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Making philosophy of science relevant for science students

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Making philosophy of science relevant for science students

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Introduction

Since 2004, it has been mandated by law that all Danish undergraduate university programmes have to include a compulsory course on the philosophy of science for that particular program. At the Faculty of Science and Technology, Aarhus University, the responsibility for designing and running such courses were given to the Centre for Science Studies, where a series of courses were developed aiming at the various bachelor educations of the Faculty. Since 2005, the Centre has been running a dozen different courses ranging from mathematics, computer science, physics, chemistry over medical chemistry, biology, molecular biology to sports science, geology, molecular medicine, nano science, and engineering.

We have adopted a teaching philosophy of using historical and contemporary case studies to anchor broader philosophical discussions in the particular subject discipline under consideration. Thus, the courses are tailored to the interests of the students of the particular programme whilst aiming for broader and important philosophical themes as well as addressing the specific mandated requirements to integrate philosophy, some introductory ethics, and some institutional history. These are multiple and diverse purposes which cannot be met except by compromise.

In this short presentation, we discuss our ambitions for using case studies to discuss philosophical issues and the relation between the specific philosophical discussions in the disciplines and the broader themes of philosophy of science. We give examples of the cases chosen to discuss various issues of scientific knowledge, the role of experiments, the relations between mathematics and science, and the issues of responsibility and trust in scientific results. Finally, we address the issue of how and why science students can be interested in and benefit from mandatory courses in the philosophy of their subject.

[1] This paper was presented at the ESHS workshop "How science works – and how to teach it", Aarhus, June 23-25, 2011. It is the result of joint discussions among and contributions from members of staff at the Centre for Science Studies. It is an extension of a previous publication in Danish (Andersen et al., 2009).

Implementing philosophy of science for science students at Aarhus University

When the Faculty of Science and Technology, Aarhus University delegated the responsibility for teaching the compulsory undergraduate courses in philosophy of science to the Centre for Science Studies, the Centre decided to design individual courses for each of the undergraduate programmes and currently offers a dozen different 5-ECTS courses.[2] The courses aim at making the students able to 1) describe the characteristics of their subject and its relations to other scientific disciplines, 2) relate their own professional training in a broader context, 3) discuss philosophical and ethical aspects of their subject, and 4) critically reflect on the content of their subject and its functions in society.

The courses are taught by a combination of lectures by members of the faculty and tutorials taught by teaching assistants. Typically, we lecture for 3 hours weekly for the 7 weeks that make up our quarters with an equal load of tutorials. The lectures provide theoretical background and perspectives on topics such as delineation of science, scientific methods, progress of science, institutional history, and ethics. In the tutorials, students present predefined cases for discussion; these presentations are based on a selection of primary and secondary texts in a compendium. The courses are evaluated through a 2-day take-home exam on a specified set of questions and are graded. Didactically motivated by the written examination, the students have to prepare a summary of their presentation in writing and will receive feedback from the teaching assistants during the course regarding content and argumentative style.

With the subject field of the undergraduate student as its starting point, the teaching aims at broadening and qualifying philosophical and ethical discussions in epistemological, social and ethical contexts. This is achieved through the use of selected cases from the subject discipline that are used as starting points for reflections and discussions. Thus, the courses are noticeably not taught as history of philosophy of science but rather as philosophical reflection brought about through selected historical and contemporary cases showcasing the lively, complex and relevant philosophical problems involved in doing science.

Amongst the cases currently used in bringing about such discussions, we present in the following three cases highlighting a selection of themes: 1) Using examples from the history of science we emphasize how problems do not have “natural” domains: Different scientific disciplines can address “the same” issue applying different epistemological approaches until a discipline claims authority over the solution of the problem. And even when this happens, answers are fallible and temporary. 2) Using contemporary cases, we confront the professional

[2] The Centre is also involved in other teaching efforts in philosophy of science, including at the graduate level.

ethics involved in possessing scientific expert knowledge. This applies particularly to whistle blowing in situations when certain concerns can outweigh the direct loyalty-relations of employment. 3) Using ethical dilemmas we challenge our students' concepts and innate beliefs about concepts such as 'nature' and 'life' in order to stimulate their ethical reflections and interest them in tools for ethical decision making.

Case #1: Age of the Earth

One important point to stress in a philosophy of science course aimed at science students is that scientific claims have limited scope, and different types of claims have different scopes. Many relevant scientific problems and questions cannot adequately be analysed and solved within the boundaries of one separate academic discipline. Yet, the disciplinary borders are often thought (by students and practitioners) to be natural and obvious. Thus, it can be a very provocative and eye-opening experience for the students to face the historical fact that contemporary borders of a specific discipline have resulted from intricate historical processes. Disciplinary borders have emerged as products of intense negotiation, conflicts and boundary work.

This complex of problems and processes can be illustrated by discussing which branches of knowledge can deal with the question of the age of the Earth. During the seventeenth and eighteenth centuries, this question belonged firmly in the science of Biblical chronology where scholars typically dated Genesis at approximately 4000 BC, some with considerable precision. During the nineteenth century, however, the question was transformed into a scientific one. When Lord Kelvin used advanced mathematical theories to argue that the age of the Earth was on the scale of 20-30 million years, this estimate gained a lot of support due to his status as a very accomplished physicist, although it squared poorly with predominant geological theories. In the beginning of the twentieth century, geologists developed new methods to determine the age of the Earth and they reached an estimate of the order of 100 million years. The development of further theories based on radioactive isotopes meant that in the 1930s an even higher estimate was reached (roughly 2.5 billion years); and as relatively late as 1956, a value was obtained using meteorite research which put the age of the Earth at approximately 4.5 billion years. This value is still considered to be the most precise estimate.

This historical case can be utilised to make a variety of philosophical points about science. Three of these claims are of such general nature that they form part of all the courses in philosophy of science, although they are not everywhere introduced in the same way. First, it illustrates that it is never beyond discussion and debate which branch of knowledge holds the greatest authority in answering a specific question. The boundaries between scientific disciplines and other subject areas have continuously developed and continue to do so. Second, the case illustrates the problems of scientific 'tunnel vision': The insight that was eventually to prove decisive in bringing us to our current state of knowledge about a particular problem often comes from researchers who possess knowledge about other, bordering areas. Third, the case illustrates that scientific claims are (always) fallible; not false, but potentially false and that science as the pursuit of knowledge has the inbuilt requirement that all knowledge be correctible. As with almost all of the cases which we present, they can serve additional philosophical discussions and points; for instance the Kelvin-case can also be used to argue about the mistakes and bottlenecks in science by critically examining claims such as: "Had scientists better appreciated one of Kelvin's contemporary critics, the theory of continental drift might have been accepted decades earlier" as claimed in (England et al. 2007).

Case #2: Whistle-blowing and expertise

Modern science is never confined to research in ivory towers at universities, and it is an important point of our courses to argue and illustrate that values and discussions of values enter into scientific practice. For some sciences, the majority of the students will be looking forward to careers in the private sector, whereas other fields produce higher proportions of teachers and researchers. However, regardless of their future mode of employment, it is essential that the candidates reflect upon the various consequences of producing and possessing scientific insights.

For some subjects, the ethical implications are evidently important – students in the life sciences need to be able to reflect upon how values enter into their scientific practice and theories when these deal with our fundamental understanding of self, humanity, life, nature, etc. However, all scientific disciplines have ethical questions to ponder, including the technological implications of basic research. Finally, there are important professional ethical obligations and norms that codify and shape the disciplines and their practitioners.

When the US president Ronald Reagan launched the ambitious Strategic Defence Initiative (SDI, the so-called Star Wars Project) in 1983, prominent computer scientists and physicists became involved in the consultation phase (for more on this case, see Slayton 2003). The vast project comprised enormous costs for technologically advanced research and development. Amongst the physicists on the advisory board, a widespread consensus about the relevant fundamental physical assumptions was quickly acquired, but that was not the case among the computer scientists. The production of software was (and is) not an exact science and there were only very few and small examples of complex systems developed that were sufficiently reliable for such a critical task as the SDI. When tested in realistic environments, most computer systems of that complexity would exhibit some margin of error; and even a small mistake in e.g. the decision system would have catastrophic consequences. The SDI would feature the most complex computer system developed to date, and this combination of limited past successes, critical nature of the system, and the sheer size of it made American computer scientist David Parnas, who served on the advisory board, blow the whistle and object. Although a series of concerns – personal as well as professional in promoting and developing computer science as an academic discipline – spoke in favour of entering into the project, Parnas objected to the limited scientific background in the field of computer science and withdrew from the board. Thus, Parnas acted not only in accordance with his own conscience but also based on his understanding of the ethical norms of the academic community. However, his publicised objections also threatened to question the success and integrity of academic computer science as a discipline in the American realm.

This case is useful for discussing the professional and personal ethical commitments involved in doing science in either the public or the private sector. Computer science is, today, codified by a series of ethical norms put forward by the American Association for Computing Machinery (ACM), which have been adopted by many other communities, including the Danish one. The guidelines provide a meaningful way of investigating the stakeholders in issues of loyalty, professional standards, and legal matters. Aiding students to understand and be able to apply such discussions to relevant situations is an important component of the courses. Inside the academic disciplines, such professional ethics are complemented by regulations and norms concerning responsible academic conduct which serve as similar starting points for discussing 'good research practice'. The ambition is therefore to provide the students with basic ethical understanding and fundamental positions in order to be able to apply professional ethics to relevant future conflicts in professional life.

Case #3: Should the dodo remain extinct?

In the philosophy courses on the life sciences, an important theme revolves around applied genetics as it pertains to animals. The potential cloning of racehorses or beloved pets raises issues of both emotional, ethical and scientific importance, whilst the cloning of animals of endangered or even extinct species present even further concerns about our understanding of 'nature' and the place of humans therein.

Several questions arise in connection with these different scenarios. First, there are the scientific issues: What is at all possible? How are we to access the possibilities in relation to both micro and macro levels of scientific issues? Which are the effects if we use extensive cloning on a small population? And do these effects vary by species? What are the effects on the habitats of reinstating formerly extinct species such as the *Mammuthus sungari* (the Songhua River mammoth) in Siberia and Northern China or the *Raphus cucullatus* (the Dodo) on the islands of the Indian Ocean?

Second, answers to such scientific questions are interwoven with our understanding of nature and our conception of it. We frequently employ our concept of nature in arguing about ethical problems. For instance, we might argue for or against the appropriateness of resurrecting extinct species. But even if we argue the unnaturalness of reinstating for instance a *Tyrannosaurus rex,* this does not exclude that scientists would, could, and should make the attempt either the sake of knowledge or for some other purpose such as personal gain or human vanity. But how are we to evaluate such purposes against each other? How – and by which criteria – can a line be drawn?

Such questions – when posed and discussed with a view to the cultural and ethical debates – illustrate to students the need to reflect on larger issues than pure 'scientism' and technological optimism. These are issues that are – to a large extent – value-based and yet integral to the programs in which the students are involved. Thus, the call for qualified deliberation of ethical and historical aspects simultaneously fosters awareness of the contexts and implications of science. And the way we attempt to do this critically involves addressing core issues from the curricula of the relevant scientific disciplines.

Student outcome and responses

Due to the unique Danish setup and the local implementation at the Faculty of Science and Technology at Aarhus University, we engage with a complex matrix of challenges in interesting and educating the students in philosophy of science. For instance, due to idiosyncrasies in the way the studies are planned, third-year mathematics students entering our philosophy of mathematics course are already imbued with a specific set of beliefs and norms about mathematics. Those they have acquired through their textbooks and through more informal communication among each other and with faculty and teaching assistants in mathematics. Thus, we have both the benefit of a quite homogenous set of prior beliefs and the challenge of critically examining and addressing those beliefs. More specifically, the mathematics textbooks and teaching style have presented mathematics predominantly as a formal and rigorous science which is only a limited part of the image of mathematics that our course aims to argue.

In all our courses, we have set ourselves the ambition of making better scientists of our students through teaching them philosophy of science. Therefore, the course needs both to be engaging and address professional skills of a diversified program. Some of these skills are specific to philosophy of science such as knowledge about professional identity, including professional behaviour and ethics, theories of practice of and progress in science, and the societal role of science. However, the courses have also been designed to induce other more generic skills such as reading a philosophical text, analysing philosophical arguments, as well as oral and written presentations. Whereas the first skills are shared between lectures and tutorials, the more generic skills are mainly trained in the tutorials under the guidance of teaching assistants. This has created a situation in which we rely greatly on our teaching assistants, whom we therefore need to educate and train to these tasks which are – as we are ourselves – interdisciplinary.

We have found that – with variations – the courses in philosophy of science have been well received among our students and our colleagues in other departments. Undoubtedly, a large part of this acceptance is due to the success of providing some recognisable set of skills to the students. However, the image of the courses still varies, relying also on the performance of the teaching assistants and their reflection of the cross-disciplinary work.

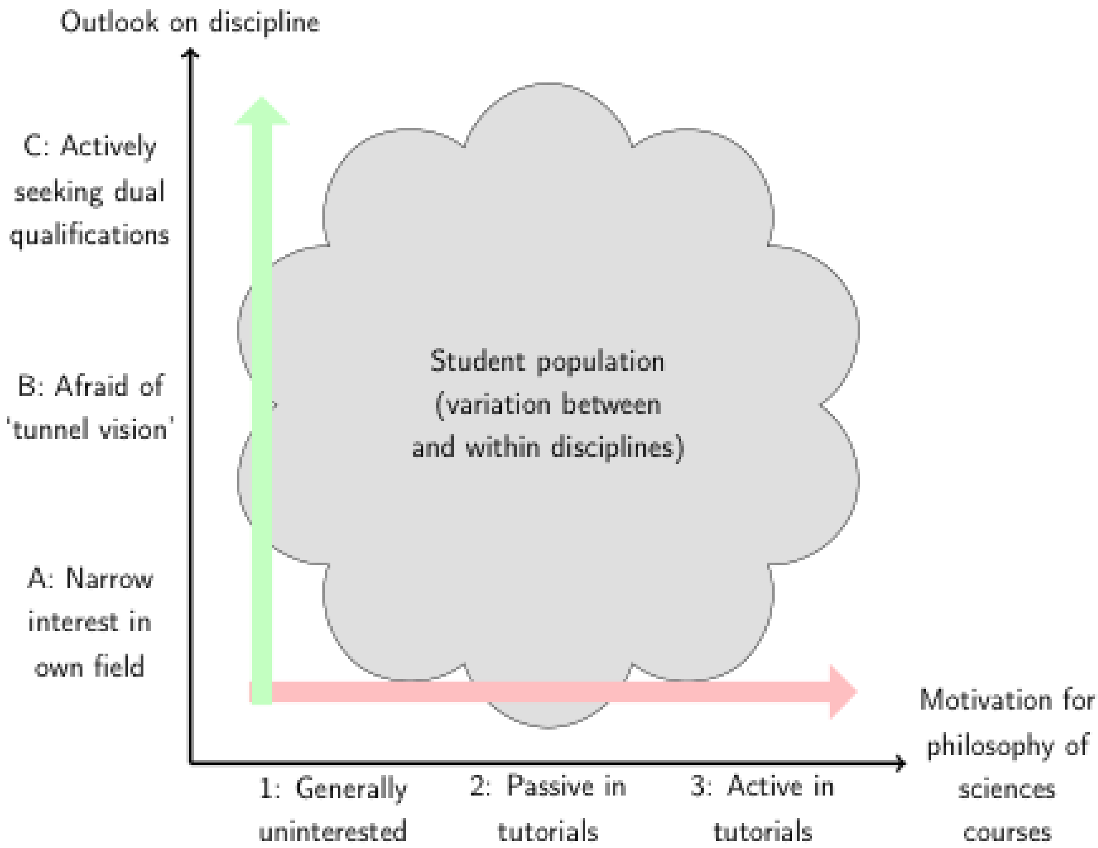
A comparison between the students' evaluations and the teaching assistants' experiences show that when the students have completed their philosophy of science course, they roughly view the course in three different ways:

1. Some found the course in general uninteresting and irrelevant for their further education and professional life.
2. Some found the lectures on history and philosophy of their field interesting in general but did not engage actively in discussions during the tutorials.
3. Some found the course interesting and relevant, engaging actively in the discussions.

The relative size of these groups varies from one year to another and from discipline to another.

Furthermore, we have found from empirical studies that students can be divided into A, B and C students (see figure), where students belonging to group A have a very narrow interest in their own field. Students in group B have an interest in their own field, but believe that inputs from other fields will help them avoid 'tunnel-vision' which is a concern to them. Students in group C know that in their professional lives they will need qualifications not provided through their science courses.

A possible hypothesis is that the students in groups 2 and 3 are mainly group B students. This hypothesis is partly supported by observations made by the teacher assistants, for instance the engineering students are aware that they will need communication skills, although they do not see our course in philosophy of engineering as an opportunity to acquire such skills. Assuming that the hypothesis is correct, in order to gain greater student interest and visibility, it would be natural to focus more of our attention to the students in group C, making it clear to them that we have something to offer them.



In a nutshell, our teaching challenges can be summarised as: "Teaching philosophy to science students is like having philosophy students do laboratory experiments". It has thus become clear to us that one of the biggest challenges, particularly for the teaching assistants, is that a many of our student do not meet the standards we might expect. Thus, the vast majority of the students have difficulties with at least some of the following related tasks:

- Reading a philosophical or historical text, identifying the important passages, and deciphering and critically examining the key arguments.
- Preparing and delivering a clear and relevant presentation of a given text.
- Using philosophical terms and arguments in an open discussion.
- Formulate clear and concise arguments and put them in writing.

These difficulties mean that many students gain insufficiently from the texts we give them. This in turn makes the quality of the student presentations, which form the basis for many of the discussions in the tutorials, rather low. And this again lowers the level of the open discussions, making it difficult to reach and support the learning objectives.

The challenges constitute something like a Gordian knot as we both want to educate and illuminate all our students to the themes of the courses and interest and attract the most engaged, qualified and active students for further studies. Therefore, a greater focus on the needs and interests of students in group C seem to be an attractive line of pursuit for creating not only better scientists but also better philosophers of science.

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