TEKST NR 53 1982

THE CONSTITUTION OF SUBJECTS IN ENGINEERING EDUCATION

Arne Jakobsen & Stig Andur Pedersen

TEKSTER fra

IMFUFA ROSKILDE UNIVERSITETSCENTER
INSTITUT FOR STUDIET AF MATEMATIK OG FYSIK SAMT DERES FUNKTIONER I UNDERVISNING, FORSKNING OG ANVENDELSER

The constitution of subjects in engineering education

af Arne Jakobsen & Stig Andur Pedersen

IMFUFA tekst nr. 53 (1982), RUC.
24 s ISSN 0106-6242

Abstract:

For some time we have worked on a theory of constitution and development of technological and scientific teaching subjects. This article gives a systematic exposition of some main elements of our theory. The idea is to consider the constitution of subjects as a process where three important components has to be integrated. These components concern, respectively, epistemological, qualificational and instructional requirements. The integration of these components occurs as a system of justification of the content, structure, and delinitation of the subject.

THE CONSTITUTION OF SUBJECTS IN ENGINEERING EDUCATION

Arne Jakobsen - Stig Andur Pedersen.

This article has been written in conjunction with a project, "An investigation into the qualifications of engineers", financed by the Danish Social Science Research Council.

I The Nature of the Theory

Curriculum theory (Fachdidaktik) is concerned with teaching subjects, their development, constitution and function, as well as the all-round educational and socializing effects of teaching itself. It is not our intention in this article to discuss all aspects of curriculum theory, but one of its important parts, i.e. the constitution of teaching subjects.

The theory of constitution of teaching subjects, which will be expounded in the following, is concerned with the structure and development of teaching subjects. We consider that some characteristic features enter into the constitution of a teaching subject, and that a theoretical discussion of the process of constitution will make an important contribution to the understanding of many problems concerned with curriculum theory and pedagogy as a whole. Thus, a theory of constitution of teaching subjects must necessarily enter into a comprehensive theory of curriculum. To judge from the existing literature on curriculum theory, little interest has been shown in the constitution of teaching subjects. Therefore, in this article, we hope to be able to demonstrate the pedagogic and critical significance of a theoretical discussion of this process.

As previously mentioned, curriculum theory is concerned with many different factors relating to the teaching and constitution of a specific subject. For example, it is concerned with the socializing and attitute-forming process to which the students are exposed. This latter forms a reciprocal relation with the constitution of the subject: the socialization of the students depends on how the subject is constituted, whereas the constitution of the subject depends upon its socializing and all-round educational functions. We shall briefly discuss this phenomenon.

Much of the knowledge and many of the attitudes possessed by educated persons exist as "tacit knowledge"[1)] we have acquired both as a direct result and a side-effect of our education. This latter has helped us to establish a framework of understanding and to adopt certain attitudes which lay the groundwork for our professional activities[2]. It is obvious, of course, that as a teacher of a specific teaching subject one contributes to the constitution of this subject in the light of the framework of understanding derived during the course of one's own education. In this sense, any socialization undergone in such manner will affect the constitution of the subject.

The general educational circumstances affect the constitution of subjects in yet another way, namely by way of pedagogic conceptions, principles and theories. A teacher's contribution to the constitution of a subject is intimately connected with his or her conception of education and of how a teaching course ought to be organized, e.g. as to whether he or she wishes to employ an "exemplaricsh", structural, or other principle when organizing the teaching material.

It is very important to study these relations between socialization and general education on the one hand and the constitution of subjects on the other. It is also important to analyse and determine the all-round educational effects of advanced technological education, this involving both "technical rationality" and the formation of political attitudes established during the study of engineering[3].

In this article, however, we shall confine ourselves to the more limited task of considering some specific aspects of a theory of constitution of subjects. For the present we shall suspend the connection with the theories of socialization and all-round education, well knowing that these are essential aspects of an adequate theory of curriculum.

By way of introduction we shall briefly discuss the nature of our theory. It is not our intention to evolve a descriptive theory to be used for classifying existing technological subjects. We regard the constitution of subjects to be a continuous process of which, at any given time, a teaching subject forms a cross-section. The purpose of our work is to describe the mechanism that underlies the process of constitution, providing it with its dynamics. If it thus proves possible to analyse the dynamics of the process of constitution, the theory will obviously possess explanatory power. Although it will not constitute an empirical description of various subjects, it will be able to form the basis of an explanation as to why the subjects, at any given time, possess the structure and function they in fact have. The theory can be used to identify some important preconditions for the actual structure and function of certain subjects. Thus, not only can it be used for systematizing various subjects and discussions thereof, but can be used critically as a basis for an assessment of the structures, importance and weighting of these subjects within the system of technical and scientific education.

The theory of constitution of teaching subjects has the specific subject as its object of investigation. Consequently, in relation to the subject in question it is a meta-theory on a par with other meta-theories, as for instance the philosophy of science and the philosophy of technology. An epistemological analysis of a scientific subject does not constitute a contribution to the science concerned, but can contribute to an understanding of its nature and function. Similarly, the philosophy of technology is not itself technology, but can contribute to technology's understanding of its own role and significance. First and foremost, a meta-theoretical analysis helps to develop professional self-understanding and consciousness, and thus its function is primarily critical. Hereby it is also of importance to the technological subject itself, because it influences the estimation of the subject's significance and its developmental trends. We regard the theory of constitution of subjects as having a like function: it forms an essential part of an analysis of a teaching subject's developmental tendencies.

II The Constitution of Teaching Subjects

In all types of education new teaching subjects are being created and existing subjects altered. The constitution of subjects forms a continuous process during which the content of knowledge and skill, its structure and delimitation, are determined. It is consideration for the representation of the basic disciplines, for qualificational requirements and mode of instruction, that determines this constitutional process (see Fig.1). Thus, we may talk about components in the constitution of subjects relating to epistemology, qualification theory and theory of instruction.

Consideration for: Determination of a subject's:

basic disciplines — contents
qualifications — constitution of subjects — delinitation
instruction — structure

Fig. 1: Constitution of subjects.

These considerations may be - though are far from always - coined in didactic principles, where, by "didactic principle" We mean an explicitly formulated precept or deliberation concerning the determination of content, structure and/or delimitation of teaching subjects.

1. The epistemological component

A teaching subject is usually constituted on the basis of a certain field of knowledge represented by one or more specific areas, the basic disciplines. For example, the teaching subject may be based on scientific knowledge, in which case the basic disciplines will consist of one or more scientific disciplines.

We shall now take a closer look at the existing relations between teaching subjects and basic disciplines in the study of engineering. The relations between these subjects, however, are not so direct and unproblematic as they are sometimes represented. This is due, firstly, to the fact that teaching subjects are related to the production of knowledge as well as to its application. Secondly, some of the subjects in engineering education are founded on technological knowledge, craftmanship and skills, as well as on scientific disciplines proper. To understand the constitution of these subjects it is necessary not only to study the interrelations between various types of basic disciplines and between various types of teaching subjects, but also the relations between basic subjects and teaching subjects. Furthermore, it is necessary to investigate the epistemological status of technology.

The different types of subjects and the relations between them can be illustrated as shown in Fig. 2, where the vertical lines represent the relations between the basic disciplines and teaching subjects, and the horizontal lines, the relations between pure science and technological knowledge, on the level of basic disciplines and teaching subjects respectively.

1. Scientific disciplines	2. Technological knowledge
3. Teaching subjects with content of scientific knowledge	4. Teaching subjects with content of technological knowledge

Fig. 2: Relations between basic disciplines and teaching subjects.

A concept central to both epistemology and pedagogics is the <u>concept of structure</u>. This concept can form the basis of an illustration of the different categories in the diagram (Fig. 2). At the same time we are able to illustrate the delimitation of the content of the subjects as well as the different types of knowledge forming part of the subjects.

Generally speaking, we define structure as the prevailing order in the relations between different parts of the content of a subject. We shall examine structures, both in basic disciplines (1 & 2 in Fig. 2) and in teaching subjects (3 & 4 in Fig. 2).

An example of the significance of the concept of structure in scientific disciplines is given by Kuhn's idea of "disciplinary matrix". According to Kuhn, the structure of a field of scientific research is that of a disciplinary matrix. Such a matrix contains, among other things, the following elements: (1) symbolic generalizations, i.e. general laws, such as Newton's Second Law; models, of both a metaphysical nature (such as the atomistic conception of a substance) and a heuristic nature (such as the hydrodynamic model for electric current); (3) values, such as specific requirements concerning consistency, exactitude, etc.; (4) models constituting prototypes of how the research is to be carried out[4].

Like other epistemological concepts of structure, Kuhn's concept of paradigm (i.e. concept of disciplinary matrix) is associated with a subject or a discipline in toto. Structure in the form of organization of knowledge around separate parts of the theories or of solutions to problems is subordinate to the disciplinary matrix constituting the primary structure.

Different, however, is the situation as regards the structure of technological knowledge. Here the primary structure or organizing principles are associated with specific practical problems and their solution. Typically, it is around the latter that technological knowledge is organized. In the field of structural engineering, for example, theory and methods are organized around certain types of constructions. In sanitary engineering, for example, the various forms of knowledge are organized around problems concerned with the design of water supplies and drainage systems.

Thus, the structure found in technological subjects (in the sense of basic disciplines, category 2 in Fig. 2) is secondary, and often based on categorizations of problems for which technological knowledge has been developed in order to solve. Seen in this light, it is understandable that the delimitation of technological disciplines is often vague and uncertain. A piece of knowledge can be applied to many different disciplines, and it may be difficult to determine the discipline to which various practical problems should be referred.

We have hereby touched upon types of structure found in basic disciplines (categories 1 & 2 in Fig. 2). In teaching subjects (categories 3 & 4 in Fig. 2), pedagogic considerations in connection with the progression of notions, the forming of meaningful sequences, making knowledge concrete, etc., will have an effect on their structure. Additionally, there have existed pedagogic principles, which have prescribed - at any rate within the teaching of science - the use of the structure of the scientific discipline concerned as structure in the teaching subject. A similar prescription with regard to a theoretical discussion of the structure of technological subjects is not seen. An investigation of structure in a number of technological subjects, carried out in conjunction with the development of the theory in question[5)] shows that such subjects often build upon a relation to the practice at which the subject is aimed.

2. Qualification theory component

In the process of constituting teaching subjects the question as to how the subject qualifies will always play a part. Such considerations are especially important in vocational training.

It is our opinion that industrial conditions and industrial development largely determine the requirements regarding qualifications, where by "industrial conditions" we mean competitiveness, division of labour, type of trade and technology, etc. It is appropriate to divide the determination of qualification requirements into three types.

Firstly, specific qualifications may of course be required at various times. These may be purely professional qualifications, or qualifications such as stability and responsibility.

Secondly, development within technology, including the technical aids used in engineering practice, and development within the organization of engineering jobs, causes a change in the type of problems engineers have to solve. This in turn may cause a change in the qualification requirements.

Thirdly, a change in the qualification requirements may be due to the altered character of technological knowledge. Thus, for example, technically-determined possibilities for more advanced - and scientifically correct - methods of calculation (i.e. computer aided calculations) may lead to a change in qualification requirements. Or it may be due to a development in which technological knowledge will be based on system theory.

3. The instruction theory component

A number of the factors entering into a determination of the constitution of subjects are internal in relation to the teaching institution in question. This applies to schedules, organization of subjects and the purely physical educational framework, as well as to the teaching methods and media employed by the institution, the background of both teachers and students, etc. We have assembled such factors, which are widely different in character, into a component we call the instruction theory component.

A good example thereof is the fact that the total contents of the study of engineering in Denmark is at present divided up into partly optional modules, each not exceeding half a year's duration. An examination is taken after the completion of each module, and the study of engineering is thus pieced together out of the recognized participation in a number of such point-giving units.

Obviously, the introduction of such a system has an influence on the content, delimitation and structure (i.e. the constitution) of subjects[6]. Firstly, it must be anticipated that the normal effect of examinations in focusing upon certain types of knowledge and understanding, and thereby upon certain types of content, is reinforced in such a system. The type of knowledge, understanding and experience which cannot be reproduced in examination form after the half year is over must necessarily be given a lower priority.

Secondly, the fact that a process of learning has to be completed within half a year must have an affect on the nature of the content and on the experience gained by the students.

Furthermore, the system splits up the students, since these tend to change group every half year. This curtails the use of pedagogic principles when compared with a longer course of concrete studies. Nor will the students have the same chance of gaining insight in the subject by means of discussion and acquiring influence thereby on the constitution of subjects.

4. Constitution of teaching subjects - an example

We shall now attempt by means of an example to indicate some possible contents with which to fill out the above schematization of the components of the constitution of subjects. At the same time we shall point out some curriculum problems resulting from the technological development which has been taking place within the field of building materials. In slightly simplified form, this development can be characterized thus:

1. More and more materials become relevant as building materials. One only has to think of the number of plastic materials developed within recent years for widely different purposes within the building sector.
2. Engineers to a greater and greater extent use the materials in the form of building components, the content and composition of which are veiled in obscurity. This probably applies most markedly to such construction elements as walls or facades.
3. Several of the "new" materials, such as the above-mentioned plastics, have a complicated scientific structure.

This development obviously affects the qualification requirements for those engineers dealing in some way or other with building materials. A closer analysis of this development and of the qualifications required of various groups of engineers concerned in different ways with building materials belongs under the qualification theory component.

Under the epistemological component belong analyses contributing to an understanding of the nature and development of the knowledge contained by the teaching subject. We have already outlined the main categories of knowledge contained in the study of engineering, i.e. scientific knowledge, various forms of technological knowledge and practical skills or craftsmanship.

An important element in the distinction between these forms of knowledge is the way in which they are justified. We shall consider two aspects of the justification of knowledge. Firstly, when justifying knowledge it may be important to observe the rules for verification and internal consistence. Such justification characterizes the production of scientific knowledge. On the other hand, justification may consist of practical validity, i.e. a high degree of probability of practical expediency or efficiency. This type of justification characterizes both knowledge or craftsmanship and many types of technological knowledge.

Secondly, it is a matter of importance as to whether the kind and extent of the justification is explicitly stated. In scientific knowledge, as a rule the justification - and the limits of its validity - is clearly stated. Where technological knowledge or craftsmanship is concerned, justification is not so explicitly stated, sometimes not at all; there is often very little interest in doing so. Furthermore, the determination of the limits of validity of technological theory and methods may give rise to practical problems.

The development of the constitution of teaching subjects concerned with building materials may be envisaged as proceeding in several different directions; this has in fact been observable in technological and scientific education. An attempt to keep pace with development may be made by increasing the amount of traditional technological knowledge on the curriculum. This possibility has its limits, however, not only on account of the rapidly growing amount of knowledge, but because the problems connected with determining the limits of validity for methods based on experience are growing, especially where development is accelerating.

It is also possible to develop - and to teach - methods for analysing properties determined by function and for analysing the specifications of building components and materials. Such teaching naturally provides no true understanding of the structure and properties of materials, and would only be applicable until the system is "overhauled".

In addition, it is possible to provide teaching which contains scientifically correct knowledge of the properties of materials, i.e. teaching which includes knowledge of the validity (and its limits) of the knowledge in question. Such knowledge, however, has frequently little application to other subjects, where an operational knowledge of materials is demanded.

The instruction theory component comprises among other things a consideration of the relations bewteen the teaching subject (e.g. in the alternative forms mentioned above) and other parts of the training - between the basic scientific disciplines and the teaching subject, for example, or between the subject in question and other teaching subjects to which its knowledge is applied.

Moreover, several aspects of the problems described above can be seen in the light of general pedagogic theory. Developmental tendencies which stress methods rather than facts, or which tend towards the general (here, a knowledge of pure science) constitute well-known patterns within curriculum theory. There is a danger of error here, however, if the problems are interpreted as only general pedagogic problems and a more detailed analysis of the subject in question is omitted. Although it is generally supposed that technology is a direct application of science - an applied version of pure science - a closer analysis shows that much technological knowledge is only indirectly related to scientific knowledge. Thus, a greater emphasis on scientific knowledge does not necessarily constitute a tendency towards the general.

The question as to which tendencies gain the upper hand and how teaching subjects are actually constituted will, in our opinion, partly depend on the factors outlined above. Such deliberations are often implicit, and mixed up with other interests, such as questions of institutional policy, etc. We also consider that a more widespread understanding of the matters in question would produce a more rational debate and thus a more rational constitution of subjects, for the sheer fact that the premises underlying assertions and points of view need to be clarified and made explicit.

III The Coherency of Justification

In the process of constituting teaching subjects, the content, delimitation and structure are decided upon. As indicated, this process is based on considerations regard ing qualifications, basic disciplines and matters concerning the instruction.

This determination comprises all the elements of the subject, including theory, skills and exercises; it comprises their presence and relative placing.

Thus, the presence of an element, whether it be part of a subject or the subject as a whole, may be justified according to the part played by the element in the subject. It may be justified on the basis of its relation to other elements or to the practice for which the subject qualifies. Justification, however, may also be based on values, conceptions and ideas about education, or about technology and science.

We shall examine the following forms of justification:

- justification of practical elements of content because their aim is more or less directly to provide possibilities of action towards certain types of problems in practical situations (seen from an educational point of view),
- justification of some elements of content because they constitute the theoretical basis for other elements,
- justification of some elements of content because they concretize the knowledge included in other elements,
- justification of some elements of content because they are related meta-theoretically to other elements.

Consequently, justification concerns (1) the coherency between the elements of a subject or of the content of education as a whole (2) conceptions of the particular practice at which the subject aims, and (3) the explicitly expressed purpose of the education.

Furthermore, the contents may be justified on the basis of conceptions, values or attidudes which, in principle, lie beyond such coherency, i.e. conceptions of the role of education or of the relation between science and technology. In the latter case we are in fact concerned with legitimization, i.e. the concept of justification, as used here, is more comprehensive than that of legitimization.

1. The framework of understanding

It may be difficult to determine the form of justification involved in a given context. One or more of the forms of legitimization and justification mentioned above will often appear simultaneously.

To a certain degree all justifications of content are legitimizations, in so far as justification comprises aspects which possess relations over and above the coherence between teaching subject and practical aim of the education. In the last instance the justifications, in order to be meaningful, must refer to some fundamental ontological, epistemological, political or moral assumptions and attitudes, or to some conceptions of value.

These fundamental assumptions constitute our primary orientation in the world. On the ultimate level they correspond to Heidegger's concept of "Entwurf"[7], which constitutes the fundamental categorization of the world and of our pattern of action, and forms the foundation of every understanding.

It is not our intention here to go into detail. Of greatest importance to us is the fact that, at a more abstract and fundamental level than that of epistemology and theory of technology there are some assumptions, categorizations and attitutes which are of importance for our concrete understanding, and which form a categorical framework for reasoning and argumentation. All justifications operate within this categorical framework, which we call framework of understanding.

It is on the basis of such frameworks of understanding that different attitudes to and conceptions of technology, society and technological education are outlined. This applies, for example, to both the conception of technical rationality and the attitude to problem-solving which characterizes engineering. This applies to the fundamental conceptions of the relations between science, technology and society - conceptions which among other things are coined in concrete theories of technology and science. Furthermore, this applies to the normative attitudes towards morality, politics and education which form the basis of concrete conceptions of general education and didactic principles, etc.

2. Justification

We shall now examine each of the above-mentioned forms of justification.

a. Relation to practice.
The utility-directed parts of a subject must be related to a conception of practice, because knowledge of the subject provides understanding and a possible course of action when faced with problems and situations in an envisaged practice. There are two aspects of this relationship:

1. The nature of the given possibilities of action, which may be a question of specific methods or of a wider background of knowledge.
2. The extent to which the problems and situations for which possible courses of action are provided are unequivocally defined.

For example, the qualifications provided by the teaching of such engineering subjects as that of structural engineering has in some instances consisted of exercises in the use of certain methods for calculating constructions exposed to specific loads, i.e. the question here is of directly providing courses of action in the form of specific methods for solving clearly defined problems. On the other hand, a subject like the theory of materials, at any rate in some of its forms, provides knowledge which only in a very indirect way gives increased possibilities for action when faced with problems or situations which are only very broadly defined.

A third type of relation is to be seen in subjects like the theory of construction, which aims to provide possibilities for action in a very broad spectrum of problems, such action being in the form of specific methods. The development of system engineering can be regarded as an attempt to make such a type of relation possible.

b. Theoretical preconditions.

It is possible to identify parts of a subject - even whole subjects - which are aimed at utility in the sense that the knowledge they comprise provides understanding and possible courses of action when carrying out industrial functions. Other subjects - or parts thereof - contain knowledge which forms a theoretical precondition for utility-directed subjects. This applies, for example, to certain forms of mathematics and physics, which are preconditions for the understanding of a subject like statics.

Such coherencies of preconditions can be extended "backwards", so that subjects which in themselves constitute a theoretical precondition for other subjects have in turn other subjects as their preconditions. For example, the theory of continuous functions, i.e. knowledge of limits and continuity, constitutes a precondition for differential calcules in most types of mathematics teaching.

Thus, coherency of justification in the form, coherency of preconditions, is to be found not only in the individual subject but in larger sections of education and often enters into the structure of a subject.

Moreover, the same two aspects may be found as in the relation to practice:

1. The question as to whether it is a matter of specific methods or, more loosely, of providing a framework or background of understanding.
2. The extent to which the problems or relations for which theoretical preconditions are unequivocally defined.

There may be reason to point out that such coherency of preconditions does not as a rule constitute any logical necessity, but is only one specific way of organizing the contents of a subject. For example, the teaching of mathematics can be organized in such a way that differential quotients are dealt with before - and form a precondition for - the theory of continuous functions. This does not mean that the order of these concepts is logically arbitrary, but that it is possible to adhere to different didactic principles. Naturally, fields may also be found - in mathematics, for example - in which the order of concepts is arbitrary, but where concepts - as far as teaching is concerning - form preconditions for one another. Thus, if we consider the fundamental concepts in elementary geometry, reflection, for example, may be selected as a basic concept from which the properties of congruence may be derived, or vice versa.

So far we have mentioned theory as forming the precondition for other pieces of theory, which - in advanced education - is the most common. In basic vocational training, where the utility-directed subjects (or parts thereof) often include manual skills, theory may form the precondition for these manual processes or for understanding the context in which the manual processes are carried out.

c. Concretization

It is often necessary to concretize the theory contained in the study of engineering, both the scientific and the technological theory. In many cases this need is sufficient to justify the exercises and projects, although they can of course have other - possibly legitimizing - functions[8].

Furthermore, the concretization of concepts can be used as a substitute for that part of the contents which forms the theoretical precondition for other parts. Thus, concretization will often play a role when an adequate study of the theoretical preconditions lies beyond the practical possibilities. Many such examples can be seen in technical education. In mathematics teaching, for example, a study of the extremely comprehensive theoretical preconditions for an understanding of Laplace transformations is replaced by a series of exercises designed to concretize Laplace transformations and their application.

Here, a distinction must be made between two forms of concretization, involving different relations between the theoretical system of concepts and the reality represented by the exercise.

On the other hand, the exercises can be organized so that they merely facilitate the learning and understanding of a system of concepts, i.e. so that the exercise is adjusted to and confirms the theory. This we shall term <u>assimilation</u>[9)], i.e. the exercise is assimilated under the theory or system of concepts. This has been prevalent in basic laboratory exercises, where the exercises have been so designed as not to achieve results which might cast doubt upon the theory. Circumstances necessarily involving results that might diverge from the theory are regarded as disturbance to be eliminated or disregarded.

On the other hand, circumstances may be such that practice cannot easily be assimilated under the system of concepts. In this case it is the theory, the system of concepts, which must be adjusted to practice. This we shall term adaption.[9)]

As to whether it is preferable, in teaching, to select exercises which confirm the theory or exercises in which the theory is tested and adjusted to practice depends on the circumstances, i.e. among other things, whether the content represented by the theory consists of pure scientific or technological knowledge.[10)].

d. Meta-theoretical relations

Subjects with a content of epistemology and technology assessment, as well as some types of social studies, have as their field of study aspects of other disciplines. Thus, their relation to these is meta-theoretical. In advanced technical education teaching in such subjects has in recent years been planned and carried out, especially as regards education dealing with the preconditions for, and consequences of, technological development.

3. Legitimization

When the content is justified in accordance with conceptions or values lying beyond the coherency between elements of content and the conception of practice mentioned above, it constitutes a matter of legitimization (in our specific use of these concepts).

The legitimization of teaching contents is often unconscious and, as is also the case with other coherences of justification, legitimization is seldom explicit except what appears from the educational aim of the subject.

There are many ways of determining the validity of a legitimization. In some cases it may be determined in accordance with the existence of a logically consistent relation to a conception of value, in other cases, in accordance with the truth or falsity of this conception. In still other cases legitimization lies beyond conceptions of truth or falsity. This does not make it any less important, however, to determine the type of legitimization.

Of considerable interest is the fact that invalid legitimizations often appear to be ideologically distorting, and we shall examine some examples to illustrate this phenomenon.

As previously indicated, it is characteristic for many engineering subjects that they comprise two types of knowledge, i.e. both theory and methods designed for solving practical problems (technology) as well as scientific knowledge proper. In many cases, pure science appears as a theoretical precondition for the applied parts of subjects. In many cases, however, this is not the case. The scientific component is not justified by forming a theoretical precondition, but is legitimized in accordance with a conception of technological knowledge as being synonymous with applied science.

Another example of legitimization concerns the importance of exercises in the study of engineering. It is very common to see exercises organized in such a way as to test or verify laws of nature, i.e. they concretize theory by way of assimilation. Such verification is in reality illusory, because this type of exercise is not justified according to a wish to concretize theoretical knowledge, but legitimized in accordance with an exaggerated idea of the importance of the basic sciences for engineering.

Both these examples illustrate a type of legitimization we regard as crucial as far as conceptions and values in the various forms of engineering education are concerned. It is based on a conception of engineering which, to a higher degree than there is reason for doing, emphasizes its close relation to science, while at the same time depreciating the conception of engineering work as constituting social application of technological theory and method.

IV Conclusion

Thus, the contents, limitation and structure of a teaching subject is laid down in accordance with the way in which different justifications and legitimizations have determined the presence and placing of the separate elements of the subject.

The present theory of constitution of subjects comprises different levels. The lowest level is made up of concrete forms of justification and legitimization. This in turn is subordinate to more abstract relations to basic disciplines, qualifications and instruction, whereas - on the most abstract level - is the relation to our basic framework of understanding. Connected with the theory of constitution of subjects are of course traditional pedagogic theories and principles. Thus, theories connected with our conceptions of general education (Bildung) are concerned with the intermediate (the qualification theory component) and the highest levels (our basic framework of understanding) in the theory of constitution of subjects. Correspondingly, didactic principles are concerned with the three components on the intermediate level. Consequently, as far as genetic or pedagogic principles are concerned, the instruction theory component will be given priority, while, as far as certain structural principles are concerned, great importance will be attached to the logical structure of the basic discipline. Furthermore, the didactic principles concerning key qualifications, as formulated by Mertens, are essentially connected with qualification theory.

The theory of constitution of subjects represents part of the outcome of our work on advanced technical education, from which our examples and empirical material is also derived. We consider, however, that many of the conclusions we have reached possess such a degree of generality as to be applicable to didactic investigations of other types of education.

Notes

1) Cf. M. Polanyi: Personal Knowledge, Routledge & Kegan Paul, London 1958.

2) An epistemological example thereof is the importance of examplars in the Kuhnian sense have in the formation of scientific knowledge. Cf. Thomas S. Kuhn: The Structure of Scientific Revolutions, Chicago 1962.

3) On the other hand, it must be stressed that knowledge of a subject's constitution is in fact a necessary prerequisite, if a discussion of the general educational effects of advanced studies of a specifically technical nature is to be relevant to the subject concerned.

4) See, for example, Thomas S. Kuhn's Reflections on My Critics, from I. Lakatos, A. Musgrave (eds.): Criticism and the Growth of Knowledge, Cambridge 1970, p. 271.

5) See Arne Jakobsen: Constitution of subjects in technical-natural scientific educations. Two working Papers. (Statens Erhvervspædagogiske Læreruddannelse). The Royal School of Education for Teachers in Commercial and Technical Colleges and The University Center of Roskilde, 1980.

6) This "module system" has been introduced in the study of engineering during the course of the past ten years. No assessment of the possible pedagogical consequences appears to have been taken.

7) M. Heidegger: Sein und Zeit, Tübingen, 1976.

8) See "Report on a partial investigation" concerned with the project: Reasons for undertaking curriculum analyses within vocation training: exercises, tasks and projects in the study of engineering, 1979, National Teacher's Training Course in Vocationally Orientated Pedagogics, and

see Part II in Arne Jakobsen and Stig Andur Pedersen: Didactic Analysis of Subjects in Engineering Education, the content of this being based on material from the project: "The basis of didactic analysis" undertaken by Arne Jakobsen in The Royal School of Education for Teachers in Commercial and Technical Colleges.

9) The concepts of assimilation and adaption are founded in M. Polanyi: Personal Knowledge. Towards a Post-critical Philosophy, London 1958, and diverge slightly from the way in which they have been applied in psychology.

10) See Arne Jakobsen and Stig Andur Pedersen: Didactic Analysis of Subjects in Engineering Education. European Journal of Engineering Education 4 (1980) pp. 261-284.

1/78 "TANKER OM EN PRAKSIS" - et matematikprojekt.
Projektrapport af Anne Jensen, Lena Lindenskov, Marianne Kesselhahn og Nicolai Lomholt.
Vejleder: Anders Madsen.

2/78 "OPTIMERING" - Menneskets forøgede beherskelsesmuligheder af natur og samfund.
Projektrapport af Tom J. Andersen, Tommy R. Andersen, Gert Kreinøe og Peter H. Lassen.
Vejleder: Bernhelm Booss.
Nr. 2 er p.t. udgået.

3/78 "OPGAVESAMLING", breddekursus i fysik.
Lasse Rasmussen, Aage Bonde Kræmmer, Jens Højgaard Jensen.

4/78 "TRE ESSAYS" - om matematikundervisning, matematiklæreruddannelsen og videnskabsrindalismen.
Mogens Niss.
Nr. 4 er p.t. udgået.

5/78 "BIBLIOGRAFISK VEJLEDNING til studiet af DEN MODERNE FYSIKS HISTORIE".
Helge Kragh.

6/78 "NOGLE ARTIKLER OG DEBATINDLÆG OM - læreruddannelse og undervisning i fysik, og - de naturvidenskabelige fags situation efter studenteroprøret".
Karin Beyer, Jens Højgaard Jensen og Bent C. Jørgensen.

7/78 "MATEMATIKKENS FORHOLD TIL SAMFUNDSØKONOMIEN".
B.V. Gnedenko.
Nr. 7 er udgået.

8/78 "DYNAMIK OG DIAGRAMMER". Introduktion til energy-bound-graph formalismen.
Peder Voetmann Christiansen.
Nr. 8 er udgået.

9/78 "OM PRAKSIS' INDFLYDELSE PA MATEMATIKKENS UDVIKLING". - Motiver til Kepler's:"Nova Stereometria Doliorum Vinarioum".
Projektrapport af Lasse Rasmussen.
Vejleder: Anders Madsen.
Nr. 9 er p.t. udgået.

10/79 "TERMODYNAMIK I GYMNASIET".
Projektrapport af Jan Christensen og Jeanne Mortensen.
Vejledere: Karin Beyer og Peder Voetmann Christiansen.

11/79 "STATISTISKE MATERIALER"
red. Jørgen Larsen

12/79 "LINEÆRE DIFFERENTIALLIGNINGER OG DIFFERENTIALLIGNINGSSYSTEMER".
Mogens Brun Heefelt
Nr. 12 er p.t. udgået.

13/79 "CAVENDISH'S FORSOG I GYMNASIET".
Projektrapport af Gert Kreinøe.
Vejleder: Albert Chr. Paulsen

14/79 "BOOKS ABOUT MATHEMATICS: History, Philosophy, Education, Models, System Theory, and Works of Reference etc. A Bibliography".
Else Høyrup.

Nr. 14 er p.t. udgået.

15/79 "STRUKTUREL STABILITET OG KATASTROFER i systemer i og udenfor termodynamisk ligevægt".
Specialeopgave af Leif S. Striegler.
Vejleder: Peder Voetmann Christiansen.

16/79 "STATISTIK I KRÆFTFORSKNINGEN".
Projektrapport af Michael Olsen og Jørn Jensen.
Vejleder: Jørgen Larsen.

17/79 "AT SPØRGE OG AT SVARE i fysikundervisningen".
Albert Christian Paulsen.

18/79 "MATHEMATICS AND THE REAL WORLD", Proceedings of an International Workshop, Roskilde University Centre, Denmark, 1978. Preprint.
Bernhelm Booss & Mogens Niss (eds.).

Nr. 18 er udgået.
Bogudgivet på "Birkhäuser Verlag", 1979.

19/79 "GEOMETRI, SKOLE OG VIRKELIGHED".
Projektrapport af Tom J. Andersen, Tommy R. Andersen og Per H.H. Larsen.
Vejleder: Mogens Niss.

20/79 "STATISTISKE MODELLER TIL BESTEMMELSE AF SIKRE DOSER FOR CARCINOGENE STOFFER".
Projektrapport af Michael Olsen og Jørn Jensen.
Vejleder: Jørgen Larsen.

21/79 "KONTROL I GYMNASIET - FORMÅL OG KONSEKVENSER".
Projektrapport af Crilles Bacher, Per S. Jensen, Preben Jensen og Torben Nysteen.

22/79 "SEMIOTIK OG SYSTEMEGENSKABER (1)".
1-port lineært response og støj i fysikken.
Peder Voetmann Christiansen.

23/79 "ON THE HISTORY OF EARLY WAVE MECHANICS - with special emphasis on the role of realitivity".

24/80 a+b "MATEMATIKOPFATTELSER HOS 2.G'ERE".
1. En analyse. 2. Interviewmateriale.
Projektrapport af Jan Christensen og Knud Lindhardt Rasmussen.
Vejleder: Mogens Niss.

Nr. 24 a+b er p.t. udgået.

25/80 "EKSAMENSOPGAVER", Dybdemodulet/fysik 1974-79.

26/80 "OM MATEMATISKE MODELLER".
En projektrapport og to artikler.
Jens Højgaard Jensen m.fl.

Nr. 26 er p.t. udgået.

27/80 "METHODOLOGY AND PHILOSOPHY OF SCIENCE IN PAUL DIRAC's PHYSICS".
Helge Kragh.

28/80 "DIELEKTRISK RELAXATION - et forslag til en ny model bygget på væskernes viscoelastiske egenskaber".
Projektrapport, speciale i fysik, af Gert Kreinøe.
Vejleder: Niels Boye Olsen.

29/80 "ODIN - undervisningsmateriale til et kursus i differentialligningsmodeller".

Projektrapport af Tommy R. Andersen, Per H.H. Larsen og Peter H. Lassen.

Vejleder: Mogens Brun Heefelt

Nr. 29 er p.t. udgået.

30/80 "FUSIONSENERGIEN - - - ATOMSAMFUNDETS ENDESTATION".

Oluf Danielsen.

Nr. 30 er udgået.

Udkommer medio 1982 på Fysik-, Matematik- og Kemilærernes forlag.

31/80 "VIDENSKABSTEORETISKE PROBLEMER VED UNDERVISNINGSSYSTEMER BASERET PÅ MÆNGDELÆRE".

Projektrapport af Troels Lange og Jørgen Karrebæk.

Vejleder: Stig Andur Pedersen.

32/80 "POLYMERE STOFFERS VISCOELASTISKE EGENSKABER - BELYST VED HJÆLP AF MEKANISKE IMPEDANSMÅLINGER OG MÖSSBAUEREFFEKTMÅLINGER".

Projektrapport, speciale i fysik, af Crilles Bacher og Preben Jensen.

Vejledere: Niels Boye Olsen og Peder Voetmann Christiansen.

33/80 "KONSTITUERING AF FAG INDEN FOR TEKNISK-NATURVIDENSKABELIGE UDDANNELSER. I-II".

Arne Jakobsen.

34/80 "ENVIRONMENTAL IMPACT OF WIND ENERGY UTILIZATION".

ENERGY SERIES NO.1.

Bent Sørensen.

Nr. 34 er udgået.

Publ. i "Renewable Sources of Energy and the Environment", Tycooli International Press, Dublin, 1981.

35/80 "HISTORISKE STUDIER I DEN NYERE ATOMFYSIKS UDVIKLING".

Helge Kragh.

36/80 "HVAD ER MENINGEN MED MATEMATIKUNDERVISNINGEN ?".

Fire artikler.

Mogens Niss.

37/80 "RENEWABLE ENERGY AND ENERGY STORAGE".

ENERGY SERIES NO.2.

Bent Sørensen.

38/81 "TIL EN HISTORIETEORI OM NATURERKENDELSE, TEKNOLOGI OG SAMFUND".

Projektrapport af Erik Gade, Hans Hedal, Henrik Lau og Finn Physant.

Vejledere: Stig Andur Pedersen, Helge Kragh og Ib Thiersen.

39/81 "TIL KRITIKKEN AF VÆKSTØKONOMIEN".

Jens Højgaard Jensen.

40/81 "TELEKOMMUNIKATION I DANMARK - oplæg til en teknologivurdering".

Projektrapport af Arne Jørgensen, Bruno Petersen og Jan Vedde.

Vejleder: Per Nørgaard.

41/81 "PLANNING AND POLICY CONSIDERATIONS RELATED TO THE INTRODUCTION OF RENEWABLE ENERGY SOURCES INTO ENERGY SUPPLY SYSTEMS".

ENERGY SERIES NO.3.

Bent Sørensen.

42/81 "VIDENSKAB TEORI SAMFUND - En introduktion til materialistiske videnskabsopfattelser".

Helge Kragh og Stig Andur Pedersen.

43/81 1. "COMPARATIVE RISK ASSESSMENT OF TOTAL ENERGY SYSTEMS".

2. "ADVANTAGES AND DISADVANTAGES OF DECENTRALIZATION".

ENERGY SERIES NO.4.

Bent Sørensen.

44/81 "HISTORISK UNDERSØGELSE AF DE EKSPERIMENTELLE FORUDSÆTNINGER FOR RUTHERFORDS ATOMMODEL".

Projektrapport af Niels Thor Nielsen.

Vejleder: Bent C. Jørgensen.

45/82

46/82 I+II "EKSEMPLARISK UNDERVISNING OG FYSISK ERKENDELSE - ILLUSTRERET VED TO EKSEMPLER".

Projektrapport af Torben O. Olsen, Lasse Rasmussen og Niels Dreyer Sørensen.

Vejleder: Bent C. Jørgensen.

47/82 "BARSEBÄCK OG DET VÆRST OFFICIELT-TÆNKELIGE UHELD".

ENERGY SERIES NO.5.

Bent Sørensen.

48/82 "EN UNDERSØGELSE AF MATEMATIKUNDERVISNINGEN PÅ ADGANGSKURSUS TIL KØBENHAVNS TEKNIKUM".

Projektrapport af Lis Eilertzen, Jørgen Karrebæk, Troels Lange, Preben Nørregaard, Lissi Pedersen, Laust Rishøj, Lill Røn, Isac Showiki.

Vejleder: Mogens Niss.

49/82 "ANALYSE AF MULTISPEKTRALE SATELLITBILLEDER".

Projektrapport af Preben Nørregaard.

Vejledere: Jørgen Larsen & Rasmus Ole Rasmussen.

50/82 "HERSLEV - MULIGHEDER FOR VEDVARENDE ENERGI I EN LANDSBY". ENERGY SERIES NO.6.

Rapport af Bent Christensen, Bent Hove Jensen, Dennis B. Møller, Bjarne Laursen, Bjarne Lillethorup og Jacob Mørch Pedersen.

Vejleder: Bent Sørensen.

51/82 "HVAD KAN DER GØRES FOR AT AFHJÆLPE PIGERS BLOKERING OVERFOR MATEMATIK?"

Projektrapport af Lis Eilertzen, Lissi Pedersen, Lill Røn og Susanne Stender.

52/82 "DESUSPENSION OF SPLITTING ELLIPTIC SYMBOLS"

Bernhelm Booss & Krzysztof Wojciechowski.

ISSN 0106-6242