Integrated Training of Engineers for a Changing Society

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SUMMARY *The profound societal impacts of technological developments call for a drastic change in the education of engineers. The paper describes the development of training practice at the University of Twente, where a programme of more or less disciplinary philosophy and social science courses for engineers is evolving towards increasing integration with the technical curricula. This transformation is described by paying attention to the content of programmes and courses in philosophy and social sciences for engineering students, to their institutional context and management, and to trends in appraisal of these courses by students as well as by faculty. The latter topic is treated by using data derived from evaluations carried out on a regular basis. The development described reveals a trend from broad, general philosophy and social sciences courses for all engineering students towards specialized courses treating the societal trends and concerns which relate specifically to the technical domains of the separate engineering departments of the university.*

1. Introduction

The ever-increasing speed of technological change in the twentieth century calls for a drastic reorientation of technical design practices, i.e. for a paradigmatic change in the way engineers work. Realization of the 'sustainable society', for example, requires that sheer technology push will be abandoned in favour of developing technology which is receptive to wider societal demands. To reach this goal, it is crucial to introduce changes in the training of engineers.

At the University of Twente, a young technical university with a well-developed social science and philosophy branch, the teaching of social and philosophical aspects of technology to the engineers in training has been an important part of the university's mission right from the start, in 1964. A specific institutional setting of departments organized around two cores bridged by a School of Philosophy and Social Sciences supports the realization of this mission.

This paper starts by giving information concerning the organizational setting, the programmes of relevant courses and the way the latter have been developed. The next part of the paper deals with the experience gained from the teaching of social and philosophical themes to engineers as it has been practised over the years. This part is based on formal evaluations of the present practice extended with our own assessment. To illustrate on a micro-level how the content of relevant courses is now being redesigned according to recent insights, an extended example will be given in the final section of the paper.

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2. Institutional Context

The present institutional setting in which the teaching of social and philosophical courses occurs is the outcome of a development which started in the early 1960s when the University of Twente (UT; in those days called Twente Technical University) was founded. Beside the older ones at Delft and Eindhoven, the UT is the third technical university in the Netherlands. It is a fully accredited university, largely funded by government but earning a considerable part of its research funds (30%) from external contracts. With approximately 7000 students enrolled it is the smallest of the three technical universities mentioned.

Right from the start, education at UT has been dedicated to join engineering and applied sciences on the one side with philosophy and social sciences on the other. Therefore, the new university started with six engineering departments and a School of General Social Sciences ('Algemene Wetenschappen') accommodating chairs in philosophy, economics, law, sociology, social psychology, educational science and business administration. The main *raison d'être* of the school was 'service teaching' to the engineering departments. The goal of service teaching is to improve the education of the engineers by offering courses which broaden the engineers' perspective on society. By teaching such courses UT sought to distinguish itself from the other Dutch technical universities.

In 1972, two new departments were split off from the school, Public Administration and Management Science. Later on a third social science department (Applied Educational Science) was established. The remainder of the school, in which new chairs had been established (linguistics, history, science and society, ergonomics), was renamed School of Philosophy and Social Sciences. Together, these developments have resulted in an organization which presents itself as a university consisting of two 'cores'. The engineering departments represent one core, while the remaining departments are taken together as the second core called 'social sciences'. The School of Philosophy and Social Sciences intends to fulfil a bridging function between the two cores (see Fig. 1).

3. Courses

3.1 Ph&S Courses

In the framework of their technical curriculum, students in the engineering departments have to spend a certain share of their programme on courses in philosophy and social sciences, the 'Ph&S courses'. These courses are developed and taught by the School of Philosophy and Social Sciences, together with the newly established departments of Management Studies, Public Administration and Applied Educational Science ('service teaching'). Formally, the responsibility for the Ph&S courses is shared between the engineering departments and the departments which supply service teaching. In the beginning of Ph&S teaching these departments cooperated enthusiastically in the Ph&S Coordinating Committee on which they were represented. However, in the 1970s the involvement of the engineering departments dropped. This caused a discussion about the restructuring of the Ph&S programme—which had become necessary due to a restructuring of the academic curricula on the national level—to drag on for years.

Developments regarding the implementation, management and content of the Ph&S programme of courses can be made comprehensible by summarizing this discussion, which occupied the period 1972–84. During this period, a robust

Ph&S practice developed which persisted for almost a decade. Only recently have new changes in this practice been made (see below). Significant (and sometimes sensitive) issues in this discussion are given in the following.

3.1.1 Goals of Ph&S. According to the initial goals the Ph&S courses were to provide:

- understanding of the internal and external functioning of organizations;
- insight in the complexity of the social reality of engineering practice;
- orientation and critical reflection on problems concerning technical and societal developments.

In 1976 these goals were related to relevant sections of the Dutch Bill of Science Education ('Wet op het Wetenschappelijk Onderwijs'), which intend to foster "the preparation for a profession in society", "the coherence of the sciences" and the "the social responsibility of the scientist", respectively.

3.1.2 Curriculum time devoted to Ph&S. The share of total curriculum time to be spent on Ph&S has been a matter of on-going negotiations between the faculties of both cores of the UT. In principle, the engineering faculties have authority over the layout of their own curricula, so they want to decide on the share of Ph&S time for themselves. Nevertheless, the Ph&S Board (see later) proposed a guideline of 12.5% of the total curriculum time for Ph&S (this was the approximate share in the early days of Ph&S). After extensive negotiations a share of 10% was agreed.

3.1.3 Layout and content of the Ph&S programme of courses (and the way students move through it). Ph&S courses were initially taken by students by means of a 'cafeteria system'. That is, students were free to pick the courses they chose to follow from the total package offered per year of study. This situation was changed in 1982 when a structured curriculum of Ph&S courses was developed, starting from a broad basis and narrowing into themes. This curriculum, which represented the situation till 1995, was constructed as follows:

- first year: introductory interdisciplinary course (80 hours);
- second year: disciplinary course (100 hours);
- third year: theme course + one or two follow-up courses.

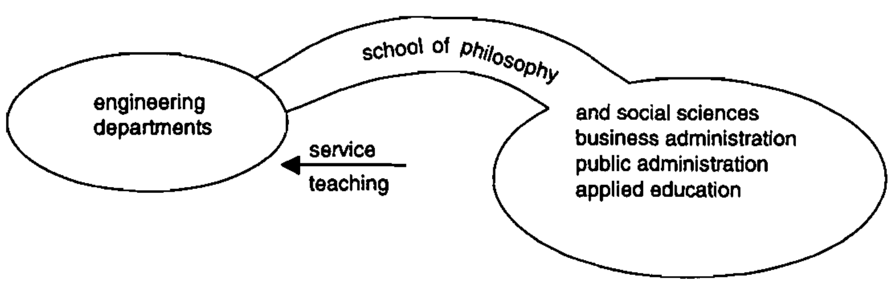

FIG. 1. The two cores of the UT with the School of Philosophy and Social Sciences functioning as a bridge

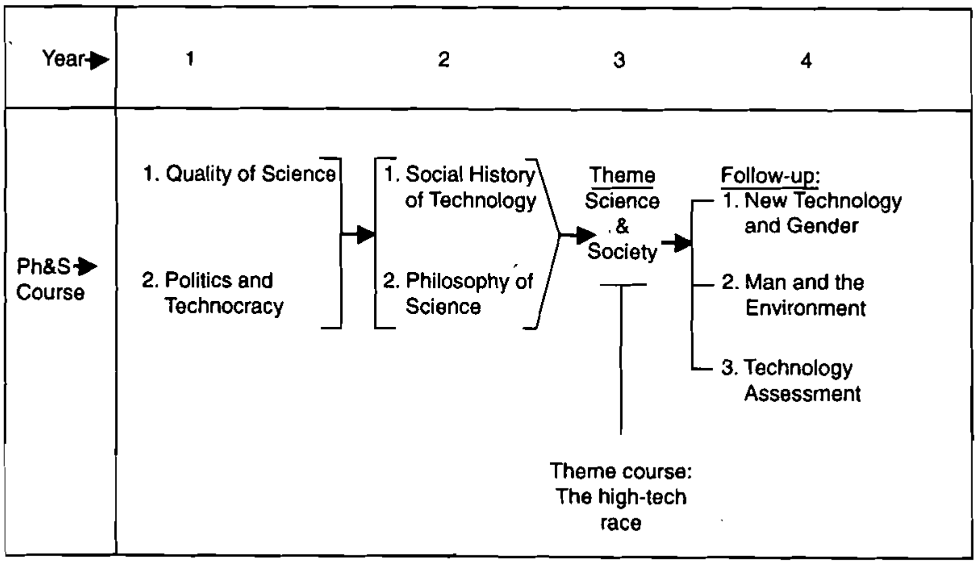

FIG. 2. Typical sequence of related courses in the Ph&S curriculum.

This structure means the end of a completely free choice for students because permission to follow certain courses depends on whether specific earlier courses have been taken. The reason for this change is the expectation that by adoption of a curriculum structure a higher level of education can be reached, because later courses build on earlier ones. In Fig. 2, a typical example is given of one of the possible sequences of Ph&S courses which can be chosen. The names of the other themes are: history and foundations of science and technology; philosophy of science and technology; man and computer science; functioning of organizations; ergonomics; economical politics; development cooperation; communication and influencing; education and training of adults.

It appears to be difficult to satisfy the demands of the engineering departments with respect to programme content. These demands vary considerably. Concerning the first-year programme, agreement is generally being reached easily. With respect to the later years, the engineering departments often call for a focusing of the Ph&S courses on the practice of their own discipline. Mainly for this reason, some departments even want to develop Ph&S courses of their own.

3.1.4 Management of the Ph&S programme. In the early years, the Ph&S programme was managed by a Ph&S Coordinating Committee, consisting of representatives of all departments and two students. During the later years the membership of the engineering departments decayed, which delayed the discussion and decisiveness of the committee. The Social Sciences departments became impatient, and established a coordinating committee of their own, the Ph&S Board ('W&M Convent') consisting of the deans for education of the service teaching departments. In 1979, the coordination of the Ph&S courses was officially transferred to this Board, and the Ph&S Coordinating Committee was disbanded. Since 1989 the Board has been advised by a committee on which representatives of the teachers in the service teaching departments sit. In the same year, a representative of the students was added to the Board.

In the early 1990s a new round of negotiations started, made necessary by a number of factors: a general shift from a 4-year to a 5-year curriculum on the national level, budget cuts, unfavourable output figures and criticism from students. The coming reorganization urged the Board to carry out a comprehensive evaluation of the current Ph&S courses (see later for outcomes).

3.2 PhSTS Programme: Training for 'Philosophical Engineers'

In 1983 the School of Philosophy and Social Sciences started its own Master's degree programme, 'Philosophy of Science, Technology and Society' (PhSTS), which trains students to become 'philosophical engineers'. The objective of PhSTS is to integrate an engineering study on the one hand and a study in philosophy, technology dynamics and history of science on the other in a 4-year programme. (In 1997 the programme will be extended to a fifth year.) The departments of the school participating in the PhSTS programme are Systematic Philosophy (i.e. disciplinary philosophy), Philosophy of Science and Technology (technology dynamics and sociology of science) and History of Science. In the original programme, all departments of the school participated in teaching PSTS. This was changed later on when the departments of Psychology and Linguistics started a programme of their own together with Applied Educational Science and Public Administration, called 'Communication Studies'. This programme started in 1993.

The PhSTS study starts after an introductory year in one of the engineering departments (including Management Science). Of the next 3 years of the curriculum, approximately 70% is devoted to philosophy and social science. In the remaining 30% the engineering component is continued, within a focused trajectory, up to graduate level (see Fig. 3).

Stimulated by an evaluation by an external committee, the programme was revised in 1992. The compulsory part of the non-technical share of the curriculum now consists of courses on the following subjects:

Second year: Philosophy of Science, Technology and Society (introductory course)
Modern Theory of Science, Technology and Policy

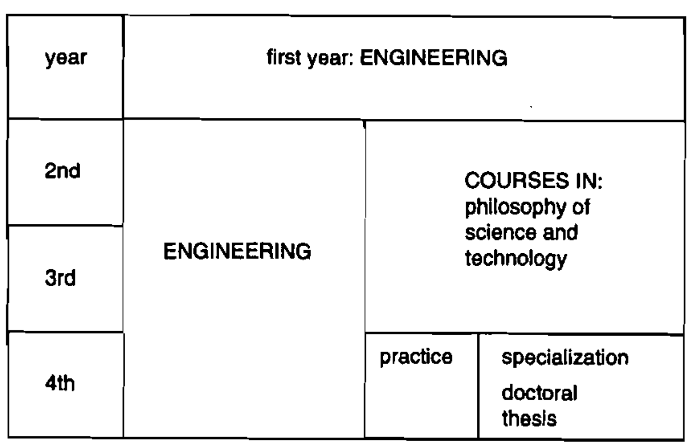

FIG. 3. Layout of the PhSTS programme.

Third year:	Influencing Science and Technology Development (projects)
	Philosophy of Science
	Methods of Empirical Research (practical)

For their final year the students choose one of the three departments of the school which participate in the programme. Each department offers an introductory training in undertaking research and supports the student in preparing a final thesis, based on a small research project and a practical period.

Which capabilities of the philosophical engineer does this programme hope to develop? The PhSTS programme advertises itself as training the following skills:

- competence for systematic reflection about technological developments;
- understanding of relevant developments in society;
- capability to communicate with technical experts on scientific, technological and societal developments.

The teaching staff still wrestles with the problems to be solved in order to realize these promises. The most demanding challenge appears to be the integration of the technical with the philosophical/sociological part of the programme, i.e. the creation of a real interdisciplinary programme.

Philosophical engineers are expected to become employed in jobs which are at the crossroads of technology and society, that is, in places where engineers must communicate with social, juridical and other experts, like advisory or consultancy jobs on matters of safety, health, environment, automation, etc. Other job opportunities are in interdisciplinary research, in product development teams of firms or in policy-making.

In general, the development of the PhSTS programme contributed strongly to the willingness of the staff of the School of Philosophy and Social Sciences to develop courses in conjunction with the engineering departments.

4. Learning from Experience

In this section, we restrict ourselves to the Ph&S programme for practical reasons (the number and accessibility of data). We can learn about Ph&S from the experience with its practice, which has now been in existence for a period of almost 30 years. We shall divide this experience into two categories. We shall first indicate some trends in the eventful history of Ph&S in our university. This is a struggle between the two cores of the UT, which takes place mainly at the level of staff. It reveals a bit of the mental frames and attitudes by which the various departments assess Ph&S. Second, there are data available from evaluations carried out. From these we collect information about the students' appraisal of Ph&S.

4.1 Trends: From the Ideals of the 1960s to the Realities of the 1990s

The start of Ph&S was rooted in the idealism of the 1960s. Science should be 'society relevant', and research which could be associated with the military or with business (especially multinational firms) was highly suspect. Thus, Ph&S was part of a case which showed that UT took these concerns seriously. Leading professors represented the engineering departments on the Ph&S Coordinating Committee, which worked in a spirit of cooperation. In the 1970s a latent conflict became visible which flamed up at several occasions in the years to come. This conflict is about a power question: who decides on the share of the engineering programmes to be devoted to Ph&S courses? As already mentioned, this share has declined over the years. The options for interpretation of this issue by the engineering departments range from "Ph&S helps us to turn out better engineers" to "Ph&S costs our students too much time which could be better spent on engineering courses". As times become harder—because of budget cuts, decreasing number of students, reduction of total curriculum time—the engineering departments tend to shift to the latter extreme of this range. The departments of the other core (social sciences) fight back, since teaching Ph&S courses is for some of them the rock-bottom of their existence, especially since universities (and thus their departments) are funded on the basis of the numbers of students they attract. Technically speaking, the engineering departments have formal authority over the arrangement of their own programmes, which is mitigated by the position of the Board of the university which maintains that a certain share of Ph&S courses should be taught in engineering curricula. Thus, the fight is over the share and the quality of the Ph&S courses, not over the existence or usefulness of Ph&S as such.

The lesson from the foregoing is that although there is lasting support for Ph&S, Ph&S is not self-evident: its legitimization needs to be maintained and refreshed. What a good legitimization is shifts along with changes in society, and thus needs renegotiation from time to time. The need for integrated training of engineers is not contested by the engineering departments. Compared with the 1960s, however, this goal has to be realized within tighter constraints of time and budget. This means that 'ethics' or 'sustainability' cannot be the waving of another flag under which philosophers and social scientists continue to sell their disciplinary knowledge through Ph&S courses. More than ever, there must be a demonstrable contribution of these courses to a paradigmatic chance in the education of engineers directed at a further integration of reflective and technical approaches to the problems that our society faces.

4.2 How Students Appraise Ph&S: Outcomes of Evaluations

In 1992/93 the Ph&S Board carried out an extended evaluation of the Ph&S programme, the outcomes of which have been published in a detailed report [1]. The data on which this evaluation was based were collected from different sources. Most of the data were aggregated data, i.e. they were collected by the Board over all courses in all faculties together. These data were complemented with data from evaluations carried out by the faculties themselves and/or by external committees reviewing the faculty's educational programmes.

4.2.1 General outcomes (aggregated over all courses). From 1991 on, most of the Ph&S courses have been evaluated by means of a standard questionnaire developed by the Ph&S Board in cooperation with the Center for Educational Science (Onderwÿskundig Centrum, OC). The students were asked to fill in this questionnaire at the end of the exam concluding the course. The following items were monitored by a score on a five-point scale:

- study time devoted to the course (as estimated by students);
- quality of courses (are they interesting and motivating?), of teaching, of study materials and of course organization;

TABLE I. Real study time devoted to Ph&S courses (in % of total course time)

Year of study	Number of courses evaluated	<50%	50–60%	60–70%	70–80%	>80%
1	11 out of 12	0	2	7	2	0
2	12 out of 16	1	3	6	2	0
3/4	17 out of 90	0	2	6	7	2

- relevance of the courses for academic, technical and personal education (this question was asked in order to probe the realization of the approximated goals of Ph&S, which were considered as very difficult to evaluate directly);
- incentives for choice of particular courses;
- output figures (percentage of students who pass exams).

The Board reviewed the evaluation outcomes on a regular basis. In cases where results fell below a certain level, the teacher and department in question were informed that the course needed improvement.

For the afore-mentioned report, the Board used the data from the 1991/92 and 1992/93 evaluations. We highlight the outcomes as follows.

Study time devoted to courses (percentage of total course time). According to the Board, these figures indicate a severe underspending, especially in the first few years (study time is no more than 50–70% of total course time). In later years the situation improved (study time going up to 70/80%, approximating study time spent on technical courses). The reliability of these figures suffers from a high number of non-respondents (Table I).

Quality. The data indicate that Ph&S courses are found interesting, but do not build very much motivation for Ph&S education, i.e. they do not raise much goodwill and interest for Ph&S-related questions and themes. This applies especially to the courses in the first year. The quality of teaching comes out as satisfactory; only in 10% of the courses did teachers score negatively. About the quality of study materials, the students' opinions are much less positive. In part this negative judgement probably relates to the share of English compared to Dutch texts.

Relevance. Of the great majority of courses, the contribution to the academic and personal education of the students scored much higher than the contribution to the technical education. The range of courses offered is in almost complete agreement with expectations and demands of the students.

Incentives to choose a specific course. For all students the most important reasons for choosing a specific course were expectations concerning the content of the course (is it an interesting course?) and the relation of the course to the technical programme. For first-year students, more opportunistic motives also counted heavily, like the level of difficulty of exams (multiple-choice tests being strongly preferred) and the costs of course materials.

Output figures. The figures in Table II refer to those students who passed their exam the first time (i.e. those who did not need a resit). The percentage

TABLE II. Percentage of students passing Ph&S course exams without a resit

Year of study	Number of courses evaluated	30–40%	40–50%	50–60%	60–70%	70–80%	>80%
1	11 out of 12	2	2	2	1	2	2
2	12 out of 16	2	1	1	1	3	4
3/4	17 out of 90	0	4	2	4	3	4

of students who pass exams during the first year is substantially lower than those who pass exams during the later years. There was no correlation found between study success and time devoted to study.

Distribution of students over the courses (or: which are the most popular courses?). The distribution over the courses in respective years of study is shown in Figs 4–6 (first year, Fig. 4; second year, Fig. 5; third year, Fig. 6), The outcomes raise the question why certain courses attract so many more students than others. Earlier research by the OC (1987) indicates that students' choices for Ph&S courses are

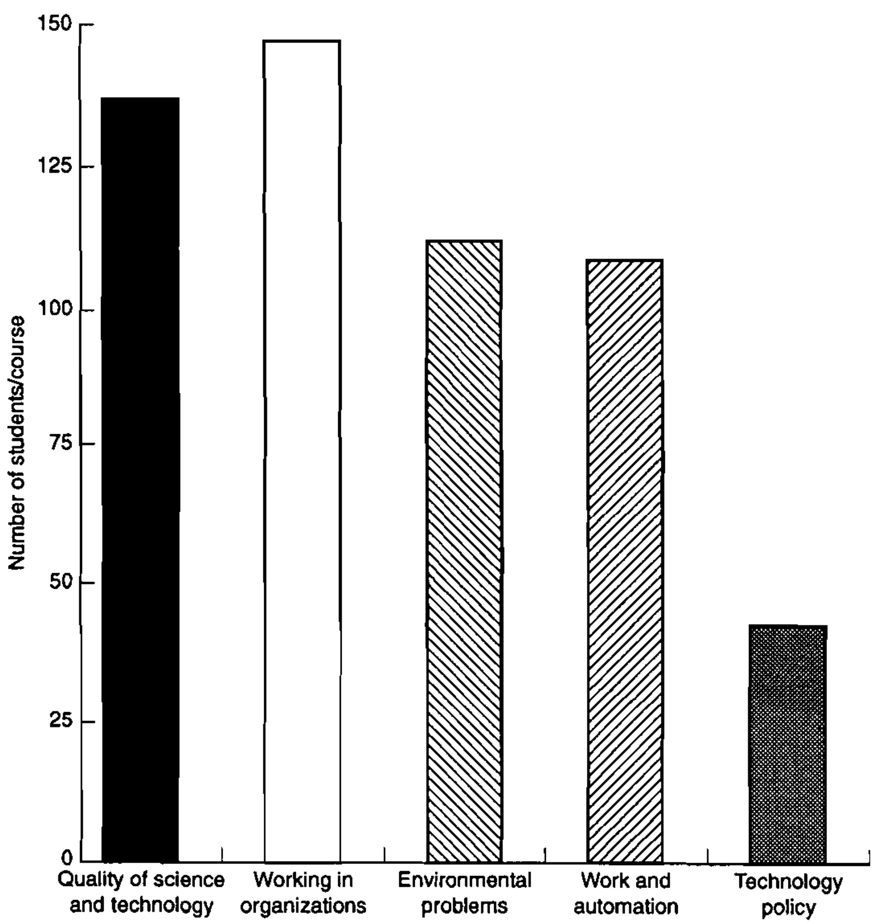

FIG. 4. Distribution of students over Ph&S courses (first year).

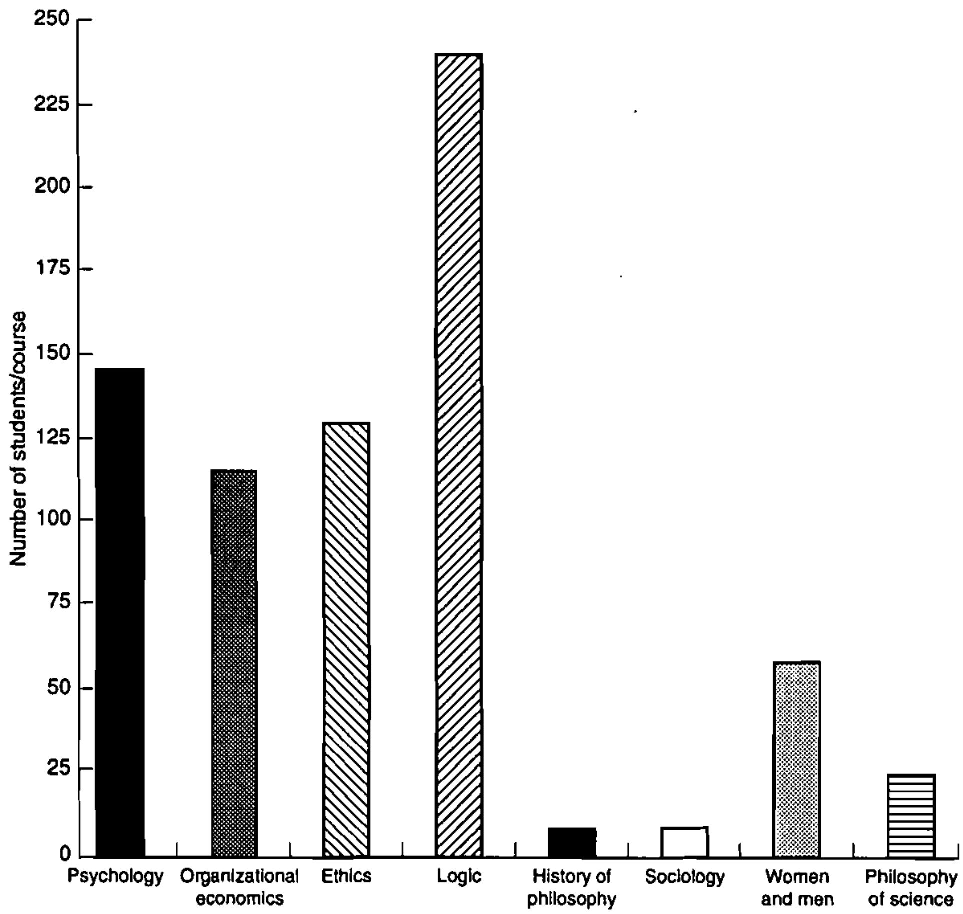

FIG. 5. Distribution of students over Ph&S courses (second year).

mainly determined by considerations of usefulness and relevance for their later career. Another important reason was the obscurity of alternatives; students often do not comprehend what alternative courses amount to. Looking at the figures about study time it is clear that some courses can be passed with less effort than others. For the less motivated students this will certainly be an important determinant of choice.

We might add that similar trends may be at work here as were indicated in the first part of this section. Where early Ph&S courses were attractive and selected mainly for idealistic reasons, nowadays a larger part of the students—confronted with a shrinking labour market and rising demands of employers—want Ph&S courses to improve their career chances. Thus, over the last few years, courses with buzz words like 'management', 'organization' or 'communication' in their title have become popular with students. For the 'softer' courses to recover their lost ground, they have to make clear that reflexivity pays.

In summary, the Board considered the outcome of the evaluation based on the questionnaires as positive. In general, the quality of the courses and of the teaching was judged satisfactory by the students. The following points were indicated by the Board as the main weak points. The study time devoted to the Ph&S courses is too low. This creates an image of Ph&S courses as easy to pass, which in turn leads to underestimation and bad output figures. Especially in the first year, the number of students passing their first exam should be much higher. Another problem is the outcome that taking Ph&S courses does not motivate the students for the goals of Ph&S very much. In the Board's opinion, these problems are not easy to solve. It has appeared that when easy courses are intensified, students drift to other courses. Part of the student population seems to appreciate Ph&S courses and the opportunity for reflection these courses offer. Another part seems to want to flee from such activity as much as possible, especially in the first years of study. This is a structural problem, which the Board perceives as very hard to solve.

4.2.2 Outcomes on faculty level

Outcomes of internal evaluations. Evaluations carried out occasionally by some of the engineering faculties confirm the interest of students in Ph&S courses. On average, however, in comparison with the technical courses, the Ph&S courses are judged as being too easy. In 1993 the Mechanical Engineering Department carried out an extended evaluation of the first year Ph&S courses. On the basis of this evaluation (1992), the faculty expressed its satisfaction with the level and the

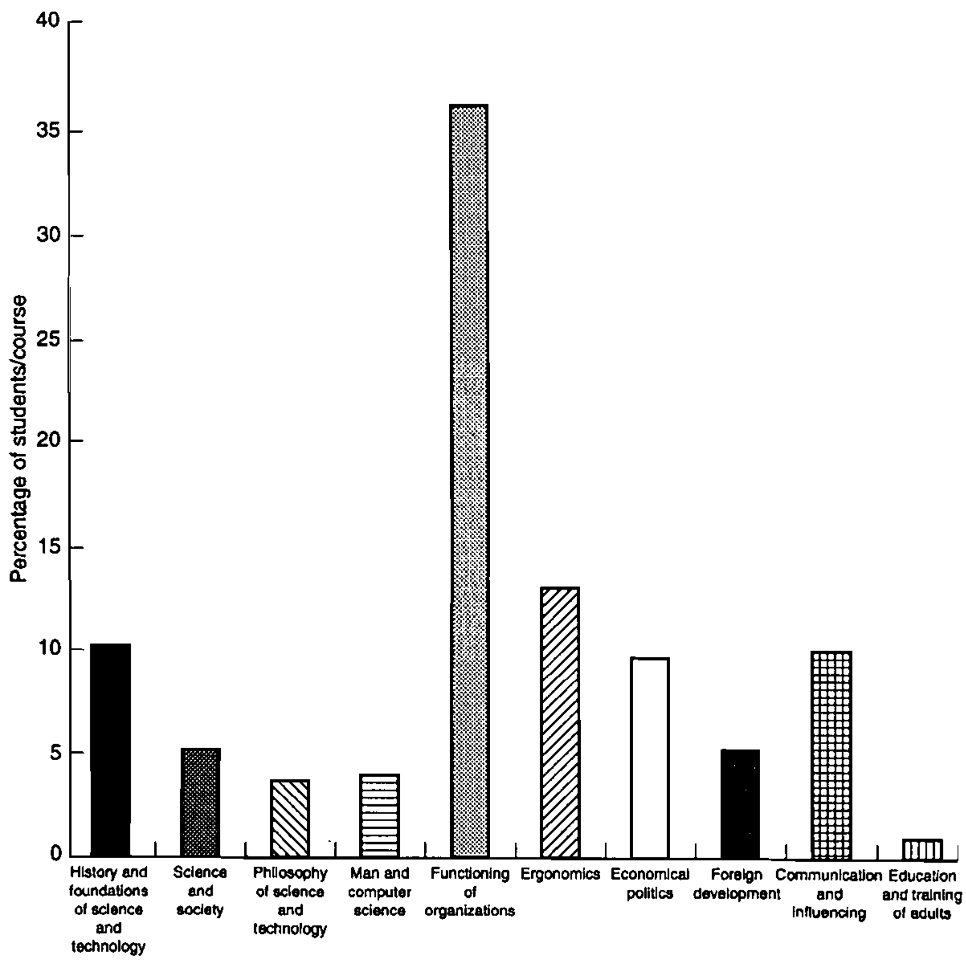

FIG. 6. Distribution of students over Ph&S courses (third year).

content of these courses. Nevertheless, the faculty wanted smaller classes and a better connection of the content of the Ph&S courses with that of its technical courses. A similar evaluation by the Department of Computer Science (1993) revealed that students do not spend enough time on Ph&S courses and achieve bad results. Students appreciate the idea of Ph&S, but they want the implementation to be improved.

In 1993 the Board organized interviews about Ph&S with the deans responsible for education in all technical faculties, and with student representatives. These interviews can be highlighted as follows. The deans agreed about the usefulness of a Ph&S component up to about 8% of the technical curricula and about room for students to choose the courses they want (although opinions on how large this room should be differed considerably). In addition, the deans wanted Ph&S courses to be more concerned about relevant aspects of the technical education of students. The Department of Mechanical Engineering took the most extreme position in this respect, demanding the exclusive right to decide on its own Ph&S education, which should be obligatory for its students in the first 2 years of study, offering courses which are well integrated with the technical part of the programme. The department of Chemical Technology wanted a shift of the more reflexive courses to the later years of study, where motivation of the students for this kind of courses is higher. Representatives of the students underlined the importance of Ph&S courses for students. They identified the easiness of the courses, the opportunistic way in which students choose courses, lack of attractiveness of (some) courses and the overcrowded classes as weak points of the Ph&S programme. Like the deans, the students complained that Ph&S and technical courses are worlds too far apart. On the other hand, these students ranked the 'reflexive' goals of Ph&S ('fostering the technician's sense of responsibility' and 'fostering insight in the cohesion of the sciences') much higher than the practical one ('preparing for the engineering profession').

Outcomes of external evaluations. Ph&S courses have also been assessed by external committees in the framework of national evaluations of the quality of academic educational programmes. We mention the outcomes of such external evaluations in those cases where attention was paid to Ph&S courses.

The committee which evaluated Applied Mathematics found the share of the curriculum devoted to non-mathematical courses remarkable, especially in the first year (9%). The committee made a similar remark in reviewing the curriculum of the Department of Computer Science. The committee added that it was astonished that, "despite this large share of Ph&S courses in the curriculum, students nevertheless often lack social and reporting skills". The evaluation report on Electronic Engineering (1991) advised changes in the share and the content of the Ph&S courses to reach a better agreement with the demands of the technical programme. The committee also established that the students diverge in their opinion about the usefulness of Ph&S. The committee got the impression that students see Ph&S courses as an easy way to collect credits. In this respect it is interesting to mention the findings of the IPR-EE committee (committee for International Programme Review Electrical Engineering) which compared nine electrical engineering programmes in six countries. In general, the committee found that the curricula under review paid too little attention to humanities and social sciences, with the exception of the UT and the ETH at Zürich. The committee advised spending at least 5% of curriculum time on non-technical courses (at UT this share was, at the time of the evaluation, almost 8%; see earlier). The evaluation committee reviewing Chemical Technology (1993) also concluded that the Ph&S courses are too easy and should be reconsidered. Moreover, the committee established that the supply of Ph&S courses and the world of the chemical engineer are too far apart. It advised that part of the courses may be better taught by chemical engineers themselves.

5. Developing the Content of Courses

Even if it is obvious that the programme which one has formulated demands an interdisciplinary approach, sticking to a disciplinary practice is seductive. To confine oneself to the fundamentals of ethics, the birth of science in the seventeenth century, the use of a learning curve or the latest management approach as the subjects of interest to be taught to engineers, indeed offers considerable advantage to the teachers. They can continue to make use of existing topics, terms and textbooks, which may be close to their own expertise and interests. The flaw of this easy and safe approach is the gap that remains with the practice of the engineers themselves. This gap prevents the goal of broadening the education of engineers to get real impact on their practice. To reach that goal one has to delve deeper and dig up in the engineer's practice the relevant issues which subsequently can be enlightened by connecting them cleverly with relevant insights derived from experience and thinking in different disciplines. That requires quite an investment and much ingenuity indeed. In fact, it turns upside down common practice in higher education. Thus, overcoming disciplinarity is an issue for Ph&S education. To clarify this issue and to demonstrate our approach, we give an example from the current practice of PhS teaching.

5.1 Overcoming Disciplinarity in Ph&S: Designing for (a Sustainable) Society

One of the current efforts in overcoming disciplinarity in the Ph&S programme concerns the development of a new course, called 'Designing for Society'. As the name indicates, this course puts designing, which is viewed as the core task of the engineer, at the centre of attention. The current concepts and textbooks which are being used in engineering curricula stress the technical side of design work. By conceiving designing as a social process, we hope both to reveal the shortcomings of the current approach and to offer strategies which may help to improve existing design practice. We undertake this by revealing the wider dimensions of design work by means of presentation and analysis of a number of brief cases.

To minimize the gap with the students' own situation, we pay ample attention to design work carried out at the engineering departments of the UT itself. A number of the cases selected are presented by staff from the engineering departments or by young engineers who have graduated from UT and now work at engineering firms, or have firms of their own. We also seek presentations by large firms which are well known for their successful design activities. As a third category, we use cases from the literature on the sociology of science and technology.

To elucidate the wider dimensions of the technical design cases, conceptual frames are needed. To this end, we mostly use concepts and frames derived from constructivist technology dynamics and constructive technology assessment [2]. Every technical presentation of a design case is followed by an analysis in terms of these frames given by one of the teachers of our department, which—if possible—is commented upon by the engineer presenting the case. The following example illustrates this approach, and also makes clear that it lends itself quite well to the introduction of the issue of sustainability into design practice.

5.2 Case: The Whispering Boat

5.2.1 First hour. The 'whispering boat' is the first case in the 1995 Ph&S course 'Designing for Society' which is attended by about 65 students who are in their first year of study in one of the engineering curricula. Being an introductory case, it is meant to serve as an exemplar of the approach chosen for the whole course. During the first hour the case is presented by a young UT engineer who has graduated recently from the Department of Mechanical Engineering. The presentation is based on his final thesis. His account is a technical one, which describes the design of an electrically propelled water-bus intended for sightseeing trips in the lake district of northwest Overijssel, the province in the southeast of which UT is located. The project is carried out under contract for an external consortium, in which a provincial foundation for environmental protection, local firms and the Ministry of Economic Affairs participate. The project's objective is to decrease the pressure on the environment by the existing tourist business whose frequent boat trips cause a lot of noise, emissions and water pollution. A compelling condition from the ministry's side is the participation of the local firms in this project which should produce a 'whispering boat'.

The design job to be carried out is in fact the redesign of an existing boat type which is propelled by an outboard gasoline engine. The presentation by the engineer highlights the (re)design problems, i.e. expected as well as unexpected problems, which have to be tackled. There are narrow design constraints to be met: to reach the necessary range of action for a trip around the lakes and canals, the electric boat has to carry a considerable load of batteries. These heavy batteries, however, should not increase the draught of the boat too much because the canals are, in many places, no more than 2 feet deep. The solution of this problem requires a change in the construction of the boat, including the use of a new type of material to mould the stern-post. But this design change meets strong resistance from the local boat-constructing firm, which lacks the necessary skills and machines to process this material.

The foregoing account is primarily a technical one. It is clear, however, that it includes several references to a wider, non-technical environment which is a condition for the development of the technical artefact in question. This environment consists of both physical and social elements which enable or constrain the work of the designer, depending on the costs of their malleability. For instance, the shallowness of the canals is a severe constraint on loading the boat with the necessary batteries, but dredging is an impossible option. Keeping involved the local firms with their bounded skills and resources is another limitation for the designer: it excludes most of the innovative options based on leading edge technology. Finally, the outcome should not only be an economically viable electric boat. Such a boat should also be optimal in terms of environmental protection and sustainability, otherwise the designer would lose the support of one of his most important commissioners. In fact, the designer–engineer has to walk on a tight-rope connecting the worlds of nature, technology, business and environment as represented by their local spokespersons.

5.2.2 Second hour. The non-technical aspects just mentioned—or better, the more concealed elements of the technical enterprise—are broached in the second hour of class. It is explained (by one of us, i.e. the teaching sociologist/philosopher) that the boat can be conceived as a web of connected elements, which are linked up with further elements in the wider physical and social environment. (This idea of a 'seamless web' in which artefacts are embedded is a very familiar one in the field of constructivist technology dynamics [3].) The message of framing the matter in these terms for the students is that the change of one of the elements by the designer compels the change of other elements to which the first is connected, and that such changes always bring costs as well as benefits. Thus, designing is a balancing act, of which the direction of optimization is guided by principles which should be made clear and maintained. In the case of the whispering boat, the main guiding principle is sustainability.

The next notion introduced is that of the design network. This is the network of (human) actors which develops the 'whispering boat' by exchanging views (like problem definitions, proposed solutions), funds, knowledge, expertise, materials, gossip, emotions, etc. Here again some lessons are communicated. Existing artefacts are embedded in maintenance networks which have evolved from previous design activities and their networks. Redesign often means that these existing networks must be changed: some old actors have to be moved out and new ones have to be brought in. This can be a difficult and sometimes painful job, as it was in the case of the 'whispering boat'. For instance, the small construction firm in the village which had developed, sold and maintained the current gasoline engine, appeared—after a long period in which it claimed the opposite—to be unable to construct and deliver a light electric engine for the 'whispering boat'. Finally, another firm from a nearby village was hired to do this job. This move caused severe tensions among actors in the design network.

The first lesson here is that design work is not restricted to the recognition and solution of technical problems, but also of social ones, that is, problems allied with the management of the design network (or better, the solution of technical problems boils down to the management of heterogeneous networks). The second lesson is that the direction the design process will take—and thus its outcome—depends on this management. It is the constellation of actors realizing a technical design which is the main force in moulding the substance and final shape of the nascent product. Thus, the sustainability of a technical product can be increased by organizing the design network to be adequately composed to this end: for a technical design to be successful it should be linked up with deliberate and adequate social design. The third lesson is that engineers should develop the management skills needed for such social design.

5.2.3 Other cases. In one hour of class the foregoing considerations can only be introduced. They set the agenda for the remainder of the course in which the approach is further developed and enriched, on the basis of additional cases partly introduced by other engineers, partly derived from the literature. A few examples from the latter are cases derived from the literature concerning efforts on technology diffusion to Third World countries. This literature abounds in cases which show what happens when design networks and user networks lack connection: the artefacts designed and developed in the West often fail in the countries of destination because of differences in habits of using the products, lack of intrastructure or maintenance context, etc. (e.g. [4]). Another case of disconnectedness of networks which may threaten the final success of a technical design is the gap between the worlds of men and women. Here we touch the gender aspect of design work. The introduction of this aspect in the face of a classroom full of male engineering students evokes the unavoidable giggling, which is the stronger because the subject is explained by a case on cooking. We use the well-researched case of magnetron design [5] to show how women have reluctantly been let into the male domain of the electronic engineering firm to test the performance properties of the magnetrons designed. Such tests require expertise on cooking and baking which the male design engineers lack. In other words, by recruiting women the firm tries to repair the gender bias in the design network of its magnetrons, be it that the 'housewives' performing the tests are kept at a safe distance from the design department where the real engineers (all male) work, and are ordered to keep the door of their 'kitchen' shut since baking smells are supposed to undermine the firm's high-tech image.

6. Present Situation

At the beginning of the 1990s a third stage of change started, initiated by an increasing tension between the ideal of the critical function of Ph&S (a concern defended mainly by students) and the interests of the engineering departments struggling for survival in an age of budget cuts and rationalization of the higher education enterprise. The most important outcome of this confrontation is an emerging trend to service teaching on a bilateral basis. That means that individual engineering departments want Ph&S courses to be developed and taught by a non-engineering department about specific topics which the former consider to be of special importance for their students. If this trend becomes dominant, it would mean that engineering students are no longer free to compose—within certain constraints—their own Ph&S programme from a general Ph&S curriculum. The engineering departments will not only prescribe the technical courses which have to be followed, but also the Ph&S courses which belong to it. At the moment there is an agreement that the total of study points for bilateral courses in an engineering curriculum may not exceed six points (one study point is 40 hours of study time). Because the total of available study points for the Ph&S programme is a minimal 14, there remain courses to be chosen freely.

Instead of structuring the programme by means of themes the Ph&S Board opted for a structure in which engineering students do a technical major and a non-technical minor. Students can also choose to do an extended minor; in that case they have to invest more time than the obligatory amount of study points.

For the Philosophy and Social Sciences departments the bilateral approach to Ph&S is an ambivalent change. On the one hand, it means a challenge to improve Ph&S courses by tightening reflexive notions and concepts in their own domain to relevant topics within specific fields of technology. On the other hand, bilateral teaching adds considerably to the working load of the staff of the non-engineering departments, since more courses have to be taught to smaller classes. Not all staff members have decided yet whether they should welcome the new trend but at the Ph&S Board level the decision has already been taken: the bilateral courses contribute more directly to the learning goals of the technical curricula and their quality will be the first priority of the Board. For the improvement of all Ph&S courses the Board of the university has allocated f 150 000 ($85 000) yearly for a period of 5 years. The Ph&S Board has already decided that the development and evaluation of bilateral courses will have priority in the first years. After that the priority will shift to courses that use cases from engineering domains and have a problem-orientated learning approach.

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