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SAPIENZA UNIVERSITÀ DI ROMA

WP2 Webinars – Day 1 – 11st June 2025

Software and tools for active learning in the energy sector

Prof. Giovanni Delibra - Sapienza University of Rome

SILKWAY-development of transver**S**al and susta**I**nab**L**e s**K**ills for the production of electricity and heat from rene**WA**ble energ**Y**
Erasmus+ Project #101179683

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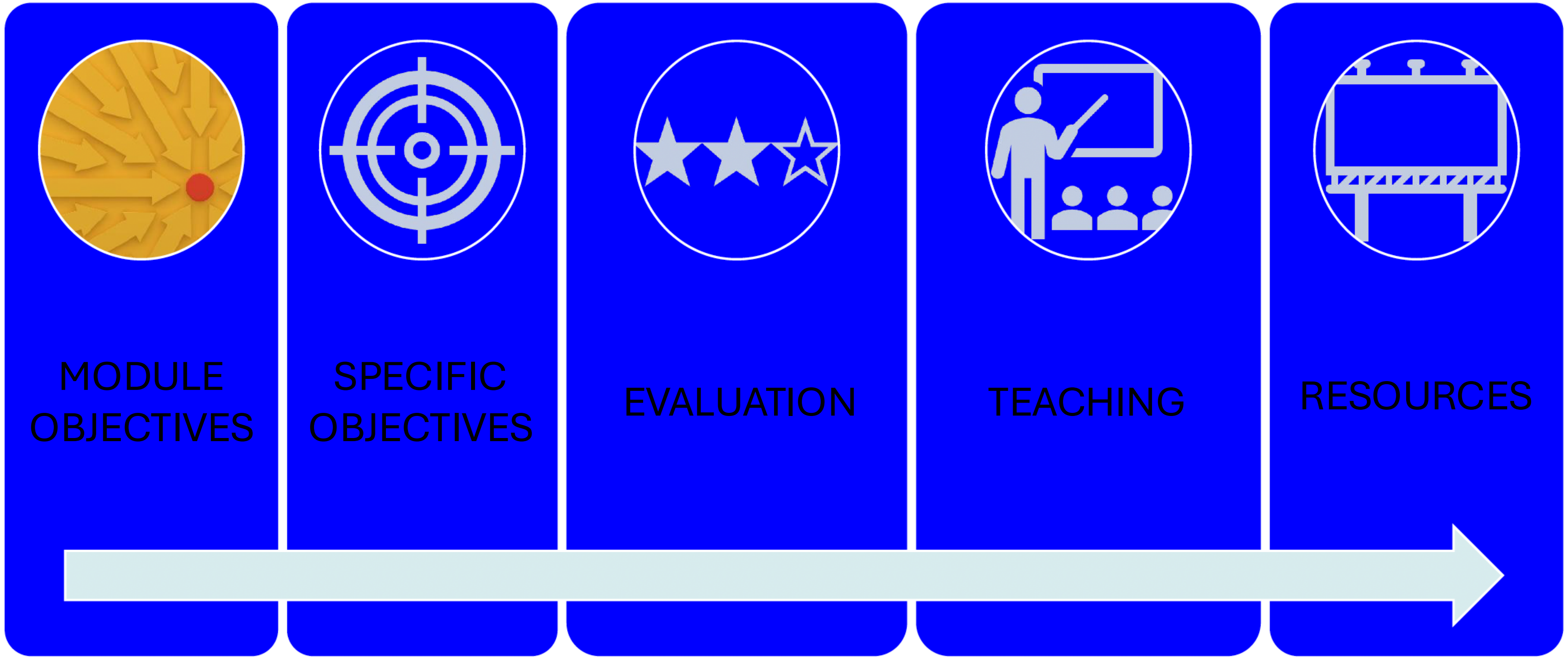
Research topics:

- Renewable Energy Communities
- Design and modelling of turbomachinery and energy systems
- Machine learning methods for turbomachinery and energy systems
- CFD modelling of turbomachinery



John Biggs 2011

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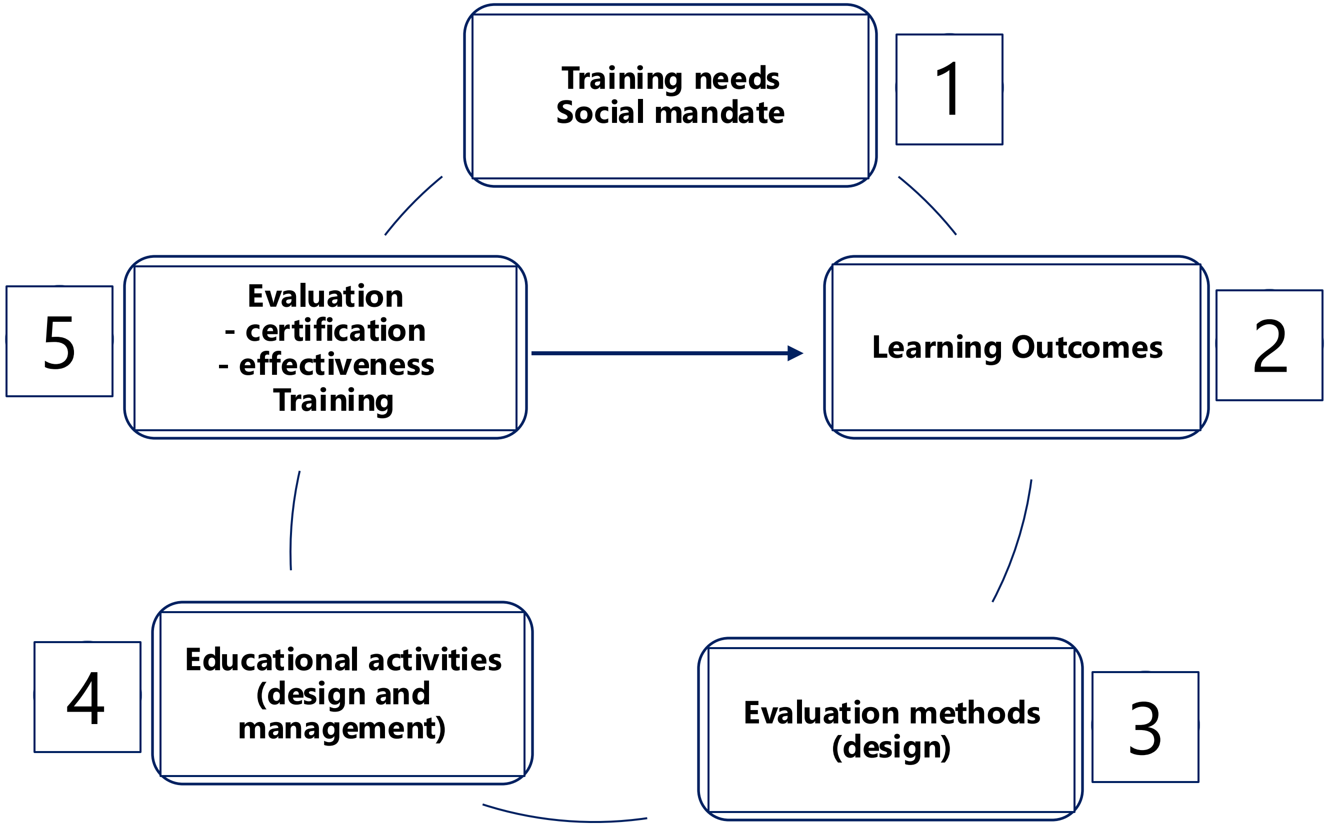
- Identify teaching methods that promote **active learning and engage students** in knowledge production
- Illustrate the relationship between learning outcomes and the choice of teaching practices that promote their achievement
- Reflect on potential difficulties in introducing activities that promote active learning in university teaching
- Propose strategies to overcome obstacles from using active learning practices in university courses.



JJ Guilbert. Guida pedagogica per il personale sanitario. OMS, 2002

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Learning outcomes and design assessment

What method?

Which metric?

How many "measurements"?

DUBLIN DESCRIPTORS

1. **Knowledge and understanding**: listing, defining, describing, correlating and interpreting
2. **Ability to apply knowledge**: choosing, deciding, solving, designing
3. **Making judgements**: evaluating, criticizing, discussing ethical, social, economic implications...
4. **Communication skills**: oral, media, professional, dissemination, education
5. **Learning skills**: life long learning

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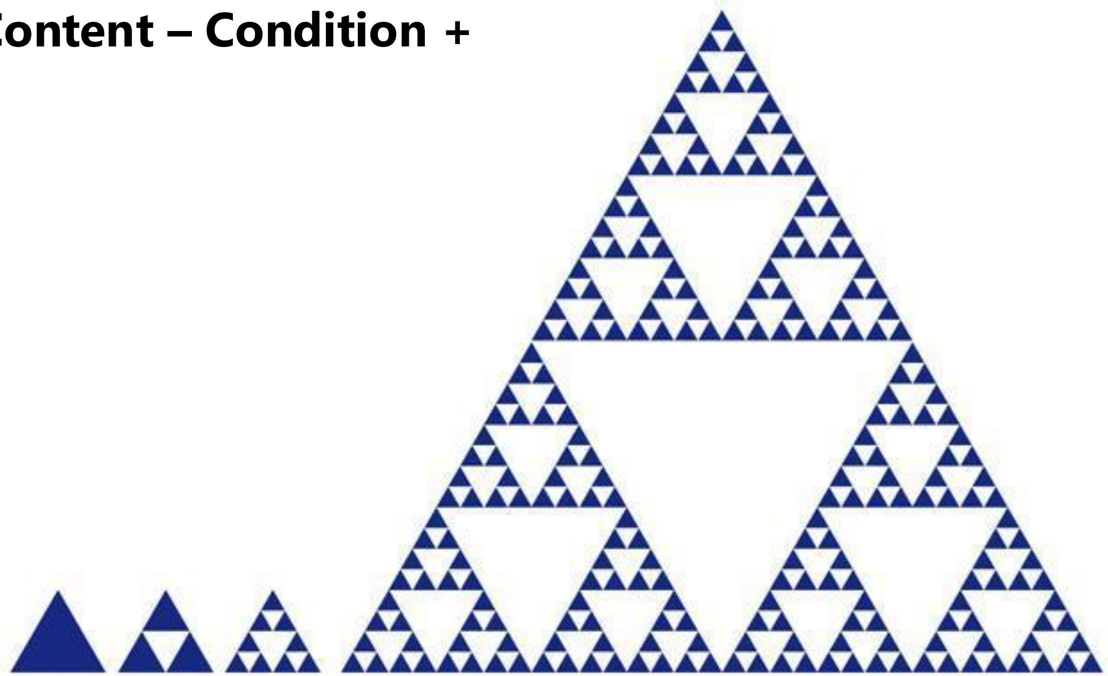
From the logic of content catalogue to fractal design of the modules

A Single Repeated Scheme: Action Verb – Content – Condition + Criterion

A descent from the more complex structure (professional competence) to the simplest (specific learning outcome)



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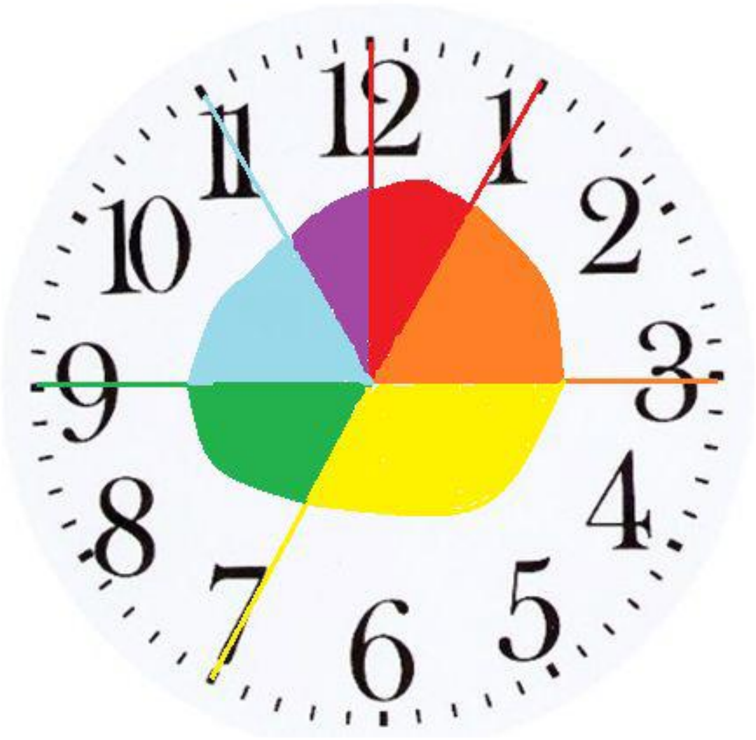
Lectures structure

- What we will do: objective and/or topic and/or activity.
- Warm-up: recalling pre-knowledge from other courses, previous lessons, "flipped" materials, and triggers.
- Teacher speaks: new content.
- Use knowledge: short exercises, individual or group.
- Discuss: feedback and comment on exercises.
- Free: questions, notices, chatter.



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Inquiry-Based Learning

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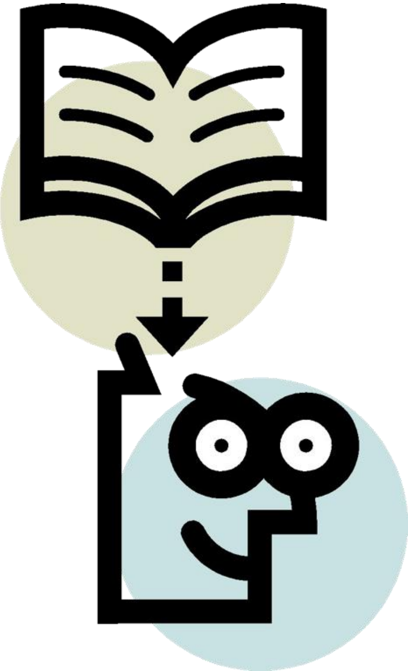
Fundamental Principle



Learning is not a **passive process** but a **dynamic process**

Knowledge results from personal effort by the individual who builds their own

'systems of meaning'

through inevitable interactions with both cultural and historical contexts.

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Inquiry Learning Levels

There are four levels described for inquiry learning activities, each transitioning gradually into the next.

LEVEL	Problem	Procedure	Solution
1° - Confirmatory Inquiry	Defined	Indicated	Known
2°- Structured Inquiry	Defined	Indicated	To find
3° - Guided Inquiry	Defined	To define	To find
4°- Open Inquiry	To define	To define	To find

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Level 1- Inquiry Learning

LEVEL	Problem	Procedure	Solution
1° - Confirmatory Inquiry	Defined	Indicated	Known

What does the student do?

Solved exercises: the students comment on the exercise:

- What type of problem was it?
- Which theory, method, or procedure was applied?
- How did they proceed from the initial data to the solution?
- How generalizable is this example?

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Level 2 - Inquiry Learning (Case-based Learning - CBL)

LEVEL	Problem	Procedure	Solution
2°- Structured Inquiry	Defined	Indicated	To find

What does the student do?

CBL exercises: The student starts with the initial data and should know the type of problem and the procedure:

- Which theory/method/procedure fits this type of problem?
- Solve the problem.

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Integration Strategies for Inquiry Learning - Level 2

Example (ML course):

Predicting Customer Churn for a Telecom Company

Case Scenario:

A telecom company is facing a high rate of customer churn and wants to develop a predictive model to identify customers at risk of leaving. They need insights into factors contributing to churn and actionable recommendations to retain customers.

Steps

1. Case presentation
2. Problem identification
3. Data exploration and analysis
4. Model development
5. Case discussion and solution development
6. Implementation Strategy
7. Presentation and discussion

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Level 3 - Inquiry Learning (Problem-based Learning - PBL)

LEVEL	Problem	Procedure	Solution
3° - Guided Inquiry	Defined	To define	To find

What does the student do?

PBL exercises: The student has initial data but does not know everything they need to understand and make decisions:

- What do you need to know (i.e., what MUST you study) to 'understand' the problem?
- What hypotheses can you formulate to 'explain' the problem?
- [What types of solutions might you propose for the hypotheses made?]

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Problem-Based Learning Introduced in courses and curricula

A student-centered teaching method where learners gain knowledge and skills by working on complex, real-world problems.

Key Features:

- **Student-Centered:** Focuses on students' active involvement in their learning process.
- **Problem as the Starting Point:** Learning is initiated with a problem to be solved, not with traditional lecture.
- **Collaborative:** Encourages teamwork and communication among students.
- **Self-Directed Learning:** Students identify their learning needs, resources, and strategies.
- **Facilitator Role:** Instructors act as guides or facilitators rather than direct sources of information.
- **Integration of Knowledge:** Promotes the integration and application of knowledge across different subjects.

Benefits:

- Enhances critical thinking and problem-solving skills.
- Develops lifelong learning abilities.
- Improves retention and understanding of knowledge.
- Encourages the development of self-directed learning habits.
- Prepares students for real-life scenarios and professional environments.

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Integration Strategies for Inquiry Learning - Level 2

Example (ML course):

Develop a predictive model to forecast housing prices in a metropolitan area

Case Scenario:

A real estate company wants to predict future housing prices based on various factors such as location, size, amenities, and market trends. They need a reliable model to assist in their investment and pricing strategies.

Steps

1. Clarify the terms
2. Define the problem
3. Formulate explanatory hypotheses
4. Prioritize hypotheses in order
5. Identify study arguments
6. Independent study
7. Synthesize the acquired information

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Level 4 Inquiry Learning (Research Activities)

LEVEL	Problem	Procedure	Solution
4°- Open Inquiry	To define	To define	To find

What does the student do?

Research activity: The student must:

- Identify a significant problem (a research question)
- Design an 'investigation,' starting with the method
- Conduct the research and find a result.

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Innovative Methods for Engineering Students

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- Students don't like to listen to lectures or study (!)
- To engage them in the learning process we have tested a strategy that starts from the basic courses at BSc level and becomes more complex as they advance to MSc and work on their final project
- Our courses in Energy for Mechanical and Energy Engineering are structured as follows:

BSc	Year	Topics	Approach	Tools
Energy Systems 9 ECTS	3rd, 1st semester	Steam and gas turbines, hydroelectric power plants, wind energy and photovoltaic	Black box approach: the system is considered and the whole conversion process, not the single components	• **Jupyter notebooks** • **Google Colab** • Matlab
Renewable Energy Communities 6 ECTS	3rd, 2nd semester	RECs and their implementation in Italy and within EU. Electrification of end-use. Time dependant simulation of electricity and thermal energy production and loads. Water-energy nexus	Modelling of RECs with quarter-hour resolution	• pyRES • TRNSYS • Jupyter notebooks • Google Colab

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MSc	Year	Topics	Approach	Tools
Fluid Machinery 9 ECTS	1st, 1st semester	Basic design of turbomachinery	Euler approach for velocity diagrams, stage thermodynamics	• Jupyter notebooks • Google Colab • Matlab
Diagnosics of Energy Systems 6 ECTS	3rd, 2nd semester	Machine learning for predictive maintenance, fault diagnosis and weather forecast for energy systems	Time-series analysis	• pyRES • Jupyter notebooks • Google Colab

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MSc	Year	Topics	Approach	Tools
Advanced Energy Conversion Systems 9 ECTS	1st, 2nd semester	PVs, Wind Energy, Biomass, Fuel Cells	Black Box System Approach	• Jupyter notebooks • Google Colab • Matlab
Green Hydrogen and Chemical Storage 6 ECTS	1st, 2nd semester	Green Hydrogen and Chemical Storage	Detailed Modelling of Green Hydrogen Production and Storage, Fuel Cells and Chemical Processes	• Jupyter notebooks • Google Colab
Turbomachinery Design 6 ECTS	2nd, 1st semester	Detailed TM design	Development of a Python code for design of a specific TM (Wind turbine, Axial Compressor…)	• Jupyter notebooks / Python

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- Our courses in Energy for Mechanical and Energy Engineering are structured as follows:

MSc	Year	Topics	Approach	Tools
Thermal Power Plants 6 ECTS	2nd, 1st semester	Detailed Modelling of Thermal Power Plants	Component Approach Energy and financial metabolism of the system	• Matlab

- The Mechanical and Energy MSc Courses in Sapienza also offer about 12 labs (3 ECTS each) on specific energy related technologies (Wind Energy, Turbomachinery, Biomass… with practical experiences in lab or on software platforms). Students are required to follow at least 2 labs to graduate (not necessarily on energy)

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Example of Exercise on Steam Cycle Condenser

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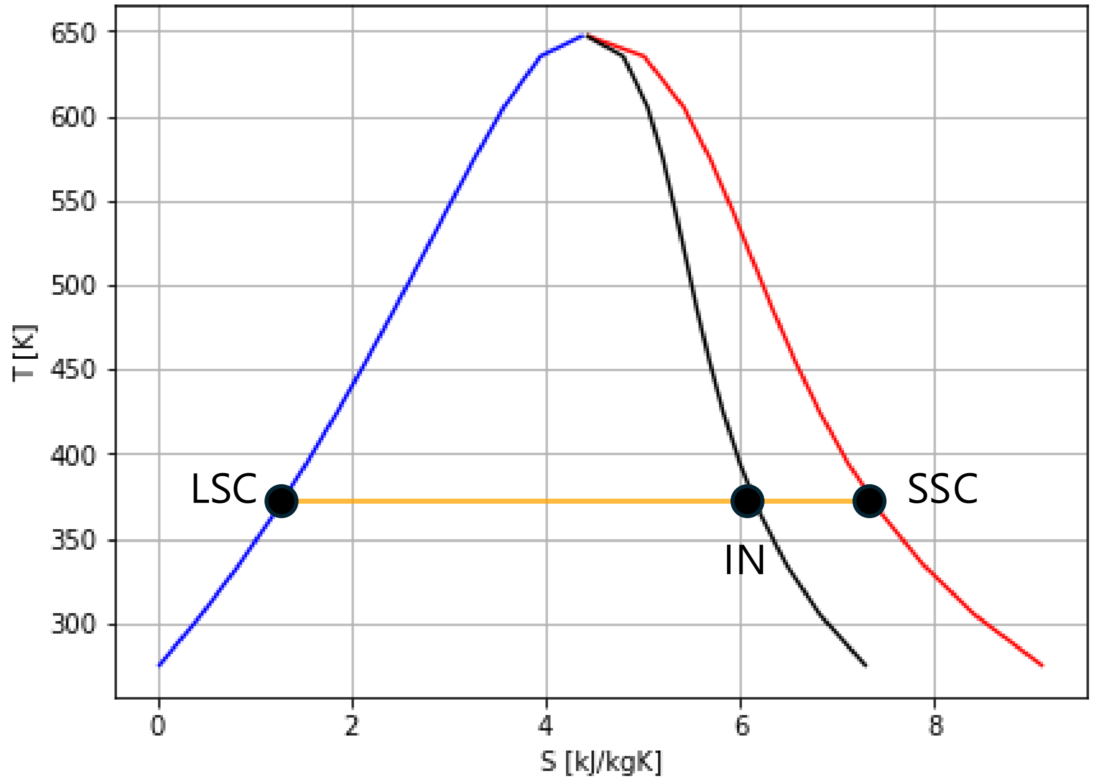
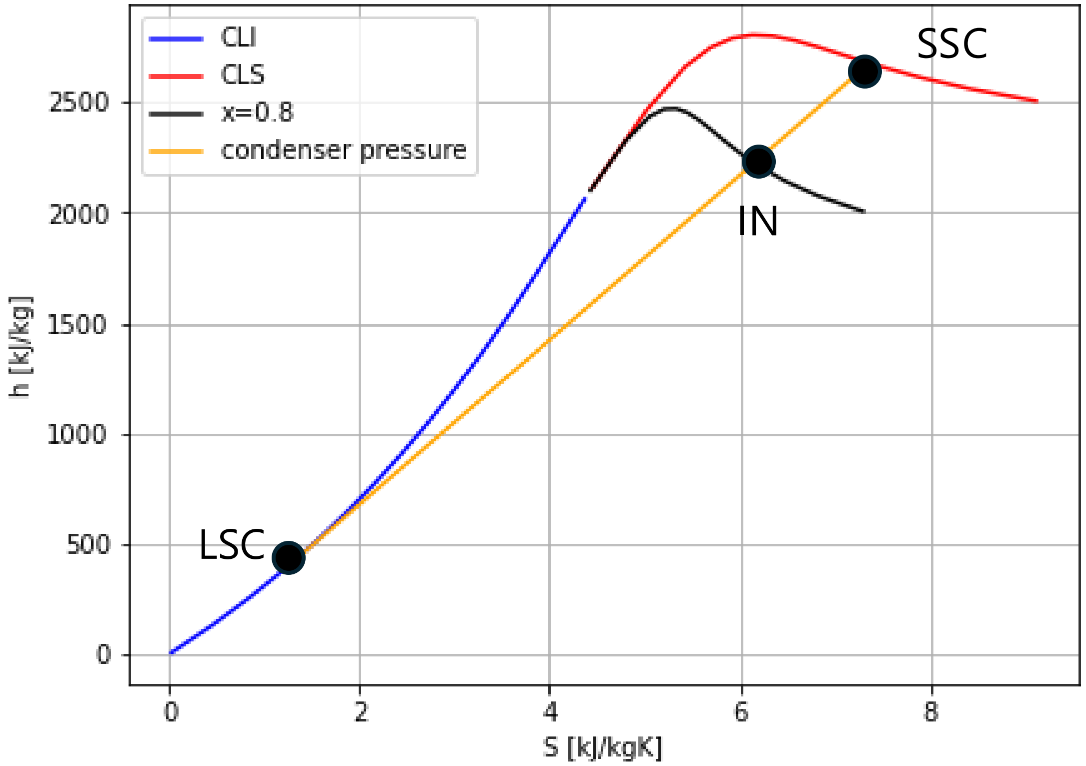
A condenser must condense a mass flow rate of 1t/h of water steam with a steam quality x=0.8 operating at a pressure of 0.1bar

Water at ambient temperature of T=15°C is available as heat sink for condensation

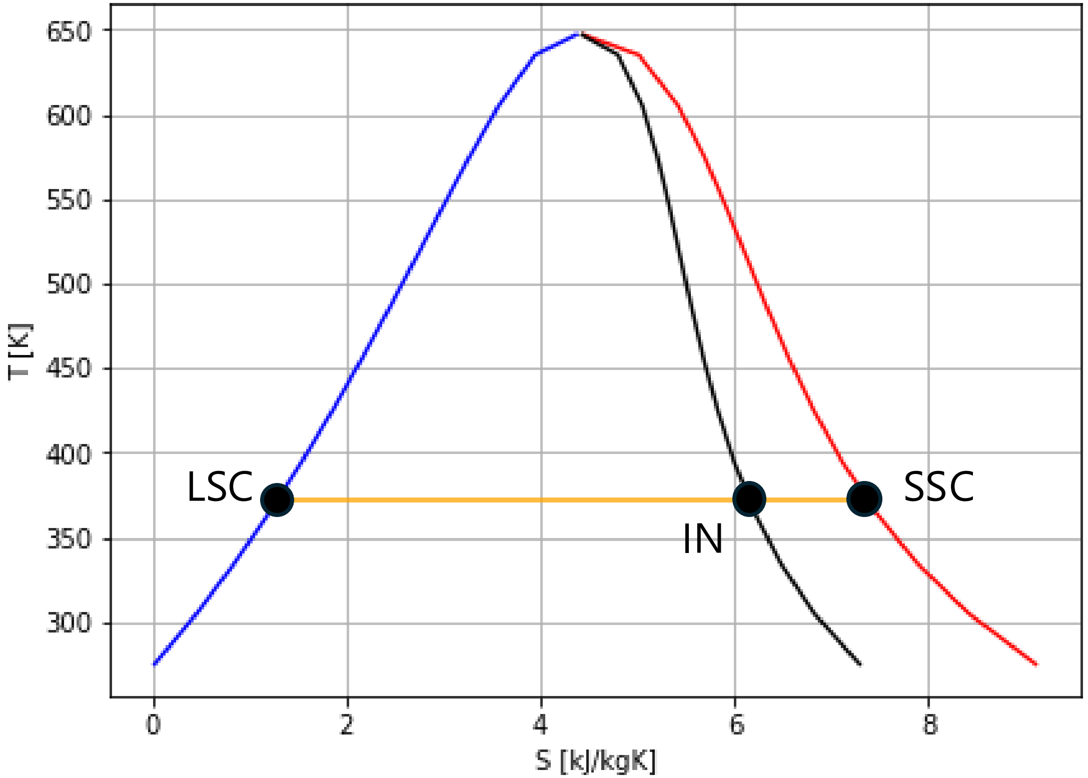
The maximum admissible temperature rise is 10°C

Determine the cooling water flow rate


650
600
550
500
450
400
350
300
T [K]
0
2
4
6
8
S [kJ/kgK]
LSC
IN
SSC


CLI
CLS
x=0.8
condenser pressure
2500
2000
1500
1000
500
0
h [kJ/kg]
0
2
4
6
8
S [kJ/kgK]
SSC
IN
LSC

We apply the first law of thermodynamics to a stationary system (du/dt=0) and without exchange of work and heat with the environnement



$$\sum mh = 0$$

$$m_{H_2O}\,\Delta h_{H_2O} = m_{steam}\,\Delta h_{steam}$$

$$m_{H_2O}\,\mathrm{c_p}\Delta T_{H_2O} = m_{steam}\,\Delta h_{steam}$$

From the steam tables:

$$T_{CON} = T_{sat}(0.1\ bar) = 45.81°C$$

$$h_{LSC}(0.1\ bar) = 191.81\ kJ/kg$$

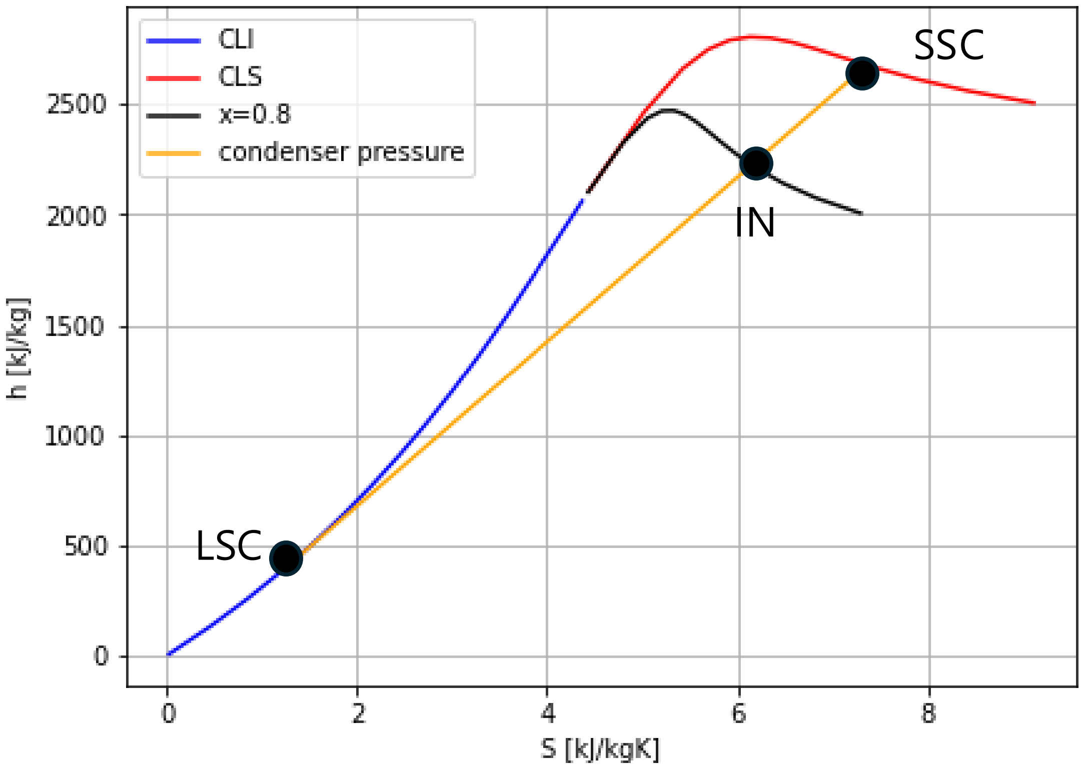
$$h_{SSC}(0.1 bar) = 2583.89\ kJ/kg$$

We apply the first law of thermodynamics to a stationary system (du/dt=0) and without exchange of work and heat with the environnement

$$\sum mh = 0$$

$$m_{H_2O}\,\Delta h_{H_2O} = m_{steam}\,\Delta h_{steam}$$

$$m_{H_2O}\,c_p \Delta T_{H_2O} = m_{steam}\,\Delta h_{steam}$$



From the steam tables:

$$T_{CON} = T_{sat}(0.1\ bar) = 45.81°C$$

$$h_{LSC}(0.1\ bar) = 191.81\ kJ/kg$$

$$h_{SSC}(0.1bar) = 2583.89\ kJ/kg$$

Since the water is in a condition of saturation at the condenser outlet, it is necessary to be careful of the possible cavitation of PE

$$h_{IN} = h_{LSC} + x_{IN}(h_{LSC} - h_{SSC}) = 2105.47\ kJ/kg$$

The thermal power (quantity of heat per unit of capacity) that must be exchanged is therefore:

$$q = h_{IN} - h_{LSC} = x_{IN}(h_{LSC} - h_{SSC}) = 1913.66\ kJ/kg$$

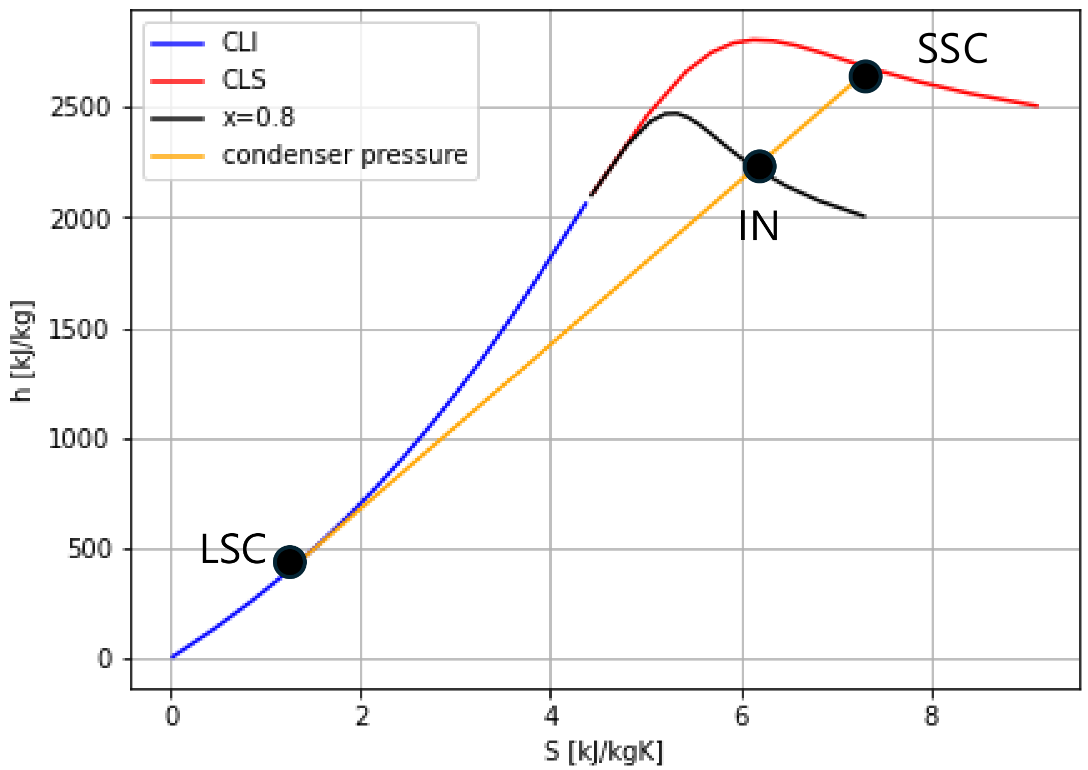
From the enthalpy balance of the condenser:

$$\frac{m_{H_2O}}{m_{steam}} = \frac{\Delta h_{steam}}{c_p \Delta T_{H_2O}} = \frac{q}{4.186 * 10} = 45.71$$

Let's calculate the flow rate of water in the condenser:

$m_{H_2O} = 45.71 * 10\ t/h = 126.97\ kg/s$

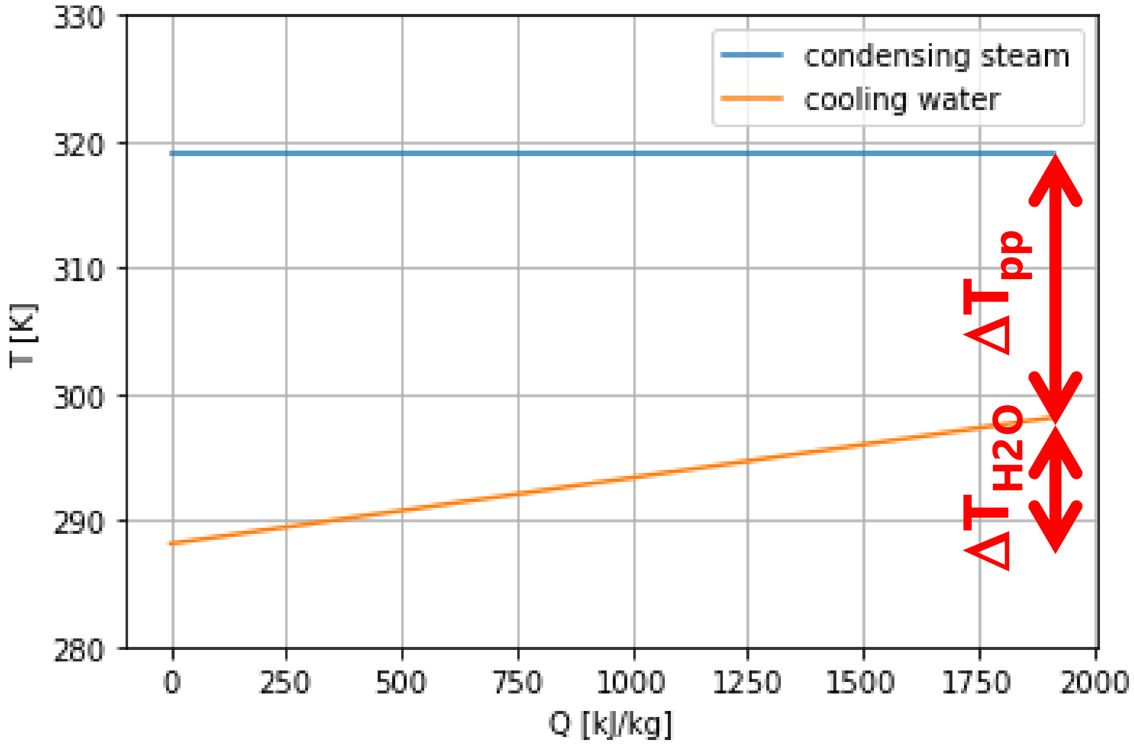
and the amount of heat transferred to the water in the condenser: $Q_{H_2O} = 0.127\ m^3/s$



Finally, we calculate the temperature of the water leaving the condenser and the $\Delta\, T_{pp}$ (see figure):

$$T_{H_2O,out} = 15 + 10 = 25°C$$

$$\Delta T_{PP} = T_{sat} - T_{H_2O,out} = 45.81 - 25 = 20.81°C$$



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- After giving this lecture in a traditional way it’s time to move to the innovative version
- The aim here is to show student not how to solve a simple excercise in class, but how to interact with more modern tools in a more realistic engenering environment
- Bear in mind: they are starting the 3rd year of the BSc and it’s basically one of their first experience with Python calculations

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- Here comes Jupyter…

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What about more complex courses?

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Course Description

The **Turbomachinery Design** course aims at:

- discussing advanced turbomachinery design strategies, involving loss mechanisms within different TM
- derive an iterative design strategy for a specific TM class
- implement this strategy in a Python environment and design a specific TM working in a group of 4-5 students
- Write a technical report on the work done
- Present the work to a panel of experts and peers

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Learning objectives:

- To understand the thermo-fluid dynamic principles that govern the operation of turbomachinery
- To understand how to select the most suitable machine for a given design point and estimate its efficiency by applying dimensional analysis methods and the theory of similarity
- To understand how to size a machine through a series of design algorithms that implement Euler's theory for preliminary sizing
- To understand the typology of losses in turbomachinery to implement a design performance estimation in a real operating conditions
- To understand how optimization algorithms work
- To be familiar with the types of instabilities that occur in machines: rotating stall, pumping, choking, cavitation...
- To implement the design procedure of a selected turbomachinery in a Python environment as an annual project for the course
- To learn how to present one's project to peers and in front of a panel of reviewers
- To learn how to write a technical report on the annual project

Assessment

- The Final Project consists of designing a machine up to the definition of a prototype geometry (provide a CAD model of the device)
- The work is carried out in groups of 4-5 people and includes various stages of progress, identified year by year and described in the course program.
- The project includes the assignment of a score up to 100%
- The oral exam consists in the presentation of your project to a panel of experts (professors, researchers, stakeholders from industry) and a panel of your peers.
- During the presentation, each group is required to listen to the presentations of the others and ask at least one relevant question.
- The presentations are competitive and the final score will be determined by your presentation, your technical report and your capability of pointing out weak elements in your peers presentations.

Project partners

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Jalal-Abad State University
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URGANCH DAVLAT UNIVERSITETI URGENCH STATE UNIVERSITY

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