

Technological Challenges of Teaching Mathematics in a Blended Learning Environment*

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Abstract

This paper describes the following technological aspects of blended learning of mathematics: effective preparation of electronic teaching materials suited for different students' needs, videotaping of mathematics lectures, automated (self)testing of subjects taught using the computer algebra system Maple and preparation of interactive teaching materials with the MapleNet technology. Authors describe results achieved during preparation and implementation of these challenges in a Calculus course taught at the Faculty of Science, Masaryk University in Brno, in autumn 2006.

Keywords: teaching, mathematics, technologies, MathML, PDF, blended learning, tex4ht, Maple, \TeX , MapleNet, maplets, format conversion, video

1 Motivation

Teaching of mathematics is specific as are the technological challenges of our digital age for its support. Teaching of mathematics has its traditions, settled over centuries and glorified by traditional professors, in stark contrast to the possibilities of information communication technologies (ICT) change every year.

We have prepared several electronic materials and tried several new approaches to supporting students of mathematics at Masaryk University in Brno, who are enrolled in a Calculus course.

2 Objectives and Their Realization

The Information System of Masaryk University (<http://is.muni.cz>, IS MU) is currently being enhanced to support blended learning methods which includes an extensive usage of ICT. It allows authenticated access to structured study materials, there is support for students' (self-)testing and examination, and new functions are continuously being added with the aim of it becoming fully-fledged learning management system (LMS). As several specific needs for supporting the teaching of mathematics were missing, we have investigated the possibilities of their realization in the pilot project of support of the course M3501 Calculus III (Metric spaces and Calculus of several variables) in the autumn semester 2006.

2.1 Study Materials in Different Formats

Every student is different. 'Put yourself in the reader's place,' is the oft repeated incentive. Students study by reading the course materials on their notebook or computer screens, doing exercises with pen

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and paper or using a computer algebra system (CAS) on the computer, testing themselves by solving special tests in IS MU or even hearing and watching the lectures repeatedly.

Mathematics textbook authors prefer writing their text and exercises once only (usually in $\text{T}_{\text{E}}\text{X}$), rather than changing their setup every semester. On the other hand, there are the new possibilities: of high resolution computer screens, Internet and PC availability almost everywhere by almost every student. New formats brings new possibilities: PDF allows high fidelity of textbook delivery, MathML (or OMDoc) soon to be accepted as the structured text format for exchanging and delivery of mathematics electronic documents. On the other hand, $\text{T}_{\text{E}}\text{X}$ notation remains preferred by authors for editing and authoring.

For Calculus III course there were two textbook materials prepared in $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ [1, 2]. We have evaluated that at least four formats are of interest to the students:

1. PDF suitable for printing: electronic copy of the printed textbooks (no colors).
2. PDF suitable and designed for PC screen reading: PC screen has different aspect ratio, resolution, allows usage of colors, easy searching.
3. HTML for reading in the ‘old-fashioned’ web browsers, with math formulas as pictures.
4. XHTML/MathML for reading in ‘new generation’ web browsers, allowing ‘cut&paste’ functionality with CAS systems.

We have managed to automate the generation of all four formats of the two textbooks (more than 300 pages) from single $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ sources. We have used pdf $\text{T}_{\text{E}}\text{X}$ (<http://en.wikipedia.org/wiki/PdfTeX>) and tex4ht (<http://www.cse.ohio-state.edu/~gurari/TeX4ht/>) programs.

We have added conditionals in the single $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ source file for every book to switch settings for these four versions, and prepared Makefile to automate the processes as much as possible.

2.1.1 PDF suitable for printing

Printing without colors is sufficient for both textbooks, however pictures need to be adjusted as high-resolution bitmaps or vectors only. Several versions were generated for different paper formats (A4 with wide margin for comments, and B5). Navigation and references in the text were implemented by standard $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ citation macros.

2.1.2 PDF designed for screen reading

A special version for reading on standard computer screen (width:height ratio 4:3, cca 100ppi, color) has been designed. Color is used extensively for the reader’s navigation in the hypertext. Animations have been added too, based on the possibilities on embedded JavaScript in the PDF [4].

2.1.3 Conservative HTML

Having documents published as web pages in HTML 4 is one of the safest and most foolproof options. We have tested several possible options for automatically generating HTML versions of the books from $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}$ sources: $\text{L}_{\text{A}}\text{T}_{\text{E}}\text{X}2\text{html}$, $\text{T}_{\text{E}}\text{X}4\text{ht}$ (<http://www.cse.ohio-state.edu/~gurari/TeX4ht/>), home-grown converter in Python, tex2page (<http://www.ccs.neu.edu/home/dorai/tex2page/>), hyperlatex, Hevea and others. We ultimately chose $\text{T}_{\text{E}}\text{X}4\text{ht}$ for its stability and power, although it is a rather complex system and has to be enriched for new authors’ markup. For mathematics not expressible in HTML, small transparent images in PNG format are generated.

2.1.4 Progressive MathML

MathML is a W3C proposal for math in XML on the Internet, already supported by several browsers and almost all computer algebra systems. There are several tools converting $\text{T}_{\text{E}}\text{X}$ to presentation

MathML (Tralics (<http://www-sop.inria.fr/apics/tralics/>), LaTeXML (<http://dlmf.nist.gov/LaTeXML/>), Omega and others). We have stayed with $\text{T}_{\text{E}}\text{X}4\text{ht}$, as it can be configured for MathML generation as well. This version is especially useful for blind people, as math covered by MathML does not use any picture and the text rendering scales well and quickly in web browsers. It fulfills WAI (Web Accessibility Initiative, <http://www.w3.org/WAI>) suggestions.

All conversions were done by free software and tools, available as part of the TeXlive project (<http://www.tug.org/texlive>). The support of MathML has not yet been fully implemented in all web browsers, but we expect that the situation will improve as the benefits are easily seen and widely accepted. We envisage that $\text{T}_{\text{E}}\text{X}$ notation will remain preferred in math authors community *for authorship*. This trend is supported by a plethora of tools supporting $\text{T}_{\text{E}}\text{X}$ math notation on the web (ASCIIMath <http://www1.chapman.edu/~jipsen/asciimath.xml>, JSMath <http://www.math.union.edu/~dpvc/jsMath/>, IBM texplorer) or publishing systems that allow $\text{T}_{\text{E}}\text{X}$ notation for input (MathType plugin for Word, 3B2, etc.).

2.2 Videotaping Lectures

Mathematics professors are used to deliver their lectures ‘the good old way’ using the blackboard table and chalk. This has several advantages: introducing new definitions and proof deductions cannot be increased to an incomprehensible speed of reading Powerpoint bulleted items [3].

There are students who benefit from hearing the teacher, and those who have to see the teacher talking or writing on the board. We have videotaped all the lectures using the two 3CCD miniDV cameras (Canon DM-XM2). One view was from static camera and the second was by the cameraman taking the details of the teacher and the blackboard. The teacher uses a wireless micro-port microphone to grab high quality voice, but in general, very few constraints are imposed on the teacher. Every videotaped lecture is available in the AVI format to students in the IS within a few days. A short example of video has been put on the web so that reader may have closer look at current videotaping possibilities <http://www.fi.muni.cz/usr/sojka/videos/M3501examples.avi>.

Last but not least, we have experimented with Flash technology, where PDF and downsampled videos were loaded in separate windows. We made both materials mutually crosslinked—seeing a new page in PDF searches for an appropriate sequence in the video window and vice versa.

2.3 Automated Testing and Evaluation by Maple

The greatest obstacle to automated exercising in LMS IS (and to the best of our knowledge in other systems, too) is the automated evaluation of results of mathematical exercise and subsequent checking of the results. We have designed and implemented a new type of testing exercises using the computer algebra system Maple. It evaluates the math the student types into the browser form.

So that students were not tempted to cheat by using the powerful Maple functions (`ad diff` for derivation tasks), a system of allowed and forbidden function names (white-list and black-list) was introduced. The functions listed in the blacklist are not allowed for an exercise solution. In the case where a teacher does not explicitly lists the function names allowed, a white-list is generated from the canonical solution.

Figure 1 shows an Example test with results. The first question is solved by means of Maple function `diff`, which is not allowed in this case. The second question has a wrong answer. The third question is solved successfully although the equation is written in a form different from the given result.

2.4 Interactive Study with MapleNet

MapleNet (<http://www.maplesoft.com/products/maplenet/>) is a technology allowing on-the-fly Maple computations in web applications. With MapleNet, one can create interactive

Testing the new type of question (for testing mathematics)

1 Derive the function $f(x) = x^5$.

Hint: $5*x^4$

`diff(x^5, x)` ❌ **whitelist test failed** ($5*x^4$)

body = nok = 0

2 Derive the function $f(x) = -\frac{\cos(2x)}{2}$.

Hint: $2*\sin(x)*\cos(x)$ or $\sin(2*x)$

`cos(2*x)` ❌ **wrong answer** ($\sin(2*x)$ w[\sin, \cos])

body = nok = 0

3 Find the general equation of a line which goes through the points $[1,0]$ and $[2,1]$.

Hint: $-x+y+1=0$

`x-y-1=0` ✅ ($-x+y+1=0$)

body = ok = 1

End of the test

Total score: 1 (total number of questions: 3)

Figure 1: Example test with results

teaching materials with Java applets, Maplets or Maple worksheets. To read these materials, the user needs a web browser with Java support enabled and a plug-in client for connection to the MapleNet server. Students do not have to have Maple installed on their computer, but may use the power of symbolic computation on their desk: an important new portable tool for blended learning. Special interactive graphic applications called Maplets, written in the Maple programming language bring exciting new possibilities.

These interactive graphical applications were prepared for support of Calculus III course and are posted in LMS IS MU using the interactive structured curriculum tool. Their overview can be viewed on <http://melian.ics.muni.cz:8080/maplenet/glozar/>, Figure 2 shows Partial Derivatives Maplet. The purpose of this Maplet is to help the user to compute and visualize partial and directional derivatives to a surface in three dimensions. The Maplet is directly accessible from the adress <http://melian.ics.muni.cz:8080/maplenet/glozar/ParcDerE:14444/>.

3 Conclusion and Further Work

Detailed evaluation of the new generation of support for the Calculus course remain to be seen after the exams. Current statistics of usage show that new aspects of the of course are used by the students differently. New possibilities allow students to choose studying materials according to their preferences, skills and studying methods.

Stepping in the new technology e-learning possibilities is an adventurous exercise with many “no way” experiences. However, once set up and the students used to them, we are certain that learn-

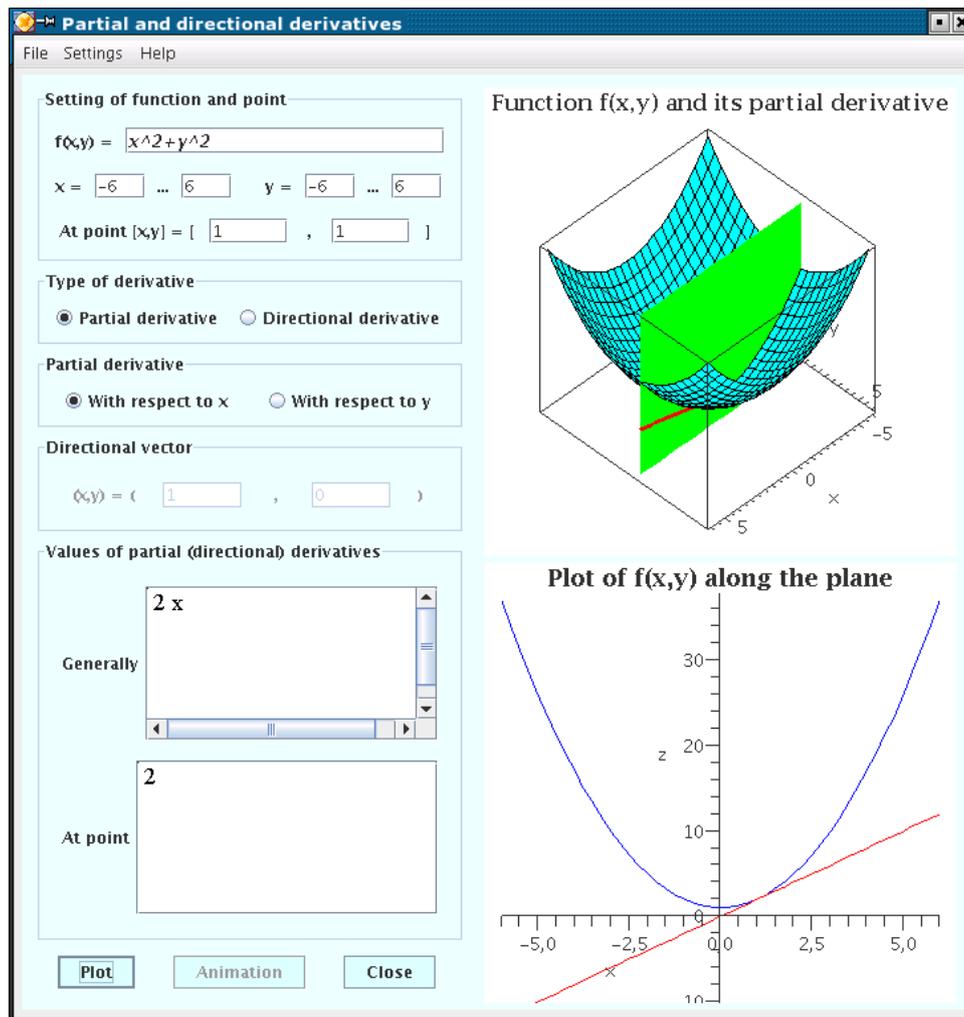


Figure 2: Partial Derivatives Maplelet

ing productivity increases considerably. Rather marginal changes in the teachers' uses of available technologies may have a drastic impact on the usefulness of math teaching materials.

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Conference topics: 1) Integration of ICT into learning processes
 2) Designing and using Dynamic Mathematics environments