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Learning Outcomes of Mathematics and ICT in Mechanical Engineering

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Overview

- Objectives and motivation
- Existing literature review - Actual state in general
- ME curricula in Western Balkan countries (WBC)
- ME curricula in Bosnia and Herzegovina (B&H)
- Conclusions

Objectives and motivation

- Motivation
 - Mathematics and ICT play important role in engineering, but...
 - Open discussion
 - Should academic staff with engineering or with mathematical background deliver mathematical courses in engineering?
 - What are the most appropriate ICT competences for ICT teachers at engineering higher education institutions?
 - The main purpose of the HE reform
 - To improve the learning process
 - Study achievements estimated by learning outcomes: *what a student knows, understands and can do*
 - Learning outcomes as the main principle for the cooperation in the European education system, the qualification framework being based on learning outcomes

Objectives and motivation

- The question arising
 - How to formulate the learning outcomes of mathematics and ICT in mechanical engineering to be unambiguous, specific, realistic and feasible to serve their purpose?
 - Not a trivial question: a student may achieve the same learning outcomes by using different learning concepts
- Objectives
 - From experiences of a Joint EU/CoE Project "Strategic Development of Higher Education Qualification Standards"
 - Identify a list of learning outcomes for mathematical and ICT courses in mechanical engineering curricula in B&H
 - Identify a list of competences the teachers should have
 - Determine whether these courses should be delivered by mathematicians or engineers
 - Compare the practices in WBC and B&H

Existing literature review – Actual state

- Learning Outcomes
 - Important in context of Bologna process
 - Shift to a new "student-centred" replacing the previous traditional "teacher-centred" approach
 - Huge national/international projects initiated (PISA and DeseCo by OECD, Danish KOM, ABET, MWG by SEFI, EUR-ACE by ENAEE, ...)
 - EUR-ACE Framework Standard, six outcomes of accredited engineering degree programmes
 - Knowledge and Understanding
 - Engineering Analysis
 - Engineering Design
 - Investigations
 - Engineering Practice
 - Transferable Skills

Existing literature review – Actual state

- SEFI Framework for mathematics curricula in engineering education, eight competences
 - A. Thinking mathematically
 - B. Reasoning mathematically
 - C. Posing and solving mathematical problems
 - D. Modelling mathematically
 - E. Representing mathematical entities
 - F. Handling mathematical symbols and formalism
 - G. Communicating in, with, and about mathematics
 - H. Making use of aids and tools
- IT-related competences
 - Commonly related to computer modelling and computer simulation

Existing literature review – Actual state

- Main findings – mathematics (last decade!)
 - Mathematical competence is the ability to understand, judge and use mathematical concepts in relevant context
 - Mathematics should be focused on practical tasks rather than be a collection of knowledge of theorems and proofs
 - Move some mathematical topics to engineering courses to which they directly apply
 - New abstract concepts need to be accompanied by plentiful numerical examples
 - Mathematics instructors often have a limited understanding of how mathematical concepts are applied in engineering
- Main findings – ICT
 - Much less investigated
 - Advances in ICT transformed engineering analytical technique
 - Open questions: how much programming, which language (Fortran, C/C++, Matlab), ...?

Mechanical engineering curricula in WBC

- Mathematics 1, 2 and 3

	University (Country)	Teacher	Defined Learning Outcomes	SEFI contents
Mathematics 1 and 2	Zagreb (HR)	Math.	(objective)	+
	Rijeka (HR)	Eng.	+	+
	Slavonski Brod (HR)	Math.	+	+
	Split (HR)	Math.	+	+
	Belgrade (RS)	Math.	+	+
	Novi Sad (RS)	Math.	+	+
	Niš (RS)	Math.	+	+
	Ljubljana (SI)	Math.	n/a	+
	Maribor (SI)	Math.	+	+
	Total	8/9 Math	7/9 +	9/9

	University (Country)	Teacher	Defined Learning Outcomes	SEFI contents
Mathematics 3	Zagreb (HR)	Math.	(objective)	+
	Rijeka (HR)	Math.	+	+
	S. Brod (HR)	Math.	+	+
	Split (HR)	Math.	+	+
	Belgrade (RS)	Math.	+	+
	Novi Sad (RS)	Math.	+	+
	Niš (RS)	n/a	n/a	n/a
	Ljubljana (SI)	Math.	n/a	+
	Maribor (SI)	n/a	n/a	n/a
	Total	7/7 Math.	5/7 +	7/7

Mechanical engineering curricula in WBC

- Mathematical competences

	University (Country)	SEFI competences	Total
Math. Competences	Zagreb (HR)	H	1/8
	Rijeka (HR)	C, H	2/8
	Slavonski Brod (HR)	C, H	2/8
	Split (HR)	C, H	2/8
	Belgrade (RS)	A, C, H	3/8
	Novi Sad (RS)	H	1/8
	Niš (RS)	C, H	2/8
	Ljubljana (SI)	n/a	n/a
	Maribor (SI)	A, C, H	3/8

- Information technology (IT)

	University (Country)	Teacher	Defined Learning Outcomes	Contents
ICT	Zagreb (HR)	ME	(objective)	Programming
	Rijeka (HR)	ME	+	IT basics
	Slavonski Brod (HR)	ME	+	IT basics
	Split (HR)	EE	+	IT basics
	Split (HR)	EE	+	Programming
	Belgrade (RS)	EE	+	Programming
	Novi Sad (RS)	ME	+	IT basics
	Niš (RS)	ME	+	IT basics
	Ljubljana (SI)	ME	n/a	IT basics
	Maribor (SI)	ME	+	IT basics
	Total	7/10 ME, 3/10 EE	8/10 +	7/10 IT basics, 3/10 Prog.

Mechanical engineering curricula in B&H

- Mathematics 1, 2 and 3

Mathematics 1 and 2	Public university	Teacher	Defined Learning Outcomes	SEFI contents
	Zenica	Math.	n/a	+
	Sarajevo	Math.	(objective)	+
	Tuzla	Math.	(competency)	+
	Banja Luka	Math.	+	+
	Bihać	Math.	(competency)	+
	Mostar	Math.	(competency)	+
	Total	6/6 Math.	1/6 +	6/6 +

Mathematics 3	Public university	Teacher	Defined Learning Outcomes	SEFI contents
	Zenica	Math.	n/a	+
	Sarajevo	Math.	(objective)	+
	Tuzla	Math.	(competency)	+
	Banja Luka	Math.	+	+
	Bihać	Math.	(competency)	+
	Mostar	Math.	(competency)	+
	Total	6/6 Math.	1/6 +	6/6 +

Mechanical engineering curricula in B&H

- Mathematical competences

Math. Competences	Public university	SEFI competences	Total
	Zenica		n/a
Sarajevo		C, H	2/8
Tuzla		B, H	2/8
Banja Luka		A, B, C, H	4/8
Bihać		H	1/8
Mostar		D	1/8

- Information technology (IT)

ICT	Public university	Teacher	Defined Learning Outcome	Contents
	Zenica		ME	n/a
Zenica		ME	n/a	Prog.
Sarajevo		ME	(objective)	Prog.
Tuzla		ME	(competency)	Prog.
Banja Luka		EE	+	IT basics
Banja Luka		EE	+	Prog.
Bihać		ME	(competency)	Prog.
Mostar		ME	(competency)	Prog.
Total		6/8 ME, 2/8 EE	2/8 +	2/8 IT basics, 6/8Prog.

Conclusions

- Learning outcomes are generally not well defined
 - there is a basic lack of understanding how this should be done
 - poorly defined in B&H, slightly better in all WBC for both mathematics and IT
- Teachers with mechanical engineering background
 - responsible for IT as common practice, not for mathematics
- Most of curricula lack practical engineering examples
 - Therefore mechanical engineers could teach mathematics if mathematical background is not of great importance
 - Mathematicians and engineers should cooperate to create a better learning environment for solving engineering problems
- No common approach for IT learning outcomes
 - In mechanical engineering and engineering in general
 - Further analysis if students should use standard or proprietary programming languages

Main references

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