Interactive Documents - Yet Another Way to Activate Students in Mathematics

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- underdeveloped mathematical reasoning
- problematic learning behaviour
- too little engaged and active learning

There are different means to activate students!
Interactive documents support active learning!
Examples – numerics & tests – show potential.

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1. Context of Mathematics at HSB

- degree courses:
  (technical) informatics (national/internat.), media informatics
  electrical and electronic engineering, micro systems engineering
- colleagues (at least in informatics) agree on math syllabus!
- financial conditions:
  no tutorials, heterogeneous equipment
- organisatorial conditions:
  no adequate personnel, e.g. no tutors
- universities competing for regional ressources:
  International University Bremen, University Bremen
  Hochschule Bremerhaven, Hochschule Bremen

1.1. Heterogeneous Mathematical Qualifications of Computer Science Students

Students have highly heterogeneous

- school knowledge
- precognition, e.g. practical experience
- background knowledge, e.g. physics
- ability to abstract
- basic algebraic understanding, e.g. analysis of expressions
- basic geometric understanding, e.g. 3D comprehension
- ability of mathematical reasoning

1.2. Mathematical Education of Computer Science Students

Efforts to even out students deficits on all levels of math education

1. by offering a preparatory course and an online test to decide participation in this course, see vorkurs.pdf (in german)
2. by providing and experimenting with different means of computer support, e.g.
   - lecture notes, exercises, old exams etc on servers,
   - learning programs,
   - visualisations,
   - computer algebra systems,
   - virtual experiments,
   - lectures online and on demand etc.
3. by offering optional courses on computer algebra systems

see e.g. http://www.weblearn.hs-bremen.de/risse/mai/docs/

2. Learning Behaviour

motivated, active ⇒ winner	looser ⇐ unmotivated, passive
curious, inquisitive, initiative	consumers attitude; expecting to be entertained & motivated; waiting
interest in respect of content	Only marks are essential!
engaged, independent, initiative, critic	unassertive, do not overdo; not monitoring own development; 'math just is not my cup of tea'; accepting
(self) critic, reflective	disavowing, repressing, lasy
networked thinking, interdisciplinary	pigeon hole thinking – with blinders; application orientation as additional burden

2.1. Activating Teaching, Active Learning

$$\left.\begin{array}{l}\text{to hear is to forget}\\ \text{to see is to remember}\\ \text{to do is to understand}\end{array}\right\} \Rightarrow \left\{\begin{array}{r}\text{learning by doing}\\ \text{explorative learning}\\ \text{active, engaged learning}\end{array}\right.$$

- motivate students – secret of true pedagogues
- get students interested in the subject
  e.g. by attractive application examples
- get students active
  traditionally e.g. by exercises, assignments, etc.
  additionally e.g. by learning programs, virtual experiments, etc.
- challenge students
  e.g. by competition, contests, prices, distinction, etc.
- bewilder (perturbate) students, in oder to provoke new insights, alternative approaches and new solutions
- coach students

2.2. Computer Supported Activating Teaching, Active Learning I

- lecture notes, exercises, old exams etc on web servers,
- learning programs, e.g.
  Math online, *e-Calculus*, *Algebra in 10 Lessons*, *Geonet*, *Smart* etc. – to name just a few
- visualisations and animations, e.g.
  geometric objects, fractals, IFS, algorithms ...
- computer algebra systems, e.g.
  Mathematica, Maple, MuPad, ...
- virtual experiments, e.g.
  algorithms, generative computer graphics, control ...
- lectures online and on demand

see e.g. http://www.weblearn.hs-bremen.de/risse/mai/links.htm

2.3. Computer Supported Activating Teaching, Active Learning II

- in class, e.g.
  - programs which demonstrate, visualize, animate etc.
- in class or at home, additionally e.g.
  - learning programs
  - computer algebra systems
- at home, additionally e.g.
  - intelligent tutoring systems
  - interactive documents

3. Interactivity

3.1. Standard Interactivity in Learning Programs

- question/answer
  - problem/solution, e.g. *Smart*
  - multiple choice questions, e.g. *Algebra in 10 Lessons*
  - matching, e.g. *Math Online*
  - puzzles, e.g. *Math Online*
  - read and set meters, e.g. *Math Online*
- feedback
  - right/wrong (with more detail in tutoring systems)
  - recognition/rejection (repetition recommended or enforced)
  - adaptive
  - score

3.2. Standard Interactivity in Lecture Notes

- navigation
  1. browse
  2. footnotes
  3. indices
  4. internal links, e.g. problem ⇔ solution
  5. externe links, e.g.
     Math online http://www.univie.ac.at/future.media/mo/
     e-Calculus http://www.math.uakron.edu/~dpstory/
     Mathematica http://www.wolfram.com/ etc.
- (partial) print
- copy and paste

4. pdfTEX and pdfLATEX

Comfortably and platform independently generate lecture notes using pdfTEX or pdfLATEX

- freeware typesetting programs on all platforms
  Donald Knuth: TEX, Leslie Lamport: LATEX
- unmatched mathematical typesetting
- very many packages for specialities, e.g. graphs, quizzes etc.
- pdfTEX or pdfLATEX generate pdf-documents directly
- browsable by free Adobe Acrobat Reader/Acrobat plugin
- high quality, all pdf-features

TEX-lecture notes offer all features listed above, see e.g.
http://www.weblearn.hs-bremen.de/risse/mai/docs/

5. Interactive Documents

Adobe Acrobat Reader/Acrobat plugin offer a built in

JavaScript-Interpreter $\Rightarrow$ { pdf-documents can compute & / pdf-documents run algorithms!

using pdfLaTeX JavaScript code can be embeded into pdf-documents!

- take advantage of students play instinct
- let students try, test and experiment with algorithms
- stimulate investigations by questions/problems
- support explorative learning

5.1. Basic Numerics I

Make students engage in basic numerics,
make students experience stability and convergence.

- determine the relative precision of (JavaScript) computations!
- experience examples for violation of the law of associativity due to limited user specified precision!
- experience vector calculus in the plane and in three dimensional space by computation of scalar and vector products etc!
- solve systems of linear equations per Gauß' Elimination algorithm (with and without pivot) as well as per Gauß-Seidel algorithm!
- get to know some constants and use algebraic expressions to generate new functions from given elementary functions!

5.2. Basic Numerics II

- evaluate trigonometric and hyperbolic functions together with their inverse functions!
- find zeroes of explicit functions per nested intervals, regula falsi or per Newton-Raphson!
- integrate per trapezoidal and Simpson-rule!
- solve first order ordinary differential equations numerically! compare Euler-, Heun-, Euler-Cachy- and classical Runge-Kutta-methods!
- solve systems of first order ordinary differential equations numerically!

see numerics.pdf and numerik.pdf (german version)
Further planned applications: probability calculus, optimisation ...

5.3. First Experiences

In a little opiniionnaire students worked on numerics.pdf 1h on average and marked it on a scale from 5 (worst) to 1 (best) as follows

property	mark	students remarks
lucidity	1,7	pdf very good, pages too cramped, vector calculus good
usability	2,1	help too terse, partly inconsistent usage
detailedness	3,0	too terse, more documentation, use tool tips

Students rated their own learning success as follows

topic	students ratings
precision	demonstrative, convincing
vector calculus	pretty observably, graphics were better
systems of linear equations	Gauß comprehensible, Gauß Seidel not clear
zeroes	very clear, very good since unfeasible by hand
integration	no rating (lack of time/interest?)
differential equations	no rating (lack of time/interest?)

6. Conclusion and Outlook

Interactive documents nicely supplement lecture notes!

- benefit has to become manifest in every day usage (evaluation)
- encouraging reactions of students
- inherent limitation: no graphics
  (after all see function graphs in the appendix of `numerics.pdf`)

Independent of new techniques to boost interactivity
important duties remain to be addressed further on

- integration of mathematics, physics, programming, graphics, ...
- didactic workshops, hospitation, evaluation, quality control ...