Environmental engineering education in conjunction with or as part of social sciences curricula

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Abstract Traditionally in Germany environmental engineering education took place within the context of a civil engineering programme. There were reasons for this: the beginning of much of what we understand today to be environmental works fell within the parameters of city engineering. There were and are advantages mostly in view of the necessary planning, construction and operation of environmental infrastructure. There are also disadvantages which become more and more pronounced as the field of environmental protection expands: the civil engineer frequently lacks basic training in disciplines such as biology and chemistry and carries a large and sometimes burdensome knowledge of other less relevant subjects. Thus, educators begin to look for alternatives.

This paper deals with an alternative that was developed some ten years ago and therefore has proven viable and successful: at the University of Karlsruhe students may choose to major in environmental engineering within the context or on the basis of an economics and business administration curriculum. The basic question here is as to what extent the student masters the field of environmental engineering if he or she has predominantly a solid background in social sciences and very little in natural sciences.

The paper will describe the curriculum in structure and intensity and evaluate the accumulated knowledge and suitability of these students in terms of actual environmental problems. This will be done in terms of examination performance parallel and/or relative to traditionally trained civil environmental engineers as well as in terms of topics successfully treated in Masters' theses. In conclusion, it is argued that such combination of curricula should not be confined to economic sciences and environmental engineering but also be planned for legal sciences and environmental engineering.

Keywords Environmental engineering curriculum; business administration curriculum; combined business and environmental programme; distribution of subjects in combined programme; evaluation of curricula

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Introduction – environmental engineering programmes presently

In academic institutions programmes of instruction and/or research generally resemble the evolutionary pattern of microbial populations: after an initial lag-phase or time of incubation there is a period of rapid growth in terms of initiatives, interest, output and practical results. Sooner or later, however, a phase of slowing down or even stagnation occurs which finds its expression in fewer students, established professional hierarchies and a shortage of readily discernible progress in theory and practice.

This process of maturing or even "aging" of classic disciplines can be illustrated, for example, by an analysis of the present situation in so-called classical hydraulic engineering: this subject is defined by coherent structures of theoretical and practical concepts. Progress in this field in terms of new theories or further impact upon practice has become less virulent than it was some decades earlier. Presently the most exciting developments in hydraulic engineering happen at its boundaries, for instance in the application of hydraulic principles to solve problems of mixing, transport and transformation in complex bodies of water.

One is tempted to state that progress in many academic fields is more visible at the very borders of a field, at interfaces between classical fields and not so much in formerly essential areas. So-called "hyphenated" subjects, such as bio-engineering readily illustrate this phenomenon.

The earliest roots of environmental engineering as an academic subject date back to the turn of the century when hydraulic engineering pioneers such as Rehbock developed instruments to simulate the movement of water in complex river and estuarine systems in laboratory models thus allowing the identification of consequences of anthropogenic processes and facilitating the compensation of negative effects of such man-made changes in natural systems. Likewise so-called sanitary or public health engineers, in German academia most frequently referred to as "urban water resources engineers", developed first instruments for the compensation of negative effects on water quality stemming from anthropogenic impacts upon natural water systems in terms of (simple) wastewater treatment plants.

From that time on, programmes for the education of hydraulic engineers or sanitary engineers, i.e. in some sense environmental engineering, developed foremost within the realm of schools of civil engineering. There were some definite advantages to this configuration in terms of planning, design and operation of such infrastructure. However, there were also definite shortcomings of the civil-engineering-based education in environmental engineering: the competence of civil engineers for solving structural problems tends to be significantly larger than their understanding of the chemical and biological processes being hindered or changed as a result of their actions.

This has led already in the past to some sort of interdisciplinary "education" in the form of "on-the-job" training: the classical hydraulic or sanitary engineer either supplemented his curriculum by subjects of a chemical or biological nature or he engaged in laboratory-type work with chemical and/or biological methods frequently in a matter of trial and error; thus he left the centre of his discipline for other additional experiences. One might say that he moved to or even crossed over the boundaries of his academic field. It is easy to illustrate such developments by pointing, for example, to the computer-sciences-oriented civil engineer.

It is readily understandable that we need more effective and faster methods of adapting a teaching programme to developing insights into the specific problems of an academic subject and the resulting change of concepts and instruments for its solution. To leave this adaptation to the young, less experienced and developing professional might be reasonable in the case of a highly motivated and very gifted individual. It will not be sufficiently effective for the average student.

A recent evaluation of the environmental research and teaching sector in Germany, carried out by the Commission on Scientific Research and Teaching (Wissenschaftsrat 1994) confirmed this concept. The multi-disciplinary group of specialists analyzing all German programmes gave noticeably higher grades for all those institutions where good interdisciplinary programmes of training and research existed in a combination of engineering disciplines with natural sciences or life sciences.

However, they also identified weak or insufficient programmes or pointed out needs for development in environmental research and teaching in terms of the integration of social sciences. Environmental engineers or engineers in general are frequently hesitant to include such aspects in their deliberation, i.e. they rarely move across the boundaries of their own discipline with those fields.

The Karlsruhe situation in terms of education in environmental engineering

A strong environmental programme with old tradition

The former Institute of Technology of Karlsruhe, the predecessor of the University of Karlsruhe (Technische Hochschule Karlsruhe) is amongst the oldest technical academic institutions in Europe. The founder of the Institute was J.G. Tulla who has become known for the so-called rectification of the river Rhine. In terms of his training (as a geodetic engineer at the École Polytechnique in Paris) and his subject of study, i.e. the Rhine, he should

be counted amongst the first environmental engineers, even though the correction of the Rhine, transformed by his successors into a channelization, would be looked at very critically today. He not only founded the Institute of Technology in the year 1825 but established one of the first programmes in civil engineering.

Rehbock, a hydraulic engineer, was the first to define and test around the turn of the century theorems that allowed model investigations on the movement of water in complex natural bodies of water, reconstructed according to Rehbock's laws in large hydraulic laboratory stations. He also established one of the first and still largest hydraulic testing stations at Karlsruhe. Shortly thereafter, two rather practice-oriented chemists, Engler and Bunte, began work on gas, oil and water chemistry questions that rather soon led to the establishment of the Engler-Bunte Institute, an institution that dealt very early with resource management and conservation.

Today there are very strong environmental programmes at the University of Karlsruhe which cater alternatively to civil and chemical engineering students (i.e. environmental engineering) or to geo- and biosciences scholars (hence environmental sciences). The relative strength of the programme can be seen from the large number of students choosing theses subjects as well as the depth and width of the different programmes that the university offers. The programmes are, however, not confined to the identified schools of geosciences, biosciences, civil engineering and chemical engineering. Their very modular structure allows or even suggests that engineering students include environmental sciences topics such as geo- and biosciences. Students frequently augment their curriculum with pertinent engineering topics. The teaching staff itself has informal or formal appointments in more than one programme or school. The research done by students and teachers in these programmes impresses not only by the large financial scale but especially by the prize-winning theoretical and practical results. All in all, one can conclude that environmental programmes at the University of Karlsruhe are well established, attracting students and researchers alike and produce innovative results. These positive experiences could be summarized as set out in Table 1.

Strong applied economic training programme

The University of Karlsruhe has offered classical programmes in economics and business administration since the early nineteen-thirties. The "youngest" curriculum, the so-called economic engineer ("Wirtschaftsingenieur") has turned out to be so attractive and success-

Table 1 Characteristics and desiderata of effective environmental engineering programmes

Important From	Realized by
Students' point of view	Focus on basics (application left to practical position)
	Close interaction of junior and senior staff from research and teaching
	Multi-unit programmes (allowing flexibility and individual selection)
Professional viewpoint	Interdisciplinary (allowing the combination of and the complementary addition of different fields)
	Science and Engineering oriented
Development of field point of view	Research connected (spawning and supporting innovation)
	Oriented to the solution of practical problems (technology transfer)

ful that the former division of economics had to be enlarged to a separate school of economics, and this school counts today amongst the largest of the whole university.

This (quite recently developed) programme of economic engineering is continuously evaluated and adjusted according to the students' needs and the prospective employers' suggestions. It could be called a compacted or curtailed business administration curriculum with a strong minor in an engineering subject. The latter subject is chosen by the student. The programme begins similarly to other business administration programmes, i.e. its basis is business administration. The engineering subjects, which might also comprise computer sciences or computer engineering, appear in the latter third of the curriculum. This programme is intended for professionals who predominantly will work in an industrial and business management environment wanting or needing a reading and/or speaking knowledge of the technical side of the business or industrial operation.

The present structure of this curriculum in terms of the different contributions from the two disciplines, i.e. the quantitative distribution of economic and engineering subjects can be seen from table 4 (column 3). It becomes clear from this ratio of economic to engineering subjects that the students completing this programme should apply predominantly or most frequently for positions of business administration. However, there are numerous examples of such graduates who find good and influential positions in engineering environments. And there are more numerous examples of high achievement and impact within engineering fields by former students of economic engineering. This is not dependent on whether they are now predominantly engineer or business manager.

The acceptance of these programmes by students as well as employers is significant and has confirmed that this idea is a good one. In fact, the acceptance by students is so good that this programme became the largest in the whole university in terms of student numbers. It also became the most prestigious, due to the German academic situation where the universities must take all High School graduates until the schools capacity is exhausted. Only then the school can select according to a ranking of the applying student in agreement with his

Table 2 Characteristics of the economic engineering programme at Karlsruhe University

Partners	Observed Action/Reaction
Faculty	Recently developed – no limitations in programme development in terms of tradition
	No existing chairs or traditional teaching subjects that are automatically to be included in the curriculum
	Large number of applicants for programme leads to highly selective procedure of acceptance
Prospective students	Intellectual characteristics of students and achievements reflect this selective process
	Selection, achievement, positioning similar to autocatalytic growth processes
	Due to large student numbers the teacher to student ratio is not sufficiently large and student organizations have to help in curriculum development etc.
	The students engagement in curricular matters again leads to higher identification with the programme and better suitability from the students point of view.
Prospective employers	Harmonized with expectations of prospective employers
	Graduates readily find good positions
	High rating in university ranking list, both from view point of students and from viewpoint of "practice"

academic achievements in High School. This means that this much sought-after programme can select the best students, i.e. it will in an autocatalytic way increase its attractiveness.

Possibilities and limitations of closer cooperation between programmes

The question then arises whether it would be fruitful and desirable to establish a joint curriculum by combining the advantages of both programmes described: the long tradition and high professional acceptance of the environmental school and the productiveness of the applied economic programme. Why does such a question arise? There have been students crossing programmes, adding various elements of either curriculum. Also there have been research projects involving faculty from both programmes; upon fruitful cooperation these specialists decided to explore the possibilities of a more planned cooperation, both in research and in teaching.

Basically in a German university, where curricula and degree responsibilities always rest with one so-called "Fakultät", i.e. school, there would be two avenues to such cooperation: a programme developed by the civil engineering school, including a sizeable input from the economic curriculum or vice versa an economic engineering programme with one major pillar of environmental engineering. Both alternatives have advantages and disadvantages in terms of additional subjects to be included for the new programme as well as those subjects that are desirable only from the point of view of perpetuating the traditional or existing curriculum. The decision then depends very much on the relative flexibility of existing programmes.

At Karlsruhe University, or rather between the two schools of civil engineering on one hand and the school of economics on the other (since it is the schools that are initiating, advocating and taking on responsibilities for curricula) it had been implicitly or silently agreed that such a joint programme would best be located in the relatively "young" school of economics. There the list of established chairs and subjects represented by those chairs and thus obligatory elements of a standard curriculum was considerably shorter than in the tradition-bound civil engineering school. Furthermore past experience (see previous paragraph) seemed to indicate, that economic (engineering) students appeared to cross traditional subject boundaries more frequently and more readily than their civil engineering colleagues, and their programmes permitted this more easily than the respective civil engineering programme with its long list of obligatory subjects.

The present combined programme is then at core a business administration curriculum with a very strong orientation towards mathematics (owing to the tradition at the Karlsruhe University). In this respect both original curricula, the economics one and the civil engineering one do not differ too much (see table 4). While the classical environmental programme within the civil engineering school allows for substantial teaching of applied natural sciences (applied physics, applied geosciences) the respective economic programme presents to their students applied economic and legal subjects. Here is a definite difference between both original teaching concepts and the resulting joint programme: the environmentalist emerging from the economics school has less exposure to applied natural sciences and significantly more input from social sciences. (Vice versa, the option of a joint programme based at the civil engineering school would have led to a certain deficit in social sciences and good input in environment relevant natural sciences.)

The quantitative analysis in terms of credit hours (as shown in table 4) points out quite clearly the definite strength as well as possible shortcomings of the present programme. This becomes particularly clear if one compares the new curriculum with two existing ones for environmental engineering, one offered by the Karlsruhe school of civil engineering (a variation on the classical civil engineering programme) and one offered by the Dresden University which developed very early a rather specialized programme for water resources

engineering, not directly descendent from a classical civil engineering programme. It is seen from this comparison that the "core-subjects" in the environmental field (here the alternative for water resources engineering) take up a similar number of credit hours in all three programmes. What has been said earlier in terms of basic training in mathematics, i.e. similarly strong elements for economics students as for engineering ones, is also seen from this table. The economic environmentalist from Karlsruhe University in addition takes many courses in information technology and computer sciences which puts him at an advantage in competing with other environmentalists. What then are the disadvantages of the programme? Is the very limited exposure to natural sciences as compared to the subjects that the civil engineer takes in applied physics (and very little chemistry or biology) a drawback?

This question should be answered by those students who have taken this programme or even better by the careers that those students have been able to follow (see Table 3). First of all the programme appeared very successful on the basis of number of applicants or students who have opted for it. But this may seem an argument which appears too superficial or too one-dimensional. Second, the programme proved its validity in terms of good graduates who do find interesting positions and enter promising careers. This, the potential employer's point of view in evaluating an academic programme, might also be too one-sided in another respect. Finally the third party in these activities of developing academic programmemes, the academic research and teaching staff, also evaluates the programme as very successful, not only because it attracts students in significant numbers, but much more because it attracts very gifted and highly motivated students who excel in academic achievements culminating in very convincing theses. It is in particular on the basis of the topics and results of these students' theses that one can argue the significance or insignificance of the lack of natural sciences training in that curriculum. At present there does not seem to be any necessity to significantly increase those students' exposure to applied natural sciences in comparison with the level of knowledge of their contemporaries graduating from the two "classical" programmes.

Concluding remarks

Will there be more such joint programmes, now that the one described here has proven feasible and effective? The answer is yes and this is for two reasons: first of all the classical environmental field (or going back even more, the classical civil engineering field – as is true for all established fields) no longer attracts the significantly large number of curious and motivated students as it used to, when this field emerged. Second, there are other disciplines that would equally profit from such combined programmes, since the essence of their teaching and research is of great significance to environmental issues: disciplines from the field of social sciences at large and in particular the legal disciplines.

The University of Karlsruhe is fortunate in that the city of Karlsruhe houses the two highest German courts, the Federal Constitutional Court and the highest court of appeal, the

Table 3 An attempt at evaluating the existing environmental programme within the school of economics at the Karlsruhe university.

How Should One Evaluate	Parameters of Evaluation
The "quantity" argument	Number of students choosing the programme
The "market" argument	Career options offered to graduates form this programme
The "quality" argument	Topics of Master's theses as compared to "classical" environmental programmes and results obtained
The "competition" argument	Academic prizes and distinctions obtained by economic environmentalists as compared to other environmentalists

Table 4 Comparison of three different environmental engineering programmes

	Civil Engineering **EEE Training (Typical German)**	*Specialized* **EEE Training (Dresden)**	*Economics* **EEE Training (Karlsruhe)**
First Stage (Grundstudium)	Natural Sciences plus Mathematics 41%	Natural Sciences plus Mathematics 20%	Mathematics (incl. Statistics) 25%
in	Introductory Civil Engineering 15%	Geo Sciences 5%	Introductory Courses Economics 15%
Second Stage (Grundfachstudium)	Computer Sciences 4%	Computer Sciences <4%	Computer Sciences 31%
	General Studies 1%	General Studies 5%	
	General Civil Engineering Subjects 10%	General Civil Engineering Subjects 23%	Special Economic Subjects 11%
Third Stage (Verteifungsstudium)	Water Resources (incl. Groundwater) 18%	Water Resources (incl. Hydrobiology+Groundw.) >19%	
	Environmental Engineering (incl. Surfacewater/Land Aspects) 11%	Environmental Engineering (incl. Surfacewater/Land Aspects/Hazardous W.) 22%	Environmental Engineering 8%
	Legal Aspects 1%	Legal Aspects >1%	Legal Aspects 10%
	6 written exams in aggregated civil eng'g subjects	5 (written) exams in aggregated subjects	7 written exams in aggregated economics subjects
Exam Requirements	1 written exam in major field (8% of all credits)	1 (written) exam in major field (7% of all credits)	1 oral exam in environmental field (8%)
	1 oral exam in field of concentration (<3% of credits)		3 (types of seminar) papers
	1 thesis	1 thesis	1 thesis

Federal Court of Appeals. Karlsruhe is rightly called the "residence of law". And it is the members of these courts and their staff that could develop an ideal input into another applied environment programme, one that might be called environmental law. Again the questions of where to establish such a curriculum and who should bear degree responsibilities must be analyzed and answered. Since there is not yet a school of law at the university it might well be that a technical school, even the civil engineering school could or must take on that initiative. This would mean a very good opportunity for a school whose physical and personnel layout are presently too large. The discussion of whether to reduce this school to a certain extent in direct response to a diminished number of civil engineering students could also be answered by developing a new programme at the periphery of classical engineering. Similar thoughts and arguments might hold for other classical engineering disciplines such as mechanical or chemical or electrical engineering.

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