

On Teaching Critical Thinking to Engineering Students

Luís Moniz Pereira and Ludwig Krippahl

Departamento de Informática
Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa
Quinta da Torre
2825-516 Caparica, Portugal

Introduction

Critical thinking in the Portuguese curricula

The teaching of critical thinking skills in Portugal is rare in science and engineering programmes. To our knowledge, there is no specific Critical Thinking (CT) course in Portugal in Higher Education, in any field, the one reported here being first of the kind. We have been its promoters and lecturers.

The course takes place at Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, and began in September 2006. Detailed information on the course sessions, so far (including slides and other documentation in English) can be found on its web page <http://ssdi.di.fct.unl.pt/lei/pc/>. There are 97 students enrolled at present.

Critical Thinking was introduced as a compulsory course in Informatics Engineering, formatted according to a 3-year Bologna cycle. It is already an optional course in the recently approved Telecommunications and Computers 1st cycle of the Electrical Engineering Department, to begin in September 2007. We expect enrolment of students across the board from a number of other science and technology courses at FCT/UNL, as part of the Bologna recommendations for more soft skills in higher education.

This CT soft skills course is preceded by a generalist and compulsory Expression and Communication course in their 1st year, and followed, in the 2nd cycle (for those who continue) by an obligatory course on Scientific and Technical Communication.

The relevance of Critical Thinking for engineering education

Although our CT course follows a fairly standard approach to the teaching of these skills, it is nevertheless innovative in the context of scientific and technological higher education, in that it emphasizes the stance of the specialized producer of scientific and technical information, not just that of the lay information consumer. Indeed, critical thinking skills are essential for good and apt decision making and for the understanding of problematic issues, this being especially important for engineering professionals who

are expected to make important decisions, solve technical problems, face ethical balances, employ best practices, and report and document their findings and products, as well as act in a consultant capacity.

A deeper understanding of the epistemological, philosophical, and methodological foundations of science is also a case in point, and not just for those who intend to pursue a research or teaching career, for a better appreciation and intervention in regard of the deeper context.

Most ironically, engineering and science training can discourage critical thinking by presenting the student with only well established theories and best practices during the student's training, not requiring a critical attitude from the students. This is indispensable for teaching students the correct methods and techniques, but may leave them unprepared to face real life situations, where uncertain, unreliable, or even misleading information can affect the decision process.

Even though students are prepared in their scientific field, they are hesitant and have difficulty criticizing non scientific claims in their daily lives. In practical sessions of this CT course, students have been asked to discuss subjects such as astrology, miracles, or spirit communication. Many students initially argue in favour of these beliefs based on the absence of negative evidence. While no engineering student would argue in favour of a technical claim in their field based on such weak reasons, they seem unaware of the importance of positive evidence to support a claim outside their area of expertise. This may be because technical courses always provide positive evidence, training the student to expect such evidence in technical problems. But this evidence is presented authoritatively, is not uncovered by the student through critical analysis, and it may well be this reason that leads students to underestimate the importance of positive evidence for any claim

Furthermore, critical thinking is essential for effective scientific and technical communication. In addition to the skills to assess claims and data, it is important for engineering students to develop the skills to criticise their own assumptions and inferences, as well as the way they communicate and argue for their knowledge. Again, these are important skills for the engineering professional, but ones rarely partaking of the regular technical courses, where the students are graded rather by their performance in standard examinations that focus on the application of technical knowledge and not on its actual communication.

Thus our focus on the two aspects of critical thinking, both as consumers of information, requiring the skills to assess claims and inferences critically, and as

producers of technical information, with specific training to question assumptions, put checks on their own reasoning and avoid fallacies.

The Bologna process

This critical thinking course was implemented as part of the curricular reforms motivated by the Bologna declaration on European education. Specifically, to better serve the objectives of improved mobility and lifelong education. Critical thinking is a transversal skill that can help the student in any field, thus helping those wishing to pursue a broad education spanning several areas of expertise. It is also a skill which, once acquired, will always remain of use, improving with practice, and not be replaced by new information, thus especially suited for a project geared towards long term education.

The course

Goals

We designed the Critical Thinking course with two major goals in mind: to improve the student's ability to analyse claims and information critically, and to teach the students to present results and technical information in a correct manner.

Format

The course is taught by alternating two-hour lectures presenting the subject matter to all students, with two-hour practical sessions where a smaller number of students (approximately 30) have the opportunity to discuss the subjects and practice with exercises. This gives a total of four hours per week divided into two sessions for each student. The students are also expected to work an additional six hours per week on individual study and practical exercises.

All sessions are recorded into digital audio files made available in the course web site, so students can review the sessions and also hear their own contributions to the discussions.

Evaluation is divided into a theoretical and a practical component. The practical component consists of four exercises and two essays, all individual. The exercises are up to one thousand characters long, and each focuses on a specific aspect of the subject matter, such as building an argument, analysing a scientific theory, or making a decision under uncertainty.

The larger essays are at most five thousand characters long, and each covers a broader part of the course. The first essay is on an objective issue, requiring the students to build an argument, analyse competing hypotheses, and assess the

reliability of sources. In this semester the first essay is an analysis of conspiracy theories about the fall of the Twin Towers in New York.

The final essay is on decisions involving both objective data and subjective values. The students can choose the theme for the second essay, with recommended subjects like environmental policies, immigration, abortion, copyright laws, and such. The goal of this essay is to have the student make a policy decision in the face of uncertainty, distinguish the objective aspects from the value judgements, and adequately present and defend such decision in a structured argument.

The students have approximately one week to complete the smaller exercises, and three weeks for the larger essays. Active participation in the practical sessions is also taken into account for evaluation purposes. The practical component accounts for 40% of the overall grade.

The theoretical component of the evaluation is a two-hour exam, requiring a broad view of the subject matter, whence each student will choose two out of four provided topics, form an opinion and present it as a written argument. It accounts for 60% of the overall grade.

The curriculum

The course curriculum can be divided into two stages, with the first focusing on the analysis of objective issues, and the second addressing matters involving decision and value judgements.

The first stage covers, in order, the structure and logic of arguments, abduction and the formulation of explanations, properties of good explanations, designing experiments to test alternatives, the analysis of scientific models and epistemological problems.

The second stage of the curriculum covers the assessment of statistical data, decision as satisfaction and optimisation, the consideration of consequences, alternatives and opportunity costs, and finding omitted information. Time permitting, there will also be a brief introduction to ethical concepts, as they play an important role in decision making, but the focus will be mainly on the objective aspects of decision. [This being the first edition, and the semester having not yet finished, nor exams taken place, nor students inquired, we leave for the final version of the paper, if accepted, additional resulting information]

Theory and practice are brought together in this course throughout, by the emphasis on discussion in the weekly two hour practical sessions, and on a strong practice component of the student's evaluation, demanding from each one regular work distributed over four exercises and two essays along the semester. The total workload

for each student is approximately ten hours per week, with a large part of this time dedicated to the practical application of the subject matter.

Material

The main reference book recommended to our students is Fisher's (2004) "Critical Thinking: An Introduction". This textbook was chosen for providing a clear and accessible presentation of the main aspects of our course: argumentation, evaluating reasons and sources, assessing causal explanations and deciding.

As complementary sources we also use expository material from Browne and Keeley (2004), resort to Schick and Vaughn (2004) for many examples in the discussion sessions, Giere (1997) for the analysis of scientific models, and Baron (2000) for its solid discussion of decisions, utility, and risk.

For practical sessions students are also required to read a diversity of material, from paranormal claims to scientific experiments, most of which available on the internet. Two examples used this semester were the Viking probes' experiments to detect life on Mars (Caplinger 1995), and possible explanations for near death experiences (Blackmore 1991; Newport 2005). Some exercises were based on examples presented in Browne and Keeley (2004) and in Thompson (2002).

Results

This course so far has shown that students start poorly prepared for creating sound arguments, with most resorting to rhetorical tricks and arguments from personal opinion instead of correctly identifying the important aspects of the problem. However, our experience so far indicates that students quickly grasp the important aspects, the importance of critical thinking, and there has been a noticeable improvement in the students' capacity to analyse different subjects along this semester.

Currently we are still exploring the best ways of fitting together diverse aspects covered by the curriculum, and we expect some changes in the order of the subjects for the next settlement of this course. But overall the course seems to be progressing quite well, and we feel that we are being successful at giving the students the necessary skills to properly analyse a diverse range of subjects.

Student reaction has also been positive, with most students showing they are interested in the subject and many participating in discussions. Also, a few students for whom this course is not available have been coming to the discussion classes, even though they are not enrolled, which suggests a potential for the expansion of this course to students outside Informatics Engineering.

References

- Baron, J. 2000, Thinking and Deciding, Cambridge U.P., 3rd edition.
- Blackmore, S., 1991, "Near-Death Experiences: In or out of the body?". *Skeptical Inquirer* 1991, 16, 34-45.
- Browne, M. N., and Keeley, S. M., 2004, Asking the Right Questions, Pearson Prentice Hall, 7th edition.
- Caplinger, M. 1995. "Life on Mars", at <http://www.msss.com/http/ps/life/life.html>
- Fisher, A. 2001, Critical Thinking - an introduction, Cambridge U.P.
- Giere, R.N. 1997, Understanding Scientific Reasoning, Harcourt Brace, 4th edition.
- Newport, J.F. 2005. "A Theory That Accounts For the Occurrence of All NDEs", at <http://www.near-death.com/experiences/articles006.html>
- Schick, T. and Vaughn L., 2004, How to Think about Weird Things, McGraw Hill
- Thompson, A. 2002, Critical Thinking - a practical introduction. 2nd ed. Routledge.