Interactive PDF Documents in Math Education Focused on Tests for Differential Equations

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Abstract
The progress of blended learning has given rise to the need to prepare quality electronic materials, especially those which use the greatest advantage of an electronic document – its interactivity. This paper presents several types of PDF materials – interactive exercises, tests and games created by LaTeX packages (AcroTeX eDucation Bundle) with a contribution of other supporting instruments (3D graphics, fancytooltips, AcroFLeX). Differential equations, as an important tool of continuous mathematical modeling, have been chosen to demonstrate the still increasing power of PDF documents. This strategy allowed me to introduce innovative approaches in explaining and exercising this part of mathematics at the same time. To create such materials some LaTeX knowledge is needed; nevertheless this article is for all math teachers who are looking for quality interactive materials.

Introduction

As a number of Czech university students increases and a tendency for introducing eLearning (or Blended Learning) grows, there is a big need to develop such electronic learning and training materials, which would maintain the academic level of knowledge and apply the advanced technology efficiently at the same time.
What we can expect from such materials? It is obvious that just digital substitution of a paper, whose only active elements are hypertext references, does not satisfy today needs. The most valuable benefit of these documents should be their interactivity in a sense of requiring an input from a user and providing him an instant reply. Self-testing, exercising, making homeworks, manipulation with graphics (animations, graphs or even 3D pictures), automatic evaluation or immediate feedback – this is just a short list of functionalities that in some way substitute or at least enrich the interacton between a student and a teacher.
For academic purposes there is also a necessity of widely spread document format (interchanging among universities) and, if possible, including free software tools for developing documents. Portable document format (PDF) seems not only to cover all of these requirements but offers much more.
This paper focuses on one possible way of providing interactive PDF documents (tests, exercises, quizzes, games) using AcroTeX eDucational[1] system Tools (AcroTeX). “AeST [i. e. AcroTeX] is a collection of LaTeX packages that work together to provide a comprehensive system for authoring high-quality and visually pleasing interactive digital documents.” [13, p. 2].
Mentioning all the capabilities of AcroTeX would exceed the extend of this article, so the emphasis is given to present AcroTeX exercising and testing facilities and to demonstrate them by practical examples from the field of differential equations. Also other interactive elements included in PDF such as 3D graphs, fancytooltips and AcroFleX graphics are discussed.

PDF – Background

Portable document format (PDF) is appropriate for academic purposes for several reasons. It is reliable and exchangeable format of text documents generally accepted by both dominant operating systems (Windows and Linux). It is also possible to create it by free software (e.g. pdfLaTeX) and finally it brings many new facilities and improvements to its functionality for its constant development (the key functionality being the usage of JavaScript).

1 „The word 'eDucation' is meant to connote 'Electronic Education'. “ [14].

Applying the Acrobat JavaScript brings new opportunities to implement several procedures and objects that, if used correctly, enlarge the power of PDF documents. “You can tie Acrobat JavaScript code to a specific PDF document, a page, field, or button within that document, or a field or button within the PDF file, and even to a user action.” [1]. The latest versions of PDF even support multimedia (audio/video), 3D pictures or annotations, flash animations and more.
All PDF-related features mentioned above bring a surprising interactivity to the document (e. g. you can easily modify the appearance of PDF files, make interactive forms or use form elements in them). AcroTeX user can benefit from these features even without any knowledge of Acrobat JavaScript language.

AcroTeX
“AcroTeX eDucational System provides a unified set of authoring tools” [13, p. 1], which are “designed for educator who wish to write tutorials, topical essays, presentations, exams, quizzes or assignments. The content can be written for the screen, or optionally, for paper.” [13, p. 2].
Author of these macros is university professor D. P. Story[2].
AcroTeX collection of LaTeX packages consists of several components; all helping the author to create a user friendly and edu-focused content, and thus alter white papers into dynamic electronic document. The core is AcroTeX eDucation bundle (AeB) designed for authoring exercises and interactive tests with feedback and evaluation. At this part I aim in the text below.
All informations about AcroTeX along with quality documentation and number of examples are available on the official web site [2] or on the sites of the author, D. P. Story [14].

AeB in practice
This section introduces variety of AeB tools, especially testing facilities, which I tried to demonstrate in this article by PDF materials (shown as screenshots). For my work I have used some exercises from the books [10, 12], a lot of support and inspiration I have found by R. Mařík [8] and by D. P. Story. All the graphs have been created by CAS Maple.

1. Testing facilities (`Exerquiz` package)

1.1. Type of questions
Selective questions
There are two types of questions: single choice (one right answer) and multiple choices (two or more right answers). In order to visually extinguish one type of question from another, we can choose from three types of layouts (see Figure 1). Appropriate seems to be combining circles with check boxes (1+2, Figure 1) or link style with checkboxes[3] (2+3, Figure 1).

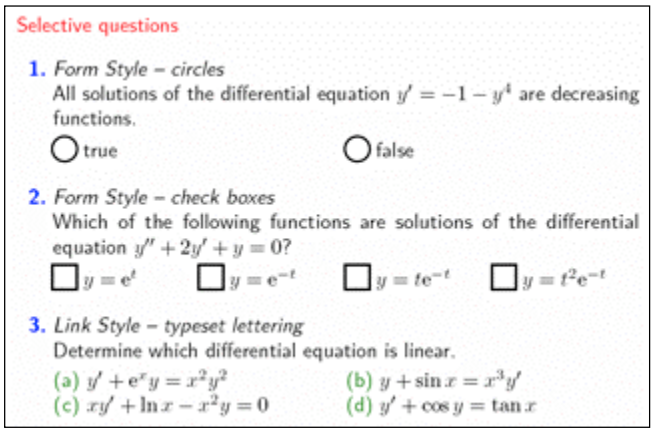

Figure 1: Selective questions.

Objective style questions
a) Text fill-in
If we request an own-words answer we create a text fill-in field using `\RespBoxTxt` command and specify all the acceptable possibilities (questions 1(a) and 1(b), Figure 2). “The underlying JavaScript compares the user's response against acceptable alternatives, as supplied by the author of the question. If there is a match, the response is deemed correct.“ [15, p. 100]. If our question claim more words as an answer (question 1(c), Figure 2) we can also use`\RespBoxTxtPC` command to “create text fill-in questions that awards credit each time one of the key words are found in the

2 The University of Akron (Florida, USA)
3 First approach is possible in the `quiz*` environment, the second in `quiz` environment, more in part 1.2.

student's input string." [15, p. 102].

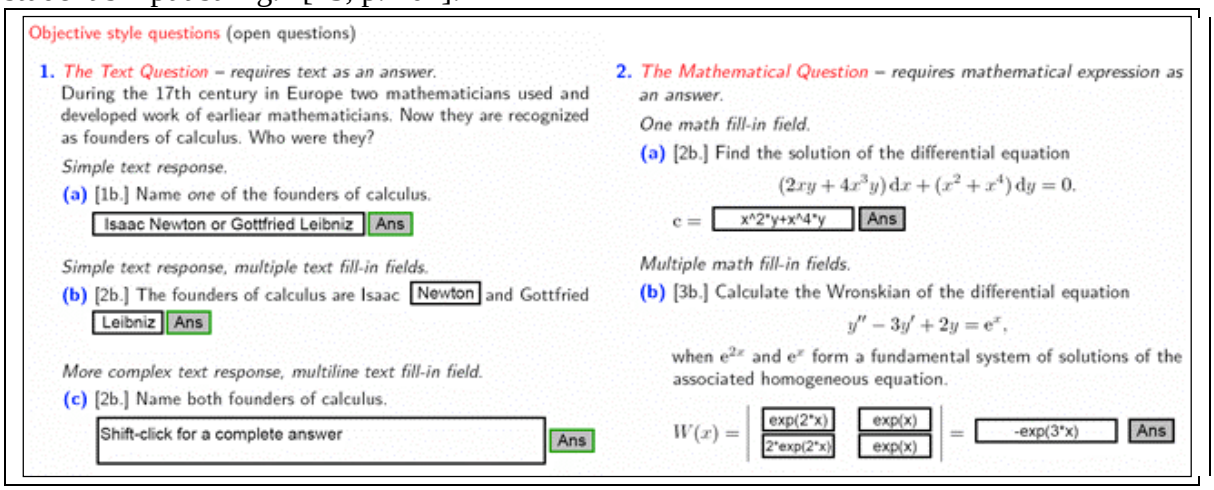

Figure 2: Objective style questions.

b) Math fill-in

AcroTeX command `\RespBoxMath` (question 2(a), Figure 2) enables such questions where mathematical expression as an answer is needed. "The algorithm used for determining the correctness of the answer entered by the user is very simple: The user's answer and the correct answer are evaluated at randomly selected points in an interval, then compared. If any of the comparisons differ by more than a pre-selected amount, an value, if you will, the user's answer is declared incorrect; otherwise, it is considered correct." [15, p. 98].

Questions 1(b) and 2(b) in Figure 2 also demonstrate a possibility of grouping single answers together, which is appropriate where a lot of fill-in answer fields appear. In this case is `\MathGrp` environment used (for both text and math questions) and only one "Ans" button (for displaying a correct response) is generated for the whole group of answer fields.

Multipart questions

For more complicated quizzes where the answer is required in few steps, both above mentioned styles of questions might be decomposed in up to three levels using command `\multipartquestion`.

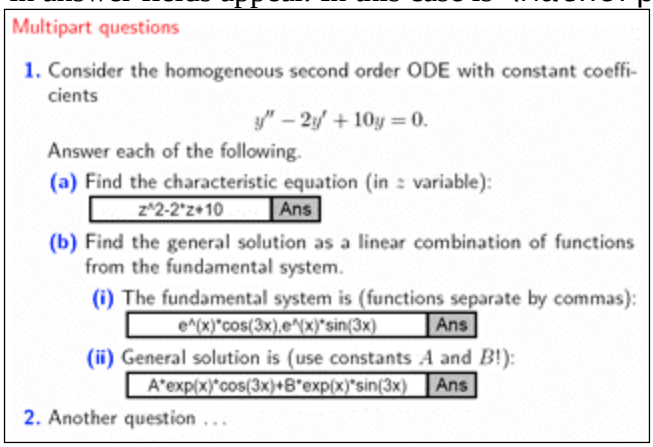

Figure 3: Multipart questions.

1.2. Exercises and tests

`Exerquiz` package provides several types of environments. Questions with solutions are possible to create with `exercise` environment; while for making tests we have more options:

1. `shortquiz` environment for tests with immediate feedback. Several tests of this type for differential equations are made by R. Mařík [8].
2. `quiz` (or `quiz*`) environment for tests with delayed feedback. The test must be initiated by hitting Start button and it is not evaluated until the End button is pressed. "Before completing the quiz, a student can easily change alternatives. This type is more suitable for longer quizzes. The choices the student makes are visually recorded for the student to review and change before clicking on 'End Quiz'." [15, p. 82] After finishing the quiz optionally points, correct answers and solutions are provided.

As an example, see the six-page PDF document *Interactive exercises and quizzes for differential equations* available at [5] with a question (`exercise` environment) and a test with delayed feedback (`quiz` environment), both with solutions at the end of material.

2. Electronic practice cards (eCards)

This tool is appropriate for the type of questions which requires from the student longer own-words answer, complicated calculations or drawing some pictures.

Example 1 – assignment of appropriate type of question:
Determine whether the statement is true or false. If it is true, explain why. If it is false, explain why or give an example that disproves the statement.
All solutions of the differential equation $y' = -1 - y^4$ are decresing functions.

Example 2 (figure 4) – demonstration of eCards with a question where sketching direction field of given differential equation is required.

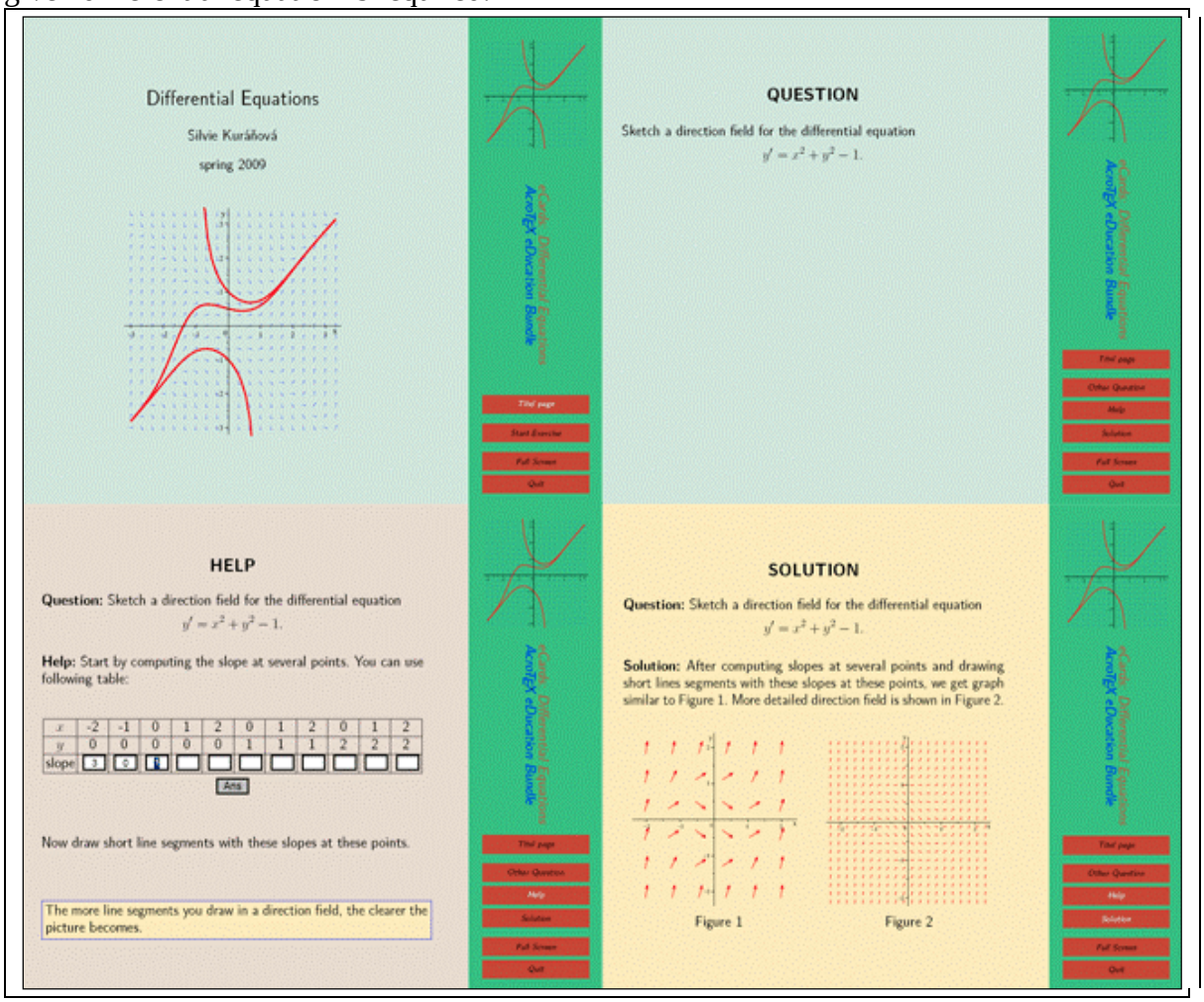

Figure 4: A four-page PDF document, example of eCards.

3. Matching games (Das Puzzle Spiel – DPS)

DPS is one of the AcroTeX game components, easy to create and providing enjoyable study material. "[...] students must match the question posed in one column with its answer in another column. Questions and answers are randomly listed."[13, p. 8]. For inspiration see e. g. matching game *Differential equation with separated variables* in [8].

Graphics in PDF: One picture stands for thousand words

All static graphics have been made by CAS Maple, exported to EPS format and then using `eps2pdf` command transformed to PDF. Incorporating such graphics into my materials required then just a simple `pdfLaTeX` command.
In case of dynamic graphics, Maple offers export to GIF, by which we can get an animated picture ready for posting on web while interlinking with PDF. Generally, dynamic graphics, such as animations or interactive graphs with changeable parameters for drawing, are all very contributory instruments however embedding them directly into PDF document is more complicated. An easy

solution of this challenge provides AcroFLeX.
We can even give PDF document a third dimension by including 3D objects, very useful for visualizing the geometric meaning of mathematical problems, and thanks to JavaScript have an opportunity to manipulate with them (moving, zooming, rotating, changing light etc.).

1. AcroFLeX Graphing Bundle
While AcroTeX is developing since 1999, AcroFLeX is quite new (since 2008). It "is used to create a graphing screen that can be incorporated into a PDF document and viewed within Adobe Reader, version 9.0 or later. The graphing screen can be interactive or non-interactive." [16].

2. Three-dimensional graphics
Adding perspective to simple graphs used in teaching materials can open the doors to a higher imagination and thus understanding of the topic. Concerning this advantage, we have supported the teaching of calculus at Masaryk University by two types of PDF materials with included 3D graphics (see [6 or 7]).
Our 3D graphs have been drawn in CAS Maple, then exported to VRML format and using commercial software Deep Exploration [3] transformed to Universal 3D format[4] (U3D) which is accepted by PDF. Correct viewing of these elements is then assured by using Adobe Reader, version 8.1 and later.

Fancytooltips
Fancytooltips, made by R. Mařík, are very useful for remembering key informations or providing quick connections to the theory within the exercise or quiz. After clicking on the emphasized keyword, a short review (called tooltip) containing important facts, pops up immediately. See an example in Figures 5 and 6 (tooltips are adapted from examples for fancytooltips package [10]). Text, mathematics, graphs or even animations, are possible content of a tooltip. "The buttons are created using `eforms.sty` which is a part of AcroTeX bundle." [9].

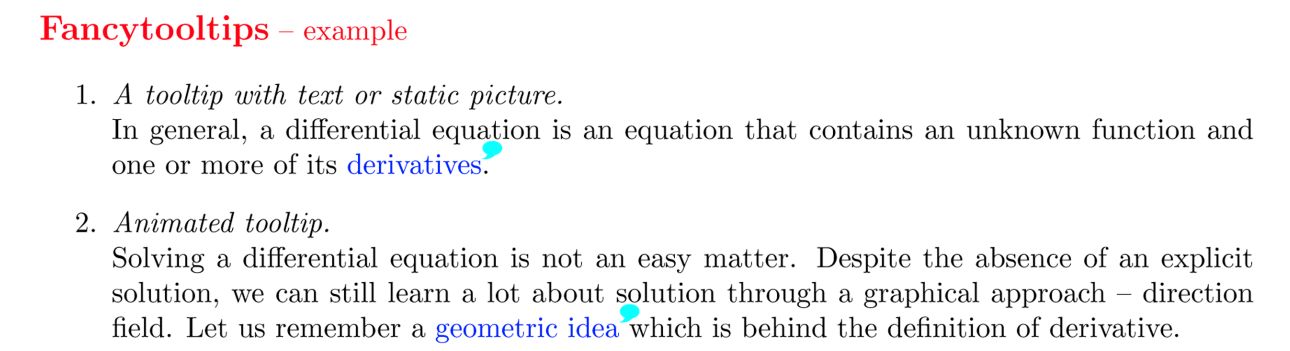

Figure 5: An example of fancytooltips usage 1.
Key words "derivatives" and "geometric idea" are emphasized.

Conclusion
The appropriate use of PDF document in the field of mathematics gives us much more then traditional study materials. The aim of this paper was to introduce advanced technology which enables educators to produce variety of quality interactive materials. The most attention was dedicated to the instruments such as testing facilities, exercises, electronic practice cards or didactic games for training and reflecting the needs of practice, fancytooltips for making connections with theory, 3D graphs for illustrating mathematical problems etc. It is hoped that this type of eLearning support engages students in self-studying (and thus improve their skills in Mathematics) and brings interactivity which is especially helpful to distance students.

4 For more information about the approach see [11]. The noncommercial alternative is also available, however not yet fully documented, discussed in [4].

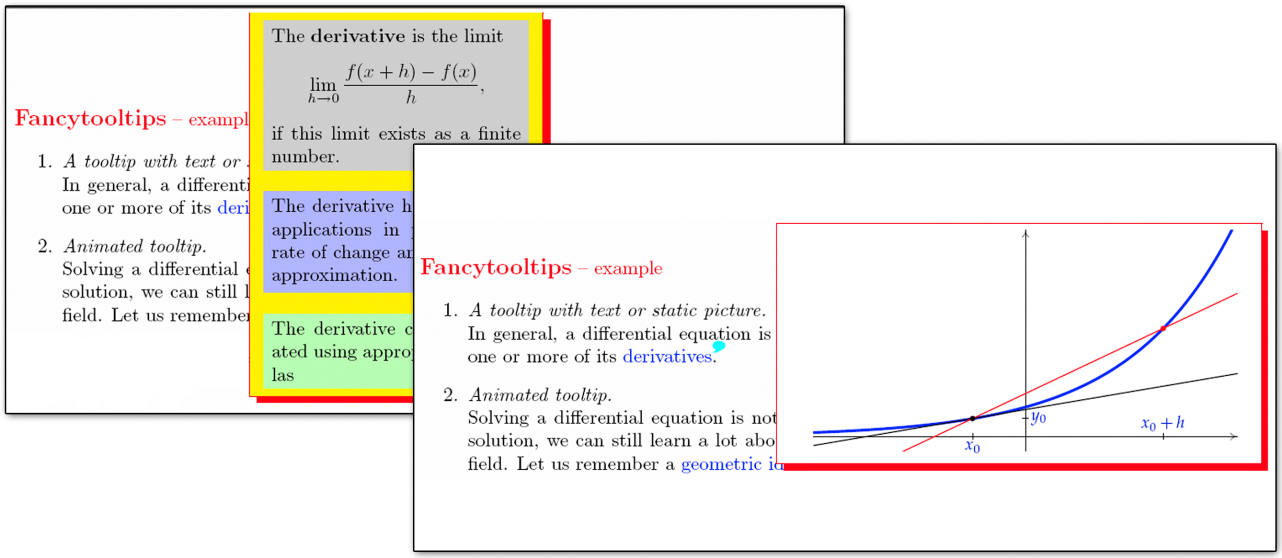

Figure 6: An example of fancytooltips usage 2, screenshots of tooltips for different key word. The higher one for "derivatives", the lower one for "geometric idea".

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