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THE AIM AND STRUCTURE OF APPLIED RESEARCH

ABSTRACT. The distinction between basic and applied research is notoriously vague, despite its frequent use in science studies and in science policy. In most cases it is based on such pragmatic factors as the knowledge and intentions of the investigator or the type of research institute. Sometimes the validity of the distinction is denied altogether. This paper suggests that there are two ways of distinguishing systematically between basic and applied research: (i) in terms of the "utilities" that define the aims of inquiry, and (ii) by reference to the structure of the relevant knowledge claims. An important type of applied research aims at results that are expressed by "techical norms" (in von Wright's sense): if you wish to achieve A, and you believe you are in a situation B, then you should do X. This conception of "design sciences" allows us to re-evaluate many issues in the history, philosophy, and ethics of science.

1. BASIC AND APPLIED RESEARCH – A NEGLECTED DISTINCTION

Philosophers have mostly been concerned with sciences which explain and interpret the world; now it is time to pay attention also to sciences which change the world.

This remark may sound a little pathetic, but it conveys an important truth. The most influential philosophers of science in our age – both within the analytical and hermeneutical traditions – have usually grounded their analyses of the aims and methods of inquiry upon models provided by such basic sciences as mathematics, physics, biology, history, psychology, and sociology. Much less attention has been devoted to fields like applied mathematics, computer science, aeroplane engineering, forest technology, dairy science, agricultural chemistry, veterinary medicine, sport medicine, pharmacy, nursing science, logopedics, didactics, homiletics, household economics, social policy studies, library science, military science, peace research, and future studies.

This neglect by philosophers – of course with some notable exceptions[1] – is both surprising and harmful in many ways.

In the first place, the students of the more exotic "practical sciences" may of course learn important lessons about science by reading Carnap, Hempel, Popper, Kuhn, Lakatos, Feyerabend, Laudan, Stegmüller,

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Ruse, Apel, and other important authorities. But it is by no means clear that conceptions founded upon the model of the basic sciences would do justice to the peculiar characteristics of the applied sciences.

Secondly, the converse error has been committed by the instrumentalist philosophers (represented by many pragmatists and Marxists, among them Dewey, Bernal, and Habermas)[2] who treat all science as if it were applied. An extreme expression of this trend is the claim that the Scientific Method is to be identified with the techniques of practical problem-solving in Operations Research.[3]

Thirdly, despite its frequent use, the distinction of basic and applied research is often presented in a vague and confusing way within science policy. This fact – together with the fashionable instrumentalism among policy makers – has led to an "epistemic drift",[4] whereby the category of fundamental research seems to fading away or melting into that of applied research.

Fourthly, the failure (or refusal) to distinguish basic and applied research has led many historians and sociologists of science astray in their criticisms of what they regard as the "ideology" of "pure science".[5]

2. PRAGMATIC OR SYSTEMATIC DIFFERENCE?

The standard distinction between basic and applied research was codified by OECD in 1966.[6] First, within *R&D*, *research* is defined as the pursuit of knowledge, while *development* uses the results of research to develop "new products, methods, and means of production". Secondly, *basic research* is defined as "the systematic pursuit of new scientific knowledge without the aim of specific practical application", and *applied research* as "the pursuit of knowledge with the aim of obtaining a specific goal".

The distinction between research and development is systematic in the sense that it is couched as a difference in their products: knowledge vs. artefacts. But the basic-applied distinction is vaguely based upon the "aims" of research – without any specification *whose* aims are in question.

Most of the attempts to separate basic and applied research appeal to pragmatic factors, i.e., to contextual features that may vary in time and location. Examples of such factors include the knowledge of an individual scientist ("the applied researcher has in his or her mind a possible practical application"), personal motives ("the motive of basic research is pure curiosity, that of applied research utility"), the intentions of the funding institutions ("applied research is financed because of its economic utility"), research sites ("basic research is done in the universities, applied research in the polytechnics, business schools, and industrial laboratories"), and the speed of utilization ("strategic basic research leads to practical applications in the long run, mission-oriented research in the short run").

Criteria of this sort are vague, ambiguous, and incompatible with each other.[7] The same activity may be classified as basic research on one criterion, applied research on another. It is no wonder that the validity of these distinctions if often doubted or denied. It is, therefore, important to ask whether they could be replaced by some non-pragmatic division. In this paper, I look for a systematic distinction in two directions: (i) the "utilities" that define the aims, progress, and rationality of inquiry, and (ii) the structure or logical form of the knowledge claims.

3. BASIC SCIENCE AND EPISTEMIC UTILITIES

Basic or *fundamental research* can be understood as the activity of the scientific community to produce new scientific knowledge by means of the scientific method. This knowledge should provide answers to cognitive problems: it should describe, with as good justification as possible, what the world (i.e., nature, man, culture, society) is like. The success of this activity thus depends on the amount and the correctness of the obtained information about the world. Basic science can thereby be characterized as the attempt to maximize the "epistemic utilities" of *truth* and *information* – or, as their weighted combination, *truthlikeness*.[8].

This description of basic research follows the course of *scientific realism*.[9] According to realism, the primary task of basic science is cognitive: the so far best results of science give us the elements of a dynamically developing *world view*. Knowledge about the current state and the regularities of the world also allows us to *explain* and *understand* reality.[10]

In treating truth, information, and explanatory power as epistemic utilities, a scientific realist does not claim that they constitute the intentional goals of individual scientists or the motives of funding institutions.

Rather, they are the cognitive virtues which define the success and progress of inquiry. They also have normative force in the sense that the arguments for or against a scientific hypothesis or theory may appeal only to its cognitive status in the light of the available evidence – not, e.g., to moral, political, religious, or economic factors. Indeed, the standard methods of scientific inquiry (e.g., sampling and experimental techniques, statistical methods) have been designed so that they tend to promote the cognitive goals of realism.

Many historians and sociologists of science have been keen to show that real-life scientific work does not always fit the picture drawn by realism.[11] These studies have given us valuable (in the realist's sense!) new information about scientific practice. But, as a criticism of scientific realism, they seem to involve two flaws.

First, examples of behavior violating a normative command do not disprove the norm: for example, criminal acts do not disprove criminal law. A norm is shown to be invalid only if its violation is not punished by the associated sanction.[12] To disprove the normative force of the epistemic utilities of basic science, it should be shown that their violation, when uncovered in public, does not lead to any sanction. But this is not the case with the methodological and ethical norms of science: if someone is found to be guilty of fraud, manipulation of data, or bias in favor or against a hypothesis on political, racist, sexist, nationalist, religious, or economic grounds, the credibility of his or her arguments will be demolished or at least seriously weakened within the scientific community.

Secondly, the arguments against the "false ideology" of "pure" or "objective" science often involve examples of the value-laden choices between medical technologies or social policies.[13] However, the study of such topics belongs to applied rather than basic science – and, as we shall see (Section 9), there is a sense in which applied research is not "value free" (i.e., normatively restricted to epistemic utilities and descriptive languages) in the same way as basic research.

4. TECHNOLOGY AND PRACTICAL UTILITIES

By *technology* I mean the design and use of material and social artefacts which function as tools in the interaction with and the transformation of reality.[14] The word 'technology' may also refer to the products of this activity. In this sense, 'development' is a name for science-based technology.

Unlike the linguistic products of scientific research, tools and artefacts are not true or false. Rather, they are intended to create new powers and possibilities of action, and thereby to increase man's positive freedom. Hence, the basic "technological utility" is *effectiveness* relative to the intended use (e.g., the power of an engine). Besides creating new possibilities, the use of tools consumes resources and has intended and unintended effects on the material and social reality. Therefore, technologies can (and should!) be assessed also in terms of their *economical efficiency* (relation of costs and effects) and their *ergonomical* (man-tool relations), *ecological* (man-nature relations), *aesthetic*, *ethical*, and *social* aspects.

It is important to emphasize here the crucial difference between the decisions to "accept" a scientific hypothesis or a new technological tool. The decisions to develop and use, e.g., nuclear power plants, agricultural fertilizers, or missiles means in effect the introduction of new artificial entities in the world – and therefore they are inherently value-laden, i.e., their rationality depends on the balance of their practical utilities and disutilities. On the other hand, even though the acceptance of a scientific theory (e.g., theory of evolution, theory of relativity) may also have indirect social effects, such a theory has a truth value independent of our opinions, interests, and negotiations.

5. APPLIED SCIENCE

Engineering sciences, agricultural and forestry sciences, medical sciences, and practical social sciences are often mentioned as examples of applied sciences. Falling between basic science and technology, they produce new knowledge which is intended to be useful for the specific purpose of increasing the effectiveness of some human activity. The produced knowledge functions as a tool. Hence, the value of the results of such applied sciences can be evaluated *both* in terms of epistemic and practical utilities.

As applied science aims at knowledge, its products should be assessed for their correctness, informativeness, and truthlikeness. But the requirement of practical applicability suggests that – besides the epistemic utilities relevant to basic science – applied science is also concerned with *simplicity* or *manageability*.[15] The choice of the simplest among equally well supported hypotheses, if it will be used as a resource in human action, is often assumed to be justifiable by economic reasons. Further, to make the calculations easier or practically possible, approximations and simplifications may be introduced to quantitative laws – even at the expense of their truthlikeness.[16]

Beside epistemic utility, the knowledge provided by applied science is expected to have *instrumental value* for the associated human activity. Applied science is thus governed by what Habermas calls the "technical interest" of controlling the world. But to extend this conception to basic natural science as well, and thereby to treat all natural science as it were applied, is to commit oneself to instrumentalism.[17]

It might be objected that the double assessment – by epistemic and practical utilities – is superfluous here, since there is a conceptual connection between them. It is true that "practice is a criterion of a theory", i.e., the pragmatic success of a theory in guiding human action is a fallible indicator of its cognitive virtues. But the truth of a theory of applied science implies only its *potential* pragmatic success: e.g., it may happen that someone makes a theoretical proposal for an educational reform, which *would* have its claimed effect, but this proposal is actually never implemented. In this sense, it is possible that there is cognitive progress in applied science which is not, nor will be, cashed out in practice.

The interplay of epistemic and practical utilities can also be illustrated in decision-theoretic terms. Suppose we are interested in the health risks of radiation, and a choice has to be made between linear and quadratic dose-response models.[18] If the problem is purely theoretical, then the loss of a mistaken model could be equated with its distance from truth. But if the model will be implemented in the adoption of safety standards, with the interest of protecting the public and workers in nuclear facilities, then the loss function could be transformed to give higher penalties in the direction of lower risk estimates.

Our discussion so far has not yet helped to understand the relations between basic and applied research, and it has not clarified the crucial issue of how a piece of knowledge may have instrumental value. To approach these questions, the analysis of applied science in terms of its aims or utilities is not sufficient, but it is necessary to try to uncover the logical form of its typical products.

6. DESCRIPTIVE SCIENCE: EXPLANATION AND PREDICTION

Basic sciences are *descriptive* in the sense that they primarily describe, with sentences in the indicative mood, singular and general facts about the world. They seek to establish theories which express true and lawlike (nomic) connections between properties or types of events. A typical result of basic research is a deterministic or probabilistic causal law of the form

(1) X causes A in situation B

or

(2) X tends to cause (with probability p) A in situation B.

By fulfilling its descriptive function, basic research also provides the opportunity to give scientific *explanations*. Assume that event of type A has occurred in a certain situation b. Then laws (1) and (2) allow us to construct deterministic or probabilistic explanatory arguments with A as the explanandum:

(3) X causes A in situation B
X occurred in situation b
The situation b is of type B
Hence, A occurred in b.

Laws of form (1) and (2) can also be used for *prediction*. Suppose an event of type X has occurred in a situation b of type B. Then the occurrence of A in this situation can be predicted (certainly or with probability p). The structure of this predictive argument is again (3).[19] For example, the same laws of celestial mechanics can be used for both explaining past eclipses and predicting future ones.

Predictive sciences are often considered the basic type of applied science. Human cultures have been interested in successful prediction for various practical reasons. A scientific theory, which is able to produce reliable predictions about future events, has *predictive power*. Practical astronomy, meteorology, and social statistics are examples of applied sciences which have predictive power as their central epistemic utility.

In spite of the structural similarity of explanatory and predictive arguments (cf. (3)), there are good explanatory theories without much predictive power (e.g., theory of evolution). Further, some useful "models" for prediction may be so simplified or idealized that they are not taken seriously as premises of explanation. Still, explanatory and predictive sciences are two subtypes of descriptive science – with a difference which is only pragmatic in nature.

7. DESIGN SCIENCE

It would be a serious mistake to generalize the observations of Section 6 to the claim that the basic-applied distinction coincides with the explanatory-predictive distinction. This move is seductive, since the descriptive account has almost universally been accepted to be *the* model of science.

Some – not very successful – attempts have been made to formulate alternative views, which would allow also for a special kind of "normative science" or "critical science".[20] But the supporters of the descriptive ideal have liked to knock out these proposals, since they seem to openly bring or to smuggle into inquiry moral or political valuations.

An important exception is Herbert Simon's insightful book *The Sciences of the Artificial* (1969). He argues that the traditional model of science (and science education) gives a misleading picture of such fields as engineering, medicine, business, architecture, painting, planning, economics, education, and law, which are concerned with *design* – i.e., not how things *are*, but "how things *ought to be* in order to attain goals, and to function".[21]

Let us say that *design* in the broad sense includes all "artificial" human activities, i.e., the production, preparation, or manipulation of natural systems (e.g., human body, forest) or artefacts (e.g., an aeroplane, city, legal order).[22] This concept of design thus ranges from environmental, economic and social planning to engineering, architecture, industrial design, crafts, and the fine arts. Then research aiming at knowledge that is useful for the activity of design – i.e., enhances human art and skill (Greek *techne*, Latin *ars*)[23] – may be called *design science*.

Before discussing the nature of design science in more detail, it is important to distinguish it clearly from *scientific design*. (I think Simon's account is ambiguous here.) Scientific design is a species of design, i.e., the activity of solving design problems by using scientific methods and scientific knowledge. Operations Research (OR) provides methods for finding optimal or satisfactory solutions to design problems (e.g., game

PROFESSION	PRACTICE	ART	SCIENCE
medicine man physician	therapy healing	medicine	medical science
nurse	nursing	art of nursing	nursing science
pharmacist	preparation of medical drugs	pharmacy	pharmacology
farmer	farming agriculture	art of farming	agricultural science
engineer	design of mechanical works	engineering	engineering science
soldier	warfare	strategy art of war	military science
?	peace-making	?	peace research
politician administrator	politics	politics	political science
social worker	social service	social policy	policy science
merchant tradesman	commerce trade	art of trading	economics
teacher	teaching	didactics	didactics
athlete	sporting	athletics	sport science

Table 1.

theory, decision theory, linear programming). In this sense, scientific design is the result of the "scientification" of art, technology, management, or development.

On the other hand, design science is the activity of generating instrumental knowledge for the production and manipulation of natural and artificial systems. Design science produces knowledge which may then be applied within scientific design.

More generally, it is important to distinguish *applied* science from the *applications* of science. The former is a part of knowledge production, the latter is concerned with the use of scientific knowledge and methods for the solving of practical problems of action (e.g., in engineering or business), where a scientist may play the role of a consult.[24]

These distinctions can be clarified by Table 1, which separates from each other a *profession* (e.g., a farmer), the related *practice* (e.g., farming, agriculture), *art* or *skill* needed in this practice (e.g., the art

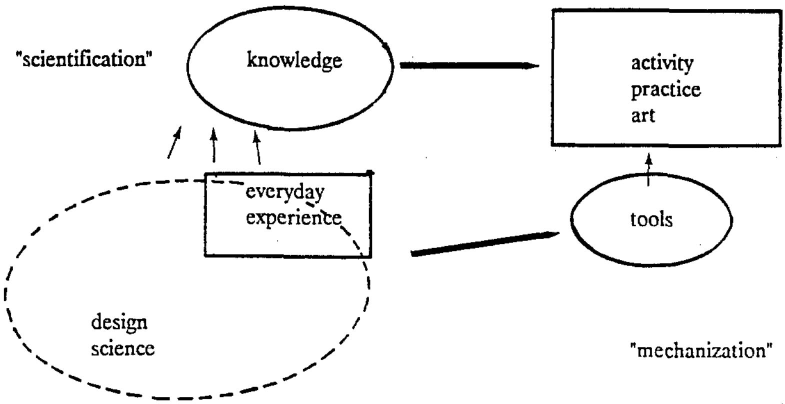

Fig. 1.

of farming), and a *design science* aiming at improving the art (e.g., agricultural science).

Sometimes one and the same person may simultaneously act in a profession and do research about his or her own practice: a physician may heal patients, keep record of this activity, and write a doctoral dissertation using its results. But it is nevertheless possible to make a conceptual distinction between the practice of an art and the research of the associated design science. The fact that today sport science studies the sliding properties of skies, the effective training of male and female skiers, and the best skiing styles, does not mean that the skiing champions suddenly become "scientists".[25]

Another way of illustrating the conception of design science is given in Fig. 1. Already Plato was well aware that some arts require more background knowledge and exactness than others. In the dialogue *Philebus* (55d–56c), he pointed out that some crafts use "numbering, measuring, and weighing" (e.g., the building of ships and houses employs instruments like straight-edge, compass, and plummet), while others are based on "guesswork" or "experience and rule of thumb, involving the use of that ability to make lucky shots which is commonly accorded the title of art or craft, when it has consolidated its position by dint of industrious practice". The latter class of arts include, Plato said, medicine, navigation, warfare, and music.

Originally all human arts or technologies have been based upon expertise consisting of the practical skills and "rules of thumb" of the masters: they have presupposed or employed knowledge only at the level of everyday experience. Their later development has followed two patterns which may be called the *mechanization* and the *scientification* of practices or arts.[26] First, human activities have become more and more effective through new mechanical inventions (e.g., tools of warfare, agriculture, architecture, sport). Secondly, knowledge which serves some art has been collected into systematic bodies of rules. This process started already in the ancient times with the arts of counting, measuring, warfare, medical care, arguing, building, and judging – with the emergence of the first guide books of arithmetic, geometry, military strategy, medicine, logic, architecture, and law. Later the operation of such rules is put in scientific tests – and a design science is created through the "scientification" of the background knowledge serving a practice (cf. Table 1). In this sense, the treatment of rules for geometrical constructions in Euclid's *Elements* is a classical exposition of design science. Pharmacology is an example of an empirical design science which tests the efficacy of medical drugs.

These observations give us new insight into the history of science. The standard view that all scientific disciplines have emerged from philosophy may be true for some basic sciences (physics, biology, psychology, sociology), but many practical disciplines have been created through the scientification of professional activities.[27] This process continues in our age with new disciplines – such as nursing science – which, I believe, gain illumination about their identity by the conception of design science.

8. TECHNICAL NORMS

If a design science is expected to contribute to the scientification of human practices, its results should be some kinds of rules of action (Fig. 1). But *rules*, as normative statements in the imperative mood, are usually thought to lack truth values. How could they, then, at the same time constitute *knowledge*?

The solution can be found in G. H. von Wright's concept of *technical norm*, which is a factual statement about the relation between means and ends:

(4) If you want to make a hut habitable, you ought to heat it.

Both the antecedent and the consequent of such a *conditional* norm are descriptive statements, the former about the wants or preferences of a person, the latter about the existence of a "technical ought" for him. The technical norm (4) is true if and only if heating the hut is necessary condition for making it habitable.[28]

More generally, a technical norm is a statement of the form

(5) If you want A, and you believe that you are in a situation B, then you ought to do X.

The categorical normative statement, which corresponds to the consequent of (5), may have stronger or weaker forms

(6) You should (ought to) do X.
It is rational for you to do X.
It is profitable for you to do X.

The conditional norm or recommendation (5) (with alternative consequents given by (6), respectively) can be defined to be *true* if and only if doing X is

(7) a necessary cause of A
a sufficient cause of A
probabilistic cause of A

in situation B.[29]

If (6) is read in the imperative mood, it has no truth value. If (6) is treated as a descriptive statement, which is a consequence of "practical inference", its truth presupposes some valuation as a premise ('you want A'). Therefore, singular statements of the form (6) can hardly be proposed to be the theorems of any science. However, the case with technical norms is different: the truth or falsity of (5) is an "objective" and general feature of the world, which does not presuppose any commitment to the valuation in the antecedent of (5).

Hence, we may propose that technical norms of the type (5) express the typical structure or logical form of the knowledge provided by design science. Examples from sciences of Table 1 are easy to find:

If you want to heal a patient with these symptoms, you should use this treatment.
If you want to increase the productivity of fields, you should use these fertilizers.
If your aim is to build safe aeroplanes, use this material.

> If we wish to increase the probability of peace (reduce the risk of war), a disarmament programme ought to be accepted.
> If we want to avoid unemployment, we should lower interest rates.

There are two ways in which a technical norm may be supported, so to speak, from above and from below.

Support "from above" means the derivation of a technical norm from descriptive statements provided by basic research. Bunge (1966) has given a good example of this process:

> Magnetism of iron disappears above the temperature 770°C.
> ↓
> If the temperature of iron exceeds 770°C, it is not magnetic.
> ↓
> If a magnetized piece of iron is heated above 770°C, then it is demagnetized.
> ↓
> In order to demagnetize iron, heat it above 770°C.

More generally, assume that basic research has established a causal law of the form (1) or (2), 'X causes A in situation B'. If the cause factor X is not manipulable by us, but is chosen *by nature*, then this law can be used for predictions: if we observe X in situation B, we may expect A as well. But if X may be chosen *by us*, then the causal law can be converted to a technical norm (5): if we want to achieve the aim A, and the situation is of type B, then we should bring about the cause X.

Design science can, in this precise sense, be applied science: its knowledge is derivable from the results of the descriptive basic sciences.

In many cases, however, there is not available any general theory from which a technical norm can be deduced. Then technical norms are supported "from below" by building up a simplified model of the situation, using trial-and-error procedures and experimental tests to investigate the dependences between the most important variables, and trying to find the optimal methods of producing the desired effects. When the result is expressed as a general rule, a technical norm with some empirical support is obtained.

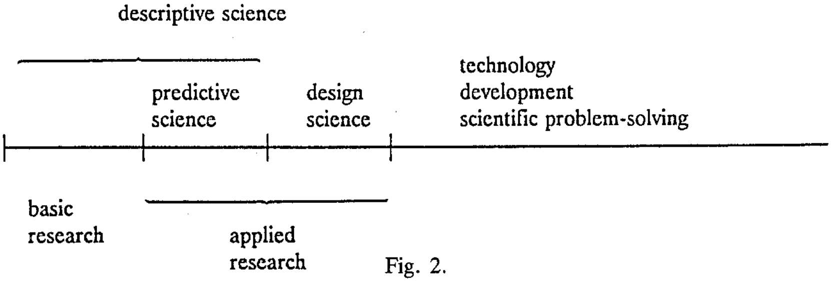

Fig. 2.

9. DESIGN SCIENCE, ETHICS, POLITICS

Design sciences differ from explanatory basic sciences and predictive applied sciences in a systematic way, because technical norms are not descriptive statements about the world. They don't tell us what *is*, *was*, or *will be*, but what *ought to be* so that we can attain given goals. Nevertheless, they are true or false statements, and can, in principle, be supported by theories and experiments in an objective fashion. These conclusions are summarized in Fig. 2, which in a sense suggests that the old basic – applied dichotomy is less fundamental than the descriptive – design distinction.

It should be emphasized that the border between descriptive and design science splits many scientific disciplines.[30] Let S be some activity which can be studied by science, e.g., S might be farming, nursing – or science itself which is the object of "science studies".[31] Then descriptive research of S includes at least the *history* of S, the *psychology* of S, the *sociology of* S, and the *economics* of S. Basic research about S tries to describe the present state of S and to establish some systematic regularities about S – in this way, we may speak about basic research within technical sciences, life sciences, medicide, social sciences, and jurisprudence. Design science contains only a part – the practical kernel, so to speak – of these discipines.

In one sense, however, we have found that the border between predictive and design science may depend on the pragmatic question about the *human manipulability* of causal factors. Astronomy and meteorology are today predictive sciences, since their regularities cannot be transformed to useful technical norms – the rule 'If you want an eclipse, place moon between the Sun and Earth' is irrelevant in relation to human possibilities. But scientists are already speculating about making planets habitable. Whether the causal factor X in a law

'*X* causes *A* in *B*' is manipulable *by us* depends on the stage reached by human technology.

This conclusion already suggests that, unlike basic research, design science has to satisfy a special condition of *social relevance*. A technical norm (5), where *X* can be brought about by us, is useful for practical purposes only upon two further conditions: (i) there are in fact situations that are (excatly or at least approximately) of type *B*, and (ii) the goal A should be at least potentially acceptable for some social group or "auditory".

As technical norms contain evaluative and normative terms, design science seems to radically differ from the "positivistic" ideal of "value-neutral" science. But as a conditional statement, a technical norm does not require a commitment to the value premise of its antecedent. For example, a militarist and a pacifist may both agree on the truth of the conditional recommendations of military studies, even if they sharply disagree about their relevance. A technical norm is *binding* only for those who accept their conditional value premise.[32]

At the same time, in spite of value-neutrality in this sense, a person contributing to applied science is *morally responsible* for the tools (technical norms) he or she has created.

How is the value *A* in a technical norm chosen? In the case of some design sciences, the answer is straightforward: medicine aims at promoting health, business economics at maximizing profits, peace research tries to reduce the risk of military conflicts, and social policy studies promote the welfare of society. Aims of this kind are so tightly fixed with the professional goals and the self-identity of these sciences that they often present their conclusions categorically, as if forgetting the overall value commitment. Still, the content and desirability of these aims may be put into question within *philosophy* and *ethics*: the philosophy of medicine discusses the definition of health, social philosophy the "health" of society, business ethics and environmental ethics the legitimate goals of human actions towards other agents or nature.

For example, as medicine takes it for granted that a patient must be healed, technical norms of the form 'If you want to heal a person with symptoms *B*, use treatment *X*' may be expressed simply by 'Use treatment *X* for patients with symptoms *B*'. Such a move becomes problematic only if it is denied that the "symptoms" *B* constitute a "disease" (e.g., drug use, mental abnormality).

In many cases, the choice of A involves a *political* debate. Policy issues, where the experts differ in their recommendations, can be analyzed into their elements by the concept of technical norm. If two groups of experts advocate conflicting policies 'Do X_1!' and 'Do X_2!', respectively, their disagreement may be due to at least three separate reasons:

(a) disagreement about the relevant goals A_1 or A_2
(b) disagreement about the current situation B_1 or B_2
(c) disagreement about the underlying causal mechanism between X & B and A.[33]

Here (b) and (c) are *factual* disputes, in principle solvable by empirical research, but (a) is a difference about *valuations*. Disputes about policies concerning energy, environment, and society often contain both factual and evaluative assumptions – and the latter tend to be concealed under the guise of "neutral" experts.[34]

There is one further, rather subtle way in which a technical norm may involve valuations. In making a distinction between the manipulable factors X and the unchanging situation B, we in fact bring in an assumption that B must be kept constant.[35] For example, an economic policy recommendation in a capitalist (resp. socialist) country may presuppose that the economic system itself must not be interfered with. Therefore, to eliminate such hidden valuations, a technical norm should be formulated so that the goal A includes all the relevant value assumptions (e.g., A=to improve gross national product, to preserve the market economy, and to avoid such and such side effects).

10. CONCLUDING REFLECTIONS

As it is not true that "the aim justifies the means", a technical norm should include among its antecedent A all the relevant valuations that concern the direct and indirect consequences of the recommended action X. That this requirement has not always been respected, and applied science has been utilized with a very narrow scope and distorted content of human valuations (usually only technical and economic efficiency in the short run), has led to a justified criticism of the dangers of "instrumental reason".[36]

However, the "legitimation crisis" of modern science does not imply the need to reject the idea of basic science or to invent a new type of science, with aims and standards differing from other forms of inquiry.[37] The concept of design science covers in fact a whole variety of different possibilities. They include cases of blind *technocratic* approach (where the scientist accepts uncritically the goal A, without questioning it or without understanding his or her moral responsibility in producing tools for reaching A), *piecemeal social engineering* (where the goal A proposes only small reforms to the social system), and *emancipatory research* (where the goal A is critical of the status quo and proposes radical, even utopian changes in the prevailing order).

The last point illustrates the fact that, in a social design science, the goal A need not be a demand imposed "from above" by a bureaucratic planning officer over the citizens. Instead, it may express the "we-intention" of a democratic community. The concept of design science thus covers also the so-called participatory planning or action research, where the researcher goes to live with his or her "clients" and helps them elicit their own preferences. It also thereby shows that the "incrementalist" criticism of planning theories (i.e., the alleged impossibility of separating subject and object) is not a sufficient reason for rejecting the idea of instrumental rationality.[38]

But, on the other hand, the concept technical norm shows how extremely *difficult* applied science may be. For many systems (e.g., economy, technosystem) it may be very hard to find any approximately true and lawlike regularities. For some systems involving both material and human elements (e.g., a city), it may be an immensely complex affair to give a correct and sufficiently detailed description of its present state. And for many situations (e.g., animals, human patients) it may he highly controversial what goals and means are legitimate from a moral point of view.

Is the attempt to establish design sciences, in spite of all these difficulties, still a worthwhile enterprise? Many professions think so today, obviously with hope that the making of their practice and education "scientific" would given them a higher status in society.

The real challenge to design science seems to come from the arguments of Hubert L. Dreyfus, whose criticism of artificial intelligence and expert systems is directly applicable to know-how represented by technical norms. Dreyfus argues that skill based upon rules belongs only to "novices" and "advanced beginners", while the true "expert" acts by "intuitive intelligence" without reliance on action-guiding rules.[39]

The important issue, which remains to be settled in further philosophical and empirical work, is to analyse and to classify human skills into those which can, or cannot, be improved by their "scientification".

NOTES

[1] In my view, the most interesting account is due to Herbert Simon (1969) (cf. Section 7 below). Useful discussions have been presented by Polish praxeologists (see Gasparski et al., 1983) and analytical philosophers of technology (see Rapp, 1974). A special issue on applied science was published in *Synthese* 81:3 (1989). The work on the Finalization Thesis (cf. Schäfer, 1983) seems to me inconclusive (cf. Niiniluoto, 1984a, Ch. 10). My own ideas about applied science have been developed since 1983. See Niiniluoto (1984a), Chs. 10–12, (1984b), (1985b), and the Finnish papers (1985a) and (1987b).
[2] For Bernal, see Niiniluoto (1990a).
[3] See Ackoff (1962) and the criticism in Niiniluoto (1984a), Ch. 11.
[4] This nice term is due to Elzinga (1985). An example of this drift is the distinction *within* basic research that Irvine and Martin (1984) make between pure curiosity-oriented research and strategic research, where the latter provides the knowledge base for tomorrow's technologies. This terminology does not appreciate the fact that curiosity-oriented basic research is also "strategic" relative to the *cognitive* goals of inquiry.
[5] A recent example is Latour (1987), who operates with many – surprisingly sharp – Janus-faced dichotomies, but finds no difference between science and technology.
[6] Cf. Sintonen (1990).
[7] After listening to my queries about the basic-applied distinction, Commission of Basic Research (appointed by the Ministry of Education in Finland in 1989) decided to include within "basic research" all publicly funded research (about 40 percent of the R&D volume in Finland).
[8] See Levi (1967), Niiniluoto (1987a).
[9] See Popper (1963), Niiniluoto (1984a).
[10] Some realists would take explanation to be more fundamental notion than truth. Cf. Leplin (1984) and Tuomela (1985).
[11] See, e.g., Mulkay's (1979) summary of the criticism against the Mertonian norms of science.
[12] For norms, see von Wright (1963, 1983).
[13] See, for example, the interesting example of research on drug use in Restivo and Loughlin (1987).
[14] Cf. Skolimowski (1966), Rapp (1974), Mitcham and Mackey (1983), Niiniluoto (1984a), Ch. 12.
[15] See Rescher (1990) and Niiniluoto (1992).
[16] See Niiniluoto (1984a), p. 262.
[17] Cf. Habermas (1971) and Niiniluoto (1984a), p. 221.
[18] See Longino (1989).
[19] Cf. Stegmüller (1969) on the symmetry between explanation and prediction.

[20] Cf. Habermas (1971) and Held (1980). Note that a science *about* the norms valid in a given society (e.g., legal dogmatics) may be descriptive. See Niiniluoto (1985b).
[21] See Simon (1982), p. 7. For comments on "design" in the narrower sense of industrial design, see Niiniluoto (1984b).
[22] For such a broad concept of design, see Bunge (1979). However, I don't assume with Bunge that technology always is based upon science.
[23] For the concepts of *techne* and *ars*, see Mitcham (1979).
[24] This distinction is denied by the view L. J. Savage called "behaviouralism": to accept a scientific hypothesis is always a decision to *act as if* the hypothesis were true. For a criticism of behaviouralism, see Levi (1967).
[25] But it might be mentioned that the gold medalist of javelin at the Olympic Games in Soeul (1988), Tapio Korjus, wrote his Master's Thesis in physical education about javelin throwing.
[26] Cf. Niiniluoto (1984b).
[27] I am not suggesting that such practical disciplines became sciences before the birth of theoretical science in Greece: the scientification of a practice presupposes that science (as a method) has already been invented.
[28] See von Wright (1963, 1988).
[29] A complication with the weaker conclusions in (6) arises from the problem that concepts such as 'rational' and 'profitable' can be defined by several different formal criteria. Sharper formulations of (6) and (7) could be given in (Bayesian) decision theory, where a technical norm is generalized to a statement of the form 'If your value system is V, your belief system is B, and your favourite decision criterion is C, then you ought to do X'.
[30] My own experience is that some scientists fear that the idea of design science is too much tied with instrumental rationality or technocratic values. I am *not* by any means suggesting that disciplines such as future studies, library science, or nursing science are entirely reduced to design science, since these activities should also be investigated by philosophy, history, psychology, sociology, etc.
[31] The design science corresponding to scientific research (as a subsystem of "science" as a whole) is nothing else than "methodology". Laudan (1987) has suggested that methodological norms in science are "hypothetical imperatives" (i.e., technical norms). Another design science related to science is science policy studies.
[32] Cf. Niiniluoto (1985b) for the relevance of this observation to auditory-relative conceptions of truth.
[33] A fourth factor is the choice of the criterion of rationality (e.g., Bayes-rule, minimax). See Levi (1980), Appendix.
[34] For the suggestion that the so-called "technological imperatives" are really technical norms, with a hidden value antecedent, see Niiniluoto (1990b).
[35] A remark to this effect has been made, in the context of ecological theories, by Dr. Yrjö Haila.
[36] See Held (1980) and von Wright (1986).
[37] See, e.g., Restivo and Loughlin (1987) on the new standards of "validity" in the "science for the people" movements.
[38] Cf. Lindblom and Cohen (1979).
[39] See Dreyfus and Dreyfus (1986).

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