and objectives to be achieved. Once these were understood it would be possible to determine the instructional methods that would create the learning that would achieve those aims and objectives. These are systems models. For example, when they applied the principles of guided design to the design of the curriculum Wales and Stager (1972) were clearly influenced by Tyler among other educators of that era as Waina (1969) acknowledged. The psychological principles they listed are shown in Exhibit 1.2.

Tabulations of method against objectives, method against learning styles, and method against cognitive development have been made by Weston and Cranton (1986), Svinicki and Dixon (1987), and Culver and Hackos (1982). Fromm and Quinn (1989), add the salutary reminder, that revamping a curriculum requires significant changes in attitudes, goals, curriculum content, and teaching methods. And that may not be palatable to many teachers. Hence the requirement that those who would change the curriculum should have an understanding of change and diffusion processes. They would be helped in this matter if those who apply educational theories would agree a common terminology, but sadly this is not the case as the brief section that follows and Chapter 2 will show.

1.5. Confusion in Terminology

For example, the heading in Figure 1.4 relating to aims and objectives serves to illustrate two points. First is the confusion in terminology that has arisen during the 50 years since Tyler first enunciated his principles of the curriculum. What, for example, are the differences between aims, goals and mission statements? These will be explored below, and in Chapter 2. Second, as will be explained, there has been a marked reluctance to stick to the terminology related to objectives. Today, the term *outcome* is preferred to objectives. Some writers infer differences between objectives and outcomes that were not in the minds of those with whom the so-called '*objectives movement*' is associated. In any event the terminology has become thoroughly confused (Heywood, 2000). Yokomoto and Bostwick (1999) summarized the position with respect to ABET's criteria for Ec 2000 as follows: *"Dissimilar words are used as synonyms, such as "outcomes," "attributes," and "competencies to describe what students must demonstrate." Sometimes the term "performance outcome" is used.*

The same applies to the terms assessment and evaluation. In the models, evaluation is now commonly called program assessment. In this way the assessment of student learning becomes confused with programme evaluation (see Chapters 15 and 16).

The second point is that discussion about aims and objectives has been very restricted to the developments associated with Tyler and his colleagues. It tends to ignore content in favor of learning skills in the cognitive, affective and psychomotor domains, yet the understanding of a key concept is as much a learning objective as are the development of skills in analysis and synthesis. It also undervalued statements of aims or goals, and in consequence, the effects of the institutional mission on the curriculum, and it caused teachers to ignore process in favor of product (Knight, 2001).

1.6. The Curriculum Process in Action. An Illustration

As indicated previously, these models are unusual in that they incorporate the syllabus (content). They are intended to illustrate the syllabus as being the outcome of a complex design activity involving the declaration of objectives and the simultaneous design of assessment and instruction procedures that will cause those objectives to be obtained.

The process may be illustrated by consideration of the student complaint that courses are overloaded. By this they mean that the syllabuses are so detailed that they cannot be covered adequately by the teacher or themselves in the time allowed. This does not, however, mean that they would want the course lengthened. Seymour and Hewitt (1997) found that science and engineering students in the United States, (in the sample they interviewed), already felt that the courses were long enough. All of this raises the question as to whether all the material that is put into courses is essential. Very occasionally engineering tutors have suggested that the length of courses might be reduced (e.g. Swaim and Moretti, 1991).Van Valkenburg (1991) had an article entitled "*Too many topics, covered too fast.*" But, it is this writer's experience that those concerned with the design of new courses tend to overload them with content and subsequently face the task of reducing them. He has been found guilty of this offense (Heywood, 2000). There is also the problem of information overload (Rockland, 2000).

At the same time, length of course has been a key factor in the professional judgment of the standard of courses. Thus, when in the 1980's comparisons were made between engineering courses in England and Germany, there was a demand in England for enhanced courses of 4 years duration instead of 3. (Jordan and

Carter, 1986).[7] By contrast, at least one American comparative study of programs in Europe concluded that American programs were too short (Dorato and Abdallah, 1993), although there has been at least one plea for a reduction in the credit hours for the BS degree in the United States (Swaim and Moretti, 1991). The Goals of Engineering Education Final Report (ASEE, 1968a) said: *Engineering education...has attempted to provide within the confines of a traditional four-year period both a broad general education and a specialized technical education of great and growing complexity.*

The point here is that it is only by following the curriculum design procedures outlined below that a satisfactory teaching, learning syllabus can be defined within the time constraints available.

To determine whether or not a course would be overloaded the estimates of times taken for each instructional procedure required for the learning of a key concept or a higher-order thinking skill are summed. If the sum of the periods required to complete all these strategies comes to more than the time allowed for the course, then the course is overloaded. This is irrespective of any overloading caused by home study requirements. Therefore, the tutor should be prepared to reduce the number of key concepts, and/or higher order skills taught. This will involve him or her in a ranking exercise.

Tutors have to cope with the reality of learning, which is, that the rate of internalization necessary for understanding is, relatively slow for many students.

Stice (1976) quoted in full in Chapter 2 reported that the use of objectives helped him distinguish between essential and nice-to know knowledge. This enabled him to cover a course that had never been fully covered before.

Mansfield (1979) writing about the design of mini courses said, *"try to be as realistic as possible, total up the times for all activities on your mini-course outline. Adjust any item to meet the overall goal within the allotted time trading, deleting activities or even reducing the number of realizable objectives.*

Alternatively, consider providing more total time for the course ... .be brutally honest in your time estimates."[8] This is why the syllabus (content) has been put at the centre of these models because it is the outcome of the design process and not its beginning (e.g., Figure 1.4). It is also the reason why the key concepts to be considered are as much a component of the objectives as are the statement of skills that have come to be associated with objectives (e.g., problem solving, critical thinking). Transfer of learning will not be obtained without an understanding of the appropriate principles and concepts. For this reason a teacher should concentrate on ensuring that these concepts and principles are understood even if that means that some parts of the course cannot be covered. Wales and Stager (1972) recognized the importance of concept learning, as well as higher-order thinking as the illustrations taken from their paper in Exhibit 1.3 show. How concepts are learned will be discussed in Chapter 4. The selection of key concepts for the curriculum is a critical stage in the process of curriculum design, as is the evaluation of whether or not they have been learned (see Chapter 4).

The same general principles apply to the development of a program. It is possible to fit the models so that they will derive the subjects that would make up a whole discipline-based program, as, for example the work undertaken in Thailand by Yeomans and Atrens (2001). They derived their objectives from those stated by the Institute of Engineers of Australia. The same can be said of the course development matrix suggested by Sinclair and Bordeaux (1999).

1.7. Assessment and Evaluation

As indicated above assessment and evaluation are also terms that have had a chequered history. In present-day parlance assessment is sometimes used in place of evaluation (see Chapter 15). In Figures 1.3 and 1.4 assessment has been separated from evaluation. Assessment is taken to mean the assessment of student learning by tests of some form another for the purposes of grading. It may include both summative and formative components.[9] The inclusion of the term examinations reflects the different educational cultures prevailing in the United Kingdom including those countries whose education systems derive from the United Kingdom (e.g. Australia, Ireland), and the United States. Evaluation is intended to indicate something that is broader in intent and takes into account all the factors that contribute to course design and student learning including the quality of teaching. It would embrace the term program assessment which is now in common usage. The term evaluation is preferred because there is a very substantial literature on the theory and practice of evaluation. The theory and practice of evaluation will be considered in detail in Chapters 15 and 16. A key role for evaluation in these models is to ensure that there are no mismatches between (a) the assessment strategies for checking that outcomes have been obtained, and (b) the learning

[7] Monograph published from The University of Salford circa 1986. Contains detailed discussion of the meaning of enhancement. Initially eight universities were selected to offer enhanced courses. Now it is expected that a chartered engineer will have pursued a 4 year course resulting in an M.Eng degree.

[8] On the assumption that the syllabus must remain the same Felder, Stice and Rugarcia (2000) cite Felder and Brent who argued that much of the material that is used in lectures can be assigned to handouts or even a coursework pack. The handouts should have spaces for the students to fill in missing steps. I have used this technique, but at the appropriate point I told the students what to put in the space. The blanks were always for key concepts or important principles. In another course a self-study guide was designed to accompany the lectures (Heywood and Montagu Pollock, 1977).

[9] Summative refers to what is often termed the final exam. In some systems, feedback about performance might be given to a student. In other systems, no information is given. In systems that make performance assessments during the course, feedback is likely to be given, and sometimes this may be diagnostic. In any case, such information is formative.

strategies implemented to bring about these outcomes. Often innovations are made in assessment that are not reflected in the learning strategies desired to bring about improvements in performance (e.g. Segers and Dochy 2001, see Chapter 16). The expertise that is required will depend on the level at which it is practiced.

Accrediting institutions often require that the student participants evaluate the course. There have been two consequences of this requirement. The first has been a massive research effort to discover the validity and reliability of student rating questionnaires. The second has been that teacher's and program designers feel that all that is necessary for the evaluation of an innovation is the collection of student opinion by means of either a discussion or a questionnaire. Many of the innovations described in the engineering education literature report evaluations of this kind. However, such evaluation is inadequate more often than not.

There is, of course, a point at which there is a conjunction between the assessment of student learning and evaluation. In this respect a first level of evaluation is exemplified by the classroom assessment techniques (CAT's) developed by Angelo and Cross (1993). They described 52 such techniques. A distinction was, however, made between these techniques and classroom research, which is a more substantial exercise (Cross and Steadman, 1996). To illustrate this point, they suggested a number of simple ideas for "probing" the prior knowledge that students have. Responses to the "probes" were not meant to be graded. This meant that the teacher could hope to ask questions that would yield "thoughtful answers." Another example is the use of concept maps to evaluate the student's ability to think holistically.

A second level of evaluation is classroom research. Neither classroom assessment techniques nor classroom research are solely concerned with the evaluation of cognitive achievement. They are equally concerned with, for example, the assessment of attitudes. However, classroom research and more generally research that is able to obtain data from engineering students as a group is more likely to be able to evaluate in more depth those factors that contribute to performance. The first two levels of curriculum leadership correspond with these levels of evaluation.

1.8. The Role of the Teacher Institution in the Curriculum Process

If the instructional methods should be designed to meet objectives, so too should the procedures for assessment. It is for this reason that a single method of assessment is unlikely to assess whether all the objectives are being obtained. In these models assessment is an integral part of the curriculum process. These models are multiple-strategy in their approach. Whether they focus on the design of the curriculum, or a method of instruction, or an assessment procedure, or learning, or even the evaluation of an institution, the starting point is the same. It is the understanding and expression of what we are trying to do in the parlance of the day (e.g. outcomes). Whether it is at the level of the program, a specific course, a topic, or a classroom session their objectives (outcomes) derive from the mission statement of the institution. In its turn the institution is responsible for the resources and organizational structure that will bring about these ends. This point was illustrated in Figure 1.1.

Given this understanding of the curriculum process then, subject to the rules of the department, institution or professional body the role of the teacher is to:

1. Determine the aims and objectives (outcomes) that are to be obtained by screening.
2. Determine the instructional methods to be used to obtain the aims and objectives (outcomes).
3. Determine the sequence of instruction.
4. Evaluate the extent to which the aims and objectives (outcomes) have been achieved.

At the department level this model implies that the following questions should be addressed:

- What educational purposes should the school (engineering department) seek to obtain?
- What educational experiences can be provided which are likely to attain these purposes?
- How can these educational experiences be effectively organized?
- How can we determine whether these purposes are being attained?

1.9. Establishing Aims and Objectives (outcomes). The Process of Screening

As Furst (1958) recognized the problem with lists of aims and objectives is that it is very easy to generate long lists. These can become as self-defeating as a long list of content and may end up being just that. Unless objectives, or outcomes, call them what you will, are strictly limited, their number is likely to overload courses as teachers struggle to obtain them. Applied to the goals of an institution, Furst (1958) pointed out that *"some of these goals will be more important than others; and some will be inconsistent in the sense that they call for contradictory patterns of behaviour. Clearly the school (institution) must choose a small number of important and consistent goals that can be attained in the time available."* (p, 39).

This applies at all levels of the educational process be it at the level of policy or the level of the curriculum. Helsby (1999) has shown how government policies to school education in the United Kingdom have been contradictory. With respect to engineering programs and course design, it has been argued that the number of domain objectives should be limited to only those that are significant, and that within them the sub-abilities to be tested should also be limited (Heywood, 1989).

Furst (1958) argued that in order to choose these domains, the lists that are developed have to be screened for consistency and significance. He argued that the

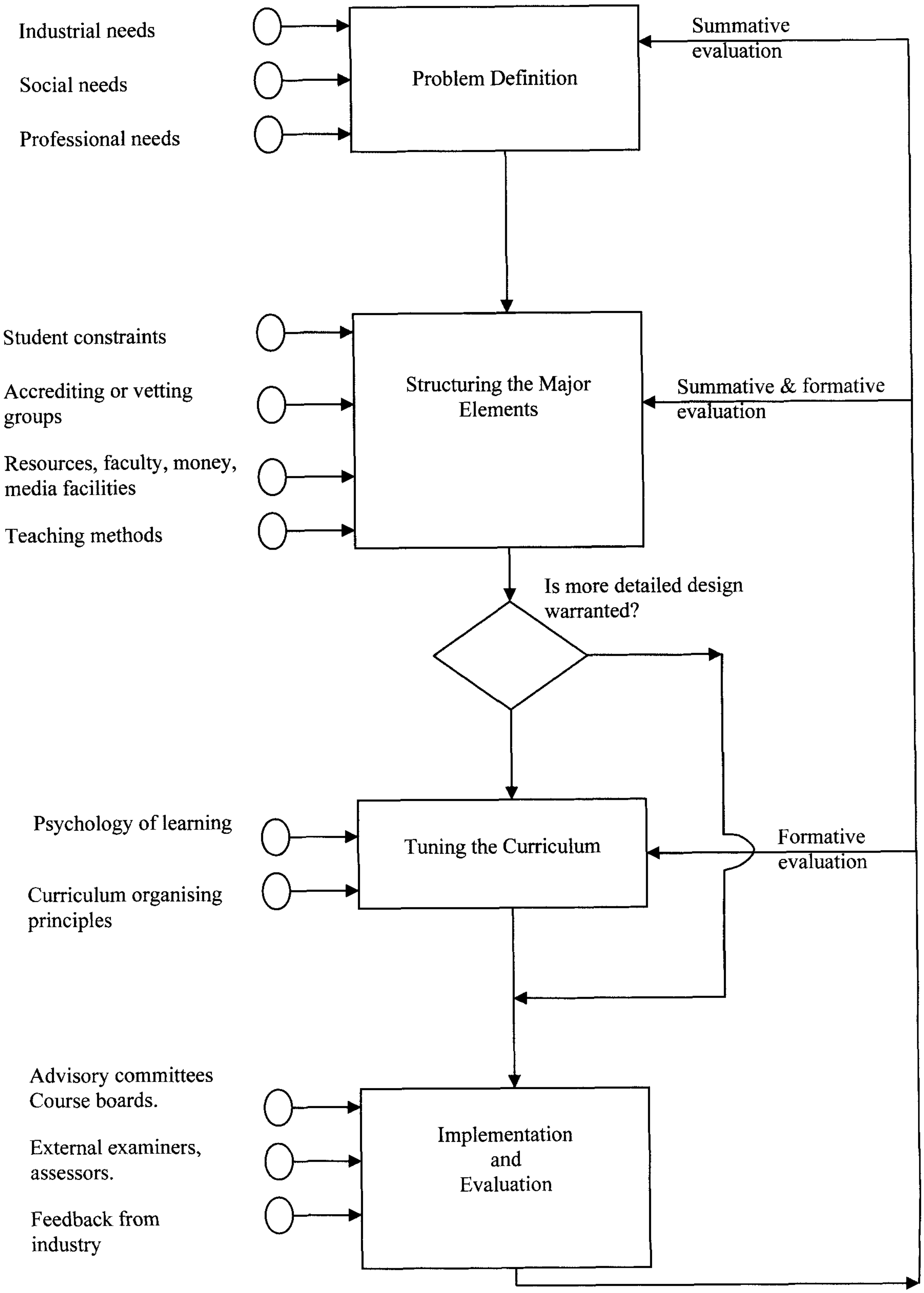

Figure 1.8: Grayson's model of the curriculum process. (Reproduced with the permission of Lawrence, P. Grayson).

Organize the Subject Matter for Presentation to the Student.

1. Identify the specific concepts and principles the student must learn.
2. Arrange the concepts and principles in sequence from simple to complicated.
3. Provide Organizers (9a) verbal, and visual, and (b) concrete empirical illustrations and analogies.

Organize the Student's Practice of the Intellectual Modes and Abilities.

1. Identify the specific modes and abilities the student will practice.
2. Integrate these modes and abilities with content.

Organize the Student's Intellectual Development.

1. Guide the student as he/she learns.
   - (a) Demonstrate or model and/or provide a situation in which the student can experiment and/or discover the desired behavior.
   - (b) Supervise the student's initial trials.
   - (c) Use the necessary prompts. Withdraw this support gradually as the student's ability develops.
   - (d) Describe to the student the intellectual modes and abilities involved in his work and relate each to specific activities.
   - (e) Help the student to learn to evaluate his own performance.

2 Provide for practice.
   - (f) Ensure that the student is active.
   - (g) Pace his work, spaced practice is best.
   - (h) Vary the context.

3 Evaluate and provide feedback.
   - (a) To reinforce correct responses.
   - (b) To correct inadequate responses.
   - (c) Immediately during initial learning.
   - (d) Frequently thereafter.
   - (e) Formative: provide the student with diagnostic progress information about his performance.
   - (f) Summative: Determine if the student has mastered stated objectives and is ready to move on.

4 Motivate.
   - (a) Encourage the desired behaviour.
   - (b) Show the value of (1) learning, (2) the concepts and principles to be learned by showing their relevance to meaningful work.
   - (c) Help the student achieve success.

5 Individualize.
   - (a) Provide for students who learn at different rates.
   - (b) Enrichment for the fast learner.
   - (c) Extra help for the slow learner.

Exhibit 1.2. The late Wales and Stager's (1972) list of psychological principles involved in curriculum and instruction.

Intellectual Ability	**Action**
Recall	Write the concept.
Manipulation	Restate the concept in a new
Translate.	form
Interpret.	Convert the concept from verbal to graphical or symbolic form.
Predict.	State the results derived from the use of the concept.
Choose	State the expected effect of the concept. Independently select the concept and use it to solve a problem.
(b) Content-performance objectives for decision making;	
At the end of a period of study, each student should be able to solve an open-ended problem using: **Decision- making skill**	**Action**
Gather information	Gather required information from appropriate sources
Problem identification.	State the basic objective of the project
Basic objective	State the basic objective of the project.
Constraints/assumptions	List the constraints assumptions which affect the project.
Possible solutions	Generate possible solutions which appear to meet the
Analysis	objective.
	Combine elements from many sources into a pattern not
Synthesis	previously known to the student.
	Make purposeful judgements
Evaluation	about the value of ideas, methods, designs of defects. Report the results and make
Report	recommendations.
Action.	Implement decision.

Exhibit 1.3. The late C.E.Wales and R.A. Stager's (1972) concept performance objectives for a concept and decision making.

educational and social philosophy to which the school (department or institution) is committed should provide.the first screen. In the first instance, it is concerned with the mission statement that should raise key questions

His examples of such questions for schools (presented in italics) are highly relevant to engineering education, as the text in normal type shows, even though they do not use today's terminology. The questions included, *Should the school prepare young people to accept the present social order?* (Should engineering students be prepared to accept the current mores of the engineering profession, or should they be enabled to review and challenge them?) *Should different social groups or classes receive different kinds of education?* (Should minorities receive different kinds of engineering education? Should engineering education be designed to cater for different personality types?)

Should the school (engineering department) *try to make people alike or should it cultivate idiosyncrasy?* (Should an engineering department encourage creative and innovative behaviour among its students?)

Should the school emphasize general education or should it aim at specific vocational education? (What is the role of general/liberal education in engineering education?)

There is much in the engineering literature that deals with such issues. Furst's point was that the education that will be provided is a function of the stance taken on such issues. He pointed out that if a school prepares students for the present social order, it should emphasize conformity and emphasize mastery of fairly stable and well organized bodies of knowledge Whereas if a school wants to encourage students to improve society, it will emphasize sensitivity to social problems, skills in analysing problems and proposing solutions, independence and self direction, freedom of inquiry, and self-discipline (p, 40). Answers to these questions have to be consistent and not contradictory. He described in great detail how philosophy functioned in the formulation of content in the program of general education in the University of Chicago, at that time

Furst also argued that the psychology of learning and human development should serve as a second screen for selecting and eliminating goals. As with philosophy he offered a series of questions that might be asked. Three of these follow:

At what level of maturity are particular objectives obtained?

What is the optimum growth that may be expected of different kinds of student with respect to the objectives? (Should an engineering school design its curriculum to take into account the cognitive and emotional development of students?)

What is the transfer value of different kinds of outcome? (Answers to this question should be helpful in evaluating a curriculum that is said to be overloaded.

In a different context the National Post-Secondary Education Cooperative (NEPC, 1977) suggested criteria for the screening of policy performance indicators. The conceptual criteria for their first screen were relevance, utility and applicability. The conceptual criteria for their second screen were interpretability, credibility, and fairness. Their methodological criteria for the third screen were scope, availability, measurability and costs. They said that, *"conceptual criteria involve philosophical and political considerations. They can be thought of as a set of questions relating to the question 'Why should this outcome be included in the data set under development?' Methodological criteria involve technical issues of measurement availability and data* *collection design.. methodological questions ask 'How sound is the data likely to be?*

It is evident from the foregoing, and as at least one illustration of its use in engineering showed, that screening is by no means an easy task (Heywood, 1981; see also Staiger, 1983). It should also be evident that satisfactory answers to these questions will entail knowledge of philosophy, sociology, and psychology as they are applied to pedagogy. In so far as the design and implementation of the curriculum is concerned Furst (1958) argued, that every teacher should have a defensible theory of learning, and that must go for philosophy as well. The need to screen aims and objectives provides the rationale for including the study of appropriate philosophy, psychology, and sociology in the student teacher's curriculum. Similarly, it is the rationale for curriculum leaders in engineering education to be conversant in these areas in order that they can advise and lead in the design and evaluation of the curriculum and its renewal.

As Furst's illustration of the curriculum in general education at the University of Chicago showed, curriculum designers should approach the curriculum from the perspective of philosophy, sociology and psychology and not from the perspective of the syllabus. There are many curriculum frameworks. The most appropriate one should result from the exercise of screening. It is a substantial process as a group of designers in the engineering curriculum have shown (Heywood et al, 1966). In general education the recent report of the development of the assessment led curriculum at Alverno College more than adequately illustrates the process (Mentkowski and associates, 2000). The general idea is well illustrated by Sherren and Long (1972), who argued that engineering educators must take into account philosophy, alternative educational theories, and alternative psychological theories of learning (see Chapter 3). It is a complex process. It is not simply a matter of defining outcomes that can be tested or of relating teaching methods and assessments to those outcomes. Strong support for this thesis is provided by Felder and Brent's (2003) paper on the design of teaching courses to satisfy ABET criteria.[10] This discussion continues in Chapter 2.

It is part of the purpose of this book to, (a) explore the knowledge required for this to be achieved, and (b) illustrate from research and practice in the engineering curriculum.

1.10. Conclusion

Irrespective of the model that is used

1. Curriculum design, assessment and evaluation begin at the same point. That is the understanding and expression of what it is we are trying to do.
2. For each general objective there will be an appropriate method of testing, and that may not be of a traditional kind.
3. Specific learning strategies will be required if the objectives are to be successfully obtained, and this requires an understanding of the complexity of learning.
4. A multiple strategy approach to teaching, learning and assessment will be required
5. The combination of all these elements may lead to a substantial reorganization of the syllabus and approaches to teaching and learning.
6. This may require a substantial change in culture of the organizational unit responsible for the delivery of the curriculum

An integrated approach of this kind demands a considerable change on the part of the teacher to the planning and implementation of the curriculum. While curriculum design and change require knowledge of philosophy, sociology, and psychology as they are applied to education, change is unlikely to be accomplished, unless it is shown to follow from the notional aims to which teachers in higher education are attached. (Yeomans and Atrens; 2001).

In the Chapters that follow in part 1, the concern is with how we arrive at statements of aims and objectives (outcomes). In Chapter 2 the so-called 'objectives' approach is discussed and some methods for deriving objectives considered. Since, the danger is that long lists are produced, the question arises as to how they might be screened for relative importance and also avoid any internal contradictions. How this may be accomplished by applying philosophy, sociology, and history[11] is the subject of Chapter 3, and psychology as it is applied to the learning of concepts and principles, the understanding of our learning dispositions and cognitive development is considered in Chapters, 4, 5,and 6.

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[10] The reader interested in the history of curriculum change in engineering will find a paper on managing engineering education by Staiger (1983) of interest Like Felder and Brent he included a bibliography relevant to the design of the curriculum.

[11] The recent publication of *Retooling: A Historian Confronts Technological Change* by R. Williams (2002) (MIT Press) proposes a thesis that would have profound implications for engineering education

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