On Teaching Critical Thinking to Engineering Students

Luís Moniz Pereira & Ludwig Krippahl
Departamento de Informática
Faculdade de Ciências e Tecnologia
Universidade Nova de Lisboa
Quinta da Torre
2825-516 Caparica, Portugal

Email: lmp@di.fct.unl.pt, ludi@di.fct.unl.pt

Abstract

This paper describes the first attempt at teaching critical thinking skills in a Portuguese engineering undergraduate curriculum, at the Faculdade de Ciências e Tecnologia of Universdade Nova de Lisboa, for Informatics Engineering students. It addresses the motivation and curricular reforms that made this course desirable and possible to implement, the structure and objectives of the course, and the results obtained, both as reported by the student's personal evaluation of the course and by the academic results. After this successful experimental instalment, this course is likely to become available to other undergraduate programs in Faculdade de Ciências e Tecnologia.

Keywords: Critical thinking, teaching, engineering.

1 Introduction

1.1 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, for the first time, from mid September 2006 to end of January 2007 (14 weeks teaching plus exam study period). Detailed information on the course sessions (including slides and other documentation in English) can be found on its web site at http://ssdi.di.fct.unl.pt/lei/pc/. There were 97 students enrolled.

CT was introduced as a compulsory course in Informatics Engineering, formatted according to a 3-year Bologna cycle. We expect enrolment of students across the board from a number of other science and technology courses at the FCT/UNL campus, as part of the Bologna recommendations for more soft skills in higher education.

This CT soft skills course for Informatics Engineering 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".

1.1.1 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.

1.1.2 The Bologna process

This CT 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.

1.2 The course

1.2.1 Goals

We designed the CT 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.

1.2.2 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 at 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.

1.2.3 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. There is also be a brief introduction to ethical concepts, as they play an important role in decision making, but the focus is mainly on the objective aspects of decision.

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.

1.2.4 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 the discussion 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).

2 Results and Discussion

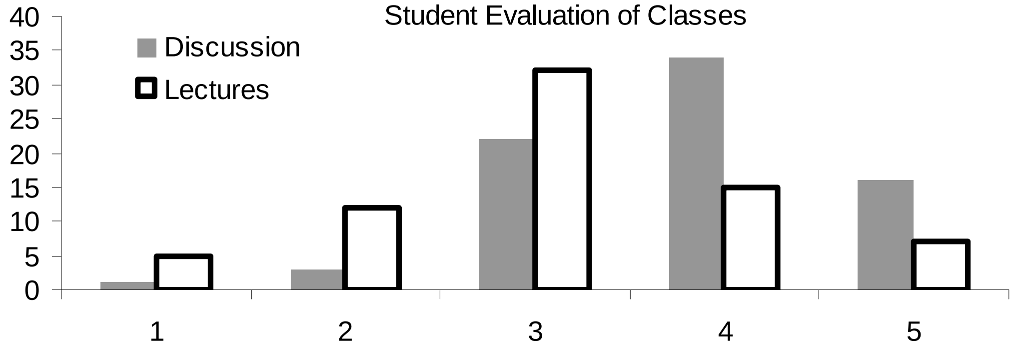
This course edition showed that students start poorly prepared for creating sound arguments, with most resorting to rhetorical tricks and arguments from personal opinion instead of correctly identifying the important aspects of the problem. However, our experience so far indicates that students quickly 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 edition of this CT course. But overall the course progressed 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.

Students scored in the course on a scale of 1 (bad) to 5 (good). The overall score was moderately positive (3.5), with a marked preference for the discussion classes (3.8) over the more theoretical lectures (3.1). Figure 1 shows the results of the student questionnaire for overall evaluation of classes, during the exam period.

Figure 1. Student evaluation of the discussion and lecture classes. Scores from 1 (bad) to 5 (good).



The results are for samples of 76 and 71 respondents (discussion and lecture classes respectively), making up most of the 97 students that were still enrolled at the end of the semester. The chi-square test comparison of the two distributions, normalising the lecture class responses to account for the difference in respondents, was very significant, with a p value well below 0.001.

This was an expected result, as critical thinking skills are much more adequately taught by practice and interactive sessions such as those in the discussion classes. Purely theoretical lectures are not the ideal means to convey critical thinking skills. In fact, our initial plan for this course consisted solely of tutorial sessions for 20 to 30 students where the theoretical concepts would be taught along with practical exercises and discussion. This plan had to be changed due to the unexpected popularity of the course. With more than twice the expected number of students enrolled we were forced to split the classes into lectures and discussion sessions. For the next instalment the situation will be corrected by allocating more teacher hours to this course.

There was a 62% approval rate for the 85 students that submitted to examination (12 enrolled students turned out to be absentee students by the end of the semester). The average grade was 60%, with a standard deviation of 10%, and the top grade was 85%, which is in line with a moderately demanding course, especially for a first instalment, where students have no access to exams or evaluation papers from previous editions.

3 Conclusion and future work

We feel that this was a successful first attempt at teaching critical thinking skills to Portuguese engineering students. Ironically, the biggest problem was the unexpected number of enrolments that forced us to structure the lessons in a way that was not ideal. However, this problem can be solved in the next edition of the course. A greater emphasis on discussion sessions and with the material now available from the first instalment to help students know what to expect should improve the academic results and student satisfaction.

Overall, it seems we met the goals of giving engineering students better skills at evaluating claims, supporting and assessing their own positions, and making decisions, al extremely useful skills that are seldom explicitly exercised in engineering curricula.

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.

Luís Moniz Pereira is Professor of Computer Science plus Director of the AI centre at Universidade Nova de Lisboa, and doctor honoris causa by T.U. Dresden. He coordinates the Erasmus Mundus European MSc in Computational Logic at UNL, and is vice-president of EASE, the European Association for Semantic Web Education. His research interests centre on Knowledge Representation and Reasoning and the Cognitive Sciences. He's founding member of the editorial boards of: J. Logic Programming, J. Automated Reasoning, New Generation Computing, Theory and Practice of Logic Programming, J. Universal Computer Science, J. Applied Logic, Electronic Transactions on AI, Computational Logic Newsletter.

Ludwig Krippahl was born in 1972, graduated in Applied Chemistry in 1997, obtained a MsC on Artificial Intelligence in 2000 and a PhD on Structural Biochemistry in 2003. He is a founder and currently president of the Portuguese Sceptics Association, and assistant professor of computer science at the Faculty of Science and Technology of the New University of Lisbon. His main research interests are in modelling protein structure and interaction, but his main personal interests are facing the rise of creationism in Portugal and other similar examples of uncritical thinking.