My Way Into and Through the Didactics of Engineering Mathematics

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Structure

- Starting position
- Main stages and themes of getting into mathematics didactics
- Consequences for daily practical education
- Main intention of the talk: Showing potential ways to get didactically involved, no autobiography!

Starting position

- 1995: Professor for Mathematics and Computer Science at Aalen University of Applied Sciences („Fachhochschule“)
- Located within the Department of Mechanical Engineering
- Predominantly teaching position (18h/week load)
- Stable environment
  - Colleagues teaching application subjects
  - Curriculum for Mechanical Engineering Study Course
  - Perspective: About 30 years of teaching
- Personal prerequisites
  - First State Examination as High School Teacher (Mathematics/History)
  - PhD in Pure Mathematics (Algebra/Geometry: Quadratic Forms)
  - Five years in Industry: Siemens Corporate R&D, Computer Networks
  - No idea of mechanical engineering
- Student prerequisites: Very heterogeneous, different routes, ~50/class

First steps

- Main intention from start: Make mathematics understandable and useful for mechanical engineering students and let students „do“ mathematics:
  - Offer opportunities for understanding for the heterogeneous student population („good“ explanations)
  - Let students actively work with and train mathematical concepts via assignments
  - Choose relevant topics well-integrated into the study course
- Initial didactical settings:
  - Lecture with engaging students by questioning (in Germany known as „fragend-entwickelnder Unterricht“)
  - Provide assignments for student engagement which are relevant for assessment
- Ask engineering colleagues:
  - Questionnaire with current list of contents (mathematical topics) (what needs to be dealt with?)
  - Reaction: Surprise
  - Result: Few insights.

Direction of first didactical projects (late 90s)

- Make connections between mathematics and application subjects directly visible via hypertext
  - Manuscripts of colleagues (Mechanics, Physics, …) as hypertext
  - Whenever mathematics is used offer link to explanatory material
  - Refering to didactical literature on multimedia learning (e.g. on design principles)
- Result:
  - Complete failure regarding usage by students
  - Lesson learnt: Integrate offerings in obligatory activities
  - Considearble improvement of my own understanding of using mathematics in concurrently running and later application subjects
  - Use in lectures (and later in assignments) to make connections explicit (why is something important, where do I need it?)
- Use of mathematical technology: CAS
  - Early ICTMT conferences, CAME conferences, German CAS conferences with professional exchange: Reflective practitioners report on how to improve understanding by experimenting with and visualizing mathematical concepts
  - Use for checking assignments and exam tasks, production of visualizations for lectures

Extending the use of technology (1)

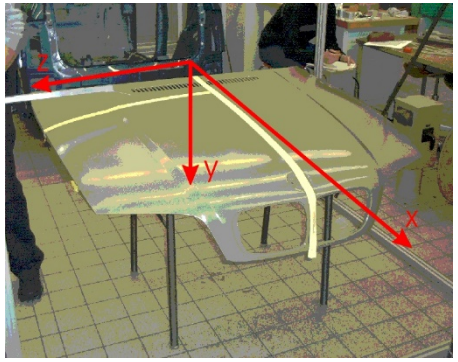
- Major goal: Use technology to let students experience the use and meaning of mathematics in engineering.
- Creation and usage of a „microworld“ for use in the Student-Engineering-Academy (for about 10 years)
  - Offer in Maple® a set of data structures and functions to mathematically model Carrera® toy racing courses and to construct and animate good motion functions; compare computed with real round times
  - Intensive study of didactical literature on microworlds and aspects of functional thinking: concept image and definition, mis-understandings, different representations, … (subject-matter didactics ; „Stoff-Didaktik“)
  - Use this to address specific facets of the function concept and to interpret observations
  - Somewhere between practitioner reflection and didactical research

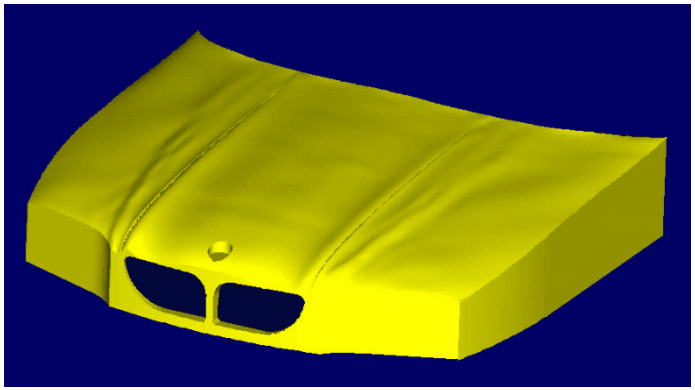
Extending the use of technology (2)

- Introducing technology-based mathematical application projects in semester 3 (from 2000 on)
  - Goal: Let students experience the use of mathematics when working on an application problem
  - Design: Group projects (3-4 students) with documentation and presentation (all different), binary assessment.
  - Identification of design criteria for good projects: mathematical part of reasonable size; application-related problem; openness; use of mathematical software; modularity for distribution of work
  - Facilitating the finding of ever new good projects: Identification of project classes
  - Examples: Reproduction of a part; take measurements of motion and test which model of friction fits best; model a hinge mechanism for a cupboard.
  - Design based on didactical literature but no research on outcome (qualitative methods observing students and investigating documents)
  - Experience: Well accepted if well supported; interesting discussions with groups where students got insight into my thinking; well remembered by students
  - Publication is my most downloaded article on ResearchGate

Example 1: Surface reproduction

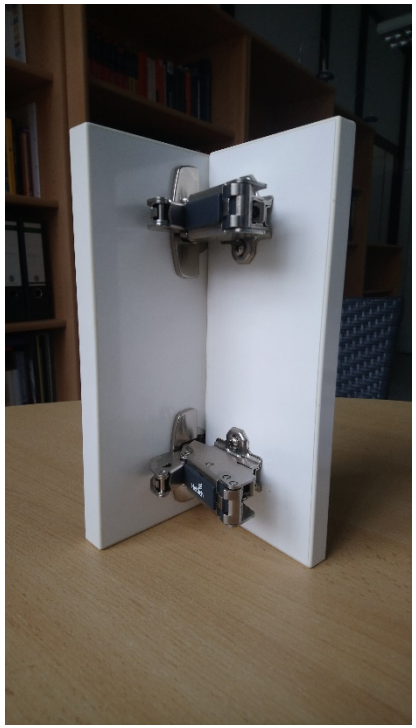
- Example: Take measurements from the BMW motor lid available in the mechanical engineering labs, redesign the surface in a mathematics program and in CAD and reproduce a model of the part using a milling machine also available in the labs.





Example 2: Analysis of mechanisms

- The pictures below show a hinge joint for a cupboard which realizes a mechanism to open and close the lid. Analyse the mechanism (which parts move how) and set up a worksheet where you compute the position of the different parts when the user opens the lid. Set up a principle construction in a CAD programme and check your results.



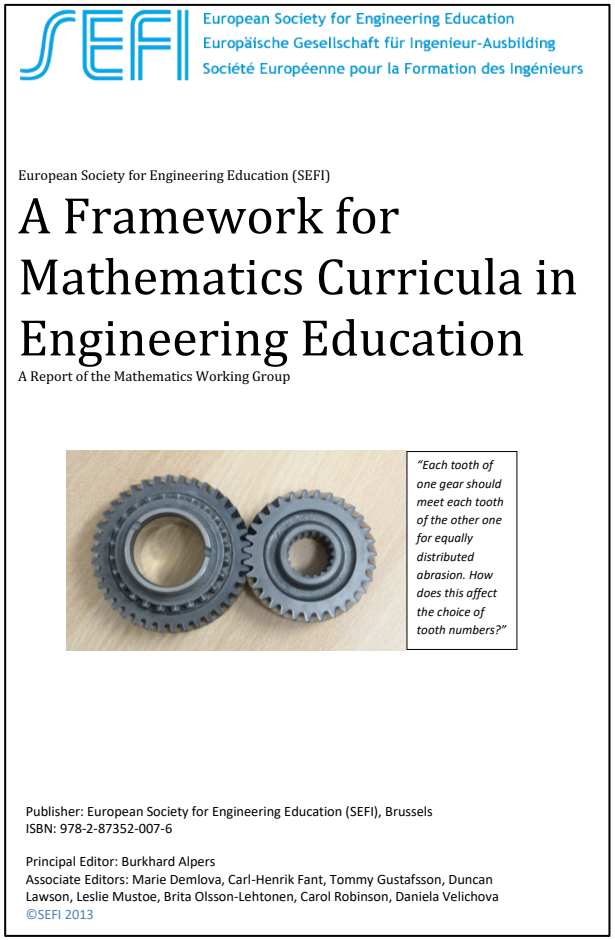
Extending usage studies to the workplace (2005-2010)

- Question: Which mathematical „qualifications“ are still required at engineering workplaces?
- Only very few studies are available regarding engineering workplaces
  - Observing students working on final project
  - „Ethnographic research“ at real workplaces
- Design of own study
  - Identify typical tasks for junior engineers with colleague from mechanical engineering, e.g. construction of an appliance in a car which should carry a device; taking and processing measurements in a test bed for steering mechanisms.
  - Let students work on these tasks using state-of-the-art technological tools (CAD, FEM) where colleague acts as mentor
  - Let students document their work, interview students
  - Try to find interesting categories from research and by own thinking, applying „basic“ qualitative research methods
- Framework for „qualifications“ was still missing, later: „mathematical competencies“

Involvement in professional exchange (1)

- From 2005 member of SEFI Mathematics Working Group
  - Bi-annual seminars
  - 2008-2014 Chairman
  - Mainly practitioners but didactical researchers invited at seminars in order to establish connections
- Normative work on „Curriculum Framework“
  - Identification of potential goals by exchange and agreement of small group of „experts“ with different backgrounds
  - In edition 1 and 2 very content-related, „higher-level understanding“ hardly covered
  - Search for framework in didactical literature
  - Result in edition 3: Concept of „mathematical competence“ (Mogens Niss): „… ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role“
- How can this be used to set up a concrete curriculum?
  - Mathematics curriculum for a practice-oriented study course in ME

Involvement in professional exchange (2): Resulting documents (sefi.htw-aalen.de)



SEFI
European Society for Engineering Education
Europäische Gesellschaft für Ingenieur-Ausbildung
Société Européenne pour la Formation des Ingénieurs

European Society for Engineering Education (SEFI)

A Framework for Mathematics Curricula in Engineering Education

A Report of the Mathematics Working Group

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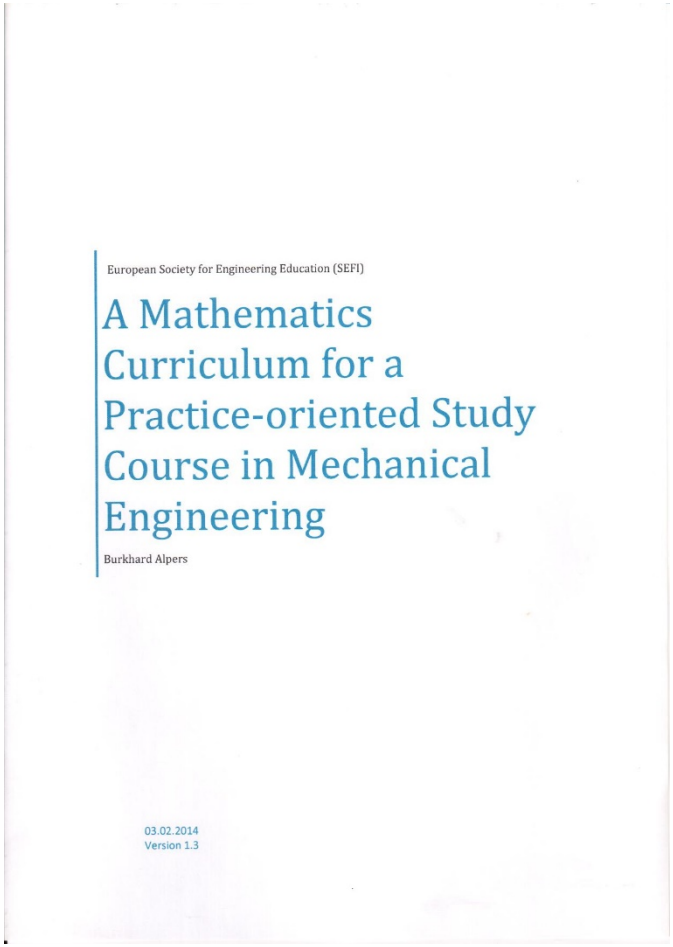


European Society for Engineering Education (SEFI)

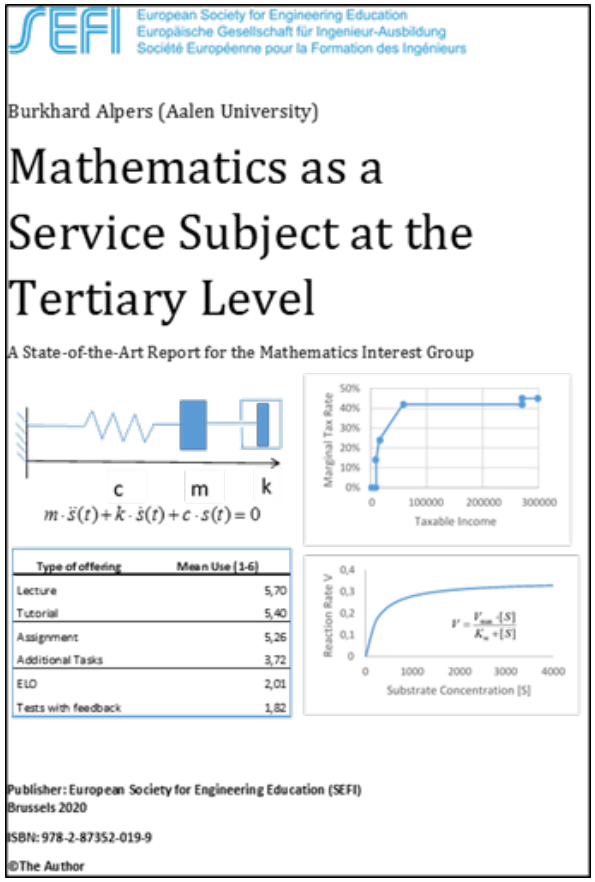
A Mathematics Curriculum for a Practice-oriented Study Course in Mechanical Engineering

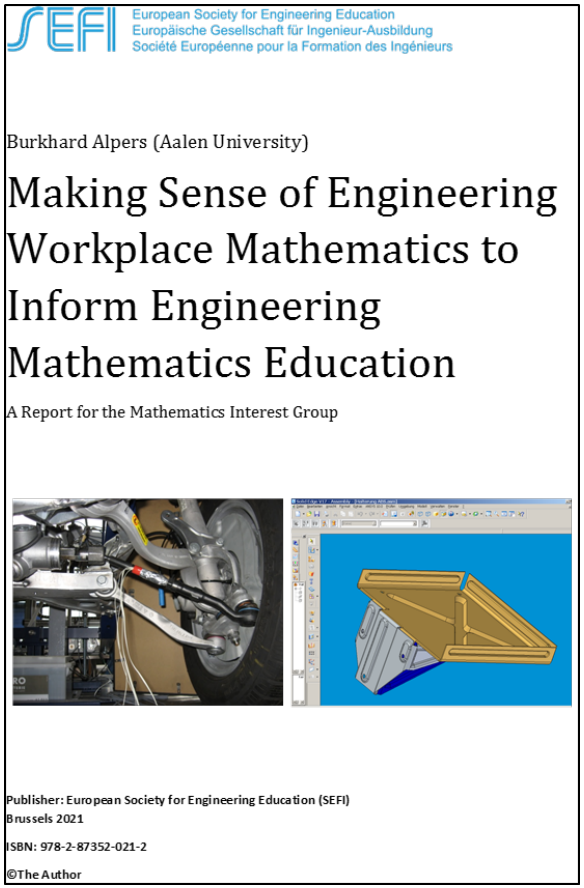
Burkhard Alpers

03.02.2014
Version 1.3

Involvement in professional exchange (3)

- Establishing connections between practitioners and didactical research by informing the community on the state-of-the-art.





Application to own teaching and research (2010-?)

- Changes in teaching:
  - Modify assignments to include use of mathematics in applications (e.g. machine elements and mechanisms).
  - Include obligatory „small projects“ in mathmatics I, II related to Engineering Mechanics I, II
- Further studies on concrete mathematical competencies needed in application subjects
  - Modelling competencies in statics tasks
  - Reasoning competencies in statics textbook
  - Mainly task and textbook analysis using competency elaboration from literature as interpretation framework
- Identification of differences between usage of mathematics in mathematical science and engineering subjects
  - Continuity of functions, concept of vectors, differentials in engineering mechanics

Summary: Different ways to relate to didactical research

- Using results from didactical literature when designing learning material and environments:
  - Multimedia didactics for hypertext
  - Microworld research and subject-matter didactics on functions for microworld
  - Project design for mathematical application projects
- Using didactical literature to clarify objectives:
  - Concept of mathematical competence/competencies
- Using didactical research to interpret artefacts, observations and experience
  - Use subject-matter didactics for understanding students‘ diffculties
  - Interpret textbooks and observations from workplaces in terms of competencies
- Performing own didactical research using qualitative research methods
  - Identification of facets of mathematical competencies in application subjects and workplaces

Conclusions and Recommendations

- The prerequisites (stable environment and dedicated teaching position) were very important for motivation and didactical engagement.
- The transfer of theoretical insights to practical educational settings (lectures, assignments, projects) is important for having a feedback cycle. If you consider something as important, offer respective learning opportunities.
- Concentrate on main ideas and the interface an engineer has to mathematics (less is more).
- Find a suitable mixture of instruction and construction.
- Find a suitable mixture of basic training and deeper conceptual thinking.
- Am I a „great pretender“?
  - Some competence-related goals sound very ambitious
  - Consider such goals as „regulative ideas“, not something to tick off