MALog: A new way to teach and learn mathematical logic

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Abstract

An international project entitled Mathematical and Applied Logic – MALog led by Tampere University of Applied Sciences (TAMK) aims to provide pedagogically high-quality learning materials, which are created, presented and distributed by innovative use of Information and Communication Technologies (ICT) based solutions. Learning materials will be produced in a manner which creates an individual adaptive learning path for each learner. Various studies indicate that students in high schools, universities and company employees need tools to help them learn mathematical logic effectively.

Reform of curricula on competence-based on is an important core task at the moment in TAMK. MALog had the objective of developing learning materials to support development of mathematical and applied logic knowledge and competencies. In order to provide robust pedagogical support for the materials produced in MALog, an ontology of mathematical logic was created.

Introduction

Recent studies have highlighted concerns about engineering students' mathematics skills ([2], [3], [4]) and have identified students' mathematical skills at entry to their course of study as being a particular issue. Rising student numbers, decreasing hours of contact time and increasing heterogeneity of student cohorts are all challenges to university teachers. These issues, and concerns raised by industrial partners, laid the foundation for the international project Mathematical and Applied Logic – MALog, that aims to develop mathematical logic teaching and learning resources to build competencies in key mathematical logic skills. The other key factor which motivated the project was a survey [1] conducted in 2007 in Tampere University of Applied Sciences. The results of the survey on engineering students' mathematical logic skills showed that their mathematical logic skills were weak and that mathematical logic should be taught more extensively.

At the moment at Tampere University of Applied Sciences is ongoing reforming work of the curricula. The process aims to establish curricula and curricula work practices that support the best possible competence-based education, flexible learning, cross-sectoral cooperation and the use of different learning environments in the teaching and advising. Curricula' reforming one aim at TAMK is to include diverse learning environments to curricula among others by integration RDI activities into learning.

One of the TAMK's RDI projects is this three-year MALog project. Project has been partly-funded from EU's Lifelong Learning Programme and started in December 2009. The project

consists of universities and schools in Finland (Tampere University of Applied Sciences, Hervanta Upper Secondary School), United Kingdom (University of Warwick) and Romania (Technical University of Civil Engineering Bucharest, George Cosbuc National College). The project also involves close collaboration with several industrial partners who help gather information on the use of mathematical logic in industry.

MALog had the objective of developing learning materials to support development of mathematical and applied logic knowledge and competencies. The material would support learners in schools, universities and companies using the information collected from a needs analysis. Through engagement with industrial partners, real-life problems would be collected to enhance the theoretical material and connect with practical applications. All the materials produced would be translated into English, Finnish, Romanian, French and German.

This paper presents outcomes, observations and results achieved during the MALog project and reflect to ongoing curricula work. In the paper the results of the project have been considered in the point of view of the framework for mathematics curricula in engineering education.

Aims and Objectives

The main objective of MALog is to provide resources necessary for students and company employees to develop their mathematical logic skills. The resources take the form of learning materials that include theoretical and practical tutorial materials on a variety of mathematical logic and applied logic topics including practice assignments, example problems and visualisations. These learning materials are designed to meet the needs of schools, universities and business throughout Europe.

These resources are structured using a novel semantic architecture developed using an ontology of mathematical logic. Domain-specific information held in the ontology is used to create individual learning paths through the available resources for learners. Using an on-line deployment of learning materials, students can be guided through resources most appropriate for their needs and required competencies.

Mathematical Logic Competencies

At the beginning of the project an electronic questionnaire was used to ascertain how much was known about mathematical logic. The questionnaire was composed by the five partners and the respondents were 360 students from three universities and two high schools. In addition to this, the three university partners interviewed enterprises in their respective countries on the need for mathematical logic in working life. The surveys and interviews were conducted to discover what is already taught, how the material is delivered, and the types of problems encountered. An analysis of the results helped establish what kinds of material should be produced in the project and how effective they will be.

Mathematical logic is a broad description for a field of mathematics concerned with the application of formal logic and deductive reasoning. Different learning environments will require the use of different aspects of mathematical logic and also present the material in different forms.

The project has identified competencies are required in several areas of mathematical logic including set theory, Boolean algebra, propositional logic, predicate logic, and proof. Information about these competencies is gathered in an ontology of mathematical logic.

Competency structure

In order to provide robust pedagogical support for the materials produced in MALog, an ontology of mathematical logic was created and released in April 2010. With the help of the ontology, MALog aims to provide an individual adaptive learning path (IALP) for each learner and to deliver learning materials as flexibly as possible. Links between the learning materials further enhance their quality and usefulness by allowing learners to discover related material and relevant real-life problems.

Developing resources

Using the information gathered during the needs analysis and from interviews with industrial partners, the project identified specific learning resources that should be developed to support key mathematical logic competencies. These were divided into sixty units of learning material and individual plans were developed for each item.

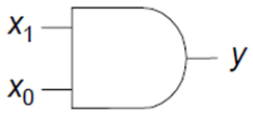
Project has made contacts with companies, representing several engineering fields, to secure the sources of learning materials, for which real life problems from the companies were collected. When producing the learning material, each partner created material reflecting the local cultural context of real working life. These learning materials are designed to meet the needs of schools, universities and business.

In the discussion with the company representatives came up among others that more and more products entail logical functions. In software design especially good mathematical thinking and reasoning ability make it possible to comprehend large entities and dependencies between matters; programming work presupposes the ability to capture the big picture in software design right from the beginning. Poor mathematical skills make it necessary to construct the program bit by bit, bottom up and the overall conception is not achieved. So the good knowledge of the mathematics and logical thinking was underlined to master programming.

In the discussions with the industrial representatives and professional teachers there has been highlighted the importance of embedded systems and how their importance will grow significantly in the future. In the discussions were mentioned that one of the key factors in the development of embedded systems is digital technology. Mathematical logic is needed in order to master digital technology and it has been predicted that in the near future the field of digital technology will significantly increase. For example, future multimedia mobile phones and their network systems require even more digital technology. It is possible to utilize digital technology, which is based on mathematical logic - Boolean algebra, in practically all aspects of technology. Thus, mathematical logic is a fundamental element in the development of digital technology, programming languages and all engineering fields.

Figures one and two presents mathematical logic application exercises that emerged from the interviews. Figures present the competencies of mathematical logic issues in the engineering professional studies and in real-life.

x_1	x_0	y
0	0	0
0	1	0
1	0	0
1	1	1



$y = x_1 x_0$

$y = x_1 \cdot x_0$

Figure 1. Truth table, symbol of AND gate and AND function.

X	Y	Z	$F = X + Y'Z$
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

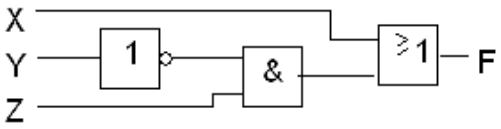


Figure 2. Truth table, logical function and circuit diagram.

For example if student wants to build a truth table for NAND logical operator. With the help of the ontology the learning path builds up in a way that it provides the materials related on this issue and additionally suggests that material on NOT and AND logical operators are related to understanding of NAND, and the student will be offered activities to ensure he has understood NOT and AND as well. When the learning materials have been built on using an on-line deployment of learning materials it provides a possibility to follow an individual adaptive learning path so that it guides the learning of the students. The student has been guided through resources most appropriate for their needs and required competencies.

All the materials produced in the project will be licensed under a Creative Commons license. Free to use and modify but not allowed for the commercial use. The learning materials being developed will be freely available on-line and will enable school children, technology students and technology professionals to further develop their mathematical skills.

Evaluation of learning resources

Evaluation of the learning resources developed was undertaken by all five partner institutions using a variety of course structures and delivery formats.

In the project the pilot courses were organised where the impact of the produced materials were tested. Feedback (in the form of questionnaires and interviews) from the courses from the students, teachers and the professionals in companies using the materials has been collected in order to receive valuable end-user feedback and student viewpoints. Based on the feedbacks and

findings, the learning materials have been updated and finalised in order to best meet the needs of the target groups. Results of the project are expected end of the year 2012.

Conclusions for Education

In today's world people encounter technological applications everywhere from cars to coffee machines. Good mathematical skills help develop the logical and critical thinking skills necessary for good design and implementation of software and technology products.

Mathematical logic is fundamental to computer science and to all engineering fields which apply computer science. Mathematical logic skills not only advance pure logical thinking, but also enhance a learner's understanding, hence simplifying key engineering activities such as mastering of programming skills and the development of digital devices and embedded systems.

In the competence-based on curriculum work of TAMK the results of the project could use in several of ways. For example in the field of the computer sciences the materials has been planned to use as a part of the professional study courses. Courses has been planned to execute together with the mathematics teacher and professional teacher. This way for the students comes up more clearly the use of mathematics studies in the field of the professional studies of engineering. The materials have been planned to combine to the professional study courses as well as there will be an own course available to conduct with these materials only. With the help of learning materials, applied learning materials related to real-life problems, on-line deployment of learning materials produced in the project students can be guided through the issues related on mathematical logic most appropriate for their needs and required competencies.

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