Qualifications for Contributing to Sustainable Development

A Survey of Environmental Sciences Graduates

Ralf Hansmann, Harald A. Mieg, Peter M. Frischknecht

A majority of Environmental Sciences graduates from ETH Zurich consider their systems-oriented, inter- and transdisciplinary education as advantageous for their professional activities – this is shown by a survey. Participants also specified skills needed for contributing to sustainability. Such information helps to further develop pertinent study programs.

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Abstract

A survey of Environmental Sciences graduates from ETH Zurich was conducted to gain insights into their sustainability-oriented activities. 567 participants provided 672 concrete best-practice examples of their professional contributions to sustainable development. The contributions addressed ecological, economic, and social aspects of sustainability, and 47 percent of them attempted to systematically integrate these dimensions. Responsible use of resources and the protection of the natural environment were the main foci of the examples, and many promoted health and safety of the public or enhanced the innovative power of the economy. Qualifications denoted as helpful for realizing the contributions included broad natural scientific knowledge and ecological systems understanding, as well as in-depth knowledge in specific fields or domains of application. Participants thus judged their interdisciplinary environmental science education as advantageous compared to conventional disciplinary programs. Social and communication skills, in particular for convincing communication, also proved important for realizing the examples.

Keywords

Environmental Sciences, expert skills, graduate survey, Principal Component Analysis, qualifications, social-communicative skills, sustainability dimensions, transdisciplinarity

Education for Sustainability-Oriented Environmental Problem Solving

According to the *Agenda 21* (UNCED 1992), education must be a driving force for achieving sustainable development at global and local levels. There is broad consensus on this view. It has been reinforced by the UN General Assembly proclaiming 2005 to 2014 the Decade of Education for Sustainable Development, and it has just recently been reiterated by the *Bonn Declaration on Education for Sustainable Development* (UNESCO 2009), which emphasizes the importance of education for addressing food, water, and energy crises as well as climate change, loss of biodiversity, health risks, and social vulnerability and insecurity.

This study investigates the qualifications which university-level sustainability education should provide, on the basis of the professional experiences of Environmental Sciences graduates of the ETH Zurich. The implementation of the Environmental Sciences curriculum at ETH Zurich in 1987 was promoted by a group of concerned scientists: the founders of the program considered a shortage of well-trained experts in environmental professions to be a major factor as to why society proved unable to satisfactorily solve environmental problems caused by human technological and economic activities in many instances (Müller-Herold 1990, Gigon et al. 1993). In their view, university education in disciplinary scientific programs such as chemistry, physics or biology failed to effectively convey specific qualifications and skills required for analyzing, understanding, and handling complex, system-bound environmental problems. They perceived an urgent need for expertise at the level of environmental systems

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based on interdisciplinary, generalist knowledge of the relevant natural sciences (Frischknecht and Imboden 1995). These insights were methodically taken into account in the development of the Environmental Sciences curriculum, which aims to convey an encompassing systems-oriented *environmental problem-solving ability* (Müller-Herold and Neuenschwander 1992, Oberle et al. 1997, Scholz et al. 1997, Woschnack and Mieg 2003). Case studies were included as a central instructional format of the education, as these can effectively combine scientific analysis of facts with the practitioner's necessity to act (Müller-Herold and Neuenschwander 1992, Oberle et al. 1997, Hirsch Hadorn et al. in press). Because of the close interrelatedness of social systems, human activities, and environmental problems, courses in environmental social sciences and technology were introduced aiming at introducing interdisciplinary thinking. An obligatory work experience was added to impart insights into the practical constraints of professional environmental activities and to promote the development of key skills such as organizational and communication competencies (Steiner and Frischknecht 2001, Scholz et al. 2004, Hansmann 2009, Steiner 2010, in this issue).

Environmental problem-solving ability involves organizational, cooperation, argumentation, and further communication skills which allow graduates with a generalist scientific background to function as mediators between science and the public, and between specialists from different branches of science (Frischknecht 2000, Mieg 2003). By including these qualifications the Environmental Science curriculum has encompassed transdisciplinarity and the goal of sustainable development right from the beginning, even if the corresponding notions, mentioned in the program now, were not used at the time.

Environmental problem solving for sustainability requires transdisciplinarity, as not only natural and social science but also the viewpoints of different stakeholder groups, including the affected population, need to be considered and integrated (Scholz and Tietje 2002, Frischknecht and Schmied 2008). Such expertise is crucial for sustainable development, as sustainability entails maintaining human-environment systems within functional limits as part of an all-encompassing ethical relationship between present and future generations (Laws et al. 2004, Scholz et al. 2006). UNESCO emphasizes that sustainability-oriented "education not only provides scientific and technical skills, it also provides the motivation, justification, and social support for pursuing and applying them" (UNESCO 2002, pp. 8/9). It is not sufficient to analyze human-environment systems and identify sustainable development paths: it is equally important to educate and motivate stakeholders and society as a whole to indeed adopt sustainable courses of action.

Previous Findings of Qualification Research by the ETH Department of Environmental Sciences

Based on the requirements for solving environmental problems, a comprehensive set of qualifications was compiled by the Department of Environmental Sciences for the purpose of program evaluation and quality control (Hansmann 2009). Continuous surveys of the successive groups of graduates were conducted two and six years after they had obtained the diploma. These surveys elicited information on the qualifications conveyed by the program as well as on the qualifications required in the graduates' current professional activities (Mieg 2001, 2003, Brunner et al. 2010). According to the graduates' judgments, the environmental problem-solving qualifications which were most strongly imparted by the curriculum were:

- natural scientific analysis of environmental problems,
- modeling environmental systems,
- detecting relevant aspects of environmental problems,
- evaluating environmental problems,
- developing concrete solutions.

The highest qualification requirements in the professions were seen for:

- detecting relevant aspects of environmental problems,
- developing concrete solutions,
- evaluating environmental problems,
- natural scientific analysis of environmental problems,
- cooperation with non-experts in solving environmental problems.

As compared to the occupational demands, graduates thus perceived a qualification surplus through their university education with respect to the natural scientific analysis and the modeling of environmental systems. This qualification surplus has been seen as advantageous in professional fields which require an integrated view of environmental systems (Mieg 2001, 2003).

The continuous graduate surveys also addressed general abilities and key qualifications which are relevant for working in various positions and professional domains. It is generally acknowledged that such key skills are highly important in the context of transdiscplinarity and sustainability (Mieg 2003, Barth et al. 2007) even though their importance is not confined to such contexts. According to the continuous surveys, the following key skills were most strongly promoted by the curriculum:

- writing reports,
- cooperating in teams,
- considering the perspectives of others,
- verbal presentation,
- managing tasks through one's own initiative.

The highest professional demand was perceived for:

- managing tasks through one's own initiative,
- flexibility regarding unexpected events,
- cooperating in teams,
- motivating oneself or others,
- writing reports.

The graduates' ratings of the corresponding occupational demands for key skills tended to be considerably higher than the ratings >

of qualification levels acquired during the Environmental Science education. While key skills are difficult to train at universities, they tend to develop further with growing professional challenges and experience (Woschnack and Mieg 2002, Woschnack and Frischknecht 2002, Woschnack and Mieg 2003, Hayward and Fernandez 2004).

Bottom-up Investigation of Crucial Components of Environmental Problem-Solving Ability

In summary, the previous findings are quite consistent with what other researchers (e.g., Mayer 1995, Ben-Zvi Assaraf and Orion 2005, Barth et al. 2007) identified as crucial for successful professional contributions to sustainable development.

However, there is a lack in previous research of an empirical bottom-up analysis of the qualifications which were actually helpful for realizing concrete contributions to sustainable development from the perspective of those persons who accomplished them. Such an analysis is important not only for validating existing qualification models, but also because specific types of qualifications might emerge which could have been overlooked or insufficiently taken into account so far. Consequently, the survey we conducted aimed at examining sustainability-oriented activities in specific rather than abstract terms, in order to gain valuable insights into the qualification profiles required for sustainability-oriented professional activities.

The Web-Based Survey: Accessing the Experience of Graduates

A survey using a web-based questionnaire was conducted in 2009 to analyze the careers of the ETH Environmental Sciences graduates from 1992 to 2005 and their contributions to sustainable development. 567 graduates visited the survey webpage responding to the first question, 441 answered the whole questionnaire, which took about 15 to 35 minutes. Considering fully completed questionnaires, the participation rate thus amounted to 41 percent of the altogether 1085 graduates of the addressed time period.

The year of graduation of the survey participants was distributed similarly to the year of graduation of all Environmental Science graduates from 1992 to 2005 (Chi-Square test, $df = 13$, $p = 0.43$). The gender distribution in the sample was, with 33 percent females and 67 percent males, also very similar to that of all graduates of the addressed years (34 percent females). In summary, these analyses suggest that the survey participants are representative of the addressed group to a considerable extent. However, as is generally true for surveys of this type, a perfectly representative sample cannot be obtained, as factors such as lacking time or motivation for participation can cause a non-response bias.

The questionnaire elicited information on professional development and current professional activities as well as on contributions to sustainable development. It also contained items addressing the Environmental Sciences background and the careers of the graduates.

The Environmental Sciences Background as an Advantage in Sustainability-Oriented Professions

Altogether 542 respondents (96 percent) were currently professionally active, whereas 25 state that they do not currently work. The predominant fields of professional activity were research (21 percent), environmental, planning, engineering offices (15 percent), public administration (15 percent), finance and insurance (10 percent), education (8 percent), and NGOs (5 percent). The remaining 26 percent worked in other diverse domains.

For the question of whether the current activity was directly related to fostering sustainable development, a five-point scale was provided: 1 = no, 2 = rather no, 3 = rather yes, 4 = yes, 5 = yes, very strongly. The average rating was $M = 3.1$, which indicates that the professional activities of the graduates were rather oriented towards sustainability.

Participants were also asked to judge whether they perceived their environmental science education rather as an advantage or a disadvantage for their current activity when comparing it to the possibility of having completed a different, more specialized program. The average rating on the five-point scale (from 1 = clear disadvantage to 3 = balanced to 5 = clear advantage) showed, with $M = 3.3$, a tendency towards "rather as an advantage". As table 1 shows, these ratings depended considerably on the relatedness of the current activity to sustainability: according to t-tests against the neutral scale value of 3 (= balanced), those who currently pursue an activity related to sustainability perceive significant advantages ($p < 0.001$), whereas those who follow other activities on average perceive neither significant advantages nor disadvantages. This confirms the specific value of the environmental science education for the promotion of sustainable development.

TABLE 1: Results of the survey of ETH Environmental Sciences graduates: experiencing the Environmental Sciences background as an advantage or disadvantage compared to more specialized university programs, as a function of the relatedness of the current professional activity to sustainability. Correlation (Spearman) of both variables: $r = 0.22$, $p < 0.001$.

Is your current professional activity related to sustainability?		**Environmental Sciences background as advantage or disadvantage** (scale: 1 = clear disadvantage, 3 = balanced, 5 = clear advantage)	
rating	***N***	***M* (average)**	**significance:** ***p*** (deviation from $M = 3$)
no	76	3.1	0.235
rather no	73	3.2	0.124
rather yes	89	3.5	< 0.001
yes	99	3.6	< 0.001
yes, very strongly	78	3.7	< 0.001
total	**415**	**3.3**	

Alternative University Programs Deemed Viable to Prepare for Current Professional Activities

In the context of advantages and disadvantages of having completed the broad Environmental Sciences program, the graduates were also asked whether they could think of other university programs which could have prepared them to fulfill their current professional activity with similar levels of success. Although the Environmental Sciences background was perceived rather as an advantage in nearly all professional fields, 69 percent of the professionally active graduates answered "yes" to the question and noted other university programs or types of programs that would allow them to work in their current position. Many graduates noted more than one specific program. In summary, altogether 521 entries resulted for approximately 60 different programs or types of programs (table 2). The broad variety of disciplines ranging from the traditional natural sciences of biology, chemistry, and physics to geography, geology, diverse engineering programs, mathematics, and information sciences, diverse social sciences, economics, and law also reflects the broad variety of fields of professional activity into which the graduates entered. Still, according to the results of the former continuous graduate surveys, their professional positions are highly adequate for their education, as more than 90 percent of the graduates judged the correspondence between acquired skills and those applied in the job to be rather or very high (Brunner et al. 2010). Accordingly, the rather generalist Environmental Sciences education seems to convey skills to the students that are useful for working at diverse interfaces to other disciplines.

In combination with the specific value of the Environmental Sciences education for sustainability-oriented jobs, the broad range of professional fields implies the possibility to contribute to sustainable development in various societal and economic sectors. This seems particularly important since the disciplinary focus and specialization of many current university programs tends to produce graduates with in-depth knowledge in their own fields but "little awareness of consequences their actions may have in other fields, such as society and nature, in both the short- and long-term future" (Lozano 2006, p. 788).

TABLE 2: Alternative university programs which could have prepared the Environmental Sciences graduates for their current professional activities.

university program/type of university program	frequency[a]
classical and biologically oriented Natural Sciences	166
environmentally oriented Natural Sciences	54
Agriculture, Forestry, Engineering Sciences and Technology	146
Economics, Management, Law	79
Mathematics, Informatics	24
Social Sciences and Humanities	33
all university programs, university degrees of all types	19

a The item was formulated open-ended, so that each of the $N = 280$ graduates mentioning such programs could name one or more university program(s) or type(s) of university program(s) (even) within each of the seven categories formed for the interpretation.

Best Examples of Contributions to Sustainable Development

The graduates were asked to provide their best or two best examples of having contributed to sustainable development through their professional activities. 397 graduates provided an example, 275 of them additionally described a second example (672 examples in total). Each participant could select one of the one to two examples for answering additional closed-ended questions.

About 45 percent of the thus selected examples were classified by the graduates as impacting on their own vocational practice and on aspects internal to their own organization. 87 percent of the examples, according to the answers, promoted sustainability outside of the organization. Only one percent of the examples exclusively concerned the graduates' own professional practice. This indicates that these professional contributions to sustainable development have considerable outreach.

Concerning the selected examples, graduates were also asked whether a systematic integration of the ecological, economic, and social dimensions of sustainability had been attempted and whether a conflict between these three dimensions had been evident. No explicit definition of sustainability was provided for these questions: the graduates have repeatedly dealt with manifold aspects of sustainability during their university studies, and according to Boons and Roome (2000, p. 53), "the concept of sustainable development (...) appeals to many people precisely because the 'openness' of the definition enables people to construct and contribute to the process of defining what sustainable development entails." Still, the questionnaire items referring to three dimensions of sustainability as well as the sustainability aspects focused on by the Schweizerischer Bundesrat (2002) (see following section) implicitly provided a common orientation regarding the concept.

Systematic efforts to consider the ecological, economic, and social dimension of sustainability in an integrative way were undertaken in 47 percent of the examples. In 46 percent of the examples, a conflict between these dimensions was evident. It turned out that the occurrence of conflicts between the dimensions and their systematic integration are interconnected: in 63 percent of the examples with conflicts between the dimensions, there were also efforts aiming at their systematic integration. Contrariwise, systematic efforts toward balancing the three dimensions were only present in 34 percent of the examples in which no such conflicts became evident. A Chi-Square test showed that this relationship is highly significant ($df = 1$, $p < 0.001$). Accordingly, resolving conflicts can be regarded as an essential part of integrating and balancing different dimensions of sustainability.

Objectives of the *Swiss Sustainability Strategy* Addressed in the Examples

The *Swiss Strategy for Sustainable Development* (Schweizerischer Bundesrat 2002) defined 15 objectives for the ecological, econom- >

ic, and social dimension of sustainability, with five objectives per dimension (WCED 1987). Graduates were asked to judge whether their example contributed to achieving each of these objectives (yes vs. no). As figure 1 shows, a majority of the examples contributed to responsible use of renewable resources, reduction in the use of non-renewable resources, protection of the natural environment, and protection of health and safety of the population. In line with the environmental orientation of the curriculum, environmental aspects are covered more frequently by the graduates' contributions to sustainable development than economic or social aspects, which are addressed to a similar extent (average percentages of the examples covering aspects of the three dimensions; two paired sample t-tests, $p < 0.001$).

Which Sustainability Aspects Go Together?

As aspects of all three sustainability dimensions can be involved in discrete contributions to sustainable development, it seemed relevant to analyze the actual interrelatedness between these aspects on the basis of our empirical data. A Principal Component Analysis (PCA) allows for investigating the dimensionality of complex constructs or other potentially multidimensional variables through the identification of factors that are underlying the inter-correlation between a set of variables. The resulting principal components are not correlated with each other and can help to group the original variables according to how closely they are correlated with each of them. A PCA was conducted to analyze the interrelationships between the 15 sustainability objectives on the basis of their (non-)coverage through the examples.

The scree diagram of the eigenvalues of sequentially extractable PCA components suggested the extraction of three components, as a bend in the eigenvalue curve could be identified at component 4 (Bortz 1999). The loading pattern of the three extracted components on the 15 sustainability aspects revealed that they partially transcended the three original sustainability dimensions. This indicates that the theoretical divide between an ecological, economic, and social dimension of sustainability does not fit with their interrelatedness and integration in practice. Box 1 shows the objectives of the *Swiss Sustainability Strategy* which loaded highly on the three extracted PCA components. Based on this loading pattern, the three components were interpreted as reflecting *nature protection and protection of humans, product and process development,* and *education and communication*.

Most of the examples focused on objectives loading highly on the two components *product and process development* and *nature protection and protection of humans,* whereas objectives related to *education and communication* were covered to a lesser extent (cf. figure 1). Typical examples mainly corresponding to one of the three components are provided in box 2.

Important Competencies for Realizing the Examples

Together with the examples, graduates were asked to specify which qualifications they considered helpful for realizing them. Analyzing these data can substantiate the qualification profiles to be aimed at by sustainability-oriented curricula. In the quantitative content analyses of the answers to the corresponding question we distinguished between 1. expert skills and knowledge, 2. social-communicative competencies, and 3. personality and motivational aspects such as personal involvement, strong commitment, or having a clear vision. The first of these captures some

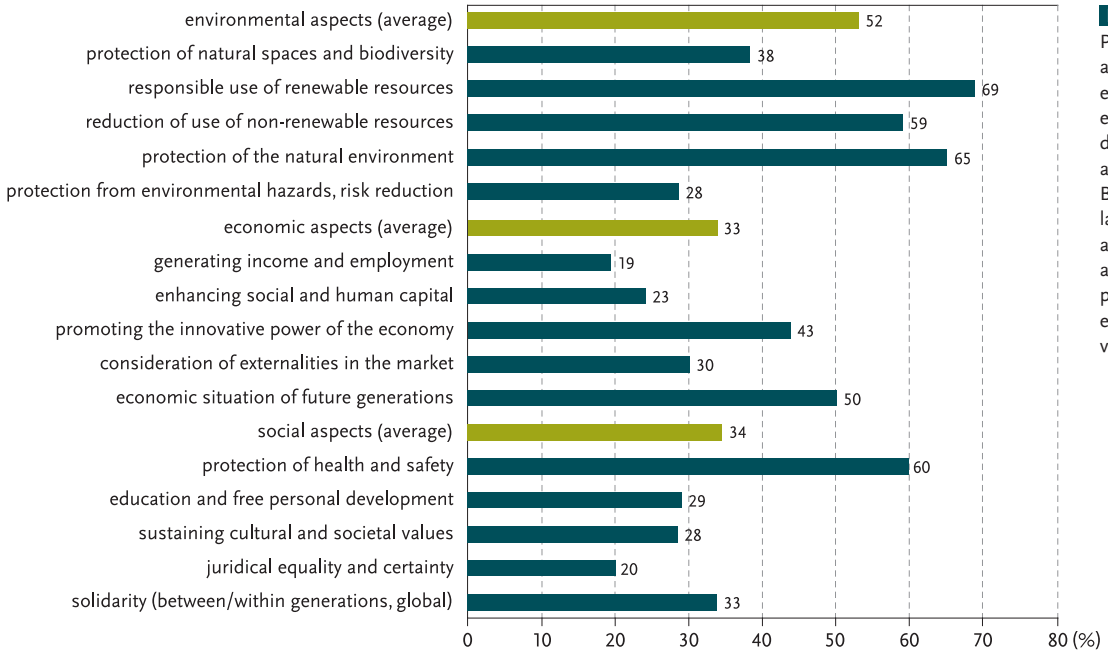


FIGURE 1: Percentages of examples addressing five aspects each of the environmental, economic, and social dimensions of sustainability (Schweizerischer Bundesrat 2002, translated by Ralf Hansmann and Stephanie Keller), and average percentages per dimension (closed-ended questions in "yes" vs. "no" format, $N = 373$).

BOX 1: Objectives of the *Swiss Sustainability Strategy*

Sustainability objectives on which three extracted components of a Principal Component Analysis (PCA, see text) with regard to 15 sustainability aspects covered or not covered by 373 selected examples loaded highly (i.e., > 0.5, loading provided in brackets).

Component names (given a posteriori) and corresponding aspects of sustainability

nature protection and protection of humans
- protection of the natural environment (0.75)
- protection from environmental hazards, risk reduction (0.63)
- protection of natural spaces and biodiversity (0.61)

product and process development
- promoting the innovative power of the economy (0.66)
- reduction of use of non-renewable resources (0.63)
- consideration of externalities in the market (0.58)
- responsible use of renewable resources (0.58)
- economic situation of future generations (0.56)

education and communication
- education and free personal development (0.78)
- sustaining cultural and societal values (0.75)
- enhancing social and human capital (0.63)
- generating income and employment (0.61)

Note: The three remaining sustainability aspects formulated by Schweizerischer Bundesrat (2002) did not load highly on any PCA component.

BOX 2: Graduates' Contributions to Sustainability

Excerpts of best examples for contributions to sustainable development as described by the Environmental Sciences graduates (translated and abridged by Ralf Hansmann and Stephanie Keller).

nature protection and protection of humans
- I cooperated in the evaluation of *NADUF (Nationale Daueruntersuchung der Fliessgewässer [national continuous investigation of running waters])* based on time series (...)
- I provided guidance for the development and realization of networking projects which concern the preservation of biodiversity (...)
- I am responsible for the strategic planning of spatial development in our canton (...)
- Development of a software program for the monitoring of air pollutant emissions (...)
- I considerably contributed to the recent recognition of "Wildnispark Zurich – Sihlwald" as a Swiss Nature Experience park (...)

product and process development
- (...) I showed in an eco-balance of a specific mobile phone that the charger, while plugged in, has major negative environmental impacts. As a consequence (...) the environmental burden could be strongly reduced.
- I conducted research supporting sustainable development (economically, ecologically, socially) of Swiss agriculture (...)
- Compilation of a special data bank (replacement of the existing database) within the range of water use for a cantonal environmental office (...)
- I contributed to the build-up of the energy region Emmental-Oberaargau (...)
- As employee of a huge solar company I founded an own Italian subsidiary (...)

education and communication
- As teacher, I (...) acquaint young persons with diverse topics of sustainability (...)
- As a freelancer I wrote a hotel guide for environmentally friendly hotels in Switzerland (...)
- Conception and implementation of a campaign for the promotion and advancement of the energetic redevelopment of real estate properties, which included among other aspects the 'Ice-block bet' (...)
- My work in a nature protection center supports sustainability by contributing to environmental education. We sensitize school classes and also the broad public (also via media) for requests of nature protection (...)

of the environmental problem-solving qualifications that were addressed in the previous annual graduate surveys, whereas the latter two capture key skills. However, the present findings do not allow straightforward conclusions regarding which qualifications need to be promoted *more* strongly to meet professional demands, as the qualifications that the graduates mention are ones which they possessed when bringing their contribution to fruition.

Expert Skills and Knowledge

Broad, interdisciplinary skills and system-oriented ecological understanding as well as scientific expertise regarding specific disciplines and application domains were mentioned most frequently as the qualifications enabling the successful realization of the examples (figure 2, p. 284). This is in line with the environmental science program that the graduates have completed. On the one hand, the curriculum imparts broad natural scientific knowledge, ecological understanding, and systemic thinking. On the other hand, detailed knowledge of specific areas and fields of application is taught in exemplary areas such that the students gain experience in accessing and developing in-depth expertise and understanding of certain topics.

In addition, professional experience as well as skills in mathematics and informatics and in various social scientific areas including law and economics were required in several examples. This shows that graduates' knowledge of social sciences proved helpful in various instances to orient regulatory processes in human-environment systems towards sustainability.

Social-Communicative Competencies

The important role that social and communication skills play for contributing to sustainable development was confirmed, as many graduates denoted such skills as helpful for realizing their contributions to sustainability. Communication skills in general were mentioned most frequently (figure 3, p. 284), followed by the specific skills of effective argumentation, persuasion, and negotiation. Moderation and conflict management skills, competencies for comprehensive and clear communication, as well as social skills, writing, and intercultural communication skills were also important. Enhancing such skills has represented a major qual- >

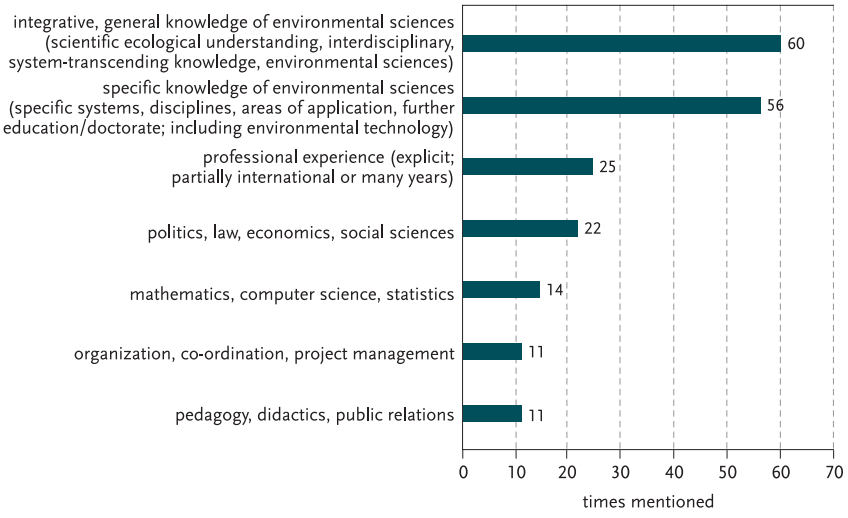


FIGURE 2: Different types of expertise and knowledge helpful for realizing the examples. Content analysis of $N = 213$ answers to open-ended questions, which could count as maximally one entry per category.

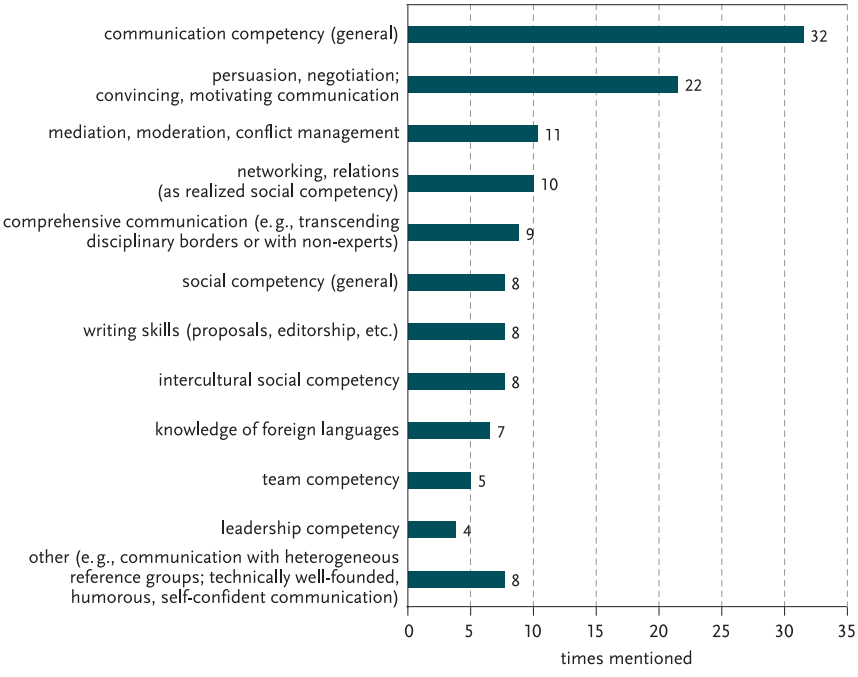
ification goal of the Environmental Sciences program since its foundation (Scholz et al. 2004, Hansmann 2009). However, skills for convincing persuasion and argumentation could merit even more special attention in the program. Having good ideas for solving environmental problems is frequently not enough. Ideas need to be conveyed to others in order to realize the viable options which have been identified.

Personality and Motivational Aspects

The importance of persuasive skills was substantiated by personal characteristics and motivations which helped to accomplish the examples: perseverance, hardheadedness, and patience were most important, followed by enthusiasm, commitment, and clear goals or visions (figure 4). These responses show that sustainability-oriented values and personal involvement are important components of the graduates' environmental problem-solving ability.

To convey value orientations and motivations in a university program is not a trivial thing (Sipos et al. 2008, Jones et al. 1999). According to Shephard (2008), students may feel indoctrinated and refrain from the concept of sustainability if its corresponding values are taught in directive ways, and therefore methods like "discussion, open debate, peer involvement, role playing, problem-based learning, engaging with role models, simulations, games, group analysis of case studies, expert engagement, perspective sharing via reflection" (Shephard 2008, p. 91) are recommended for value-oriented sustainability education. Open discussion and reflection on different perspectives, worldviews, and value systems need to prevail in sustainability-oriented education, and this is particularly true if affective learning outcomes and values are aimed at (Hansmann 2010).

Previous studies of the Environmental Sciences Department (Müller-Herold 1988, 1990, Hansmann et al. 2009) indicate that the students already have an environmental value orientation when they begin the program. These values can be strengthened and enriched throughout the educational program by teaching the scientific knowledge and ecological systems understanding as well as other aspects important for environmental problem-solving ability.



Conclusion

Consistent with the broad and generalist orientation of the Environmental Sciences curriculum, the graduates entered into a broad range of professional domains. The majority of the graduates considered their environmental science background as advantageous for successful performance in their professional activity as compared to more specialized programs. The advantage of having studied Environmental Sciences was perceived particularly strongly when the professional activity was related to sustainability. This indicates that the broad natural

FIGURE 3: Social-communicative competencies considered helpful for realizing the examples. Content analysis of $N = 213$ answers to open-ended questions, which could count as maximally one entry per category.

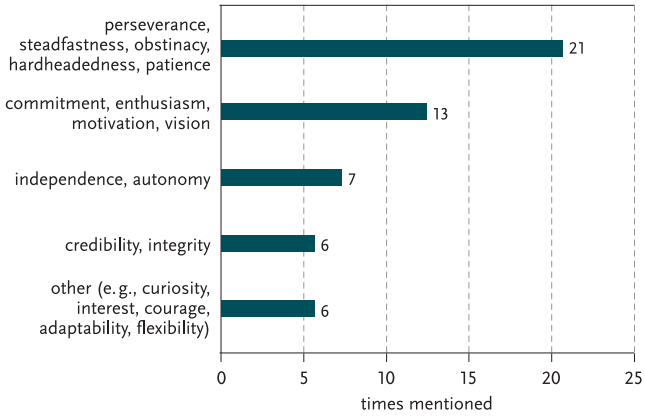


FIGURE 4: Personal characteristics considered important for realizing the examples. Content analysis of $N = 213$ answers to open-ended questions, which could count as maximally one entry per category.

scientific education and its systems orientation, which prominently includes aspects of the anthroposphere, offer a potential advantage in all fields of activity where an integrated view of human-environment systems is necessary. The presented findings thus substantiate the success of the Environmental Sciences program in educating experts for solving complex environmental problems with an orientation towards sustainability (Mieg and de Sombre 2004, Brunner et al. 2010, Mieg in press).

The results on the qualifications required for contributing to sustainable development are basically consistent with previous research and confirm the adequacy of the qualification profile targeted by the Environmental Sciences education (Mieg 2001, 2003, 2009, Woschnack and Mieg 2003, Hansmann 2009). As for (environmental) expert knowledge and skills, specific knowledge in certain disciplines and topical domains as well as generalist knowledge proved important. This indicates that the environmental scientists succeeded in deepening their knowledge in specific areas, and suggests that specific knowledge and broad generalist knowledge can complement each other in solving complex problems. Environmental Sciences graduates possessing broad multidisciplinary knowledge, integrative (environmental) systems knowledge, and interpersonal skills can thus play an important role in transdisciplinary processes aiming at sustainable development (Frischknecht 2000, Mieg and de Sombre 2004, Hirsch Hadorn et al. in press).

In line with this, communication skills, particularly skills for comprehensive and convincing communication, proved important for the graduates' contributions to sustainable development. Accordingly, competencies for profound, logical, and persuasive communication need to be high on the agenda in sustainability-oriented education programs in order to prepare students for practice. University education thus needs to provide training opportunities where students exercise comprehensive and convincing communication with other students (e.g., in oral presentations or discussions in lectures) and with people outside of academia (e.g., in the context of project work, internships, or transdisciplinary case studies).

Effective communication also profits from motivational and personal aspects such as strong involvement and having clear visions. The facilitation of corresponding sustainability-oriented values needs to remain a priority of the Environmental Sciences education at ETH Zurich.

In 2003, the Bologna Process introduced a new higher education teaching system with separate Bachelor's and Master's programs. The surveys analyzed in this paper have not yet incorporated students graduating under the new system. However, the central idea and the core elements of the former diploma program have remained, although every element of the curriculum was reviewed during the reform process. Initial feedbacks indicate that the character of the education has been maintained and even further strengthened. The established continuous survey-based assessment will go on and thus help to guarantee the continual further development of the curriculum.

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