Chapter 1
A general context for our study of prior knowledge

1 Introduction

In this chapter, we will try to state a theoretical basis which is useful for the purpose of our study. This context is related to the instructional side (i.e. modular instruction theory) and to the side of the learner (i.e. learning theories and cognitive psychology).

We will examine the origins and significance of the use of modules in higher education as well as considering the advantages and disadvantages of modularization. Modular instruction at the Dutch Open University will then be described and compared with traditional education. After that, the importance of the student's prior knowledge in modular instruction theory and related applications will be examined.

The lessons from past research into instructional and cognitive psychology, insofar as they are relevant to our study, will be summarized. We will give particular attention to the information-processing view of human cognition and its influence in understanding individual differences.

2 Student learning in modular instruction

Introduction

Modular instruction was first adopted in American higher education. From the first introduction of the elective system in 1869 at Harvard University till now, there has been great variety in the definition and use of modular instruction and the implementation of modularization.

There are various reasons for the increasing interest in modular instruction in the Netherlands in the last few decades. Cutbacks by the government and the associated restructuring and reorganization have played a role, as have the wide variety of student requirements and the demand from employers for flexible graduates. For the consumers of education, modularization means an increase in freedom of choice; for those who provide education, it means an increase in access to and/or consumption of the educational supply.

Today there is a distinction between the traditional view of modularization and a more recent and fundamental view. In this chapter we postulate this more fundamental view, which is based upon the belief that implementation of modular instruction or modularization represents a radical change to the existing

educational setting. This change will have consequences for the educational programme, the study materials, the students, the teachers and the organization as a whole. As with every educational adaptation, modularization has its advantages and disadvantages.

Before we give an outline of the way in which modular instruction is realised at the Dutch Open University, a comparison of the characteristics of traditional courses and modular courses will be made.

The final paragraph of part 2 focuses on the relationship between modularization and the prior knowledge of students: one thinks of instruction that is fully attuned to the personal needs and the prior knowledge of students, giving opportunities for individuals to work at their own pace, and of individual study paths and multifunctionality of modules.

2.1 The modularity hypothesis and modular instruction.

2.1.1 The origins of modular instruction.

Nobody seems to be entirely clear about where 'modular instruction' and the 'modularity' wave comes from. Some look for definitions in dictionaries, others mention the first applications in American and Canadian universities. It seems that some also look for the roots of 'modularity' in psychological research and in those theories which fall under the heading of the theory of mind or cognitive psychology. In this field, the rationale for modular instruction seems to reside in the modularity hypothesis. According to Brewer and Nakamura (1984), research has shown that the mind can be looked upon as modular and that it is necessary to develop different types of theoretical entities to account for the different cognitive processes (see Chomsky, 1980, for a similar argument).

Modular instruction, as we now know it, was first adopted a century ago in American higher education. Educational philosophy ensured the growing acceptance of 'student-centred learning' and of John Dewey's advocacy of selfrealization in the pursuit of studies adapted to the individual's interest.

Harvard University introduced the elective system in 1869 to replace the set curriculum. As a result of this, students were able to determine for themselves which courses to take (freedom of learning and increased specialization options).

By 1884, Harvard students had almost complete freedom of choice. In the 1890s there was a shift towards measuring progress towards a degree on the basis of the accumulation of individual courses rather than by the completion of a total course of study (Burn, 1974). In the meantime other institutions were adopting similar

practices. The movement towards electives was soon accompanied by increasing recognition of the need to quantify educational processes, allowing students' progress along the various paths towards a degree to be assessed.

The first units of measurement were the courses themselves, defined in terms of hours of classroom contact, with the measure of achievement across the varied course offerings based on a traditional time unit (Heffernan, 1973).

Thus emerged the credit system, the forerunner of the modular system, as a means of aggregating the series of varied educational experiences. Here, one also sees the origins of the view that American higher education allows students total freedom of choice, a kind of cafeteria system in which the moving tray is heaped with whatever fancy catches the mover's eye.

Such was certainly not the intention. The elective/credit system's proponents saw it, not as a curricular free-for-all, but as a means of breaking the stranglehold of the classical curriculum.

However, the elective system was not introduced across the board in higher education, as schools gave preference to adapting to the entrance requirements/criteria of colleges and universities. By way of compensation, a number of institutions introduced a major and minor system, where the student chose some department or group of studies in which he took a major (for example a series of courses presented by that department) and one in which he took a minor.

Today, the credit system has been used to accommodate a whole range of approaches undreamt of at its creation: self-paced courses and independent study (Ziegler, 1972; Allen and Christensen, 1974); life credits for mature students (Hill, 1975); contract learning ,the forerunner of negotiated learning, (Lindquist, 1975); credit for study abroad (Haas, 1982), and developments in the direction of non-attendance (Burn, 1974); developments towards award of credit by mastery of content and examination (Spurr, 1970); and the abandonment of letter/numerical grades for satisfactory/unsatisfactory assessments (Schultz, 1973).

As will be apparent, the credit system is capable of movement in virtually any direction: towards greater or diminished student autonomy, enhanced or reduced institutional control, greater curricular cohesion or more fragmentation.

2.1.2 Modules and the implementation of modular instruction: a traditional and a more fundamental view

Dictionary definitions of the word 'module' tend to suggest three underlying concepts: 1) measurement, 2) a part of a whole, and 3) repetition. The term module therefore features in construction work, especially in the erection of buildings, and it is employed to designate items of furniture which can be assembled variously over time by the purchaser.

In education, there has been a plethora of uses, for example, in timetabling, to indicate a period of teaching/learning (Allen and Christensen, 1974), and in modular instruction, to represent self-contained sub-courses in a programme of self-instructional material. In the United States, the aforementioned uses are fairly common. However, more traditional courses are described in terms of credit hours, and the general structure in which they function is known as the credit system. In Britain, it should be observed that 'module' is used, most traditionally, for credit hours; and 'modular structure/course' for the credit system. One should also note by way of caveat, that modules go by a variety of other names, e.g. units, blocks, course units, unit courses, courses (Theodossin, 1986).

The traditional view of modularization versus the more fundamental view

The plethora of uses of the word has led to several definitions and views of modularization, particularly in a complex situation as is higher education.

In the traditional view - one could say the traditional or perhaps the obsolete view -, a module can be described as an independent educational unit of limited scope, encompassing a series of educational and learning activities, which lead to a clearly defined final level (Van Eijl, 1987). At policy level, the module is seen as a useful programming unit with a predetermined scope and duration. It is said to make educational programmes easier to set up and change and to make flexible use of education possible. It needs to be stressed, that this view is very limited. Within the whole operation of modularization, the module is the central point. Van Eijl (1987) talks about compulsory and non-compulsory characteristics of modules.

The conviction that the flexibility of education can be increased by using modules, that the emphasis in this type of education is on self-instruction systems and on the individual learning paths of the students, has led to a new concept of the implementation of modular instruction.

Within this recently developed concept - let us call it the more fundamental view - modularization is much more than cutting pieces. This fundamental view arises from the belief that the implementation of modular instruction or modularization is a radical change in the existing educational setting, which has consequences for the educational programme, the study materials, the teachers, the students and the organization as a whole. It must be stressed that intervention affecting only one or a limited number of the above will be insufficient to guarantee a successful modularization.

According to the fundamental view, modularization leads to an institution focused on facilitating individual learning processes (de Wolf, 1989). Moreover, implementing modular instruction has consequences for five components of higher

education, all of which are in phase with each other. We call these the five conditions for successful implementation of modular instruction:

1. the educational programme is divided into independent and well-structured learning units;
2. it is possible for the students to start from different entry levels, i.e. different learning paths are provided inline with their varying levels of prior knowledge, background and needs;
3. the teachers prepare and present the courses in different ways (i.e. they no longer have a year or more to lead a group of students towards a set of final objectives);
4. the learning materials play a more important role;
5. and (to make conditions 1 to 4 possible) an effective organizational structure is in place.

Attention will be necessary for all of these consequences when shifting towards modular instruction. Underestimating the importance of one of these will lead to implementation problems (Dochy and de Wolf, 1989).

The difference between the traditional and the more fundamental point of view on modularization is outlined in the following schemes (figures 1 and 2).

Figure 1: Schematical representation of the common, obsolete view on modularization

In the traditional view, a module is a concise part of a curriculum with a defined entry-level and exit-level. The teacher takes decisions about the media on the basis of instructional reasons, typical for this module.

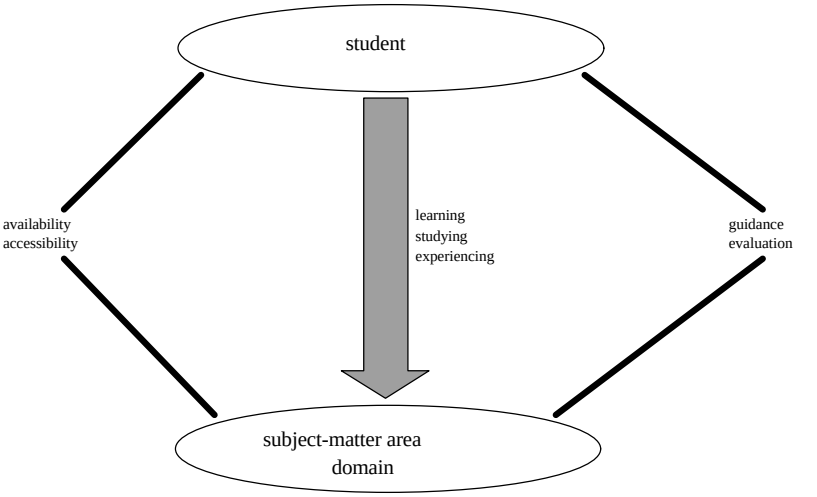

Figure 2: Schematical representation of the new, more fundamental view on modularization

The more fundamental view of modularization stresses that the student is the determinator in the whole instructional process. A module is a part of a learning process. The student is learning, studying and experiencing while moving towards mastery of a subject-matter area.

The student takes the availability and accessibility of subject- matter into account. He uses the educational materials he finds appropriate, he asks for guidance or assessment form a teacher or subject-matter expert. At the institutional level, the educational media, the guidance and tutoring can play a role in different modules related to the same or another domain.

2.1.3 Advantages of modular instruction.

The consequences of modularization can be looked upon as positive or negative, as advantages or disadvantages. However, if modularization is implemented with attention to all the stated conditions, it can have several definite advantages.

First, let us consider the advantages from the students' point of view. The advantages of modularization for students can be identified as being that:

- it allows the student to proceed at his own pace. The belief that self-pacing is desirable is based on the generally accepted assumptions that learners do not achieve at the same rate and are not ready to learn at the same time (Burns, 1971).

- it allows the student to choose his own learning mode. Choice between different learning modes is desirable if we assume that learners solve problems and learn using different techniques based on unique behavioural repertoires or prior knowledge (Burns, 1971). Modular instruction may therefore include a large variety of instructional activities, such as reading textbooks and articles, examining photographs and diagrams, viewing video-films and computer programs, examining demonstration materials, participating in projects and experiments, and participating in relevant 'extra curricular' activities.

- it provides choices between large varieties of topics within any given 'course' or discipline, which is important if we assume that students do not possess the same pattern of interest and are not purchasing the same goals (Burns, 1971).

- it allows students to identify their strengths and weaknesses and to 'recycle' through remedial modules, repetition, or a change in learning mode (Klingstedt, 1971). This is important if we assume that it is desirable to save student time (frequent evaluation permits early diagnosis) and to allow as many students as possible to attain the stated objectives (Goldschmid and Goldschmid, 1973). Recycling also means that the student does not have to restudy large amounts of subject content.

- moreover students can be tested earlier, progress and measures can be brought into line (control of duration of study);

Also, towards teachers and staff some advantages can be stated:

- a variety of instructional modes are possible within a module;
- modules are set up by an interdisciplinary team of experts;
- staff work can be reduced by means of self-study components with emphasis on the accompanying written materials;

- concentrated teaching sessions for the staff or only distance teaching, consequently providing more time for other activities;
- the option of developing new modules in that time, adjusting modules in line with the results of research and testing or in line with changes in the supply of education.

Advantages relating to the learning materials are as follows:

- the material can be presented thematically or in an integrated form;
- the material can be divided into functional units;
- the material can be adopted to the student's learning process.

Furthermore, relating to the organizational facilities, one can say that:

- there are more planning and developing options for programme designers and;
- the multifunctionality of modules can be seen as profitable.

Finally, the educational programme profits from:

- the exchange of modules with other institutions and;
- the fact that modules can be multifunctional.

2.1.4 The disadvantages of modularization.

Modular instruction can also have a number of possible disadvantages or problems (Goldschmid and Goldschmid, 1973). What students need to (but often do not) realize beforehand, is that:

- self-discipline has to be demonstrated in pursuing independent study;
- the shift from the lecture method (passive) to modular instruction (active) might be difficult for students;
- choice between the available resources (e.g. different instructional modes, modules, etc.) might prove frustrating;
- the self-pacing nature of modular instruction may have a delicate side-effect. Since some of the students will be fast and others slow learners and students will have more or less prior knowledge, learning efficiency and student output will be totally different between students.

For teachers and staff disadvantages could be:

- the considerable time required to design modules (other professional activities compete with a professor's teaching and course-preparation time);

- lack of concrete rewards;
- the tendency for time devoted to innovating instruction and optimalizing learning to go unrewarded;
- the removal of the professor's 'centre-stage billing': his feeling of authority vis-à-vis the 'audience' (his students), enhanced through one-way communication in traditional instruction, is diminished or eliminated and he might resent this loss;
- the shift from the lecture method (passive) to modular instruction (active), which could pose problems for staff just as it does for students.

Depending on the educational materials, the time required to design modules can be a major problem. Experience has taught that designing and constructing materials (written and CAI) takes more time and needs more prior knowledge than is usually anticipated.

The disadvantage in relation to the programme of the institution is as follows:

- switching between modules is possible when there is too little structure in the modular trajectories, with the result that the student does not see the connection between them.

Organizational facilities could, in some cases, be an obstacle:

- additional clerical time might be necessary to record which students have completed what modules, etc.;
- additional personnel may be required to assist in the setting up and running of equipment for several modules at a time;
- access to the instructional resources has to be maximized;
- grading and exam procedures must be adapted to modular instruction.

2.1.5 A comparison between traditional and modular

From 1960, there was a change in educational ideas which resulted in a number of necessary changes in educational practice. We can characterize these changes on a theoretical scale. A synopsis of the changed educational views is given in table 1 (Dochy and Van Luyk, 1987). We emphasize that we are speaking of a theoretical difference; consequently, in practice the division is not that strict.

Table 1: Changed educational ideas (taken from Dochy and Van Luyk, 1987)

← *Traditional views*	® *New views*
1. Knowledge is knowing that	Education is knowing that and knowing how
2. First theory then practice	Theory and practice in the curriculum
3. Subject-based education	Integrated education
4. Teacher-centred education	Student-centred education
5. Transmission of knowledge	Acquisition of knowledge
6. Educational programme	Study programmes
7. Staff is teaching	Staff is assessing, evaluating and assisting

A majority of these new insights are implemented in modular instruction. The modular course had from its inception a configuration which was in keeping with the trend towards change. As said before, these views have lead to concrete changes in practice. An overview of the differences between traditional and modular instruction is presented in table 2. The differences, mainly according to Postlethwaite and Russell (1971), must be seen as general, being applicable for all kinds of modular instruction, such as open distance education at the Open

University or problem-based learning at the University of Limburg, Maastricht. Again, the polarization is a theoretical one. In the practice of modularization, some of the characteristics move on a continuum between the stated poles.

Table 2: An overview of differences between traditional and modular instruction

Characteristic	¬ *Traditional Course*	*Modular Course* ®
Course success	Mostly judged subjectively by the instructor	Objectives and evaluation assure that the instructor is able to correct faulty instructional materials and knows when his course is successful in terms of student learning
Instructional activities	Mostly lectures and written assignments; media used on basis of instructor's personal feelings about them	Many different instructional activities are used to optimize learning; media used on efficacy established through trial use by students
Learning experience	Oriented towards teacher performance, with emphasis on teaching; knowledge transfer by the instructor	Oriented towards student performance and individual instruction with emphasis on learning; knowledge acquisition by the student
Mastery	It is expected that only a few students will do very well and some will fail	All students are expected to achieve mastery of the objectives at their own rates
Objectives	Usually not stated in precise observable terms	Stated in terms of students behaviours and presented before instruction begins
Participation	Passive	Active
Presentation of materials	Group-oriented at predetermi-ned times and places	Highly individualized materials; each student can access any or all of the instructional materials, available at preferred times and places
Rate (or pacing)	Students must all go at the same rate	Each student can proceed at his own rate
Reinforcement	Usually only after examinations	Immediate and frequent, after small units of material studied through all forms of assessment
Role of in-structor	Disseminator of information	Diagnostician, prescriber, moti-vator and resource person
Testing	Student typically takes one or two tests on the materials which determine his grade for the	Designed to measure entry-level, progress towards and mastery of the objectives stated at the

	entire course	beginning of the course; purposes are assessment of prerequisite knowledge, diagnosis of strenghts, weaknesses and mastery

In the following section we will explain briefly the nature of modular instruction as it have been used to date at the Dutch Open University. For a more extended and detailed elaboration of this matter we refer to Van den Boom (1988), Van den Brink (1989) and Van der Linden (1987).

2.2 Modular instruction at the Dutch Open University.

The programme offered by the Open University does not comprise complete pre-programmed disciplinary or year programmes, but independent courses which can be taken separately by the student in order to reach a totality of interrelated objectives. The courses are developed within domains. These are interrelated bodies of knowledge within which the different academic disciplines are represented.

Distinction is made between domains of study such as Law/Legal Studies, Economics, Business and Management Study, Technology, Natural Science, Humanities and Social Science. A course is developed within a particular domain, but will in many cases include elements from other domains. Furthermore the structure in which the courses are produced - a matrix structure in which course teams are brought together from one or more disciplines, and supplemented by educational technologists - are chosen so that the courses have a largely multi-disciplinary character. A course can therefore be applied to various programmes within various domains (multifunctionality).

A course comprises two or sometimes three modules which require 100, 200 or 300 hours of study each.

The written material is supplemented in some cases by material for computer applications, practical instructions and guidance from the study centres (for a more detailed description of the OU open learning system, see Kirschner, 1991).

In the study guide, a short description is given of each course. The description contains the following elements:

- the primary field of study within which the course has been developed;
- the number of hours required for the course;
- the level of the course;
- the entry situation, which includes knowledge and skills on which the course is predicated (the prior knowledge); and
- learning objectives, in terms of knowledge and skills that the student should possess at the end of the course.

The structure and the organization of the courses at the Open University offer the individual student maximum choice.

Flexibility is guaranteed by course structure, registration per course and the credit system. The subdivision of the courses into broad learning areas and the fact that the courses from one field can be part of study programmes in another increase the options available.

The student can make a personal choice from the courses on offer which relates to his/her wishes and preferences, in relation to occupation, interests, inclinations and/or social involvement.

2.3 Prior knowledge and modular instruction. .3 Prior knowledge and modular instruction

As we have stated earlier, when adopting a modular structure it is necessary to take account of the impact on separate components of education (see the conditions for successful implementation of modular instruction, part 2.1.2). Its impact upon the learner is, of course, one important aspect that needs to be considered.

First of all, modularization is directed towards more effective education in profit of the learner. With changing ideas about personal development in today's society, students will request a kind of instruction more fully in accordance with and appropriate to their personal characteristics and their prior knowledge.

Second, modular instruction creates the opportunity for students to work at their own pace. There is even the opportunity for students to skip a module or to work through it more quickly because of prior knowledge. This is the most radical phenomenon in respect of the return on instruction, both for the student and the institution.

Theoretically modular instruction should always include a pre-test to determine the level of the student. According to Goldschmid and Goldschmid (1973) this has the following consequences: "If the student does not have all required prerequisites, he may need prior instruction. If he is already competent in the area of a particular module, he can proceed to a more advanced module or to one with a different content. Upon completion of a module the student is again evaluated. If the post-

test indicates that the student has not achieved mastery of the module's objectives, he might be recycled through the module or through parts of it or he may take a remedial module. If he does succeed, he proceeds to the next (or, to another) module. The pre- and post-tests also allow for empirical validation of the module itself." We refer here to Goldschmid and Goldschmid not only because of their dealing with prior knowledge, but also because they are most widely referred to in all of the work on modular instruction.
The learner's options are charted in Figure 3.

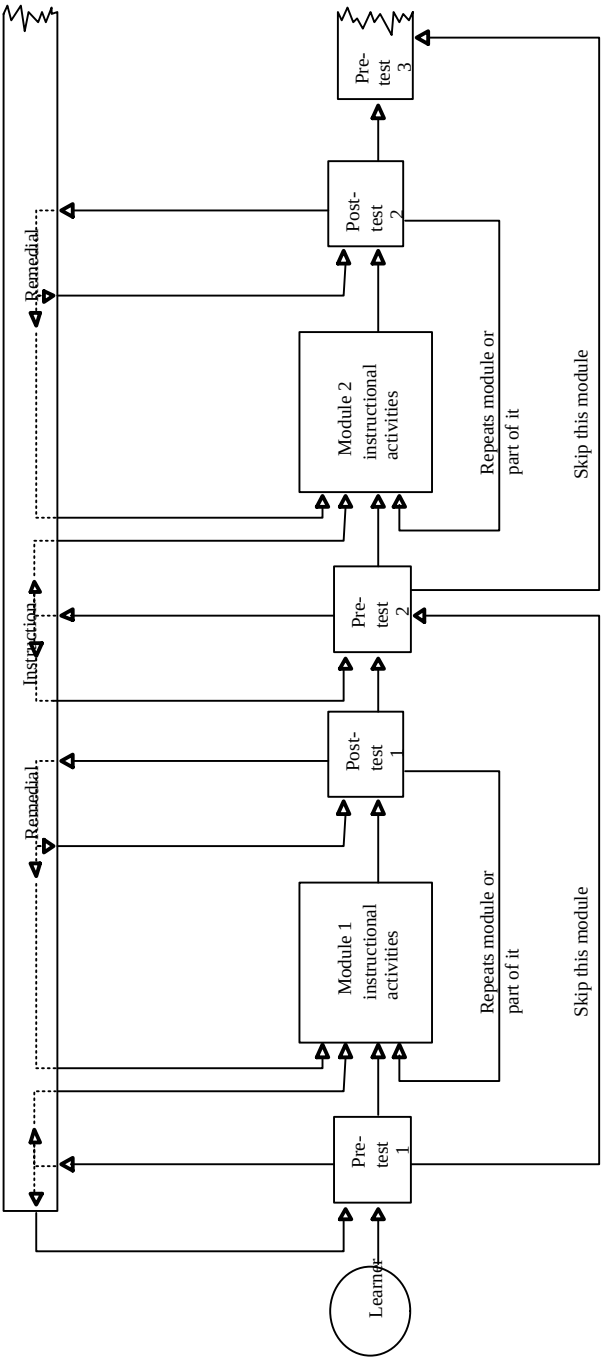

Figure 3: Flow chart of the learner's options in modular instruction (adapted from Goldschmid and Goldschmid, 1973)

This sort of approach actually makes it possible for students to follow individual paths as we described above, which relate to their prior knowledge. In this sense modular instruction is flexible and directed at individualization. There is always a spectrum of options offered in which prior knowledge in principle can be the determining factor in the choice. In this sense, it does not matter whether the prior knowledge deficiencies are made good within the module itself, within a remedial module or by the presentation of a large knowledge base. This brings us to speak about 'open learning systems', (Valcke, Dochy and Daal, 1991) which are more 'open' than the actual existing system in the following senses: the choice of learning objectives by the student is free; assessment becomes flexible in time and place; and assessment is used more explicitly for different functionalities. In open learning systems, a prior knowledge test can, apart from the above mentioned possibilities, lead students to a renewed choice of more appropriate learning objectives.

In this context, and in the light of returns to the institution and interinstitutional cooperation, the development of multifunctional modules has become a topic of discussion (de Wolf, 1988).
From the student's point of view, the domain specificity of the subject is important. When a student gets information on a subject, the first question is how much of the information can he or she understand, i.e. how proficient is he in the terminology. Science usually has its own jargon which has to be learned. Secondly, scientific arguments often present technical or scientific intellectual procedures, some even implicit ones, which have to be studied to be able to follow discussions on the subject. Thirdly, every discipline has its own
knowledge patterns and views which one can only master through much practice. Finally, every discipline requires domain-specific skills which one has to master.

The primary conditions for the design of completely multifunctional modules are that the information on the domain-specificity and on the student's prior knowledge should be taken into account. The view that the type of flexible instruction shown in the flow chart is only rendered feasible by using computer- based courses, may indeed be valid. Most forms of modular instruction offer a relatively vague indication of the required entry level.

It seems that students do not profit from these opportunities yet in every institution working on the base of a modular structure. Looking at the implementation of modular higher education at the University of Heerlen, it is striking, that few measures have been taken regarding the second stated condition, i.e. entry level. As mentioned earlier, the study guide contains a description of the expected entry situation for each course. This is rather general, i.e. in the form of subject-areas and titles of books, and without any considerations of the consequences for the intake, nor for the learning process. Hence, certain advantages of modular instruction

disappear, such as the identification of strengths and weaknesses of the student at the start.

The OU courses limit themselves to indicating the concepts assumed to be known by students, and listing the available literature. A true assessment of individual levels - with the resultant advantages that would give - does not occur. If one wants to adjust the return on education and allow the student to learn as efficiently as possible then it is necessary to explore these options. This last does seem to cause some trouble. Mapping a student's prior knowledge can be approached from various angles. Prior knowledge is more than just the knowledge acquired in earlier training and courses (see chapter 3). Experience which people acquire can to a degree influence the manner and the speed in which they learn to command new material. Furthermore, attention must be directed at relevant prior knowledge, in relation to the objectives of a certain task to be pursued. Working slowly towards an ideal situation vis à vis the learning path to be followed both within and between modules can be adopted as the basis of a research-based approach directed more explicitly at increasing returns.

3 Lessons of the past in instructional and cognitive psychology: 3 Lessons of the past in instructional and cognitive psychology:

3 Lessons of the past in instructional and cognitive psychology: the information-processing view on human cognition and individual differences

3.1 The Sternberg model of information-processing.

Past research in instructional and cognitive psychology has revealed interesting information related to the subject of our study. In general, the information-processing view on human cognition gives us useful handles.
Our choice for the information-processing view and the Sternberg model (1981, 1988) in particular can be argued as follows: first, the model starts from a dynamic view towards learning; secondly, the model holds a constructivist view by stating that new knowledge is in large part constructed by the learner; thirdly, it is mainly based on a knowledge-based approach. The knowledge-based approach assigns a central role to prior knowledge in the acquisition of new knowledge. Proponents of this approach argue that performance (e.g. use of metaphors, recall, chess performance) is due to differential knowledge states (Keil, 1984), prior knowledge in a domain (Chi, et.al., 1981) or differential knowledge structures (Chase and Simon, 1973).

Sternberg (1988) distinguishes among three kinds of information-processing components: metacomponents (control processes used for executive planning, monitoring and evaluation of task performance), performance components (processes in task performance such as stimuli encoding, inferring relations between stimuli, and applying a previously inferred relation to a new situation);

and knowledge acquisition components (Sternberg, 1988) or storage and retrieval components (Sternberg, 1981)(selective encoding, selective combination with previously acquired knowledge, and selective comparison by which the selectively encoded and combined information is related to the previously formed knowledge structures). Sternberg's information-processing model is presented in figure 4.

Prior knowledge, information-processing and individual differences

Next to the strong link between the chosen model and prior knowledge, i.e. the knowledge-based approach, also potential sources of individual differences are strongly related to prior knowledge. Research of the past decades, trying to make applications of theories of human cognition to the analysis of individual differences (Entwistle and Waterston, 1988), suggests two major dimensions along which these differences are manifested, i.e. the operating and the structural characteristics of the human information-processing system.

The operating characteristics of the system include speed and efficiency with which information is processed and managed. Analysis of high and low aptitude groups showed that individual differences exist in the speed with which stored memory representations and codes are accessed. It is also likely that differences result not only from the speed of basic processes, but the executive control or management in the selection and sequencing of these processes.

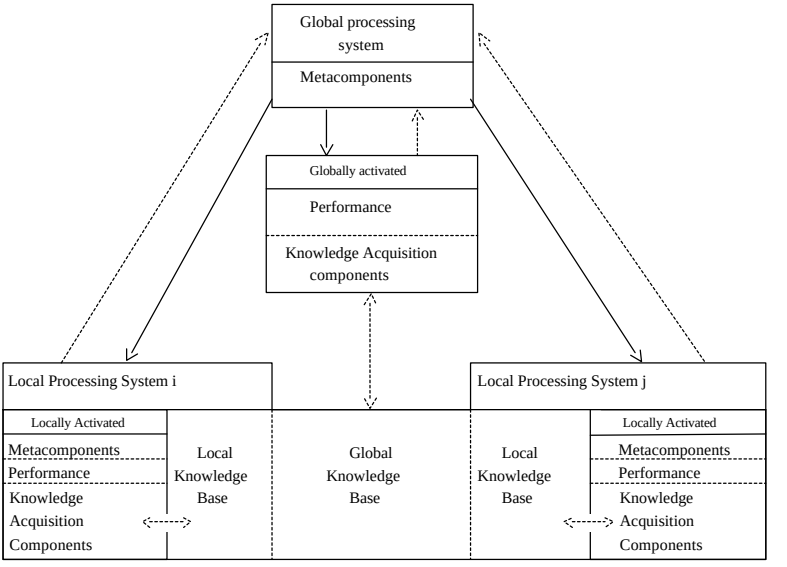

Figure 4: Sternberg's model of information-processing (1988)

Global processing is controlled; local processing is automatic. Solid arrows represent activation. Broken arrows represent passage of feedback. Metacomponents in the global processing system are able to instantiate themselves and other components in the local processing systems. Local processing systems are able to return the activation to the global system when their productions are unable to handle a problem.

Differences in the efficiency of executive control are revealed by analyses of item performance on psychometric tasks (Pellegrino and Glaser, 1979).

The structural properties of the information-processing system are discovered through task analytic studies of test item performance. These structural properties include storage capacity, knowledge structure in memory and availability of different types of knowledge. These are potential sources of individual differences that interact with the operating characteristics of the system and which will appear not surprisingly in the indexation of the prior knowledge concept (see chapter 3). Moreover, it was found that they are related to developmental level, educational history and general experience.

The components of intellectual performance, as they occur on test instruments, in environments for learning and in everyday life, can be related on increasingly more precise operational dimensions. Studies of inductive reasoning tasks have identified processes that seem to have reasonable relevance and generality. The rule induction processes involved in analogical reasoning and series completion appear to be similar to many forms of problem solving and concept formation. The essence of this similarity is the ability to search for relations among elements resulting in new interconnections between concepts stored in memory. Consistent with this contention, it has been argued that one of the learner's essential roles in learning is to recognize the structural form or pattern of the facts conveyed by instruction and to detect relations between this newly communicated material and the material already existing in a semantic network in memory (Norman, Gentner, and Stevens, 1976). As will be noted in the next chapter, the structure of prior knowledge will indeed appear to be important.

The research we will describe later on will take account of these structural and operational properties which are closely related to prior knowledge, as far as it enables a perspective of useful applications. According to Pellegrino and Glaser (1979), when we are able to specify cognitive components, we have information that enables us to do more than predict performance on a criterion task. We have information that provides a basis for doing something about performance - either by engaging in specific process training designed to improve performance or by changing the learning situation to make the attainment of criterion performance more likely.

The potential benefits that can be derived from an understanding of the cognitive components of individual differences are consistent with the nature and purposes of education. For many years, Glaser (1981, 1984, 1990) has been an advocate of what

we call the 'overall assessment prophecy'. This prophecy holds that it is no longer possible to consider assessment only as a means of
determining which individuals are already adapted to or have the potential for adapting to mainstream educational practice. A conceivable alternative goal is to reverse this sequence of adaption; rather than requiring individuals to adapt to means of instruction, the desired objective is to adapt the conditions of instruction to individuals to maximize their potential for success.

This objective can be realized if learning can be designed to take account of 'an individual's profile of knowledge and skills' (Pellegrino and Glaser, 1979). This is where the present study will aim at in the closing chapters.