

Practical training as part of higher environmental education

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Scholz, Roland W.; Steiner, Regula; Hansmann, Ralph

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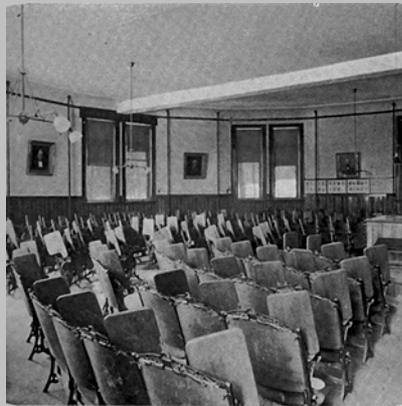
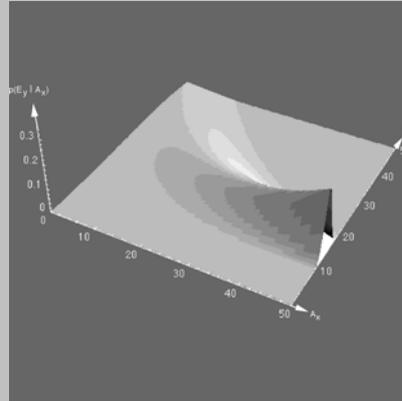
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Roland W. Scholz,
Regula Steiner, and
Ralph Hansmann

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Publisher:
Prof. Dr. Roland W. Scholz
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
Haldenbachstrasse 44
CH-8092 Zürich
Tel. ++41-1-632 5892
Fax ++41-1-632 10 29
E-mail: scholz@uns.umnw.ethz.ch

Corresponding author:

Prof. Roland W. Scholz
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
CH-8092 Zürich
Tel. ++41-1-632 5891
Fax ++41-1-632 1029
E-mail: scholz@uns.umnw.ethz.ch

Co-authors:

Regula Steiner
Departement Umweltnaturwissenschaften
ETH Zentrum HCS
CH-8092 Zürich
Tel. ++41-1-632 2564
Fax ++41-1-632 1309
E-mail: steiner@umnw.ethz.ch

Ralph Hansmann
Umweltnatur- und
Umweltsozialwissenschaften (UNS)
ETH Zentrum HAD
CH-8092 Zürich
Tel. ++41-1-632 6316
Fax ++41-1-632 1029
E-mail: hansmann@uns.umnw.ethz.ch



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Practical Training as Part of Higher Environmental Education¹

Roland W. Scholz, Regula Steiner, and Ralph Hansmann

Abstract

Role and benefits of a *compulsory practical training* in environmental science education are investigated with respect to the three *institutional goals* of university education, i.e. (1) reproduction of research, (2) professional education, and (3) general natural science education. An *empirical survey* is presented showing which student qualifications are improved by a practical training complementary to traditional university education. The survey assesses 14 qualifications of students who participated in a compulsory 15-week practical training in the 5-year diploma program in environmental sciences at the Swiss Federal Institute of Technology (ETH Zürich), Switzerland. Pre- and post practical training questionnaires of 478 students and 293 supervisors from practice are included. Vocational training improves qualifications complementary to conventional university education in particular, general abilities and key qualification, such as communication skills, report writing, organization of work, and information acquisition. Also salient qualifications of complex environmental problem solving such as the ability to deal with uncertainty and to detect relevant aspects are promoted (by the practical training). The results suggest that practical training is of high value for *professional education* and enhances general key qualifications such as the ability to operate independently. However, practical training also enhances students' *complex problem solving ability* under uncertainty, which is of importance for the development of *research capability* in the field of environmental sciences, too.

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Practical Training as Part of Higher Environmental Education

This study investigates practical training as a supplement or complement academic instruction in environmental sciences. We want to understand what skills; knowledge and aptitudes are improved by an extended experience working on practical problems in a professional context. We assess this using the views of students who participated in practical internships and of their professional supervisors before and after the internship.

We report on an empirical survey that ran over six years and documents the assessments of 478 students and 293 of their supervisors from practice. This study was run at the Department of Environmental Sciences² (Umwelt-naturwissenschaften) at the Swiss Federal Institute of Technology Zurich (*Eidgenössische Technische Hochschule Zürich, ETHZ*). The curriculum in this department has incorporated practical training since its inception in 1987. The whole course takes five years and corresponds to a combined bachelor/master education.

In order to understand the contribution of vocational learning to students' competence, we assess what purpose practical training serves as part of a scientific curriculum in environmental sciences at the university level. Though some answers to this question presumably adopt a European perspective our discussion will be of particular interest to anyone interested in the institutional role of universities (Rothblatt & Wittrock, 1993; Liedman 1993; Gibbons et. al. 1994; Häberli et al. 2001). After considering the societal role of the university, we introduce the competencies and qualifications, which are salient for higher environmental science education. Subsequently we link these qualifications to the educational and institutional goals of universities. Our analysis of the role and benefits of the compulsory practical training in the curriculum of environmental sciences consequently considers the general institutional goals of universities as well as the goals of the specific curriculum itself.

Functions of Higher Education: An Institutional View

Universities are the "second oldest institution with a continuous history in the Western world," following the Roman Catholic Church (Rothblatt & Wittrock, 1993, p.1). They are conceived of as institutions of higher learning that provide facilities for teaching and research and are authorized to grant academic degrees. One variant of the Merriam-Webster Dictionary (1993, p. 2502) definition of the uni·ver·si·ty reads: "(2) ... a continental European institution concentrating on or exclusively concerned with advanced or professional study". Universities and the technical institutes, such as MIT and ETHZ, that have developed most of the environmental science education must be understood in their particular national historical context (see Ben-David, 1977), and with regard to the considerable differences of opinion and ongoing changes that complicate questions about their institutional identity and role.

The history of technical universities such as the Technical Hochschule Berlin, the Royal Institute of Technology in Stockholm, the Ecole Centrale des Arts et Manufacture in Paris, and ETHZ, and the ongoing evolution of ideas about their role, is closely tied to the development of the industrial age. Torstendahl (1993) suggests two nineteenth century roots for understanding the role of technical education in European Society. One was "the demand from the State for a labor force for specific needs, especially in communications (roads, bridges) but also in mining . . . and construction in general." The other was in the need for experts who understood and could manage the development of the "industrial economy and capitalist agriculture" (Torstendahl, p.125).

These roots highlight two poles in the ongoing debate about the social and institutional role of technical universities. On the one hand, technical universities are supposed to meet the *demands of industry* for skilled labor. On the other, technical universities are understood to provide a *research competence* and *general knowledge* necessary to guide the development of society. The differences between these two poles have to be considered in connection with the prominence technical universities have achieved during the industrial era and the questions rose about their role by the broadly acknowledged transition into a post-industrial age.

² As the term department is used differently in various countries we want to make clear that a department at the ETH Zurich foremost corresponds to a faculty including about 20 chairs.

We see the influence of these roots in the three functions that technical universities are supposed to provide: 1) professional education in specialized fields, 2) (re-)production of research, and 3) general education of technically competent managers who both understand and can oversee the practical development and the long term impacts of the processes of industrial society. Each of these functions is highlighted in one way or another by questions posed in the empirical survey about role of the practicum in technical education at the university level. We discuss each of these functions briefly below.

Reproduction of research

Universities may be seen as an institution that guarantees a society's ability to develop and carry out research. The conception of a research-oriented university was "the distinguishing characteristic of the nineteenth century German university" (Ben-David, 1977, p. 93). In the extreme, academic knowledge production through research is seen as a self-contained "pure" form of science that is independent of societal needs and application (Touraine, 1974, p. 118). This view provides an independent and self-monitored justification for universities that confers considerable autonomy. As Ben-David (1971, pp. 94-95) has pointed out, the French universities³ came close to this extreme in the late 19th century. Technical institutes incorporated this view of the university by giving prominence to the natural sciences (physics, chemistry, and biology) and mathematics in their curricula. Some departments of physics and mathematics remain one of the best examples of this ideal of pure science. The lack of professional job tracks in pure mathematicians and theoretical physicists (beyond becoming a teacher or researcher) means that there has been no practical program in these fields to challenge the conception of the university as a domain of pure science.

Research and teaching were first unified in the German universities in the 19th century where they provided a powerful means for conducting, reproducing and communicating research. This unification accounts for much of the scientific prominence of Germany during this period (Ben David, 1977). The USA, England and other countries have followed the German model in developing their institutions of higher education. The unity between research and teaching has had positive impacts on preparing students to do research. Active scientists are able to convey substantive material and methods in a way that prepares students to do research. It is questionable, however, whether this approach has the same effect on the quality of the students' preparation for professions that do not center on research, because professional researchers might not always be as engaged and competent to teach the skills necessary for practical problem solving.

In this study we assume there is a body of basic knowledge that is central for research and that develops almost independent of its direct practical use or place in professional training. In the context of environmental science, this knowledge includes understanding of ecological processes (e.g. evolution dynamics) and causal relationships in the environment (e.g. the transport of chemicals in soil). We refer to this as general ecological understanding.

Professional education

"... [T]he term *professional education* will be used ... to describe all specialized and nonspecialized higher education that is usually acquired with a view to entering specific occupations" (Ben David, 1977, p. 30). From this general view, most university curricula are directed at professional education. The influence of labor market demand on university curricula has varied considerably both historically and nationally. Since the nineteenth-sixties, however, there has been a worldwide trend to shape university curricula to meet the demands of labor markets and to use university education as a kind of career training (see Ben-David, 1981). Higher education, in the view of proponents of "professional" education, is best organized in response to the demands of the labor market. Teaching should provide students with the skills and qualifications necessary for skilled jobs (Hochschulrektorenkonferenz, 1992). Today, this orientation shapes business, law, education, and medical schools and many engineering departments. To get a sense

³ The term "university" was not used for long in the French educational system. Instead of this the label *collège*, *polytechnique* or *musée d'histoire naturelle* or other terms were chosen.

of how influential this trend is, consider that until the end of 19th century entry to the legal profession in the USA was attained mainly through apprenticeship (Langdell, 1887).

Practical training or a "practical year" is considered part of the curricula and syllabi in many sciences. In countries such as Germany, Switzerland, and the U.S. practical training is also required for and in university programs that prepare students to work in the senior high school teacher profession. In general, we suppose that practical training becomes part of university curricula when they are linked to job practices that require coping with complex, multi-layered problems. Teachers, for instance, not only have to master the subject, but also the social reality of the classroom. Physicians have to understand the social context and psychosomatic nature of many diseases. Thus, experiential learning (Kolb, 1984), the acquisition of communicative skills, and the ability to deal with real world problems are considered a necessary part of education in these fields. We hypothesize that this relationship also holds for the environmental sciences, at least when they go beyond laboratory oriented basic research and fieldwork (see Scholz & Tietje, 2001). We assume, that practical training is an effective way to shape students' professional identities, to experience environmental problems in complex real world contexts, and to develop learning strategies that meet the demands of the labor market.

General natural science education (Naturwissenschaftliche Allgemeinbildung)

The term "Allgemeinbildung" was coined in the 19th century by Wilhelm von Humboldt. Drawing on 18th Century Enlightenment ideas, Humboldt understood the significance of education in terms of its contribution to human development. The term humanities suggests the character in which the study of languages, literature, history, philosophy, and mathematics were understood. *Allgemeinbildung* or *general education*, concluded with the *Abitur* or *Matura*, the final examination of the central European secondary school that signaled a student had "matured" sufficiently to be prepared to engage in discourse at the university.

Thus, according to von Humboldt, universities should be a place of *Bildung* (engl. education) as well as science (Blankertz, 1982, p. 131). This can be seen in the central place that *philology* – the capability of speech, argument and conversation – occupied in the curriculum. Today, many technical universities still have small humanity departments that were originally dedicated to developing students' philological competence.

The term *Allgemeinbildung*, or general education, however, was not limited to the humanities (*including sciences*) however. There were also attempts to institutionalize a *general natural science education (Naturwissenschaftliche Allgemeinbildung)*. This may have peaked at the end of the 18th century with the founding of the famous French *École Polytechnique* in 1789. As Schubring (1979, p. 285) has pointed out, this effort was motivated by the tremendous shortage of natural and technological knowledge that was perceived as necessary to master the challenges of the industrial age. The education of teachers who would address this shortfall, not of engineers, was the original purpose of the *École Polytechnique* (Schubring, 1979, p. 285), which today is seen as a prototypical institute in the field of socially demanded technology research. Historically this also led to the development of a new professional group, the *general natural scientist* (see Beisenherz, 1979), who left the university to work in the civil service rather than becoming a professor at the university or at the senior-high school (Gymnasium).

Clearly, the 19th and 20th centuries have been characterized by increasing specialization and the establishment of new disciplines, sub-disciplines, branches of disciplines etc. A permanent institutional change occurred with the founding of *Technische Hochschulen* (technical institutes or technical universities) and *Fachhochschulen* (polytechnics). The idea of *general natural science education*, survives in the basic education in physics, biology, chemistry and mathematics/statistics that comprises the first two-years of education in most natural science, engineering and life-science curricula at these technical universities. Some technical universities, such as the ETH Zurich (1999), still offer a *general natural science* curriculum and a corresponding diploma.

This idea of general, natural science education was (re)vitalized in the discussions that led to the founding of the field of environmental science and environmental studies and departments such as the Environmental Science

Department of the ETHZ. The focus on expertise at the level of environmental systems and complex environmental problems demanded a general knowledge of the relevant natural sciences for understanding environmental system changes (Gigon, 1997; Frischknecht & Imboden, 1995).

This system oriented environmental curriculum drew its rationale and justification from real world problems and often resulted in a rearrangement of natural science knowledge. Natural science disciplines such as chemistry, physics, and biology had become too specialized to make their knowledge available for understanding system bound environmental problems, such as the greenhouse effect. Since there was no profession of an environmental (natural) scientist in the 1980ies, these curricula linked the idea of a general education to becoming a specialist in the analysis of complex environmental systems. After 15 years, an ongoing professionalization is becoming visible (Mieg, 2001)

Just as the École Polytechnique, was rooted in the demands for natural science education generated by the advent of the industrial age two centuries ago, the general natural science education at ETH Zurich has been motivated by demands and pressures that characterize a post-industrial age, particularly the ability to understand complex environmental problems and assess their long term impacts from an interdisciplinary natural science perspective. The character of this turn is still emerging, for instance in the ongoing discussions on sustainable development and societal impacts on climate change (Mieg, 2001). Similar way to the end of the 18th century, societal demands to understand impacts of societal change are driving the development of university education.

In the remainder of this paper we explore what *practical training* can contribute in these environmental science curricula that focus on *understanding complex environmental problems* in a general, rather than a research focused, manner. We note that experiences gathered in specific fields of vocational training may play a role in the development of students' professional identities that is particularly important given the emergent character of the field.

Qualifications Profiles of Environmental Science Students

In the preceding sections we have discussed the institutional goals and societal roles of universities with respect to knowledge production. We will focus now on the *students' qualifications/competencies* and the question: Which qualifications does the university have to teach? The shift in our consideration is from the institution to the qualification profiles of students.

Various classifications have been suggested for student qualifications. From a general *vocational training perspective*, professional, methodical and social competence can be distinguished in students' aptitude profiles (Schelten, 1994). There are, however, different ideas about the scope of profile development that university education can or should cover. In general, two positions can be distinguished. The more focused position merely expects that the function of the universities is to teach the knowledge and technical qualifications that are specific of a scientific discipline. The university thus is a kind of knowledge generation infrastructure, which offers subjects data and methods of scholarship. More general knowledge and skills should be acquired by the college graduates themselves. This position was, for example, taken by the Federal association of the German Industry (Bundesverband der Deutschen Industrie e.V., 1998) and is compatible with the role of universities as research institutes.

Leu, Rütter and De Bary (1996) present a different position. Professional engineers in Switzerland expect universities to teach students' general skills and qualifications in addition to the knowledge specific to particular disciplines or subjects. This opinion has also emerged in several studies in Germany, particularly in connection with engineering education (De Haan, Rheingans & Schack, 1995; Henning, 1993). According to this position, students should acquire also general planning and working skills as part of their university education. The latter perspective is linked to the discussion on *key-qualifications* ([German: "Schlüsselqualifikationen"]; see Beck, 1993; Nijhof & Streumer, 1998; Dörig, 1994; Lehmkuhl, 1994; Mertens, 1974). Key-qualifications are personal and time-independent general skills and abilities, which transcend the boundaries of a specific subjects or discipline, e.g., communication skills, organization of work, and providing of information.

Scholz et al. (1997) specified *general abilities and key-qualifications* in environmental science education in a survey on qualification profiles of environmental scientists. When referring to the institutional goals of the Department of Environmental Sciences of the ETH (see Frischknecht, 1995), a set of categories and items (see Figure 1) were defined to analyze students' qualification profiles. This list of items was derived from a content analysis of documents submitted by 139 applicants for a position of research assistant at the Department of Environmental Sciences. Scholz et al. also investigated where competence in environmental problem solving is acquired and – in particular – what role professional experience outside university plays in the development of this competence.

The categories were combined into three primary groups: *General abilities* (teamwork, management, work technique, communication and presentation abilities), *scientific knowledge*, and *environmental problem solving ability* (see Figure 2). The applicants came from different countries, universities and disciplines. Among them were 65 biologists, 26 chemists, and also 10 environmental scientists from ETH Zurich.

The following conclusions were drawn from this study (see Scholz et al., 1997):

- a) There was a shortage in applicants who met the requirements of the *general environmental problem solving ability*.
- b) Classical academic qualifications like marks, publications or doctoral degrees correlated negatively with the environmental problem solving ability.

And most important in the context of this study,

- c) Applicants who have changed jobs and have work experience in project management are more likely to show environmental problem solving ability.

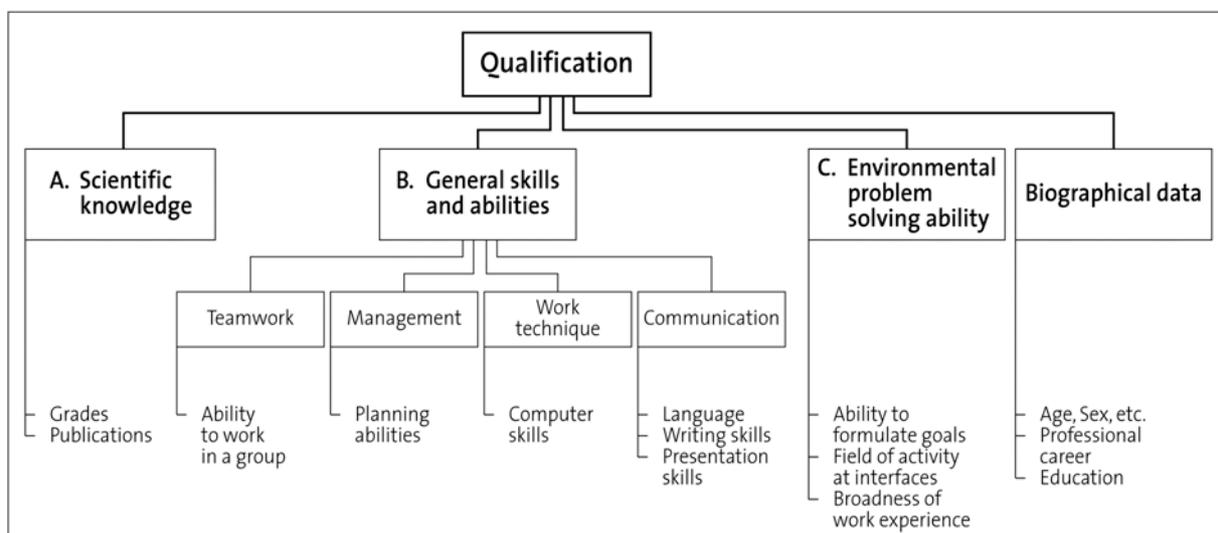


Figure 1. Structure of the category system for the qualification profile of an environmental scientist represented as hierarchical tree. Category names are inserted in boxes, the items used for content analysis are presented below (modified from, Scholz et. al. 1997, p. 39).

The Professional Practical Training in the Curriculum of Environmental Natural Sciences

The aim of the curriculum in Environmental Sciences at the ETH Zurich is to prepare students for practical scientific work in the environmental area and, at the same time, to open up the possibility for qualified research. Hence, with respect to the *institutional goals* discussed above, according to its planning by the department the environmental science curriculum at ETH is a hybrid. However, in the first 2-years of basic study, the core of the education, provide instruction in classical scientific disciplines, such as physics, chemistry, biology, and mathematics, which are partly taught in the context of environmental systems. Thus, in the first two years, an orientation towards

the *general natural science knowledge* is dominating and only few lectures on environmental law and economics are included. In the advanced studies (5th to 9th semesters) each student has to choose a scientific discipline (chemistry, physics, biology or environmental hygiene) and a particular type of environmental system (aquatic systems, terrestrial systems, atmosphere or anthroposphere) as his or her areas of specialization.

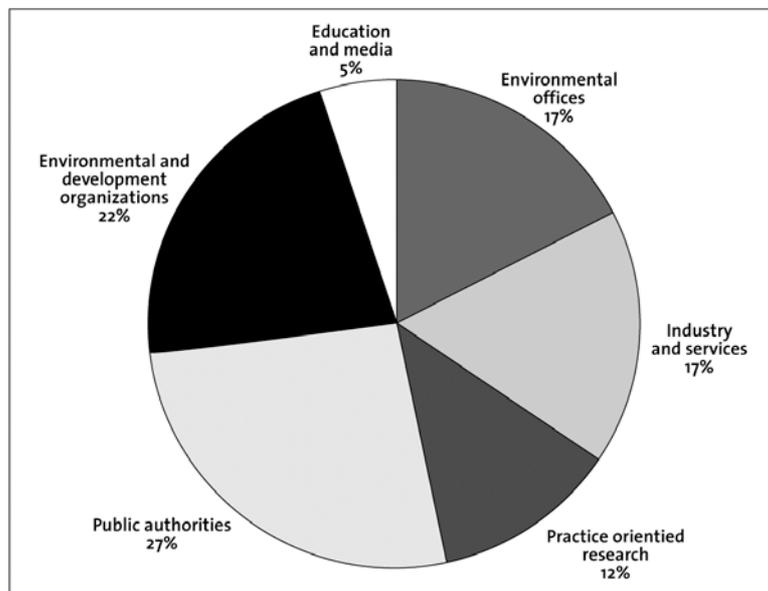


Figure 2. Distribution of the practical training in the years 1994 - 1999 in different types of organizations in percentages. The figure is based on $N = 478$ students; 336 (= 70 %) of the internships took place in Switzerland.

The *practical training*, which is the focus of this paper, is embedded in the second half of the curriculum. Students usually spend their seventh semester participating in professional activity in the environmental area. The students choose the place where they make this training on their own. The university provides information and suggestions for students as to which organizations offer such training. Acceptable organizations for the practical training are environmental offices, industry and services, practice oriented research, public authorities, environmental and developmental organizations, education and media. In general, university departments are not accepted for hosting the students. Figure 2 shows the areas the students completed their practical training from 1994/95 to 1999/00.

The practical training targets the following issues (Steiner, 1998):

The students should

- learn to operate within the environmental area outside of the university in a problem-oriented way,
- get to know the political, legal, economical and social factors and constraints (e.g. limited financial means, conflicts of interest), under which solutions are developed in the environmental area,
- experience the problems that occur when they apply their knowledge in practice (e.g. decision-making on the basis of too little or insecure information, inaccuracies of data)

From a cognitive perspective, the role of practical training is to promote the *development of the general skills and abilities* and the *environmental problem solving ability* (see Figure 1; Scholz et al., 1997; Oberle, Scholz & Frischknecht, 1997; Koller & Frischknecht, 1997). Conceptually, practical training complements *the acquisition of scientific knowledge*.

Objectives of the Empirical Study

The question of which skills students acquire in conventional university education, and which skills they acquire and improve through practical training was investigated in an empirical survey. The survey analyzes which qualifications students developed in the curriculum up to the beginning of the training and which qualifications were fostered through the participation in the practical training.

The three groups of qualifications are presented in the rows of Table 1. Group A, *scientific knowledge base and skills*, entails the basic science education and the science based ecological understanding. The latter refers to natural science oriented knowledge such as geo-ecology, chemical fate analysis, water transportation in soil. The Group B *General abilities and key-qualifications* refer to subject independent communication and working skills, which can be considered as a kind of general qualification. The last Group C are *specific aspects of environmental problem solving ability*. The three qualifications in this section focus on qualifications necessary for problem oriented mastery of complex systems characteristic of environmental sciences such as climate, water or landscape management.

Table 1. Matrix of Contingency Between the 14 Qualifications of the Survey and the Three Goals of Higher Education

Qualifications in the survey	Institutional goals		
	Reproduction of research	Professional education	General natural science education
<i>(Group A) Scientific knowledge base and skills</i>			
1 Scientific knowledge	***	*	**
2 General ecological understanding	***	*	**
3 Knowledge of technical aspects		***	
4 Lab- and field-work skills		*	
5 Methodical knowledge	***	**	*
6 Knowledge of sociological aspects		*	
<i>(Group B) General abilities and key-qualifications</i>			
7 Ability to communicate		***	
8 Ability to write reports	**	**	
9 Ability to provide information		***	**
10 Ability for organization of work		***	
11 Ability to operate independently		***	
<i>(Group C) Specific aspects of environmental problem solving ability</i>			
12 Ability to detect relevant aspects	*	**	*
13 Ability to deal with uncertainty	*	**	
14 Ability to develop practical solutions		**	

Note. The matrix represents the authors ratings on how the 14 qualifications of the survey relate to the different goals of higher education: „****“ represents a very strong contingency; „***“ a medium contingency, „**“ a low contingency and „no entry“ no contingency.

As outlined above, the educational value of a practical internship must be assessed with respect to the institutional goals of university education. Table 1 relates the three functions of higher education introduced above (i.e. *Reproduction of Research, Professional Education, and General Natural Science Education*) with the 14 qualifications. The cells of the table present the authors pre survey views on how qualifications contribute to the different functions of higher education. According to these ratings, there are two almost complementary profiles that are *Reproduction of Research* and *Professional Education*. The General Natural Science education does not show up as a separate profile.

Method

Subjects

The professional practical training module has been evaluated at ETHZ since 1994. This study includes 478 students and 293 of their supervisors from practice. There are several reasons for the mismatch between participation of students and supervisors in the survey. About 30 percent of the students spend their practical year abroad, often in developing countries. The questionnaire is only available in German, however. Students' participation in the questionnaire is a compulsory requirement for completing their vocational training, whereas supervisors participated voluntarily.

Questionnaire and Design of the Survey

The qualifications assessed are presented in Table 1. Students and their supervisors were asked to rate the qualifications of the students *before* the beginning of the practical training and *after* the practical training. All judgments were given on a rating scale reaching from 1 (= *not at all*) to 7 (= *very much*).

Table 2 shows the 4 different variants of questionnaires:

Table 2. The 4 Questionnaires and (2 x 2 x 2 =) 8 Questions, which were Applied the 14 Different Qualifications

	Before the professional practical training	After the professional practical training
Students	i. How qualified are you, because of your study? ii. How large will the improvements of your qualifications be because of the practical training?	iii. How qualified have you actually been, because of your study? iv. How large have the improvements of your qualifications been because of the practical training?
Organizations	v. How qualified should the student be, because of his/her study? vi. How much will the student improve his/her qualifications during the practical training?	vii. How qualified has the student actually been, because of his/her study? viii. How much has the student improved his/her qualifications during the practical training?

Note. The four quadrants represent the four questionnaires of the survey. The (2 x 2 x 2 =) 8 questions (i. to vii.) of the four questionnaires were applied to each of the 14 different qualifications of the survey.

First, a questionnaire was given to the *students* before the practical training started. For each of the 14 qualifications in Table 1, the students were asked to judge (i) *how qualified they were before the beginning of the practical training*. Moreover, the students were asked to estimate (ii) *how much they would learn in the professional practical training with respect to each qualification*.

Second, at the end of the professional practical training the *students* answered a similar questionnaire that required them to assess themselves with respect to each of the 14 qualifications. Students were asked to assess again (iii) *how qualified they had been before the practical training*. In addition, the students were asked (iv) *how much they had learned during the professional practical training with respect to each of the qualifications*.

Similar questionnaires were given to the students' *supervisors* in the organizations.

Third, *before* a student started his/her practical training the *supervisors* were asked to quantify for each of the 14 qualifications (v) *how qualified the student should be beforehand of the practical training with respect to each particular qualification*. In addition, they were asked (vi) to give an estimate concerning *how much the students can improve each particular qualification during the training*.

Fourth, at the end of the training, the supervisors received a second questionnaire in which they were asked to quantify for each of the 14 qualifications (vii) *how qualified the student had actually been beforehand of the practical training with respect to each particular qualification*. They were also asked to estimate (viii) *how much the student had actually learned during the practical training with respect to each particular qualification*.

Hypotheses

Our hypotheses focus on learning effects that can be attributed to the practical training. Our basic hypothesis is that the practical training is complementary to conventional university education. We assume that the *scientific knowledge base and skills* (see Table 1, Group A qualifications) are the primary focus of the conventional university education in environmental sciences. We assume that practical training enhances *general abilities and key qualifications* (see Table 1, Group B), like communication skills and writing reports. Furthermore, we expect that the features of the *environmental problem solving ability* (see Table 1, Group C) be also significantly improved by practical training. This is supposed as – up to now - these qualifications play only a secondary role in the conventional university education.

Hence, we formulated a (*Confirmatory*⁴) *Hypothesis 1*: The students as well as the supervisors judgments on the *scientific knowledge base and scientific skills* (Group A) qualifications *before* the practical training are higher than on the average for all 14 skills; the judgments on the *general abilities and key qualification* and the specific aspects of environmental problem solving ability are judged significantly lower.

According to the goals formulated by the Department of Environmental Sciences, the practical training should enhance students' general abilities (Group B qualifications) and their environmental problem solving abilities (Group C qualifications). This is expressed in the (*Confirmatory*) *Hypothesis 2*: The students and their supervisors judgments on the students' learning effects of the practical training are bigger for the general abilities (group B qualifications) and their environmental problem solving abilities (Group C qualifications) than on the average for all 14 qualifications.

Clearly the present survey postulates that the students as well as their supervisors are able to judge the qualification levels of the students and the learning effects realistically, at least to some extent. Consequently, congruent results and a kind of testing of the convergent internal validity (Krueger & Kling, 2000) can be organized when comparing the students' and their supervisors' judgments. Note that internal validity is prerequisite for the external validity (appropriateness, adequacy, correctness). Similarly, the pre-training judgments should be consistent with the post-practical training judgments, to some extent. The contingency of the four judgments (pre vs. post x students vs. supervisors) concerning each qualification, which have the same content (learning effects, and qualification level, respectively) will be considered as crucial criteria of validity in this study. We want to note that the study of the external validity of the students' and supervisors' pre- and post-ratings on their own qualifications is beyond the data of the survey and should be investigated in a separate study.

Some insight in the construct validity of the questionnaire can be gained if the students' and supervisors' judgments on the *student's learning* in the practical training show a different pattern than the judgments on the *students knowledge acquired in conventional university education*. This is our (*Structural*⁵) *Hypothesis 1*. Technically speaking, this means, that structural analyses (factorial analysis, cluster analysis) of the 8 assessments ($2[\text{pre vs. post}] \times 2[\text{students vs. supervisors}] \times 2[\text{pre-training qualification vs. learning effects}] = 8$, see Table 1) will reveal a similarity between the assessments of judgments concerning the pre-training qualifications as opposed to the assessments of judgments of the learning effects during the training.

The proposed division of the 14 qualifications into the Groups A – C in Table 1, suggests (*Structural*) *Hypothesis 2*: We hypothesize that multivariate statistical analyses (Cluster Analysis, Multi-Dimensional Scaling) will reproduce the allocation of the 14 qualifications to the category groups *scientific knowledge base and skills*, *general abilities*, and *environmental problem solving abilities*. Further we expect that, in accordance with our two confirmatory hypotheses, the scientific skills and knowledge base (Group A qualifications) are structurally differentiable from the qualifications subsumed under Group B and Group C. As a consequence, we expect that the practical training will be a crucial part of the education within the goal of professional education.

⁴ The term confirmatory indicates that a hypothesis will be tested by means of inferential statistics.

⁵ The term structural indicates that a hypothesis will not be tested by means of inferential statistics but in an exploratory respectively descriptive manner.

Results

First, the structural hypotheses will be addressed by means of the factorial Principal Component Analysis, Cluster analyses, and Multi-Dimensional Scaling. Thereafter, the two confirmatory hypotheses will be analyzed using t-tests. All analyses were performed with standard SPSS 10.0 program.

Analysis of the Structural Hypotheses

For the Structural Hypothesis 1 a Principal Component Analysis was conducted to analyze whether the four assessments of judgments concerning the pre-practical training qualification (see Table 2, i, iii, v, and vii) of the students were distinct from the four assessments of learning effects during the training (see Table 2, ii, iv, vi, viii). Factors with an Eigenvalue greater than 1 were extracted by the Varimax method with Kaiser normalization. The data of this analysis were the mean estimates for the 14 qualifications at the 8 assessments. Table 3 presents a two factorial structure that supports the Structural Hypothesis 1. The assessments of the students' and their supervisors' judgments, before and after the practical training, of the students pre-practical training level of qualification loaded, without any exception, on *Component 1* ($\underline{M} = 0.94$, $\underline{SD} = 0.04$). The estimates concerning improvement of the students' qualification during the practical training loaded, without any exception, on *Component 2* ($\underline{M} = 0.91$, $\underline{SD} = 0.03$). Conversely, the estimates concerning pre-training qualification loaded low on Component 2 ($\underline{M} = 0.08$, $\underline{SD} = 0.24$), and those concerning learning effects during the training loaded low on Component 1 ($\underline{M} = 0.04$, $\underline{SD} = 0.28$).

Table 3. The resulting factor loadings (Component 1 and Component 2) of the PCA on the 8 assessments of estimates for the 14 qualifications

Rotated Component Matrix	Component 1	Component 2
i. Students before have	0.98	-0.03
ii. Students before learn	-0.34	0.90
v. Supervisors before have	0.87	0.46
vi. Supervisors before learn	0.38	0.88
iii. Students after have	0.95	-0.20
iv. Students after learn	-0.08	0.94
vii. Supervisors after have	0.97	0.10
viii. Supervisors after learn	0.22	0.94

Note. Each of the 8 questions (i. to viii.) was applied to all 14 qualifications. Students before have (i.) indicates the mean students' judgments on the 14 qualifications (see Table 1) before the practical training of their own qualification. Correspondingly see for the other labels. A Varimax with Kaiser Normalization rotation method was applied which converged after 3 iterations.

A Cluster Analysis was performed to analyze which of the 14 qualifications were judged similar with respect to the pre-training qualification levels and learning gains of the students and in what way the three a priori groups of qualifications, i.e. *scientific knowledge base and skills*, *general abilities*, and *environmental problem solving ability* are represented in the students' and supervisors judgments as formulated in the Structural Hypothesis 2.

The clusters are suggested by the dendrogram of Figure 3. We treat a set of qualifications as a cluster if the within cluster distance is smaller than 10. According to this criteria there are four clusters. The qualifications *scientific knowledge* and *ecological understanding* form a first cluster of qualifications (Q-Cluster 1) that we call "*conceptual scientific knowledge base*."

The qualifications *knowledge of technical aspects*, *practical lab- and field-work skills* form a Q-Cluster 2, which we named "*technical scientific skills*." As we can take from Figure 3, these clusters represent different qualifications as they show a rescaled distance which is greater than 25. A third cluster, Q-Cluster 3, is formed by the qualifications *ability to operate independently* and *ability to detect relevant aspects*. This Cluster spans the border between the *Group B (general skills)* and the *Group C (ecological problem solving abilities)* in Table 1. We call this Cluster "*abilities for coping with complexity*." The three clusters described so far are markedly separated by the Cluster Analysis from the eight remaining qualifications.

The fourth cluster shows two sub-clusters. There is a homogeneous Q-Cluster 4 consisting of the qualifications ability to communicate, ability to write reports, ability to provide information, and ability for organization of work. This cluster will be called “general abilities and key-qualifications,” as it entails all but one of the Qualifications of Group B in Table 1.

The second sub-cluster, Q-Cluster 5 entails methodical knowledge, knowledge of sociological aspects, ability to develop practical solutions, and ability to deal with uncertainty. We will call this cluster Q-cluster 5 with the label “environmental problem solving in the field of human environment interaction.”

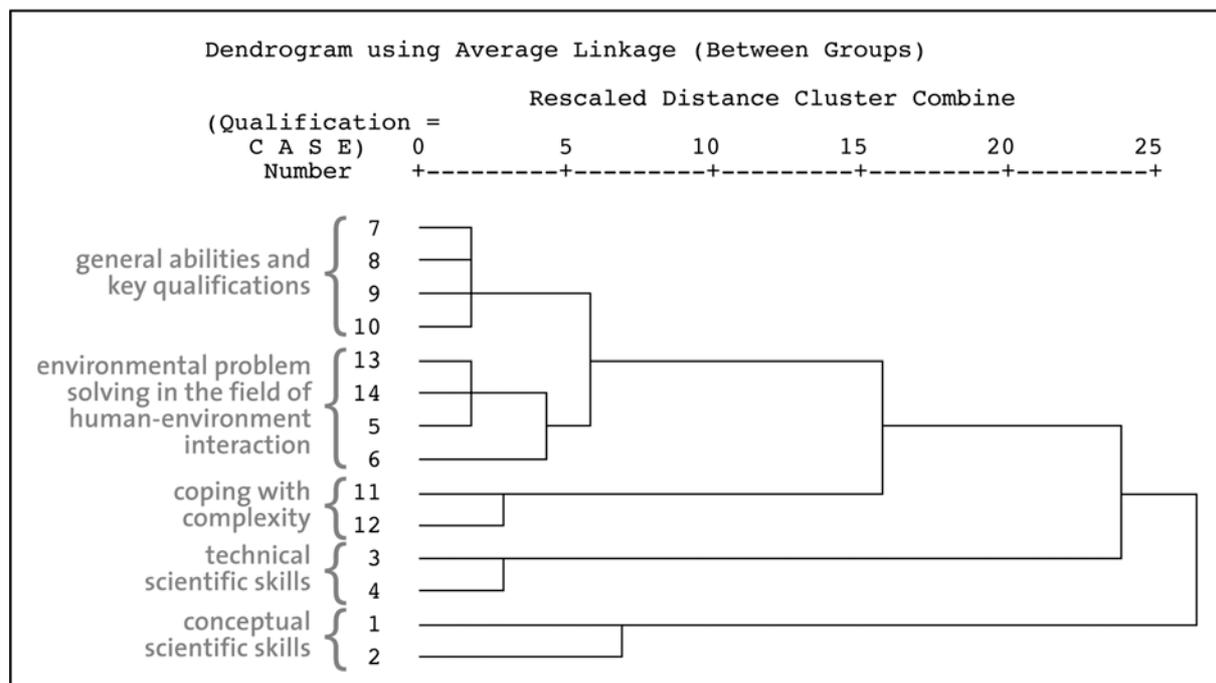


Figure 3. Dendrogram of a hierarchical Cluster Analysis using the Average Linkage Method on the 8 assessments on the 14 qualifications using the Average Linkage Method. The qualifications are numbered according to Table 1: 1 = scientific knowledge; 2 = general ecological understanding; 3 = knowledge of technical aspects; 4 = lab- and field-work skills; 5 = methodical knowledge; 6 = knowledge of sociological aspects; 7 = ability to communicate; 8 = ability to write reports; 9 = ability to provide information; 10 = ability for organization of work; 11 = ability to operate independently; 12 = ability to detect relevant aspects; 13 = ability to deal with uncertainty; 14 = ability to develop practical solutions.

In order to check for inter-method reliability an MDS was conducted for the same data. Figure 4 shows the 2-dimensional solution of the MDS. The results of the MDS are similar to the results of the Cluster Analysis. As can be seen in Figure 4, the main clusters of the Cluster Analysis can be also identified in the configuration graph of the MDS Model. The three lower clusters of Figure 3 can be located in three different quadrants of the graph.

In summary, the structural analysis of the 14 qualifications did match our hypothesized categorization of the qualifications. The empirical analysis provided a more differentiated view that did follow the general contours laid out in the hypothesized categorization. We will consider the empirically substantiated classification of the five Q-clusters in the testing of the confirmatory hypotheses.

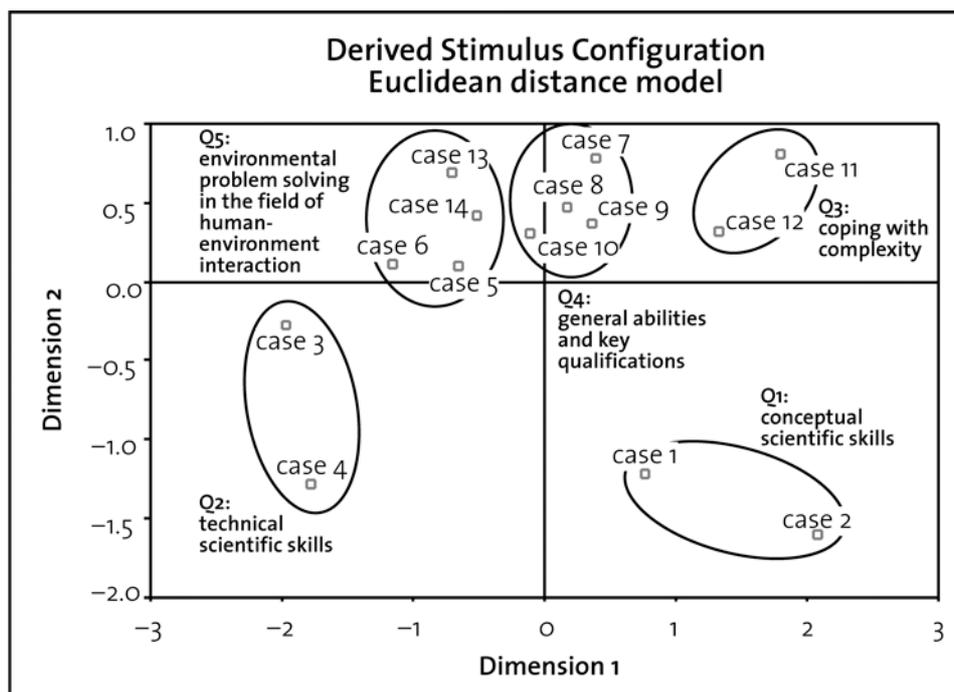


Figure 4. Graph of a MDS concerning the 14 qualifications of the survey. The qualifications are numbered according to Table 1 and are called cases. Case 1 = scientific knowledge; 2 = general ecological understanding; 3 = knowledge of technical aspects; 4 = lab- and field-work skills; 5 = methodical knowledge; 6 = knowledge of sociological aspects; 7 = ability to communicate; 8 = ability to write reports; 9 = ability to provide information; 10 = ability for organization of work; 11 = ability to operate independently; 12 = ability to detect relevant aspects; 13 = ability to deal with uncertainty; 14 = ability to develop practical solutions. The ovals were inserted corresponding to the 5 qualification areas, which we adopted for the description of the subsequent results.

Analysis of the Confirmatory Hypotheses

Confirmatory Hypothesis 1 refers to differences in the students' qualifications at the beginning of the practical training. Four ratings were given (see Table 2 and Table 3), and corresponding t-tests were performed. The estimates concerning the students' level of qualification were, for each qualification, compared with the mean estimate over all 14 qualifications as test value. The results of the $4 \times 14 = 56$ t-tests are shown in Table 3. As noted above, the convergence of the judgments in the 4 assessments is considered a prerequisite for a decent interpretation of the results. In order to acknowledge this requirement we will consider a difference of a qualification as statistically significant if the mean judgments for a qualification deviate into the same direction for all four assessments, and if at least two of the four single t-tests were significant. Whereas repeated testing on the same data usually requires for a Bonferroni-adjustment or a similar adjustment of the level of significance (Rosenthal & Rosnow, 1991), no Bonferroni corrections of significances were accomplished for these t-tests, because the probability of random significances is lowered substantially by the requirements of convergent validity.

In Table 4 the judgments concerning students' conceptual scientific skills, i.e. their *scientific knowledge* and *general ecological understanding* (Q-Cluster 1), were significantly higher than on the average for the 14 qualification in all four assessments. Hypothesis 1 was thus, supported with respect to the conceptual scientific skills.

Contrary to our expectations, higher judgments of the pre-training qualification level, as compared to the average, were also obtained, in all four assessments, for the *ability to operate independently* and *ability to detect relevant aspects* (Q-Cluster 3).

Because of contradictory tendencies in the 4 assessments, no decent interpretation could be made of Q-Cluster 4 i.e. the general abilities and key qualifications *to communicate*, *to write reports*, *to provide information*, and *to organize work*.

Table 4. Students' qualification profile before practical training - The mean pre- and post training judgments [M(Qual.)] of students and supervisors concerning the pre-training level of qualification of the students for the 14 qualifications

		Judgments of									
		Students				Supervisors					
		Before training		After training		Before training		After training			
		<u>N</u>	<u>M (Qual.)</u>	<u>N</u>	<u>M (Qual.)</u>	<u>N</u>	<u>M (Qual.)</u>	<u>N</u>	<u>M (Qual.)</u>		
<i>(Group A) Scientific knowledge base and skills</i>											
1	Q1 Scientific knowledge	368	4.77 ++	477	4.73 ++	240	4.90 +	284	5.01 ++		
2	Q1 General ecological understanding	182	5.36 ++	470	5.36 ++	130	5.24 ++	279	5.54 ++		
3	<i>Q2 Knowledge of technical aspects</i>	365	<i>3.30</i> ---	465	<i>3.23</i> ---	235	<i>3.99</i> ---	257	<i>4.18</i> ---		
4	<i>Q2 Lab- and field-work skills</i>	353	<i>3.74</i> ---	462	<i>3.64</i> ---	239	<i>3.59</i> ---	245	<i>4.08</i> ---		
5	<i>Q5 Methodical knowledge</i>	364	<i>3.90</i> ---	462	<i>3.94</i> ---	236	<i>4.48</i> ---	275	<i>4.46</i> ---		
6	<i>Q5 Knowledge of sociological aspects</i>	365	<i>3.97</i> ---	471	<i>3.78</i> ---	241	<i>4.08</i> ---	261	<i>4.24</i> ---		
<i>(Group B) General abilities and key-qualifications</i>											
7	Q4 Ability to communicate	369	4.52 ++	473	<i>3.89</i> ---	239	5.16 ++	282	4.97 ++		
8	Q4 Ability to write reports	368	4.39	474	<i>4.09</i>	241	4.99 ++	277	<i>4.63</i>		
9	Q4 Ability to provide information	369	4.30	471	<i>4.04</i>	240	5.13 ++	275	5.00 ++		
10	Q4 Ability for organization of work	369	4.30	470	<i>3.83</i> ---	241	4.81	283	<i>4.70</i>		
11	Q3 Ability to operate independently	369	4.98 ++	472	4.78 ++	235	5.61 ++	285	5.48 ++		
<i>(Group C) Specific aspects of environmental problem solving ability</i>											
12	Q3 Ability to detect relevant aspects	367	4.87 ++	471	4.77 ++	239	5.28 ++	278	5.08 ++		
13	<i>Q5 Ability to deal with uncertainty</i>	364	<i>3.83</i> ---	469	<i>3.59</i> ---	240	<i>4.74</i>	271	<i>4.40</i> ---		
14	<i>Q5 Ability to develop practical solutions</i>	365	<i>3.88</i> ---	469	<i>3.81</i> ---	241	<i>4.68</i>	271	<i>4.65</i>		
Overall mean			4.29		4.10		4.76		4.74		

Note. The Q-Clusters Q1 - Q5 are discussed in the text. t-tests were performed for each qualification against the overall mean of this assessment. Means higher than the overall mean are printed bold. Significant positive deviations from the overall mean in each assessment, are marked as follows: $p < .001 = +++$; $p < .01 = ++$; $p < .05 = +$; correspondingly means lower than the overall mean are printed in italic, and corresponding significances are marked as follows: $p < .001 = ---$; $p < .01 = --$; $p < .05 = -$. Names and numbers of qualifications with at least two significances and with deviations from the overall means in the same direction in all four assessments are printed bold for high, and italic for low means.

Contrary to the Confirmatory Hypothesis 1, significantly lower than average judgments were observed in all four assessments for the two applied scientific skills *methodical knowledge*, and *knowledge of sociological aspects* which are part of Q-Cluster 5.

In accordance with the Hypothesis 1), significantly lower than average judgments were obtained for the two complex problem-solving skills of Q-Cluster 5, i.e. the ability *to deal with uncertainty* and the ability *to develop practical solutions*. In contradiction to Confirmatory Hypothesis 1, the technical scientific skills *knowledge of technical aspects* and *lab- and field-work skills*, i.e. Q-Cluster 2, were rated significantly lower as the average qualification level in all 4 assessments. Hence, the expectation of higher judgments concerning students' scientific pre-training qualification level, which should be object of university education was supported only with respect to the conceptual scientific skills (Q-Cluster 1). Even significant results in the opposite direction emerged for the applied scientific skills of Q-Cluster 5 and the technical scientific skills Q-Cluster 2.

In summary, the results indicate that the principal focus of the conventional university education in environmental science is more specific than anticipated. However, in addition to these skills, the abilities of the students to *operate independently* and *to detect relevant aspects* were also enhanced.

We analyzed which qualifications are judged to improve during the practical training. For the four corresponding assessments (see Table 2 and 3), the mean judgments for each qualification were computed, to serve as the values of comparison in one-sample t-tests. No Bonferroni corrections of significances were accomplished as the probability of random significances is lowered substantially by the requirements of convergent validity. Learning for a qualification is judged significantly higher (lower) if all four assessments are higher (lower) and two of them are significantly higher (lower). Table 5 presents the results of the 56 (=4 x 14) t-tests that were conducted.

Table 5. Students' Learning in the Practical Training - Mean pre- and post training judgments of students and supervisors concerning learning effects during the practical training with respect to the 14 qualifications

	Students' judgments				Supervisors' judgment			
	Before training		After training		Before training		After_training	
	<u>N</u>	<u>M (Qual.)</u>	<u>N</u>	<u>M (Qual.)</u>	<u>N</u>	<u>M (Qual.)</u>	<u>N</u>	<u>M (Qual.)</u>
1 Scientific knowledge	366	4.58 ---	475	4.41 ---	239	4.64 ---	279	4.68 ---
2 General ecological understanding	182	4.23 ---	474	4.14 ---	130	4.95 ---	277	4.68 ---
3 Knowledge of technical aspects	362	4.98	465	4.70 -	236	4.74 ---	266	4.83 -
4 Lab- and field-work skills	353	4.72 ---	460	4.23 ---	239	4.53 ---	261	4.51 ---
5 Methodical knowledge	361	5.26 +	465	4.91	237	5.04	277	5.16 +
6 Knowledge of sociological aspects	363	5.40 +++	469	5.16 +++	240	4.99 -	267	4.82 --
7 Ability to communicate	366	5.41 +++	475	5.29 +++	239	5.40 ++	282	5.19 +
8 Ability to write reports	369	5.23	475	5.16 +++	240	5.33	281	5.27 +++
9 Ability to provide information	368	5.16	474	4.91	238	5.42 ++	276	5.18 +
10 Ability for organization of work	368	5.26 +	472	4.90	240	5.37 +	281	5.07
11 Ability to operate independently	369	5.38 +++	474	5.32 +++	234	5.73 +++	286	5.38 +++
12 Ability to detect relevant aspects	366	5.23	470	4.93	237	5.67 +++	278	5.25 +++
13 Ability to deal with uncertainty	364	5.29 ++	466	5.03 ++	238	5.49 +++	276	5.24 ++
14 Ability to develop practical solutions	361	5.49 +++	470	4.78	239	5.40 ++	277	5.00
Overall Mean		5.12		4.85		5.19		5.02

Note. The Q-Clusters Q₁ - Q₅ are discussed in the text. t-tests were performed for each qualification against the overall mean of this assessment. Means higher than the overall mean are printed bold. Significant positive deviations from the overall mean in each assessment, are marked as follows: $p \leq .001 = +++$; $p \leq .01 = ++$; $p \leq .05 = +$; correspondingly means lower than the overall mean are printed in italic, and corresponding significances are marked as follows: $p \leq .001 = ---$; $p \leq .01 = --$; $p \leq .05 = -$. Names and numbers of qualifications with at least two significances and with deviations from the overall means in the same direction in all four assessments are printed bold for high, and italic for low means.

For the Q-Clusters 1 and 2, the judgments of qualification improvement by practical training were significantly lower for all assessments. For the applied scientific skills of Q-Cluster 5, i.e. methodical knowledge and knowledge of sociological aspects, no definite tendency could be seen.

For all qualifications of Q-Cluster 4, the rigid criteria of significance were also fulfilled. In accordance with Structural Hypothesis 2, the practical training contributes strongly to the development of general abilities or key-qualifications of the students. Further the *ability to operate independently* and the *ability to detect relevant aspects* (both of Q-Cluster 3) as well as the *ability to deal with uncertainty* are significantly promoted by the practical training.

No clear tendencies could be found for the remaining qualifications of the environmental problem solving in the field of human environment interaction (Q-Cluster 5).

Summary, Discussion, and Conclusions

We begin this section by reviewing two core concepts in this paper: a classification of *institutional goals* and a set of *student qualifications* that are essential for professional practice in the environmental sciences. We then move to discuss how practical training contributes to the development of these qualifications. We conclude the paper by reexamining the relationship between the educational effects of practical training and the institutional goals of the universities.

1. In a historical perspective three *institutional goals* can be distinguished for university education in environmental sciences:
 - a) *Reproduction of research*. Universities embody a societal knowledge infrastructure system, which develops abstract theoretical knowledge.
 - b) *Professional education*. Environmental science curricula must prepare students for specific occupations.
 - c) *General Natural Science Education*. Modern society demands a general, non-specialized competence in the natural sciences in order understand and master technological innovations and their impacts.

The first two variants are, at least in European universities, major institutional goals. An ongoing and national and historically vivid discussion addresses how these two goals should be combined and weighted. The third variant, *General Natural Science Education*, is less directly accessible because it draws on an argument from the sociology of knowledge. In the upcoming post-industrial age, however, there is a direct societal need for professionals who can master changes, crises, catastrophes in human-environment systems. This, in turn, requires individuals who have broad non-specialized natural science education that they can apply flexibly and link to emerging problems.

The *qualification profiles* of students were assessed by judgments that the students and their supervisors made before and after the students participated in practical training. We optimized our empirical and statistical analyses with respect to convergent validity. We only interpreted findings if all assessments were consistent and multiple-significance was given (see above).

2. According the empirical survey, five qualification clusters can be distinguished for 7-th semester diploma students⁶ in environmental sciences. These are:
 - Q1 *Conceptual scientific skills*; i.e. scientific knowledge and ecological knowledge
 - Q2 *Technical scientific skills*; i.e. methodological and lab- and field-work skills
 - Q3 *Coping with complexity*, which entails the ability to detect relevant aspects and to work independently
 - Q4 *General abilities and key qualifications* characterized by the ability to communicate, write reports, acquire information, and organize work
 - Q5 *environmental problem solving in the field of human-environment systems* entailing methodological knowledge, social/sociological understanding, the ability to deal with uncertainty, and the ability to develop practical solutions

A critical question is, which qualifications are enhanced by practical training and which qualifications are developed primarily in the traditional university curriculum?

⁶ In the US educational system with a three year bachelor and a two year masters this would about correspond to second semester master student who has acquired his/her B.A. in environmental science with a major in natural science.

3. *Traditional university education* in environmental science seems to develop a smaller than anticipated range of scientific knowledge and skills focusing *conceptual scientific skills* (Q1) and, most interestingly, on *coping with complexity* (Q3). Obviously academic training contributes to students' preparation for complex system analysis. Contrary to our expectations, however, *technical scientific skills* (Q2), as well as methodological knowledge, and sociological knowledge (both part of Q5) were not developed to a higher degree than the average qualification inquired in the questionnaire by the current university curricula.
4. *Practical training* appears to particularly enhance the qualification cluster we called *general abilities and key-qualifications* (Q4), students' ability to operate *independently* (part of Q3), and – most important – students ability to detect relevant aspects of environmental problems (also part of Q3) and to *deal with uncertainty* (part of Q5). The most salient features of the general environmental problem solving ability (see Scholz et al., 1997) appear to be developed by practical training. What is interesting is that in spite of these gains, the students' and supervisors' post-training judgments - as opposed to their pre-training expectations - did not support the hypothesis that the ability to develop practical solutions would be enhanced by practical training. This maybe due to the nature of projects environmental students were involved in during their practical training. Our experience suggests that the character of vocational practice is shifting more and more to a conceptual, information based approach to practice, instead of a practical, action oriented one. (see also, Lifset, 2000).

We close by relating the educational effects of practical training to institutional goals of the universities.

5. Our analysis of survey results suggests that *practical training* is an important and valuable component of *professional education* oriented curricula in environmental sciences. It fosters just those qualifications (compare Table 1) that are considered essential for a good start in a professional career (Schurig and Berghahn, 1995).
6. At the first glance, the empirical findings might suggest, that *practical training* is not important for the *reproduction of research*. In our opinion, however, this conclusion hinges on a very restricted understanding of environmental science as a discipline. The ability to detect relevant aspects and the ability to deal with uncertainty are salient qualifications (compare Table 1) that are needed in the environmental research of real world problems, which are themselves multi-layered. Moreover, practical training contributes to the development of orientations that can be guiding ideas for organizing future learning, including the choice of topics for diploma and doctoral theses.
7. In connection with our subjective analysis of the introduced institutional goal *general natural science education* (see Table 1), *no empirical evidence* was provided to answer the question whether or not *general natural science education* is a reasonable educational goal of universities. In the authors' opinion, the answer to this question depends on how societal learning, education and knowledge acquisition are organized and what priority and importance is attached to a broad and robust understanding of environmental processes, as e.g. for environmental risk management. If, for instance, industry, business, and administrative organizations would commit to developing strong departments and educational programs where the specific environmental knowledge needed in their own business field would be developed and reproduced, *general natural science education* could suddenly become highly attractive. One might also consider how the future challenges of sustainable development and of the management of human-environment systems will affect the need for science generalists (e.g. in administration) who can help to ensure that environmental impacts are understood. As can be seen from these arguments, the importance of general science education for society might at some point even be a part of its need for professional education, and not longer as an independent goal, as suggested by its historic roots. Within the current mainframe of university education with a bachelor and master track and the obvious worldwide withdrawal of large companies from in-house educational programs, general natural science education is mostly provided at the undergraduate level.

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