Supporting engineering in STEM education: Future chemistry teachers' perceptions of single board computer hacking

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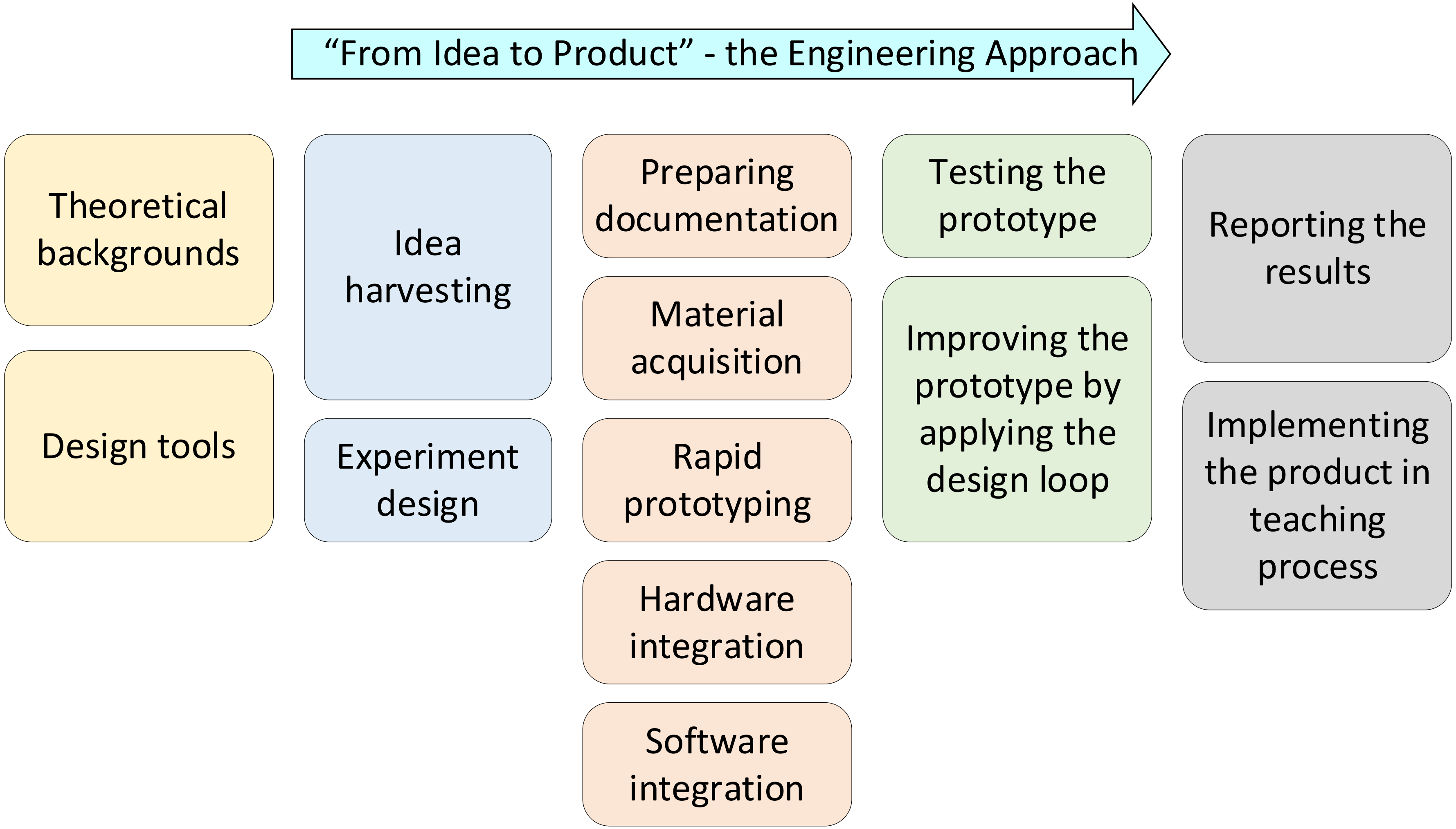
Contents

Rationale

- STEM projects have potential to support the interest towards chemistry learning (Weidman & Wright, 2019)
- But there are challenges like (Pernaa, 2022):
  - Multidisciplinarity demands diverse content knowledge
  - Limited resources in real-life teaching situations
  - How to secure students active and creative role?
- A possible solution: The application of engineering approach (CADRE, 2013; Ambrož et al., 2019)
- Initial research questions:
  - What kind of possibilities does a SBC project offer for learning?
  - What kind of challenges does the engineering approach initiate with future chemistry teachers?
  - What kind of support does a future chemistry teacher need, developing an SBC based experiment using engineering approach?

The Process

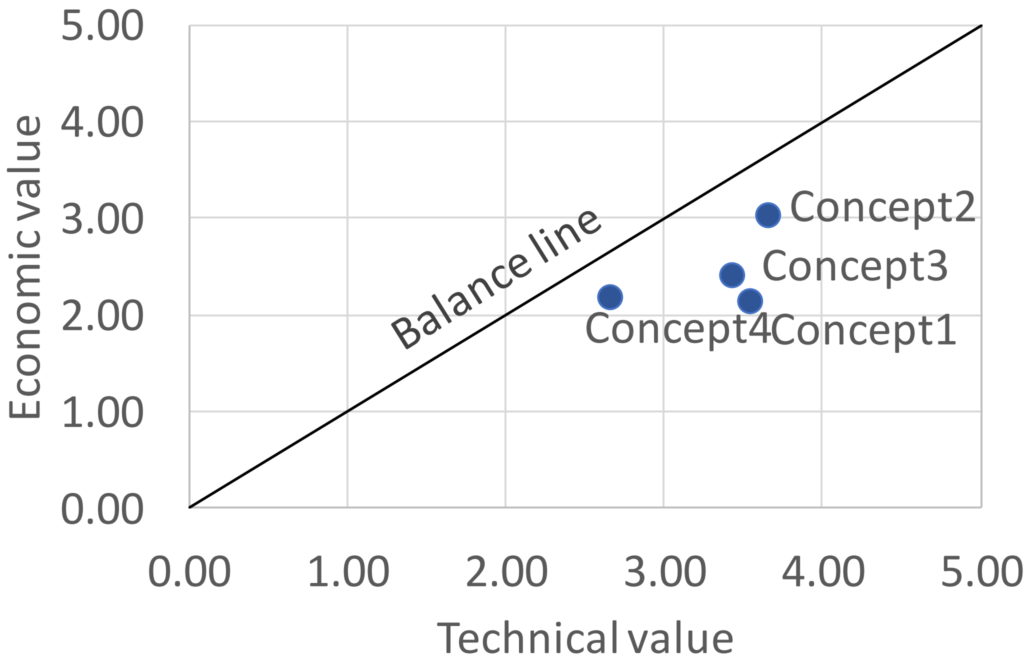


“From Idea to Product” - the Engineering Approach
Theoretical backgrounds
Design tools
Idea harvesting
Experiment design
Preparing documentation
Material acquisition
Rapid prototyping
Hardware integration
Software integration
Testing the prototype
Improving the prototype by applying the design loop
Reporting the results
Implementing the product in teaching process

The engineering approach

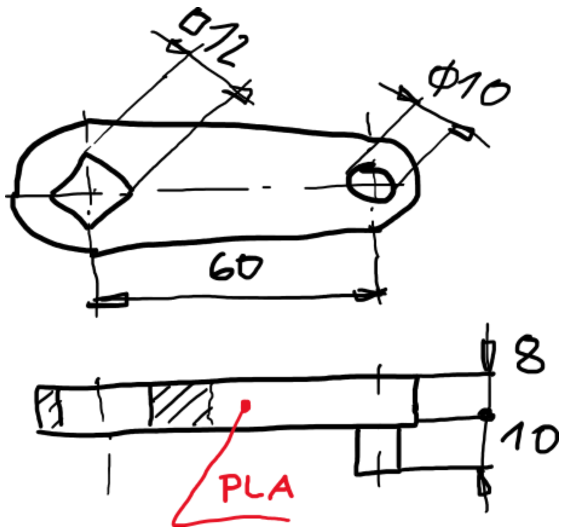
- Introduction to systematic approach to design challenges
- Practical tools to help with the design
  - Concept synthesis using morphological matrices
  - Concept evaluation using multicriteria analysis

Crank #0		Principle			
		A	B	C	D
Function	1 Construction	one piece machined	one piece 3D printed	combined plastic	combined plastic/metal
	2 Hole	integral 3D printed	machined		
	3 Pin	integral 3D printed	separate metal pin	separate plastic pin	
	4 Attachment to motor	none	tight fit	glued	screw & washer
	5 Attachment to rod	none	circlip	click fit	bushing & screw



The engineering approach

- Preparing design documentation
  - Bill of Materials
  - Schematics
  - Instructions



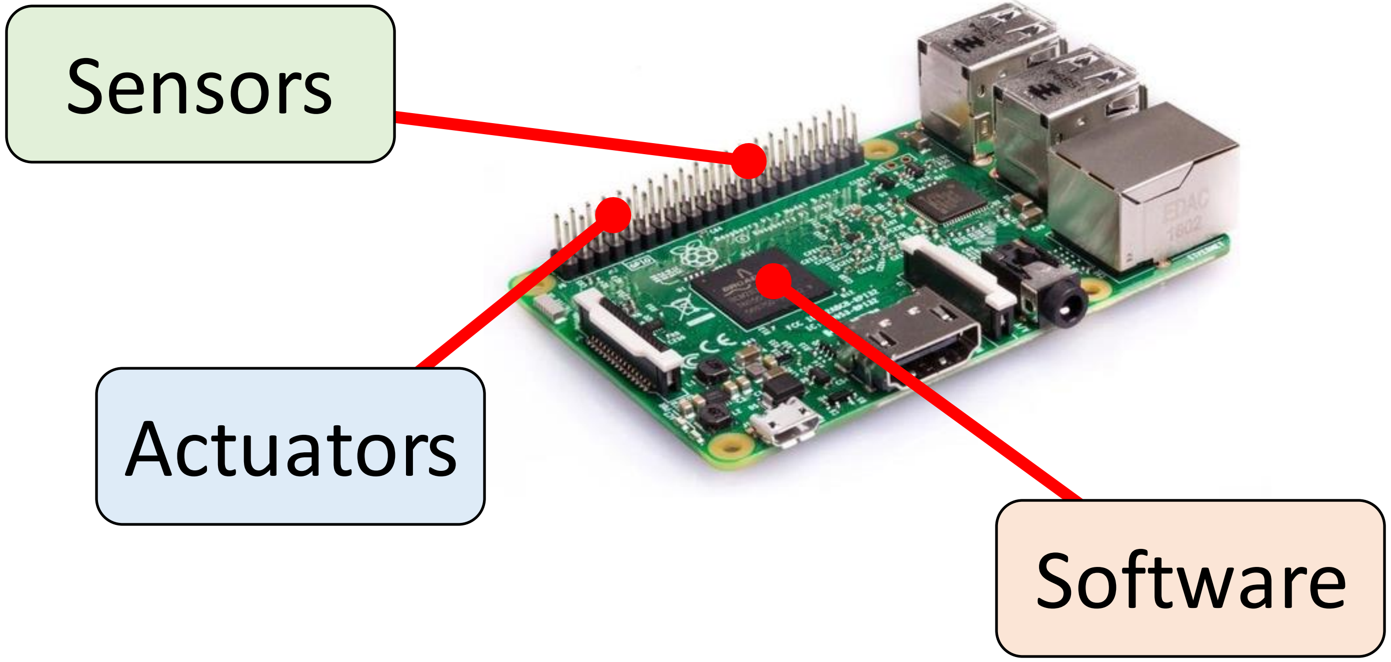
#	Name	Dim./Des.	Amt.	Unit	Price €	DOD	Supplier
1	Crank Body	60×□12×ø10	1	pc	4,10	0 d	in-house
2	Screw	M3×14	1	pc	0,08	2 d	MegaSteel d.o.o.
3	Screw	M3×8	1	pc	0,08	2 d	MegaSteel d.o.o.
4	Washer	3×8	2	pc	0,12	2 d	MegaSteel d.o.o.
5	Threadlocker	Loctite 243	8	ml	8,60	3 d	GigaGlues d.o.o.

Building an SBC based experiment

- Experiment automation raises the educational value of an experiment
  - By making the experiment clear
  - By making the experiment repeatable (reducing human intervention)
- Design of experiment
  - Measuring quantities (temperature, light intensity, force, concentration, ...)
  - Displaying the measurement results (as charts, tables, images)
  - Reacting to changes by controlling actuators (valves, heaters, pumps, ...)
- Using a SBC as the core of the automated experiment
  - Provides flexibility (multiple experiments with the same setup)
  - Provides reliable analysis of results (largely eliminating human error)

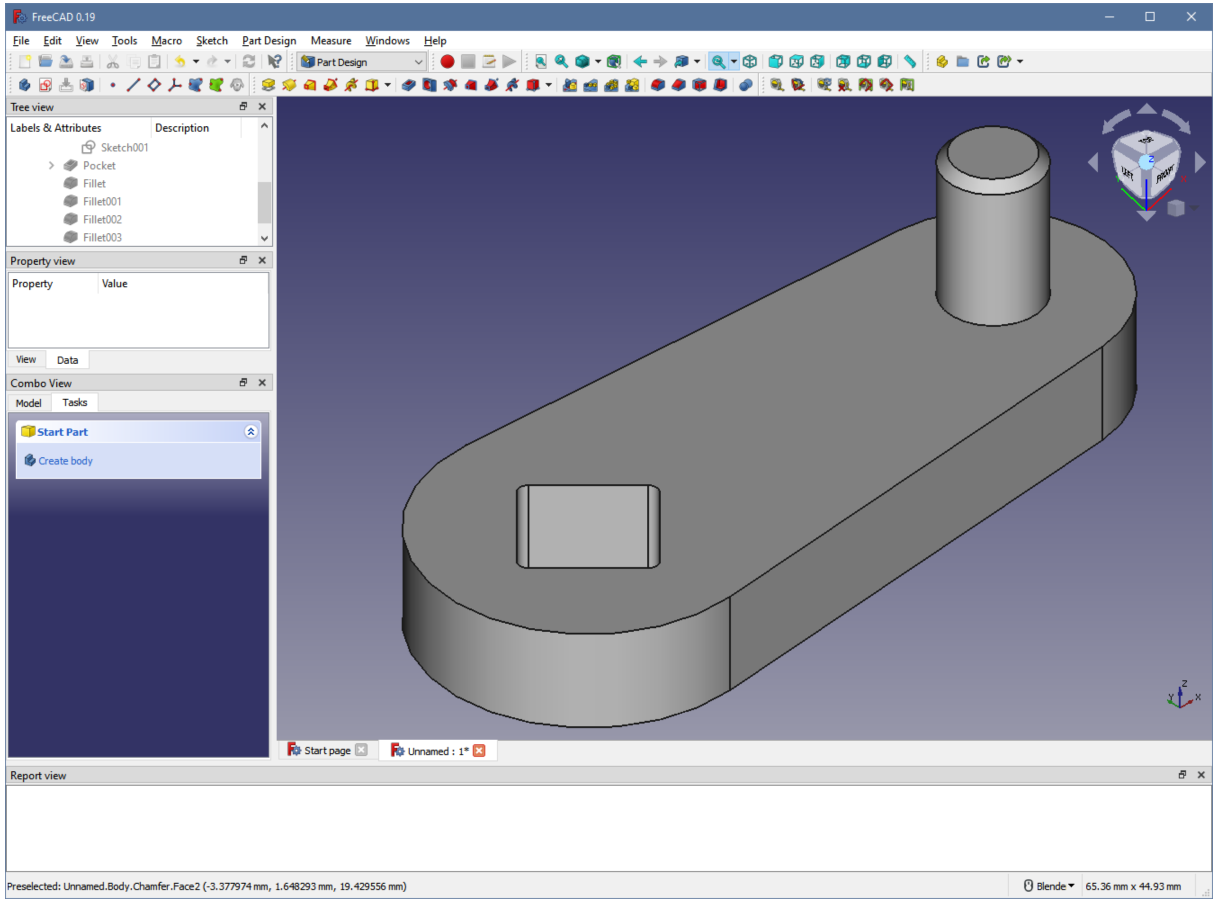
Building an SBC based experiment

- Raspberry Pi Single Board Computer as a tool
  - Fully equipped computer for a low price
  - Runs open source OS
  - Large base of open source software and support
  - Provides interfaces for connecting to physical world



Application of rapid prototyping

- Using a 3D printer to manufacture parts of the experiment setup
- Introduction to 3D modelling
  - Open source 3D modelling tools
  - Principles of 3D model creation
  - Preparing for 3D print



Research setting

- (Case study?)
- Qualitative research (Cohen et al., 2007)
  - Data protection declaration to UH
- Four participants
  - Informed consent
- Data gathering
  - During the project: Field notes
  - After the project: Semi-structured interviews
  - After the course: Articles written from the project (LUMAT-B)
- Data objectives:
  - Triangulate via diverse data
  - Saturation of the observations

Research setting

- Data processing
  - Automatic transcription via software
  - Automatic translation of essential parts
- Data analysis
  - Qualitative content analysis (Tuomi & Sarajärvi, 2009)
    - Inductive content-based?
    - Deductive theory-based?
  - The type will be decided via literature review.
- Inter-rater reliability coding (McHugh, 2012)
  - Agreement over 0,8

Timeline

- Theoretical framework is on the table
- Data gathering will continue the whole spring semester 2022.
- Data analysis in June 2022.
- The paper will be submitted before Midsommar.
- Journal: Probably Journal of Chemical Education (JUFO 1 & IF 2,979)
    - They have a history of both SBC papers and STEM papers
    - It is important to contribute to the earlier discussion of the field and of the journal.
        - We will emphasize these in the letter for editor.
- The paper will be published in 2023.
    - Review time 6 to 12 months

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