How to prepare students for a responsible use of science and engineering

Results from the workshop „Teaching ethics and peace to science and engineering students“, University of Hamburg, 15-17 Oct 2008

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Introduction

The natural and engineering sciences produce knowledge and technology which can be abused or used for the better. This knowledge and technology have led to the development of weapons of mass destruction, but are also used in the supervision of disarmament programs. They contribute to economic and social development, but their application can put health and the environment at risk. Natural science does not itself deliver values and norms which are needed to agree on the way technology is being used. However, scientists and engineers are part of decisive formative processes and need a normative orientation.

Students are often unaware of the ethical dilemmas which they will face in their future careers. Most of them will tend to obey the rules of their professional community or employer, but how should they respond if their work or organisation leads to conflicts with the larger public wellbeing?

Furthermore, our societies are faced by more and more complex ethical questions: Should we use weapons in space? Should we bury CO₂ in the ground? Should we pursue the enhancement of human abilities by brain implants?

Ethics is not the magic wand turning all these issues into answers of absolute certainty. Ethical judgement is a necessary tool that enables us to address these questions in the first place. A good ethical discourse makes conflicts transparent. It fosters the search for common values and solutions, and it strengthens responsibility and accountability in facing the consequences of the path chosen. This can be taught and learned by bringing real life situations into the classroom, augmented by theoretical
analysis. Furthermore, students of science and peace issues learn to work in an environment where open research on security questions, the perception of different views and mutual responsibility are key values for constructive conflict resolution.

In summary, students must be prepared for a responsible use of science and technology. It is the responsibility of universities to make our future scientists and engineers ethically aware and competent.

**Opportunities of Bologna**
The new bachelor and master programs of the Bologna process offer some opportunities to revise teaching content. Initiatives for establishing ethics and peace education at universities have been promoted by various national and international organisations – among them UNESCO, the UN Committee for Disarmament Education, the International Peace Research Association and the European Association for Engineering Education.

However, it depends largely on the local leadership, expertise and resources how to put such intentions into practice. Every case is a story of its own. Some of these stories are told in this brochure.

**This brochure**
This brochure aims at encouraging university teachers to engage in teaching efforts on a responsible conduct and use of science and technology. It provides an insight into possible obstacles and ways to overcome them. Thus, it also can help the leadership of universities as well as education policy makers to go for the implementation of necessary policy initiatives and structural changes.

*The workshop organisers*

From 15 to 17 October 2008, 43 participants from 9 countries gathered in Hamburg to discuss current issues of teaching ethics and peace to science and engineering students. The group, comprising mainly university teachers in science and engineering, but also education researchers and education policy makers, developed the recommendations that are presented in this brochure.

The workshop focussed on three theme areas: It presented pioneering teaching initiatives from different European countries, it evaluated structural obstacles and strategies for the introduction of such teaching, and it formulated recommendations.

The workshop was realized by a joint effort of the Center for the Philosophy of Nature and Science Studies (University of Copenhagen), Carl Friedrich von Weizsäcker Center for Science and Peace Research (University of Hamburg), Institute for Peace Research and Security Policy (University of Hamburg), the International Network of Engineers and Scientists’ Projects on Ethics within the International Network of Engineers and Scientists for Global Responsibility (IMES) and the Research Association Science, Disarmament and International Security (FONAS, Germany).

The program and presentations of the workshop can be found at: http://www.znf.uni-hamburg.de/ethics-and-peace.html
Conclusions
The participants of the workshop “Teaching ethics and peace to science and engineering students” in Hamburg agreed on the following conclusions and recommendations.

1. Responsible use of science and engineering is essential.
   Universities have an obligation to prepare students for a responsible conduct and use of science and engineering in society.

2. All students must be reached.
   Hence the respective educational modules must be compulsory both at the bachelor and the master level.

3. Natural and engineering faculties lag behind.
   While many universities offer courses on medical ethics, respective teaching units in the natural and engineering faculties are only slowly being introduced.

4. Different approaches exist.
   The pioneering programs the workshop focussed on show a considerable diversity in scope and character ranging from optional courses through minor courses to a compulsory Studium Generale for all students.

5. Bologna is an opportunity.
   The Bologna process is an opportunity to introduce new educational elements for preparing students for ethical and social responsibility. However, mechanisms that guide and safeguard the actual inclusion of such necessary elements are lacking.

6. Accreditation bodies support teaching responsibility.
   Accreditation bodies have formulated criteria for learning outcomes that relate to ethical and social responsibility. These criteria imply and support the need to introduce the educational elements referred to above.

7. External funding decisions or guidelines are important.
   External funding decisions or guidelines of governing bodies which triggered or mandated the introduction of such courses have been decisive factors in several successful cases (Denmark, Finland, some Dutch universities).
8. **A nucleus of motivated and competent staff is essential.**
The presence of nuclei of motivated and competent staff in each school and department is a necessary precondition for developing and providing adequate educational forms and contents.

9. **Staff nuclei have to be augmented.**
This can be achieved by allocating and training additional staff. The actual funding situation regarding this teaching is often inadequate.

10. **Active learning forms are important.**
They relate the learning process to real life situations. Successful programs have made good use of role plays, case studies, project and community work. The aims of these learning forms need to be made explicit and they should be linked to appropriate theoretical and empirical input.

11. **Need for teaching material.**
There is a great need for the development of suitable teaching material in print and web form. This should be nationally and internationally available at low cost.

12. **Going beyond the individualistic approach.**
The individualistic approach to teaching ethics and peace to science and engineering students which puts the ethical responsibility solely on the individual should be augmented to include a critical analysis of the broader context in which they will do their work (organisations and their cultures, laws, political decision making, economic and social pressures). Without this attention for “critical analysis of the context”, courses on ethics for scientists and engineers may end up having a negative impact, by merely making students shrug their shoulders and turn to “business as usual”.
Recommendations

The implementation of teaching modules on a responsible use of science and engineering does not happen on its own. The following recommendations might be of help.

1. **Make use of the Bologna process!**
   University leaders Europe-wide are asked to make determined use of the Bologna process in order to introduce teaching on science, engineering and social responsibility. Accreditation criteria require preparing students for professional and social responsibility. University leadership is needed to see to the proper installation of such teaching into curricula.

2. **Provide external funding and guidelines!**
   Experience shows that external funding decisions and/or governmental guidelines can be crucial to start the process. This has been successfully illustrated e.g. in Denmark, at some Dutch universities and at the University of Hamburg.

3. **Make it compulsory!**
   All students of science and engineering need to be reached. Hence the teaching elements have to be compulsory.

4. **Motivate teaching staff!**
   Motivated teaching staff is a prerequisite. Existing kernels of such staff need to be augmented by allocating and training additional staff proportionate to the teaching task.

5. **Use active learning forms!**
   Active learning forms like project work and role plays are instrumental, especially for interdisciplinary problems. Existing staff should be encouraged and supported in introducing such elements. Theoretical understanding has to be complemented with case studies and real life situations.

6. **Enhance the attractiveness for your students!**
   There are strong reasons to expect that universities will enhance their attractiveness and success by preparing their students for a responsible conduct and use of science and engineering in society. Good Luck!
The Leuphana University Lüneburg has a long tradition in teaching sustainability. In the 1990s, a faculty for environmental issues was founded to which the UNESCO Chair „Higher Education for Sustainable Development“ belongs and which offers B.Sc., M.Sc. and MBA programs related to that topic.

In 2006, a reorientation of the university was enacted. It was implemented by a new, decisive leadership that used the curricula reform towards a bachelor and master system as an opportunity to introduce the interdisciplinary Leuphana semester in 2007. This unique approach was made possible by an existing nucleus that could trigger—due to an advantageous environment—a phase shift in the development of the university. The Leuphana semester is mandatory for all 1400 first-year students. The goal is to promote the personal development of the students as well as to enable them to cope with complex situations and to make meaningful decisions. Integrating such an approach is a threefold challenge in terms of study methods, teacher integration and organisational aspects.

The semester begins with a project-work-based week that is followed by four modules. In three of them the students are made familiar with the historical, methodological and interdisciplinary aspects of science. The fourth module “Science and its social responsibility” covers responsibility and sustainable development. All students deal with questions of how the concept of sustainable development may serve as a normative framework to unfold responsible action. The module is structured in three parts. First, lectures, tutorials and e-learning content give a basic introduction to the overall topic of sustainable development (workload: 75h). Second, 50 different project seminars linking the future field of studies to a wide range of topics related to sustainable development follow (workload: 150h). The module finishes with a three-day conference, organised by the students with different presentation forms and invited experts. The related teaching units are credited with 10 points. 60 teaching staff members are involved.

The Leuphana semester is an organisational challenge, but the results of the first two years are very encouraging.
In 1995, the board of Delft University of Technology (DUT), Netherlands, decided that compulsory courses on the ethical aspects of the applied sciences and engineering professions should be introduced in the final stages of all its curricula.

This initiative was catalyzed by a strong recommendation of the Ministry for Education to all Dutch universities. At Delft, the Department of Philosophy was made responsible for developing and teaching these courses, in consultation and co-operation with the faculties for which the courses were intended. Today, the Department of Philosophy delivers compulsory courses or course elements in ethics and engineering of between 1.5 and 6 ects credit points to about one thousand students annually, in a wide spectrum of teaching programmes at bachelor and master level.

An example is the 6 ECTS course “Ethics and Engineering” for MSc students of the Faculty of Applied Sciences. This course is taught twice per year, and serves almost 200 students each year in (Bio)chemical Engineering, Life Science and Technology, Applied Physics, and Materials Science and Engineering. The teaching goals are aimed at the following competencies. After completion of the course, students

■ can recognise ethical and social aspects and problems of technology and of the professional practices of engineers;
■ have insight into the ethical, social, legal, organisational and political backgrounds of those ethical and social aspects and problems;
■ have appropriate knowledge and skills to reason on these issues in a consistent and reliable manner and to enter into solution-oriented debate with others on these issues.

In this way the course aims to contribute to preparing scientists, technologists and engineers to practise their profession in an ethically and socially responsible manner. The course explores and analyses broader topics that include:

■ the responsibility of individuals within hierarchical organisations;
■ the responsibility of business organisations;
■ the actual and possible role of the legal system in channelling the development and use of technology; and
■ the actual and possible procedures for collective decision-making regarding technology.

The course is received positively by the students. Almost always they are extremely interested in the ethical and social aspects of science and engineering, and they welcome the opportunity, provided in this course, to learn, think, discuss and write about those aspects.
Learning has to be active to be effective

For successful courses on ethical and social aspects of science and technology, active teaching forms are needed in combination with adequate empirical and theoretical teaching contents. Here, role plays can play an important role.

The active teaching forms used in the courses on ethics and engineering at Delft University of Technology include a role play based on a teleconference that preceded the accident, on January 28th 1986, of the US Space Shuttle Challenger. The role play engages students emotionally and directs them to critical and informed reflection on the organisational context that shapes their future professional practice.

The cause of the accident, in which all 7 crew members died, was a flame that leaked past a sealing O-ring in a Solid Rocket Booster. A hole was burned in the huge external hydrogen tank that subsequently exploded. In the half year preceding the accident, evidence had accumulated of problems with the O-rings. At Morton Thiokol, the subcontractor of the Solid Rocket Boosters, a task force had been formed to deal with the issue. During a teleconference on the eve of the launch between NASA Marshall Space Centre and Morton Thiokol, the latter had reversed its initial advice not to launch to a positive advice, after which NASA had decided to the launch the next morning.

In the role play of the teleconference, 3 students play NASA managers, 4 other students play two directors and two engineers from Morton Thiokol. The players should “crawl into the skin” of these individuals, which includes their organisational position and tasks, and the information they had. But it is left to the players how the teleconference evolves, and hence what the outcome is. The role play takes two hours of class, and the players should prepare in advance.

The role play makes students feel what it means to function in a complicated organisational context characterised by hierarchical relations, and lets them experience ethical problems that may arise. Supported by relevant theoretical teaching contents, the role play also helps to lead students into reflection on that organisational context and how it could be improved.

During the teleconference, managers overruled the engineers’ judgements regarding safety. A conflict is hence apparent between engineers’ actual position in hierarchical organisations, and the duty of engineers to hold paramount the safety of the public, which duty is formulated in many ethical codes. How can responsibility in hierarchical organisations be distributed so as to prevent accidents and diminish ethical problems? Unless engineers can analyse and evaluate such issues, they are unable to contribute, together with others, to the solution, reduction or prevention of structural ethical problems attached to their profession.

For a full description: go to http://blackboard.tudelft.nl/, select “Courses”, search for “wm0329tu”, select a recent course version, and go to Course Documents. Contact: Dr. Henk Zandvoort, h.zandvoort@tudelft.nl
A case-study based teaching approach

In a compulsory course at the University of Copenhagen, students of biochemistry develop their ethical competencies. Several case studies aim at preparing them for the challenges of their professional life.

Scientific life has changed. By addressing more and more complex problems scientists cannot offer results of absolute certainty any longer. And with the increase of external funding, science is often required to be useful to its stakeholders. This affects the questions taken up by researchers and leads to conflicts when different value systems meet. For example, whether or not genetically modified food is dangerous can neither be answered with absolute certainty nor can the research be totally independent of the stakeholders involved.

Preparing science students for the ethical dilemmas they might encounter is the aim of the course „Philosophy of Science and Ethics“ at the University of Copenhagen. Since the spring of 2005, it has been taught to third-year biochemistry, chemistry and nanotechnology students. The course is compulsory and is attended by about 100 students per year who can earn 7.5 ECTS credit points. It is a result of the Danish government’s directive to include philosophical and ethical aspects in university curricula of Danish Universities.

The course is case-based: concrete events and problems are analysed, by linking them to sociological, historical, philosophical or ethical theories. Each case is presented by a group of students to the rest of the class. A week before each presentation, the central concepts and theories relevant to the case are introduced in conventional lectures.

In the course the students discuss the story of a promising nano researcher who was found guilty of scientific misconduct. They meet Rosalind Franklin and the question whether she deserves substantial credit for the discovery of the structure of DNA. The third case analyses the controversy between IPCC and the so-called „climate skeptics“. Next, the experiences of a biologist at UC Berkeley, Ignacio Chapela, are addressed. Here, conflicts of interest arose due to the external funding by an agro-company. The fifth case tells the story of the German chemist Fritz Haber and his justification of his involvement in the German chemical weapons programme during the First World War. In the last case, the students are asked to imagine that they themselves are active researchers in a controversial area and to reflect on whether they think ethical considerations are important for them, addressing a very important competency: to formulate one’s ethical orientation system.

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A chair and teaching program on science and peace research

The University of Hamburg has become the first university in Germany to establish a chair and centre for science and peace research. The interfaculty centre offers a three-fold teaching program to different groups of students.

How was this accomplished? It was a synergy of several factors and actors:
- A research tradition in international relations and peace research which dates back to the 1920’s;
- the engagement of a few scientists inside the university and German-wide triggered by the peace movement of the 1980’s;
- a generous funding offer by the recently founded German Foundation for Peace Research (DSF);
- an open minded university president, who decisively made use of this opportunity;
- and the dedication of the chair to the prestigious name of a physicist who held a chair in philosophy in Hamburg from 1957-1970 and who initiated major programs of peace research in the 1960’s and 1970’s: Carl Friedrich von Weizsäcker. Many current decision makers in Hamburg had listened to his fascinating lectures as students.

The funding offer comprised Euro 250,000 annually for five years under the condition that the university would take over afterwards. Consensus inside the university, which was plagued by continuous budget cuts, was only reached by putting the load on many shoulders. Ten departments agreed to support and cooperate in the new Carl Friedrich von Weizsäcker Centre for Science and Peace Research which was established in 2006.

The appointed professor is both director of this interfaculty centre and member of the Department of Physics. He has set up a threefold teaching program directed at (a) students of physics, (b) students of all natural sciences and (c) students from the university at large. Physics and science students can take a minor in physics/science and peace research with a focus on arms control verification technologies, mathematical modelling of conflict and cooperation and other scientific issues. Courses for the university at large cover major challenges for the future of mankind. Role plays e.g. on nuclear conflicts or climate change turned out to be particularly popular and rewarding for students. The university and the Hamburg Peace Research Institute also operate a post-graduate master study programme on peace and conflict studies.

See also: www.znf.uni-hamburg.de

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Sponsors of the workshop

The program, videos and presentations of the workshop can be found at:
http://www.znf.uni-hamburg.de/ethics-and-peace.html