On Artificial Intelligence Curriculum and Problem-Based Learning

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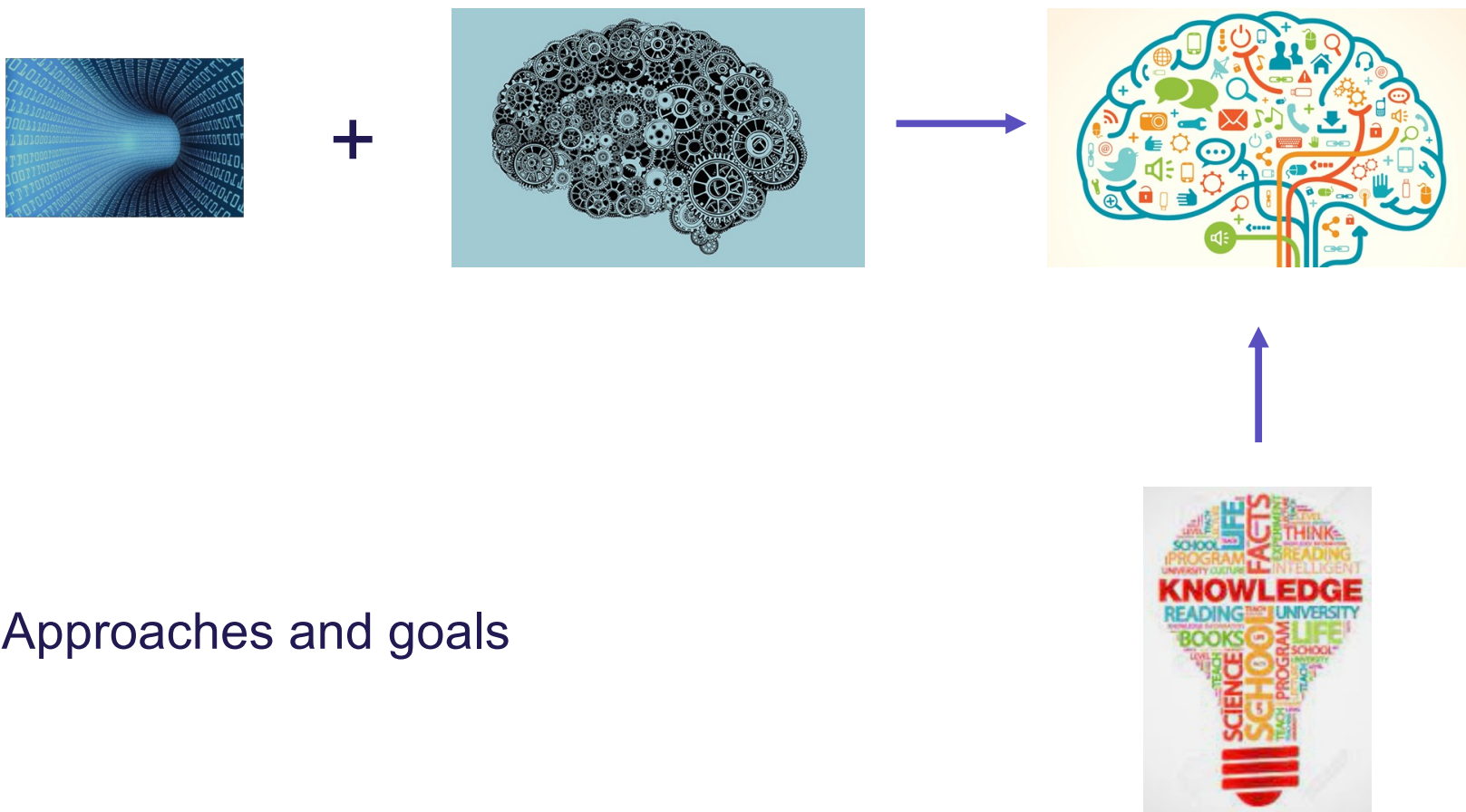Aalborg University, Denmark

Agenda

- AI curricula
    - Bachelor and Master AI program examples
    - Analysis, discussions and thoughts
    - A curriculum framework of four building blocks

- Project-oriented problem-based learning (PBL)
    - The Aalborg model

Artificial intelligence and machine learning

Approaches and goals

AI and Data (Bachelor) @ DTU

Based on mathematics, physics, statistics, cognition, and computer science, the student will

- learn to work systematically with data and software

- master the many tools that form the basis of modern AI

- **Basic sciences**: mathematics, statistics, machine learning and data mining, physics, chemistry

- **Basic technological**: discrete mathematics, algorithms and data structures, signals and data, active machine learning and agency, AI and human cognition, reinforcement learning and control, symbolic AI, bioengineering, social informatics and UX design

- **Projects and general subjects**: intelligent systems, programming and data processing, engineering theory, bachelor project

(https://www.dtu.dk/english/education/undergraduate/undergraduate-programmes-in-danish/bsc-eng-programmes/artificial-intelligence-and-data)

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(Subjects are grouped and empahsized in different colours.)

AI (Bachelor) @ CMU

- The program gives the in-depth knowledge for transforming large amounts of data into actionable decisions or enhancement of human capabilities.

- **Math and statistics**: Math foundations, probability theory, matrices and linear transformations, calculus, …

- **Computer science**: Programming, computer systems, …

- **AI**: Machine learning, AI, NLP, computer vision, autonomous agents, deep learning, …

- **Ethics**: AI and humanity, ethics and policy issues in computing, etc.

- **Humanities and arts**: cognitive psychology, perception, …

(https://www.cs.cmu.edu/bs-in-artificial-intelligence/)

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Computation and Cognition (Bachelor) @ MIT

It focuses on the emerging field of computational and engineering approaches to brain science, cognition and machine intelligence.

- Mathematics, differential equations, linear algebra, probability, statistics
- Machine learning, AI, algorithms, inference
- Programming in Python, programming
- Signal processing, circuits and electronics
- Neuroscience, neuro computation, perception, computational cognitive science
- Computer vision, NLP, ...

(http://catalog.mit.edu/interdisciplinary/undergraduate-programs/degrees/computation-cognition/)

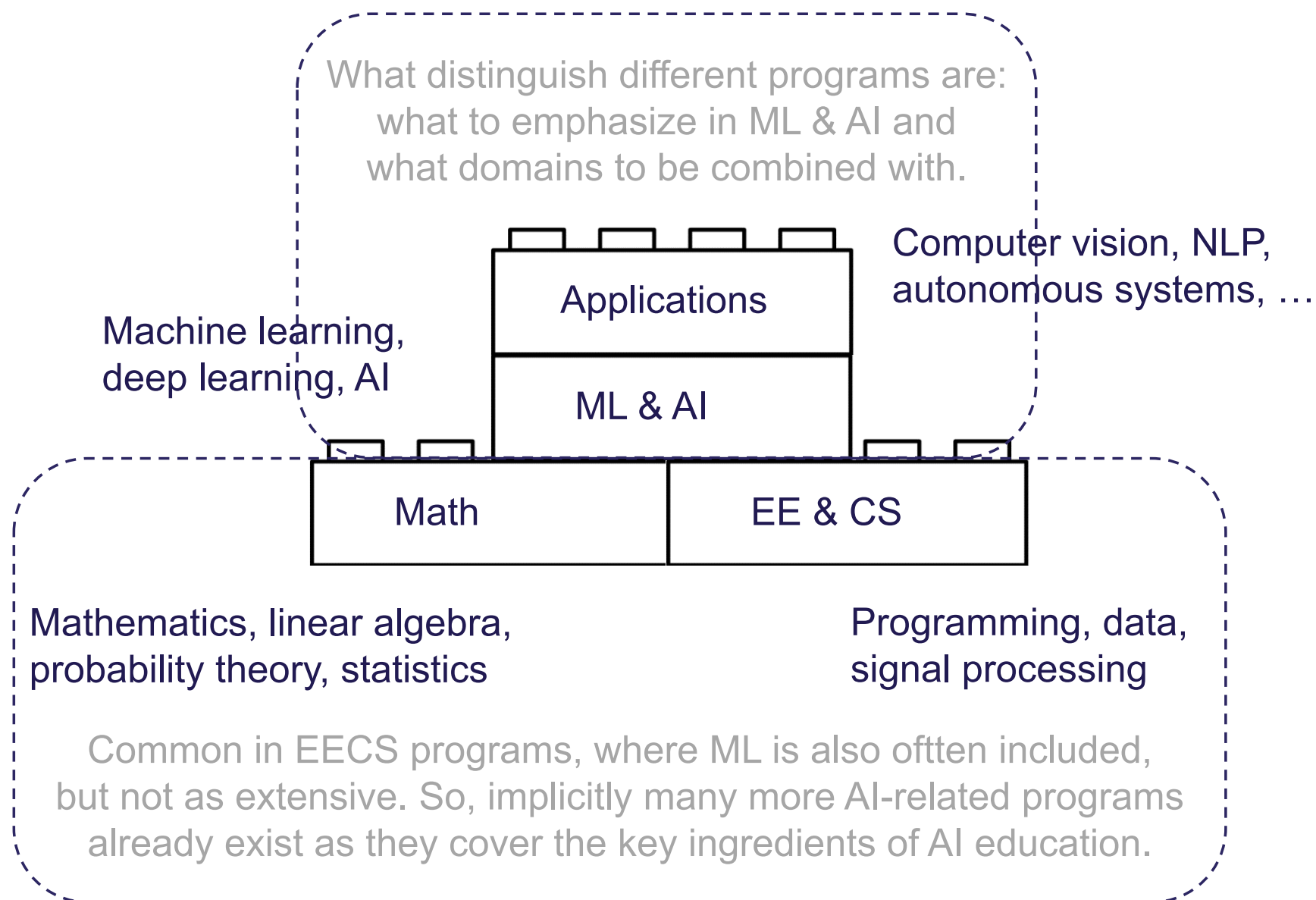# Computation and Cognition (Bachelor) @ MIT – cont'd

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- Machine learning, AI, algorithms, inference
- Programming in Python, programming
- Signal processing, circuits and electronics
- Neuroscience, neuro computation, perception, computational cognitive science
- Computer vision, NLP, ...

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Word cloud of the three curricula (Bachelor)

Word list
1. Learning
2. AI
3. Computer
4. Machine
5. Data
6. Mathematics
7. Programming
8. Statistics
9. Science
10. Vision
11. Algorithms
12. Probability
13. NLP
14. Processing
15. Theory

Categories (manually)
- ML & AI
- Math
- EE & CS
- Applications

Four building blocks in AI curricula (Bachelor)

What distinguish different programs are:
what to emphasize in ML & AI and
what domains to be combined with.

Computer vision, NLP,
autonomous systems, …

Machine learning,
deep learning, AI

Applications

ML & AI

Math

EE & CS

Mathematics, linear algebra,
probability theory, statistics

Programming, data,
signal processing

Common in EECS programs, where ML is also oftten included,
but not as extensive. So, implicitly many more AI-related programs
already exist as they cover the key ingredients of AI education.

Mathematical Modelling and Computation (Master) @ DTU

- Mathematics: Functional analysis, …

- Statistics: Stochastic simulation, multivariate statistics, …

- Computing: High-performance computing, scientific computing, …

- Optimization: Constrained optimization, …

- Technological specialization courses: deep learning, advanced machine learning, machine learning for signal processing, advanced image analysis, computer vision, time series analysis, stochastic adaptive control, advanced modeling, dynamic systems

(https://www.dtu.dk/english/education/msc/programmes/
mathematical_modelling_and_computation)

Mathematical Modelling and Computation (Master) @ DTU – cont'd

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- Another Master program is Human-centered AI at DTU, with a focus on digital media engineering.

(Subjects are grouped and empahsized in different colours.)

Machine Learning (Master) @ CMU

- Machine learning

- Deep learning

- Probabilistic graphical models

- Machine learning in practice

- Convex optimization

- Probability and mathematical statistics

- Elective: deep reinforcement learning, advanced machine learning, NLP, computer vision, algorithms, advanced statistical theory, machine learning for large datasets, …

- Another Master program is AI and Innovation, with a focus on innovation and large-scale AI solutions.

(https://www.ml.cmu.edu/academics/machine-learning-masters-curriculum.html)

Computational Science and Engineering (Master) @ MIT

- Advanced machine learning

- Bayesian modelling and inferences

- Dynamic programming and reinforcement learning

- Statistical learning theory and applications

- Optimization methods

- Numerical methods and simulation

- Stochastic processes

- Computer vision

- NLP

- Quantum computation

(https://cse.mit.edu/programs/sm/)

Word clouds

Bachelor only
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15. Theory

Bachelor + Master
1. Learning
2. Machine
3. Computer
4. Advanced
5. AI
6. Statistics
7. Programming
8. Vision
9. Computing
10. Data
11. Deep
12. Mathematics
13. NLP
14. Optimization
15. Theory

Bachelor

Bachelor + Master

Human-centric AI

Human's roles in AI

- Sources of data (privacy)

- Decision makers for data and model selection (we create AI)

- Users of AI (AI serves us)

- Governance (compilance check)

AI's responsibilities to humans

- Intepretability (observe a cause and effect or predict what to happen if changing an input or parameter)

- Explanability (explain what is happening in human terms; General Data Protection Regulation - GDPR)

- Ethics

- Fairness

Data-centric AI

- AI system   =   Code   +   Data   [1]
                    (model/algorithm)

- Raising the awareness of data importance

- Machine learning operations (MLOps) is an approach to systematically build, test, deploy and monitor ML systems in production to make the process reliable and efficient.

- MLOps is becoming a norm for practitioners in industries.

- Driving forces of this wave of AI: data, algorithms and computing.

- So, computing facilities and IT/ML support, e.g. GPU servers and IT support team (ideally campus level or national level), play an important role in AI education.

[1] A Ng. MLOps: From model-centric to data-centric AI. 2021.

Fast growth of AI – an example

Machine learning track paper submissions @ IEEE ICASSP
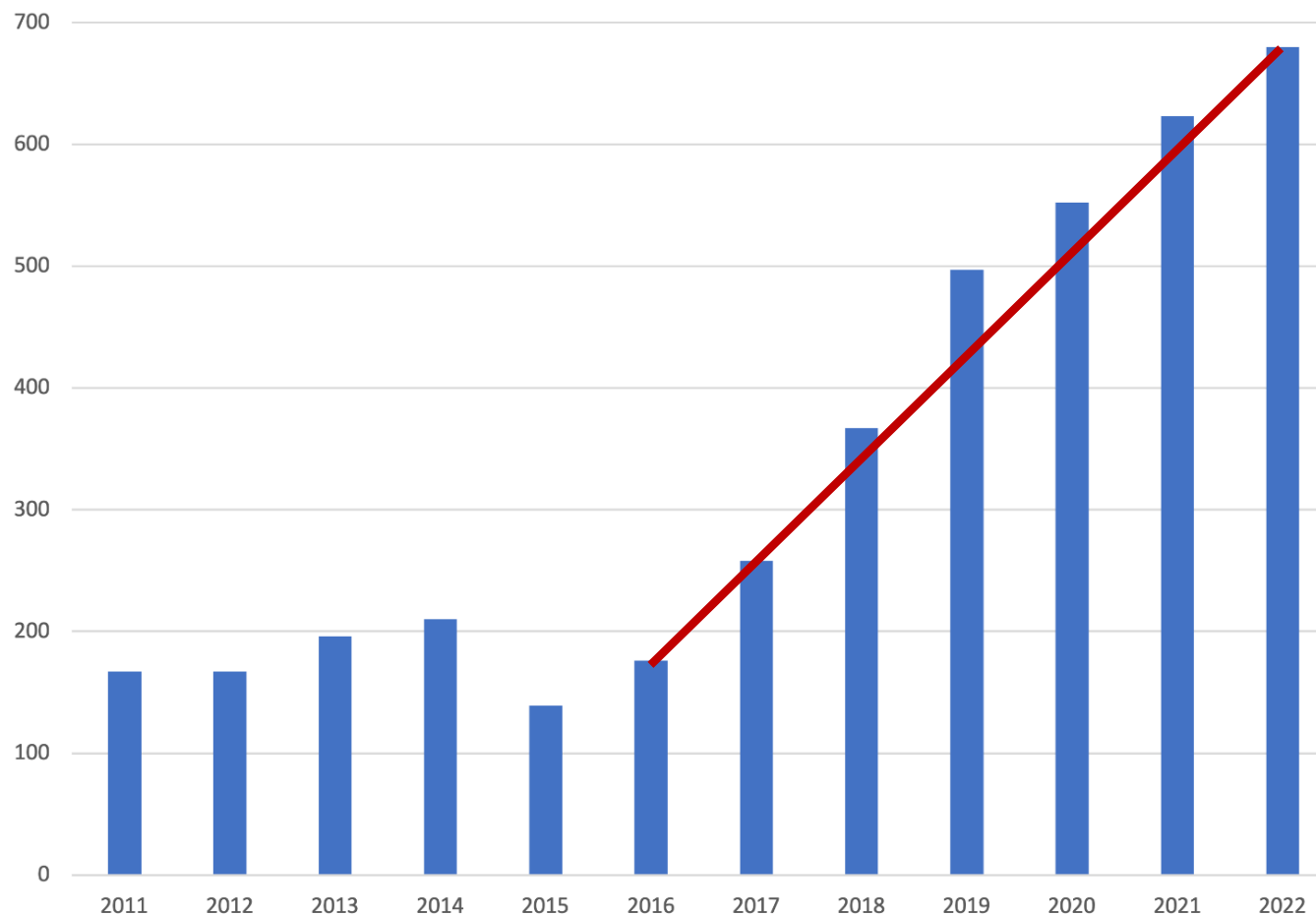
This does not include ML-related paper submissions to other tracks.
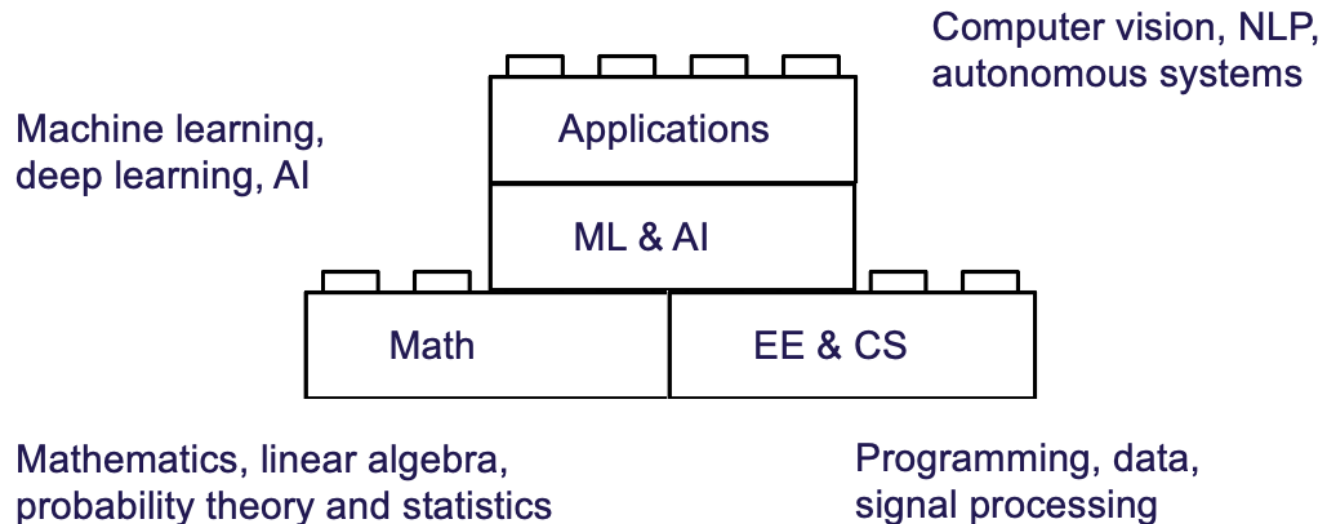
Fast evolvement of AI

ICASSP paper submission in % under Machine Learning track

Agenda

- AI curriculum

- Project-oriented problem-based learning (PBL)

Project-oriented problem-based learning

The Aalborg model of problem-based learning (PBL) [2]

- The model has been applied since 1974 at Aalborg University.

- UNESCO Danish Chair in PBL.

- The objective is to strengthen the students' skills regarding problem identification, problem analysis, problem formulation, problem solving, communication, cooperation and the evaluation of work processes and the quality of their own work.

- The problem is the starting point directing the learning process.

- A problem can be both theoretical and practical.

- A problem must be of relevance and scientifically based, be comprehensive, and can be analyzed and solved.

[2] I Askehave, et al. Problem-based learning. Aalborg University, 2015.

Project-oriented problem-based learning – cont'd

- A time-limited (usually one semester or for Master thesis, optionally two-semester) project is conducted with the problem being phrased, analyzed and solved.
- Courses support the project work (50/50, except for Master thesis projects).
- Students study in groups for the project work, to encourage teamwork.
- The project work is supported by the supervisor(s).
- At the same time, students are responsible for their cooperation, organization, outcome and reflection, so-called project ownership.
- Students write reports for their projects.
- Students are individually examined orally via a presentation and a Q&A session by the supervisor(s) and internal/external censors.

- Many projects are formulated and conducted in collaboration with industries.

Summary

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