Promoting Innovation in Engineering Training that Broadens Skills Sets of Engineering Graduates

HEPSSA WORKSHOP
15TH – 16th July 2021

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Overview

1. Responsibilities of Engineers in the Workplace
2. Top In-Demand Employability Skills for Engineers
3. Aligning Curricula to Employability Skills
4. Case Studies of Emerging Engineering Applications
5. Continuous Re-tooling of Academic Staff

1. Responsibilities of Engineers in the Workplace

1. Design and produce technological products, industrial processes, and systems that conform to set standards.
2. Conduct routine maintenance of mechanical and electrical systems.
3. Ensure safety and effective performance of products, processes, and systems.
4. Produce accurate project specifications for customers.
5. Manage projects to ensure timely completion and within budget.
6. Produce technical reports for projects.
7. Communicate project details to clients, coworkers & management.

2. Top In-Demand Employability Skills for Engineers

1. **Hard Skills:** Technical Skills in the particular engineering discipline
2. **Soft Skills:**
   - (i) Critical Thinking Skills: Logical and Analytical Reasoning
   - (ii) Creativity and Problem Solving Attitude
   - (iii) Capacity to identify, access and manage/ use information effectively
   - (iv) Communication Skills: Verbal and Written Communication
   - (v) Interpersonal Skills: Networking, Leadership, Teamwork, Emotional Intelligence, Conflict Management, Inspiring & Motivating others, etc.
   - (vi) Enthusiasm, Motivation and Commitment
   - (vii) Entrepreneurial Skills
   - (viii) Values: Professional Ethical Conduct and Integrity

(Sources: www.engineering.com ; Shekhawat, 2020)

Challenges Identified in Engineering Education

✓ Problems recognized in engineering education:

- Inadequate technical skills of new engineering graduates.
- Increase in engineering students drop out rates.
- Longer stays in engineering study programmes.

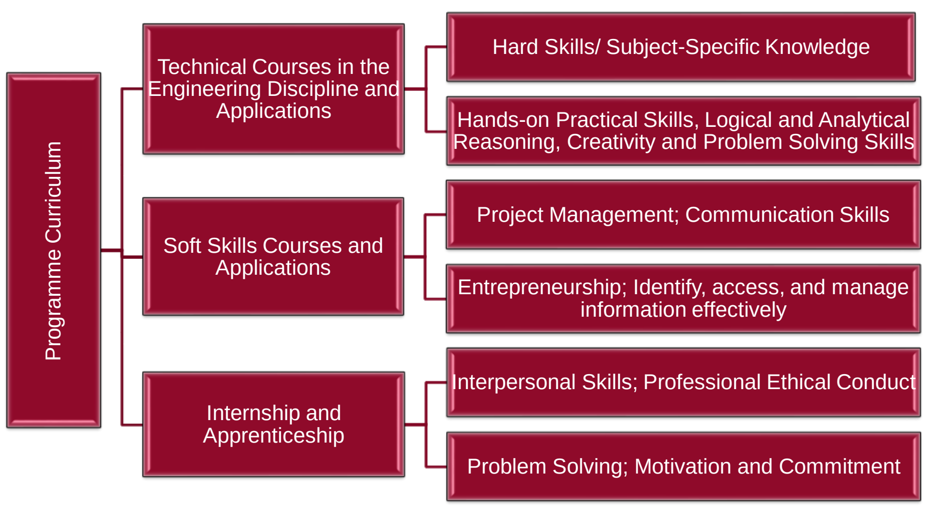
Possible Reasons for observed Challenges in Engineering Education

1. Lack of student commitment and motivation leading to poor study attainment.
2. Some engineering concepts are difficult grasp in class; makes them boring.
3. Some concepts taught don't seem to have a connection to practical life.
   - Students wonder where Engineering Mathematics is applied.
4. Poorly equipped teaching facilities
5. Inadequate skills of lecturers
   - Lecturers need re-tooling
6. **Any other reason?**

Interventions in Engineering Education

- ✓ To meet employers needs, engineering programs should be structured according to the engineer´s work process of conceive-design-implement-operate.
- ✓ Use real life problems to guide students to learn engineering concepts.
  - Solving a fluid flow problem involving determination of flowrates makes a student appreciate application of mathematical relations.
  - Solving a heat transfer problem involving construction of a thermal insulator makes a student appreciate application of concepts of thermodynamics.

3. Aligning curricula with Employability Skills



Problem and Project Based Learning

- ✓ Skills development by Problem and Project-Based Learning (PPBL) is recognized as a tool for learning skills and appreciate application of knowledge.
  - Learning inspired by real life problems/ situations
  - PPBL projects can be implemented in broader study modules with several cooperating teachers.
  - Possible for students to learn many engineering concepts and even business concepts within one project.

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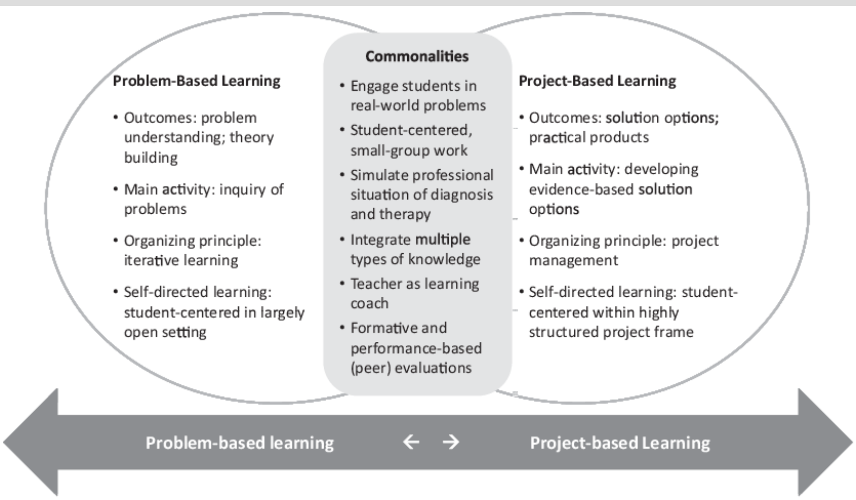
The Spectrum of PPBL Approaches



(Source: Wiek *et al.*, 2014)

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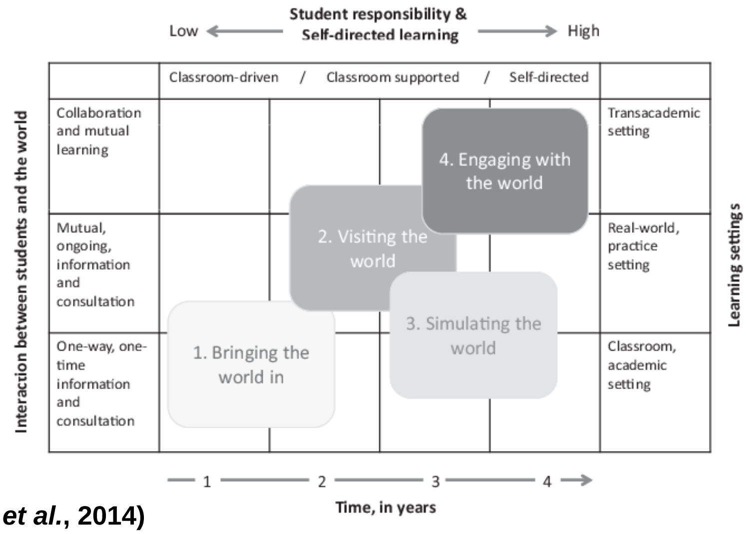
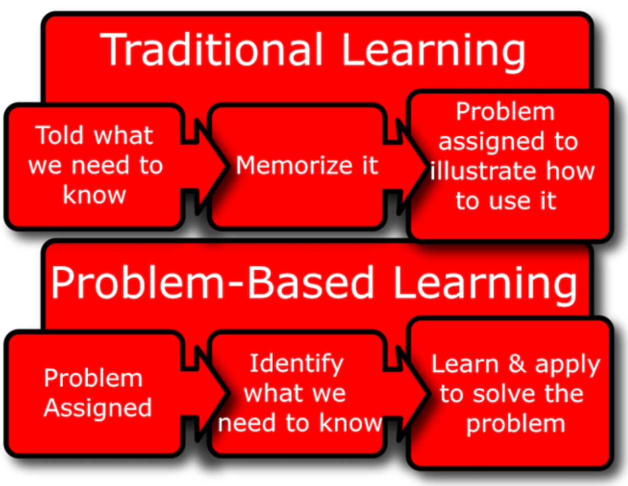
Progressive Model for PPBL

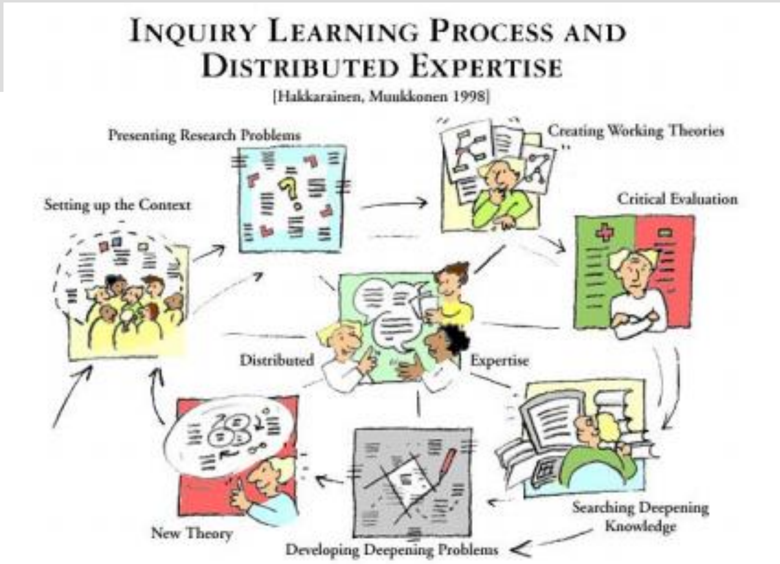


(Source: Wiek, *et al.*, 2014)

Problem and Project Based Learning



(Source: Kurt, 2020)



(Source: Fortelius *et al.*, 2015)

PPBL Study Process (1)

- ✓ Problem and Project Based Learning approach is a cyclic study process which consists of the following steps:

1. Explore the given project to identify problematic issues.
2. Choose one problematic issue to solve.
3. Brainstorming about the chosen problematic issue.
4. Discussion about the issue:
   - Students identify what they know
   - Students identify what more they need to know
   - Develop learning tasks to be done
   - Divide learning tasks among team members
   - Learning tasks to be done before the next step

PPBL Study Process (2)

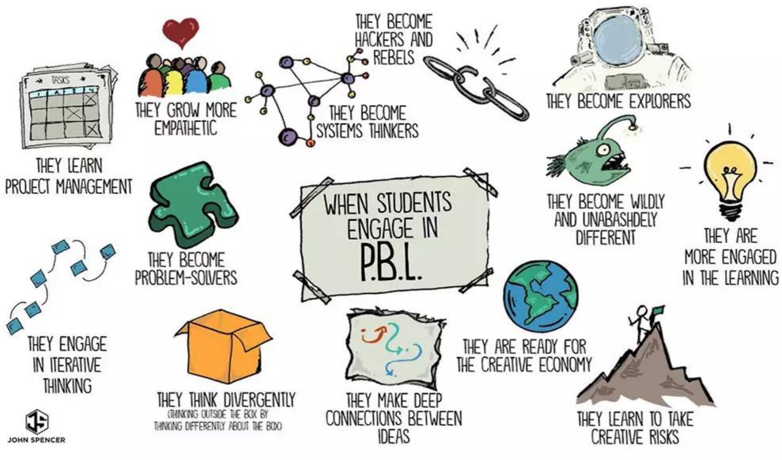
5. Discussion of new knowledge gained from the learning tasks
6. Specification of the problem to be solved
7. Writing the Project Plan
8. Implementation of the project; this involves:
   - ✓ Delivery of materials and checking equipment
   - ✓ Carrying out practical/ experimental work in workshops or laboratories
   - ✓ Reporting of the results: Report Writing
   - ✓ Presentation of the results

Structure of PPBL Projects

✓ A case of first year students performing three different projects:

- **1st Project**: Focused on introduction to the PBL process, organizing a project, roles and group dynamics with minor professional subject content.
- **2nd & 3rd Projects**: Focused on students learning professional subject content of industrial processes in their study field:
  - ✓ Building process,
  - ✓ Water treatment process,
  - ✓ Manufacturing process,
  - ✓ Surface treatment process, etc.

Benefits of PPBL Study Process



(Source: www.teachthought.com)

4. Case Studies of Emerging Engineering Applications

4.1 Advancement of Additive Manufacturing & Biomimetic Design

- Design and Manufacturing Engineers

4.2 Advancement of 3-D Printing of Houses

- Architects and Civil Engineers

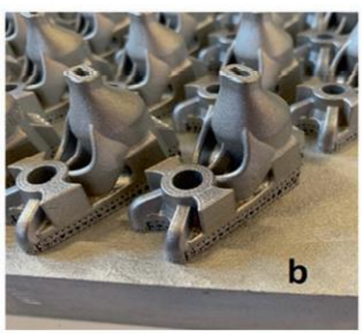
4.1 Advancements in Additive Manufacturing & Biomimetic Design

1. Additive manufacturing (AM), formerly called Rapid Prototyping, is a relatively new manufacturing method used to make complex from 3D-model data by joining materials layer by layer.
2. Additive manufacturing involves a combination of different technologies:
   - CAD (computer-aided design),
   - CAM (computer-aided manufacturing),
   - Laser and electron energy beam technology,
   - CNC (computer numerical control) machining, and
   - Laser scanning.
3. First commercial systems were available in the 1990s but AM has come of age in the 2000's.

Additively Manufactured Parts with Complex Geometry

New Skills Sets for Design Engineers, Materials Engineers, and Manufacturing Engineers!

✓ Glue nozzles with complex geometry and inner structure, made with laser-based powder-bed fusion out of an aluminum-alloy.



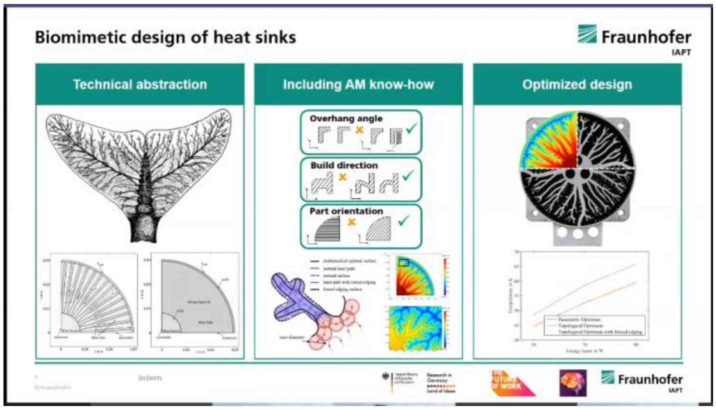
(Source: Korpela *et al.*, 2020)

Complex shaped Additive Manufactured Part

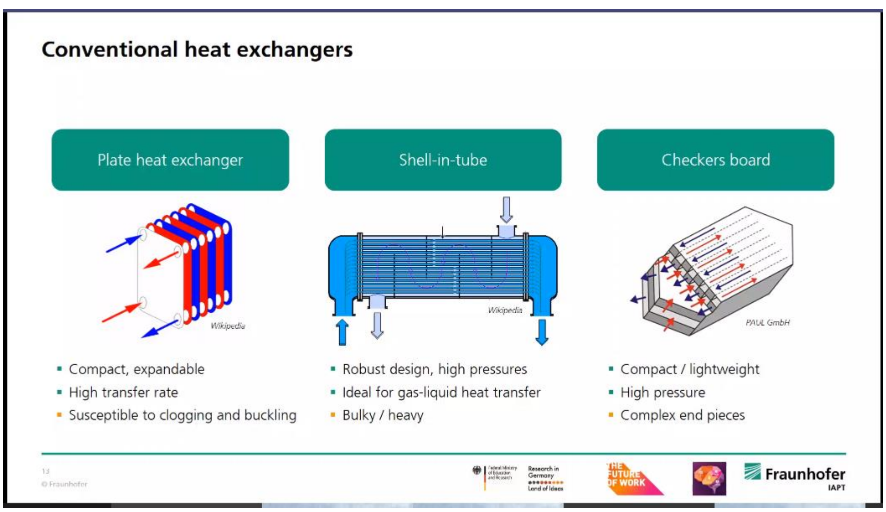
(Source: Yoders, 2014)

Biomimetic Design of Additively Manufactured Heat Sink

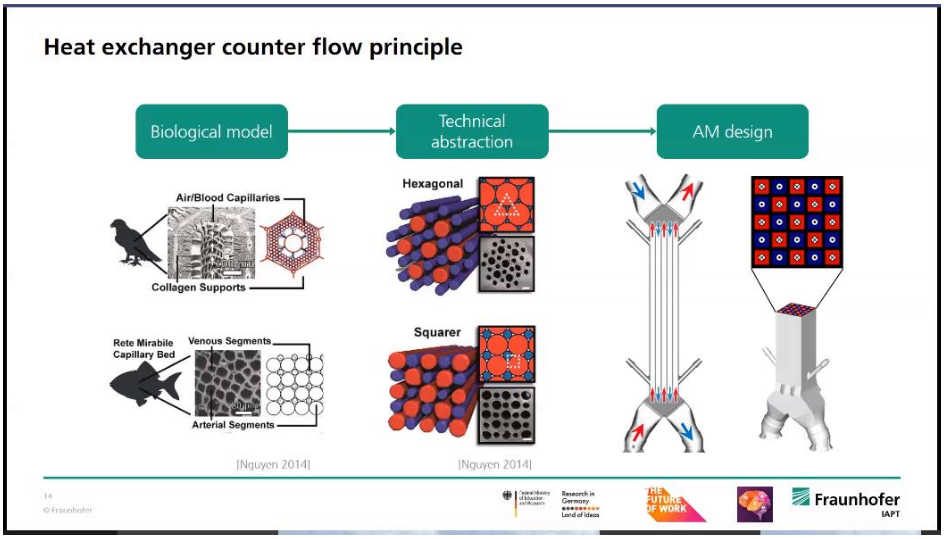
- ✓ Biomimetic design refers to designs that function like elements of nature(i.e. they work like natural things).



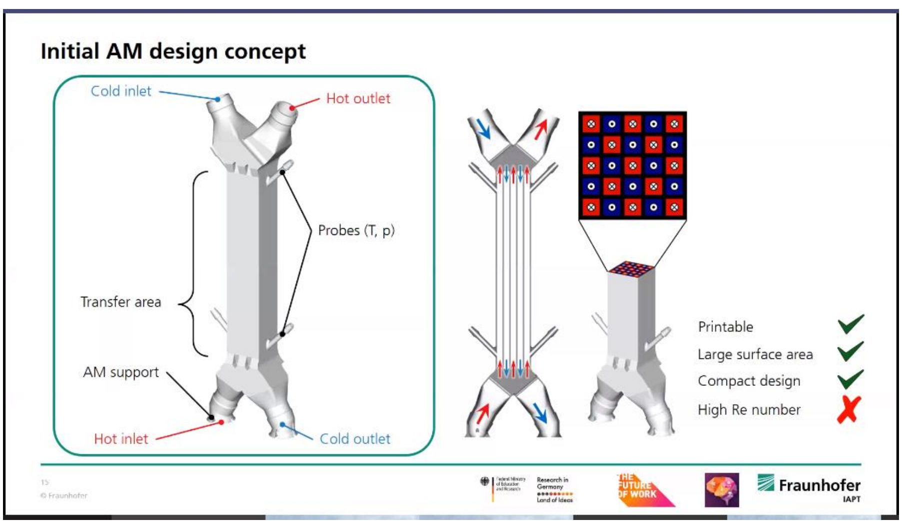
Conventional Heat Exchangers



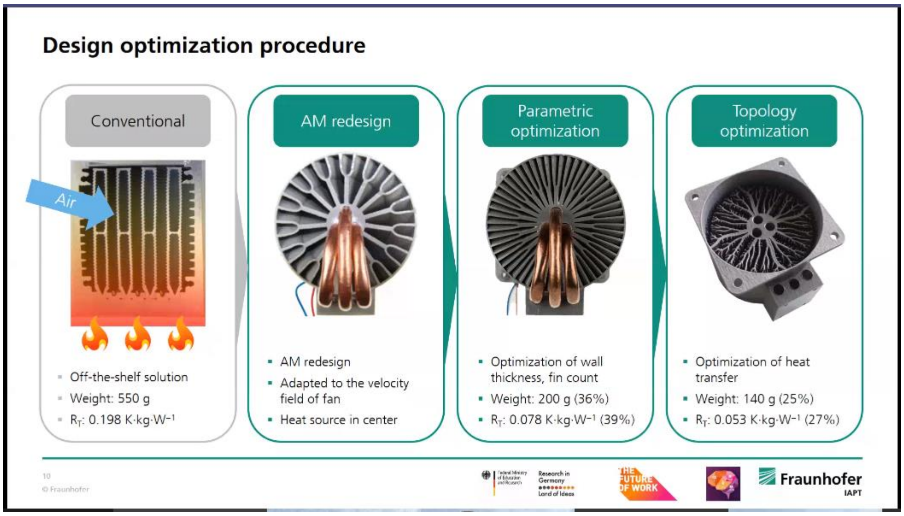
Conceptualization of Additively Manufactured Heat Exchangers



Initial Design Concept of Additively Manufactured Heat Exchangers



Biomimetic Design of Additively Manufactured Heat Exchangers



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Requirements of Additive Manufacturing

✓ Requirements for Additive Manufacturing

1. Need laser beam so is an expensive process.
2. Needs unique material properties.
3. Needs unique design of parts to prevent effects of thermal stresses.
4. Needs part optimization in design for optimization of material usage.
5. Knowledge and skills in laser technology and materials engineering.

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Benefits of Additive Manufacturing

1. Opportunities for unique and complex part designs
2. Versatility in part designs; ability to allow customization
3. Optimization of part design
4. Geometrical Tolerances
5. Development of lighter parts
6. Cost optimization of existing designs
7. Redesign and data preparation for manufacturing
8. Production and testing of prototypes

4.2 Advancement of 3D Printing of Houses

The first additively manufactured building in Europe (Walls created with material extrusion out of concrete)

(Source: Korpela *et al.*, 2020)

3D Housing Printing

The 3-D BOD2 print head is mounted on the gantry and can move along 3 axes

Cobod's BOD2 print head can print a square metre of double-skin wall in five minutes

(Source: Sweet, 2020)

On site in Beckum. Cobod's BOD2 can print a square metre of double-skin wall in five minutes (Peri)

3D Printed 160 sq m house in Beckum, Germany, 2020

- ✓ 3D construction printing of houses has a potential to change the process of residential house construction.
- ✓ Costs of 3-D printed houses is projected to come down with more experience.

(Source: Sweet, 2020)

Africa's First 3D Printed House in Malawi, 2021

Requires New Skills for Civil and Building Engineers!

- First 3D printed affordable house in Africa.
- Walls were printed in less than 12 hours.
- This house emits 70% less CO_2 than conventional burnt brick houses.

(Source: Fleming, 2021)

5. Continuous Re-Tooling of Academic Staff

1. **Capacity building of academic staff in delivery of Problem- and Project-Based Learning (PPBL)**
   - New ideas on delivery of PPBL
2. **Training of academic staff on new technologies**
   - Fast advancement of technology
   - Equipping staff with new knowledge
   - Workshops/ seminars, etc.
3. **Team building activities organized for academic staff**
   - Building a team spirit among staff for effective delivery of engineering training.

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