Bridging the gap between industry 4.0 and Academia

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Outline

- University curriculum and industry requirements
- European Federation of Chemical Engineering (EFCE) Bologna recommendations
- Digitalization of curriculum design
- Digital pedagogy
- Higher order Thinking : Making Judgement, Communication & Lifelong learning
- Conclusion

University curriculum and industry requirements

University

- Fundamentals based
- Process focused
- Research oriented
- Mathematical modelling & Simulation
- Study abroad, Internship, student exchange
- Skill development
- Start-up incubator and cohort programs
- Continuing education

Industry 4.0

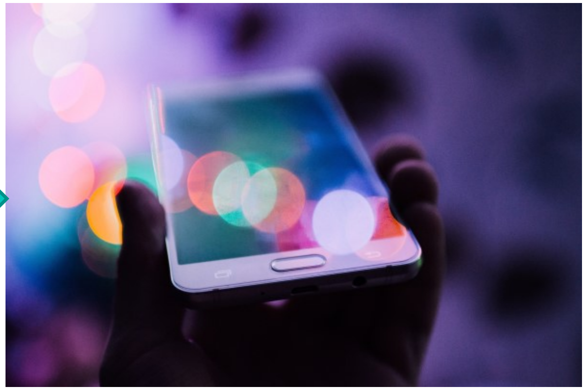
- Molecules based
- Product focused
- Practical application oriented
- Multiphysics Modelling & Simulation in AR/VR
- Data science & AI (Modern Digital tools)
- Multi-disciplinary knowledge and skills
- Sensors, Controls, IOT & Cyber Security
- Programming skills & Soft PLC
- Operator Training Simulators (OTS)

EFCE Bologna recommendations 2020

- EFCE a guide for shaping chemical engineering degree programmes recommends that chemical engineering programmes include **international experience** and **industrial practice**, which complement classroom and laboratory work, **digital exercises** and **(group) projects** at the university or other higher education institutions.
- "**More research oriented** ” and “**more application-oriented**” chemical engineering programmes and to include the knowledge of “**product engineering**” more extensively in the common core.
- Explore new teaching methods for the current generation of “**digital native"** students, **digital methods and tools** require updates within university curricula.
- **International Experience**, foreign language and **industrial experience** by immersing students into **real-world settings**.
- Problem solving, critical thinking, and other higher order thinking skills are improved in **non-academic settings**.

Digitalization of curriculum design

- Digitization, Digitalization, and Digital Transformation
- Computer-assisted tools
- AR /VR
- Studio-based Learning
- Inquiry-based learning (IBL)
- Higher order thinking

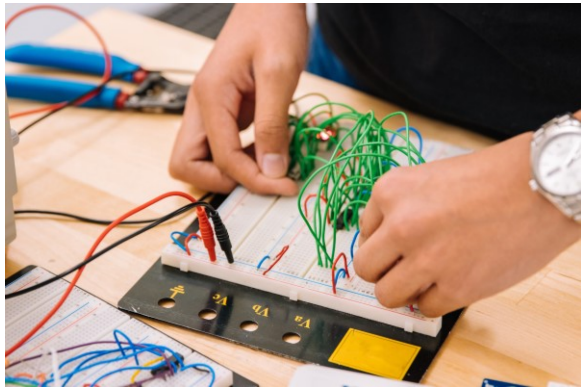
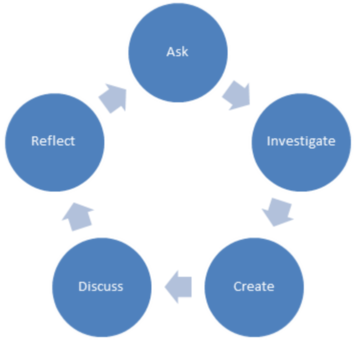




Image Source: https://unsplash.com

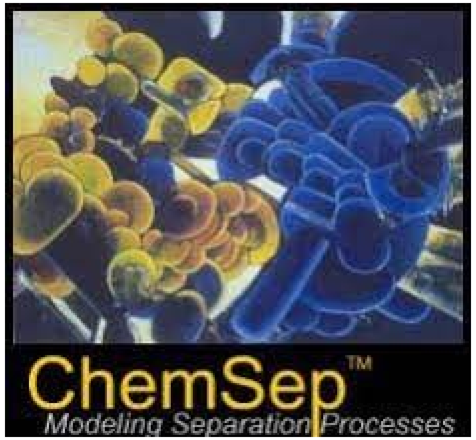
Digital pedagogy

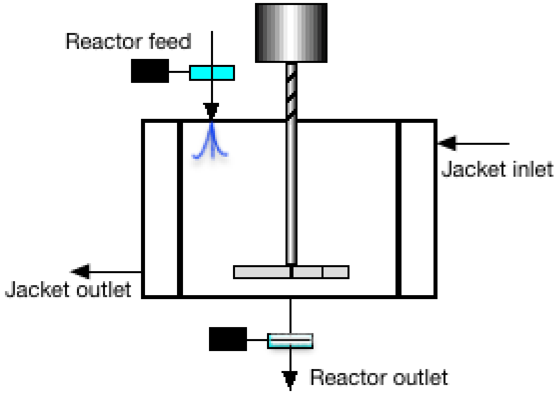
Mathematical modelling

Project/ Problem based learning

- **Scripting language**: MATLAB, R, Python, SAGE...
- **Symbolic software tools:** Mathcad, Wolfram Mathematica
- **Mathematical modelling**: Excel, Mathcad, Polymath..
- **Process Simulation:** ASPEN **+**/HYSYS, CHEMCAD, ChemSep...
- **CFD**: COMSOL Multiphysics, ANSYS FLUENT, STAR-CCM+…
- **Apps**: Matlab Apps, COMSOL Simulation Apps...
- **Scenario building:** Real-world problem-based scenarios, Open ended problems, What-if ?...

Digital pedagogy





Digital Modelling & Simulation

Virtual laboratory

Virtual Labs
An MoE Govt of India Initiative

ChemCollective

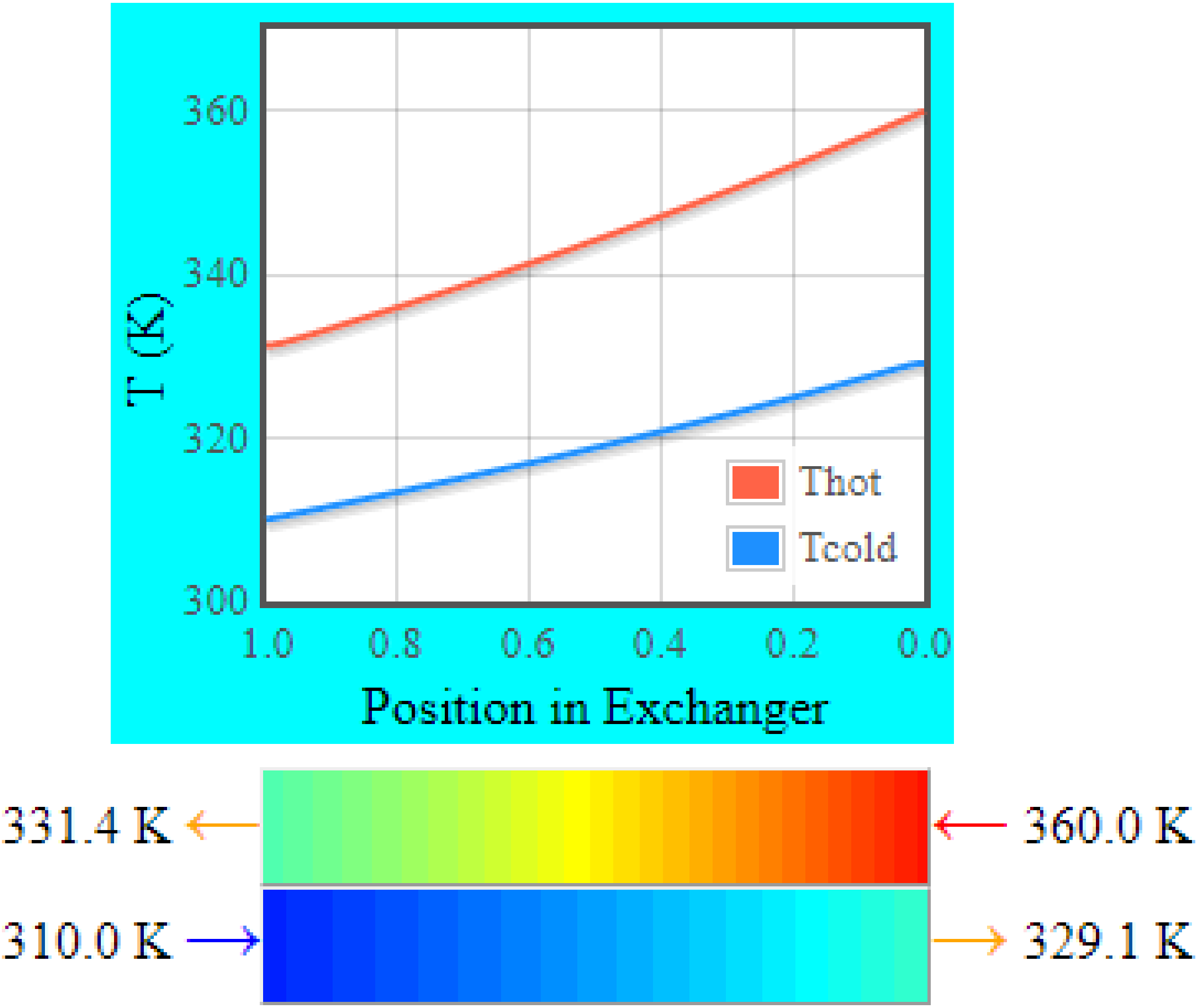
DWSIM
Chemical Process Simulator

LearnChemE

Image Source: Google images

Click the Run button to start. Change an input value, then hit the Enter key or click out of the field. More info

Pause Reset



Copy Data

- (selected) counter-current flow
- co-current flow

T in hot (300-380 K)	360
T in cold (300-380 K)	310
Flow hot (0.15-4 kg/s)	0.5
Flow cold (0.15-4 kg/s)	0.75
Cp hot (1-10 kJ/kg/K)	4.2
Cp cold (1-10 kJ/kg/K)	4.2
U (0-10 kW/m^2/K)	0.6
Area (1-10 m^2)	4
tube diam (0.02-0.20 m)	0.15

L (m) = 8.5 $Re_{hot\text{-}tube}$ = 8488

Source: https://reactorlab.net/

The effect of lagging a cylindrical pipe

l = 1 m

r_1 = 0.005 m

r_2 = 0.007 m

r_3 = 0.016 m

Θ_{in} = 80°C

Θ_{out} = 15°C

h_{in} = 1000 W/(m²K)

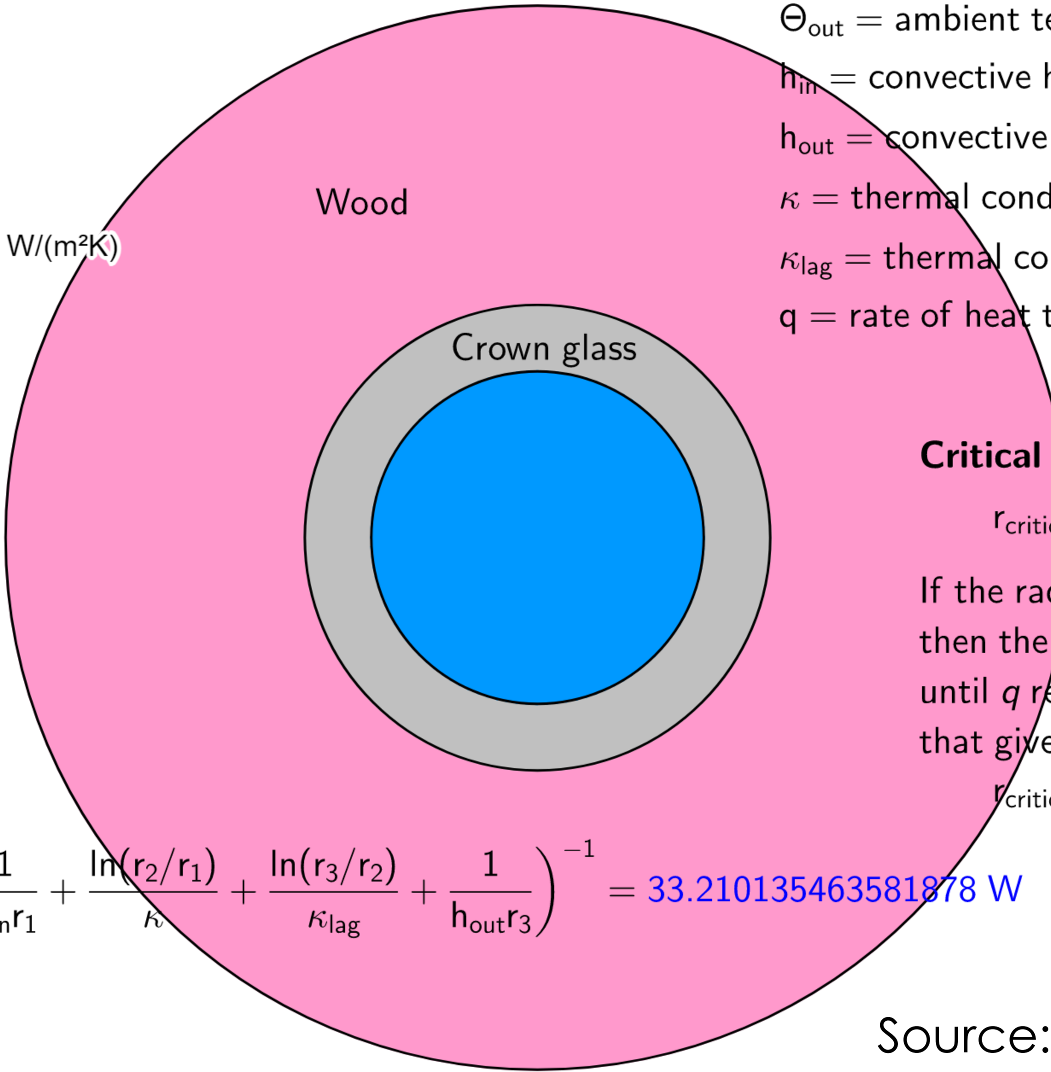
h_{out} = 10 W/(m²K)

κ = 1 W/(m²K)

κ_{lag} = 0.15 W/(m²K)

☑ Legend

☑ Text



l = length of a cylindrical pipe [measured in m]

r_1 = inner radius [m]

r_2 = outer radius [m]

r_3 = outer radius [m] of the lagged pipe

Θ_{in} = ambient temperature inside the pipe [in °C or in K]

Θ_{out} = ambient temperature outside the pipe [in °C or in K]

h_{in} = convective heat transfer coefficient at the inside of the pipe [in W m^{-2} K^{-1}]

h_{out} = convective heat transfer coefficient at the outside of the pipe [in W m^{-2} K

κ = thermal conductivity of the material the pipe is made of [in W m^{-1} K^{-1}]

κ_{lag} = thermal conductivity of the material used to lag the pipe [in W m^{-1} K^{-1}]

q = rate of heat transfer by conduction and convection through a lagged pipe [in W

Critical radius of insulation :

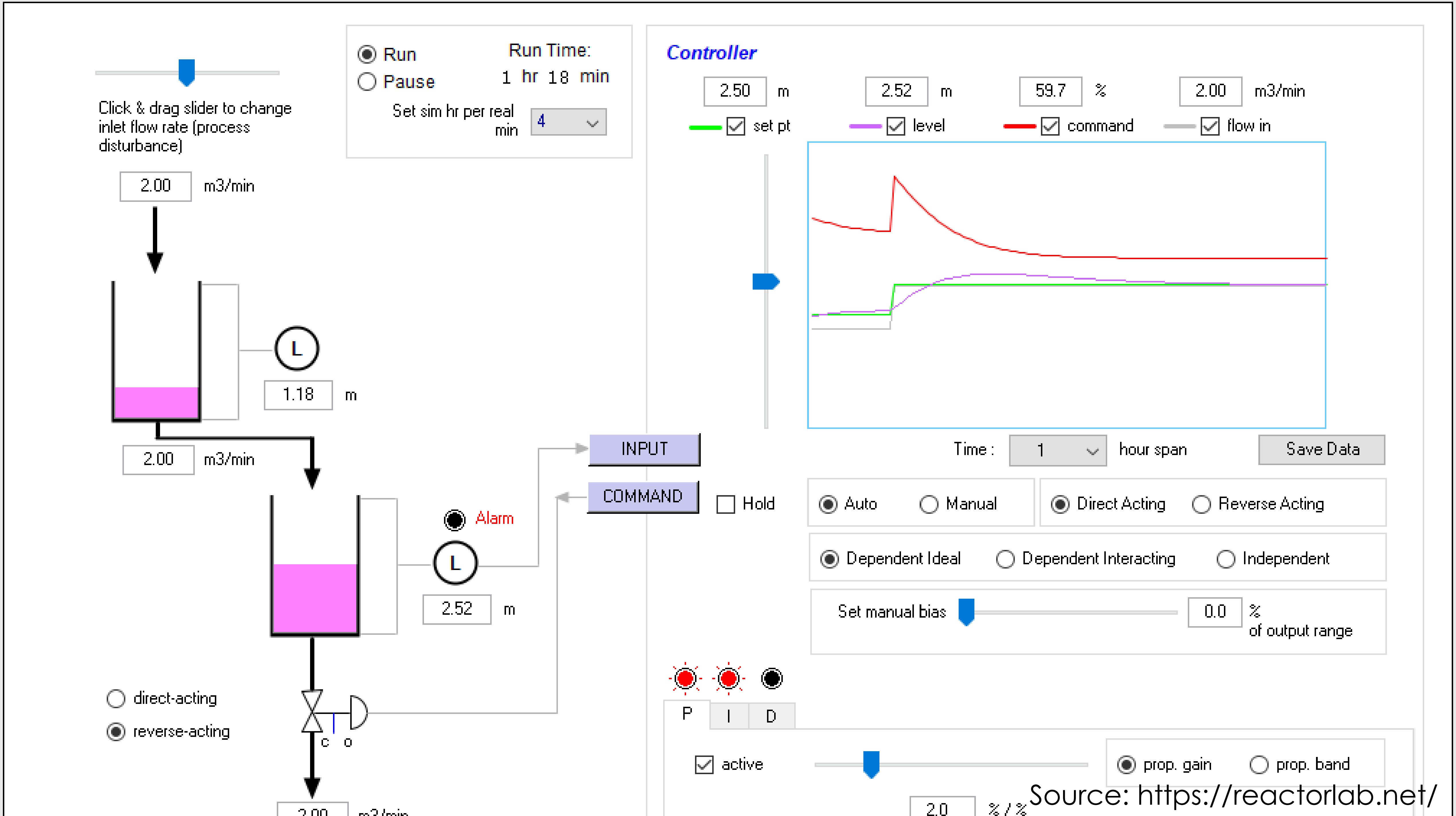
$$r_{critical} = \frac{\kappa_{lag}}{h_{out}} = 0.015 \text{ m}$$

If the radius of the unlagged pipe is less than the critical radius, then the heat transfer rate *q* increases with the addition of lagging, until *q* reaches a maximum at $r_{critical}$. So the thickness of lagging that gives the maximum rate of heat energy loss is

$$r_{critical} - r_2 = 0.008 \text{ m}$$

$$q = 2\pi l(\Theta_{in} - \Theta_{out})\left(\frac{1}{h_{in}r_1} + \frac{\ln(r_2/r_1)}{\kappa} + \frac{\ln(r_3/r_2)}{\kappa_{lag}} + \frac{1}{h_{out}r_3}\right)^{-1} = 33.210135463581878 \text{ W}$$

Source: https://www.geogebra.org/m/myvf3nme

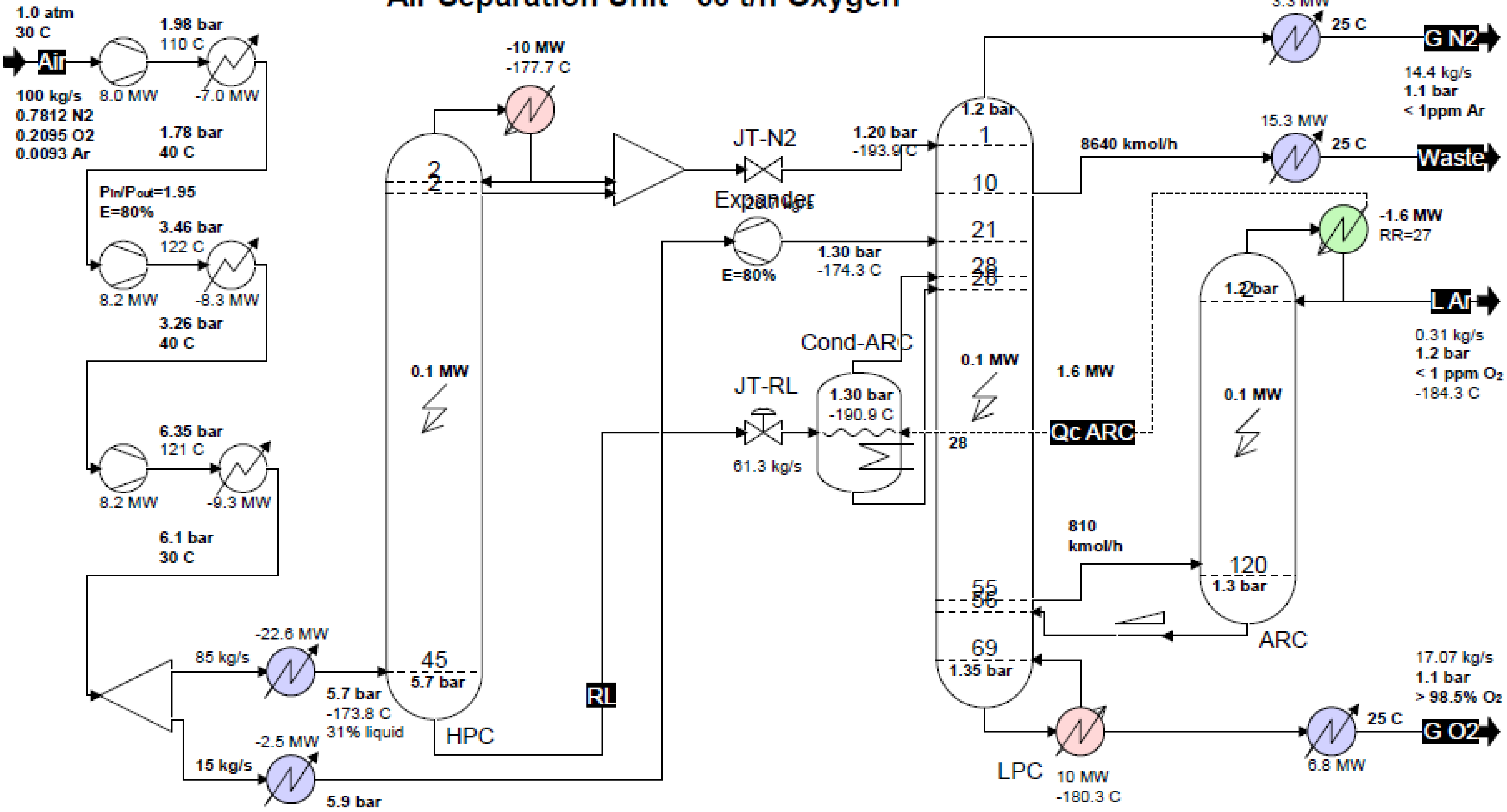


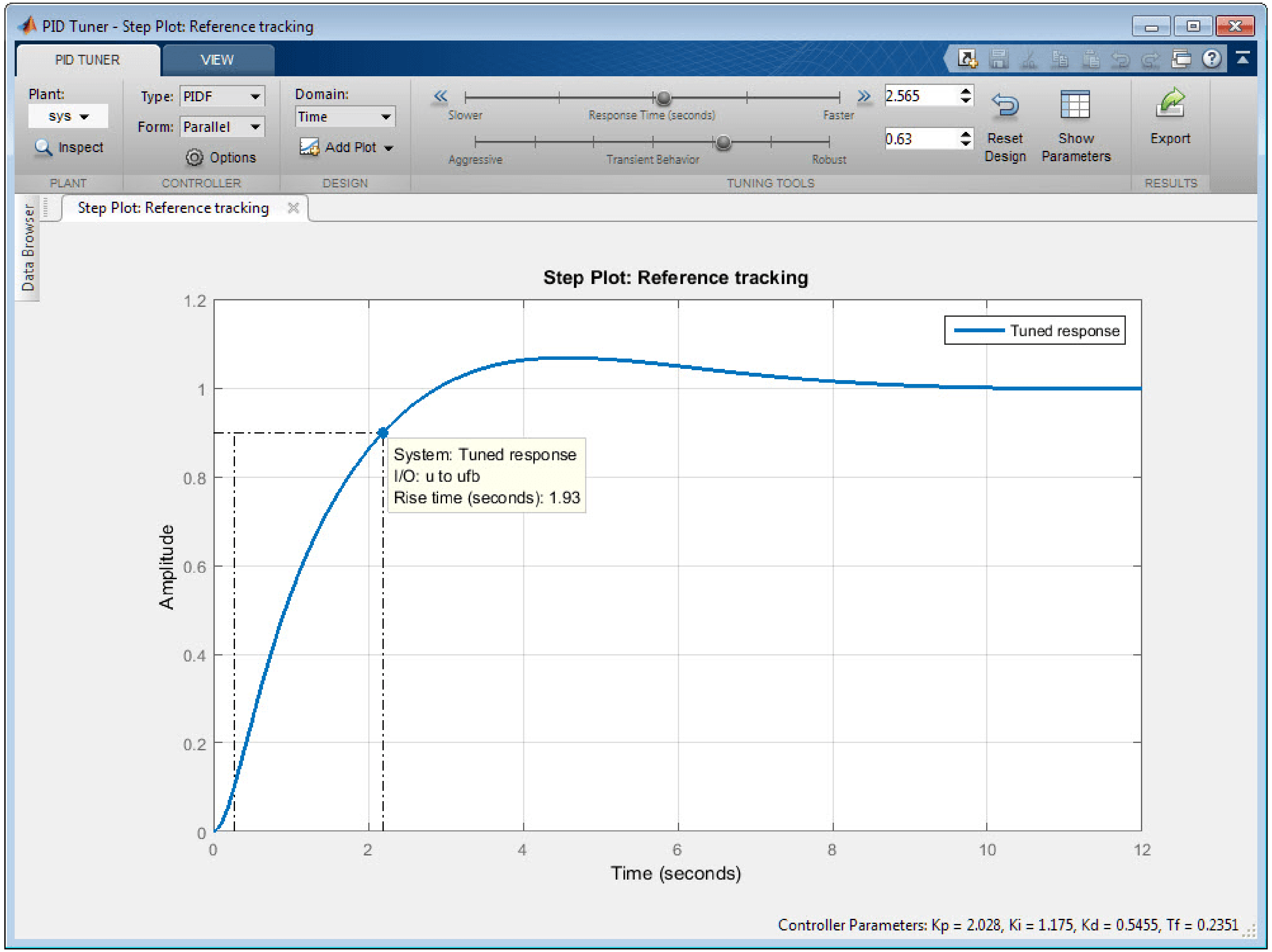
Source: https://reactorlab.net/

```
# Polymath  Example 1 - Heat Exchange in a Series of Tanks
d(T1)/d(t) = (W * Cp * (T0 - T1) + UA * (Tsteam - T1)) / (M * Cp) # Temperature in the first tank (deg. C)
d(T2)/d(t) = (W * Cp * (T1 - T2) + UA * (Tsteam - T2)) / (M * Cp) # Temperature in the second tank (deg. C)
d(T3)/d(t) = (W * Cp * (T2 - T3) + UA * (Tsteam - T3)) / (M * Cp) # Temperature in the third tank (deg. C)

# The explicit equations
W = 100 # Feed flow rate (kg/min)
Cp = 2.0 # Heat capacity (kJ/kg -deg. C)
T0 = 20 # Feed temperature (deg C)
UA = 10. # Area*heat transfer coefficient (kJ/min *deg C)
Tsteam = 250 # Temperature of steam (deg. C)
M = 1000 # Total mass in a tank (kg)

# Initial values of the differential variables
T1(0) = 20
T2(0) = 20
T3(0) = 20

# Initial/final values of the independent differentiation variable
t(0) = 0
t(f) = 200
```

Source: Polymath

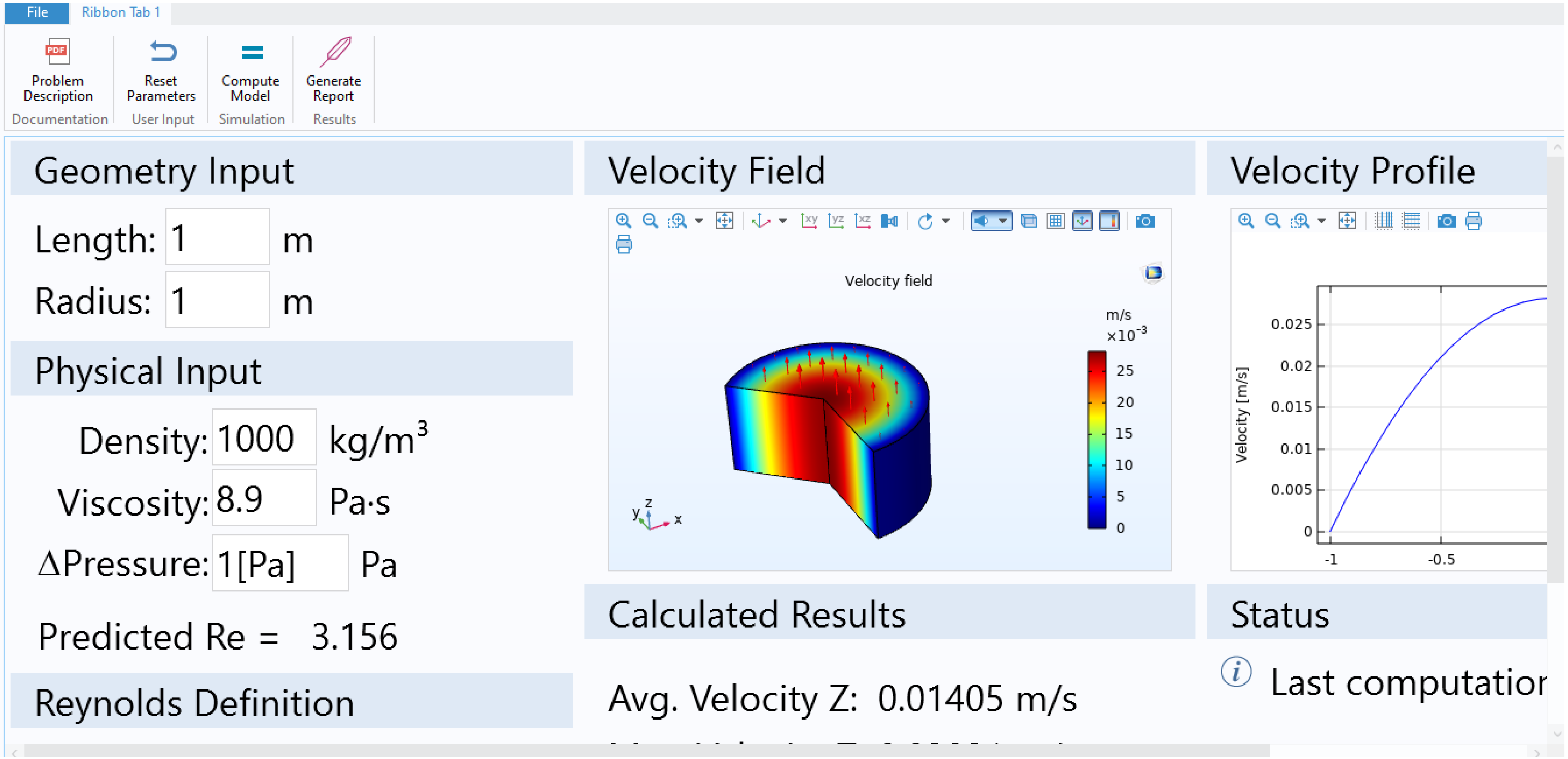
Air Separation Unit - 60 t/h Oxygen





MATLAB APPS

Source: https://in.mathworks.com/help/control/ref/pidtuner-app

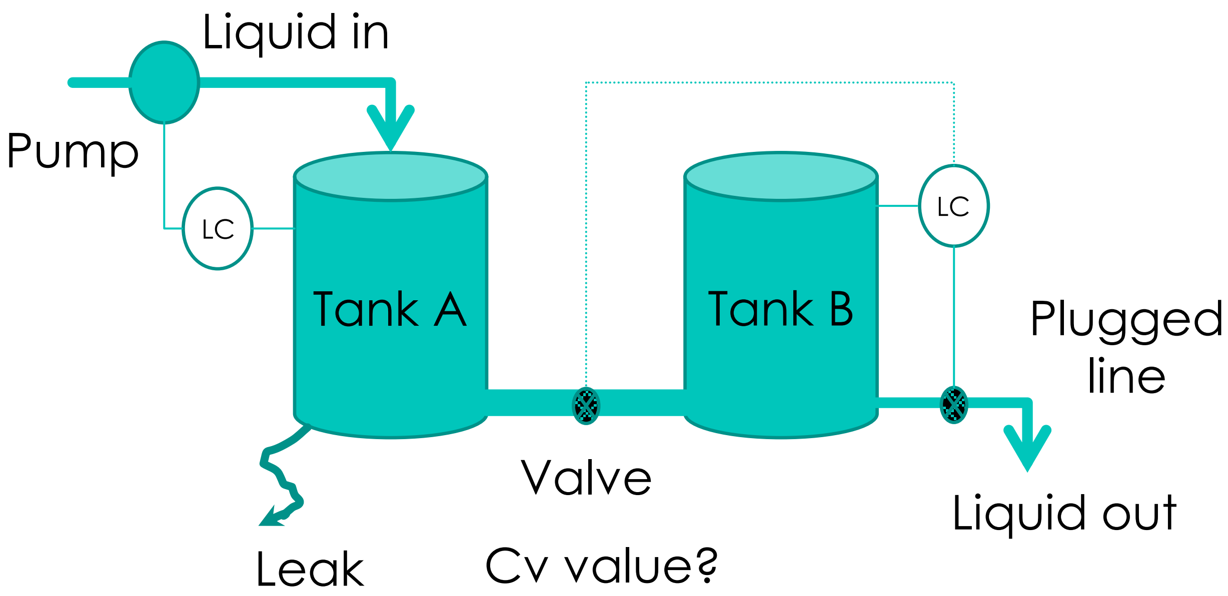


COMSOL APP

Source: https://web.njit.edu/~rvoronov/comsol-apps

Digital pedagogy

Project/Problem based learning



$$h_A(t) = \frac{1}{A}(q_P(t) - q_l(t) - q_i(t))$$

$$h_B(t) = \frac{1}{A}(q_i(t) - q_o(t))$$

$$q_i(t) = c_i sign(h_A(t) - h_B(t))\sqrt{|h_A(t) - h_B(t)|}$$

$$q_o(t) = c_o\sqrt{h_B(t)}$$

$$q_P(t) = S_{LC} - q_P$$

$$q_l(t) = c_l\sqrt{h_A(t)}$$

- Adding Complexities in the process

Digital pedagogy

Programming and coding skills

Field instrumentation

IT Competencies

Apps: COMSOL, MATLAB, ANSYS

Image Source: Google images

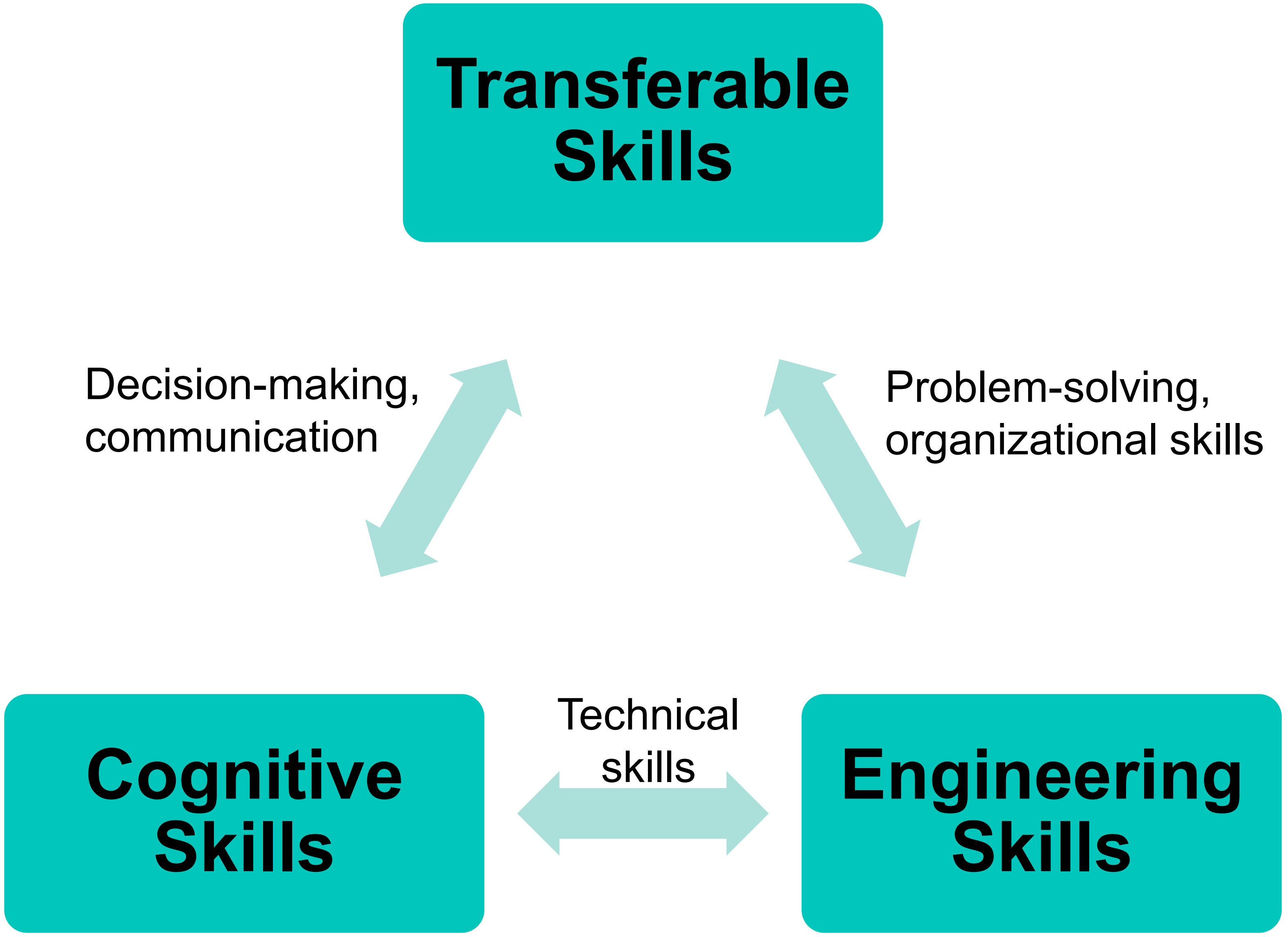
Higher order Thinking

- **Making judgement**
- **Communication**
- **Lifelong Learning**

- Service Learning
- Industry-Academia collaboration
- Internship
- Start-up Accelerator
- Lifelong learning skills


TECH-ED


WASHING / DRYING UNIT


Transferable Skills
Decision-making, communication
Problem-solving, organizational skills
Cognitive Skills
Technical skills
Engineering Skills

Source: EFCE

Industry-Academia collaboration

Imperial college London & ABB

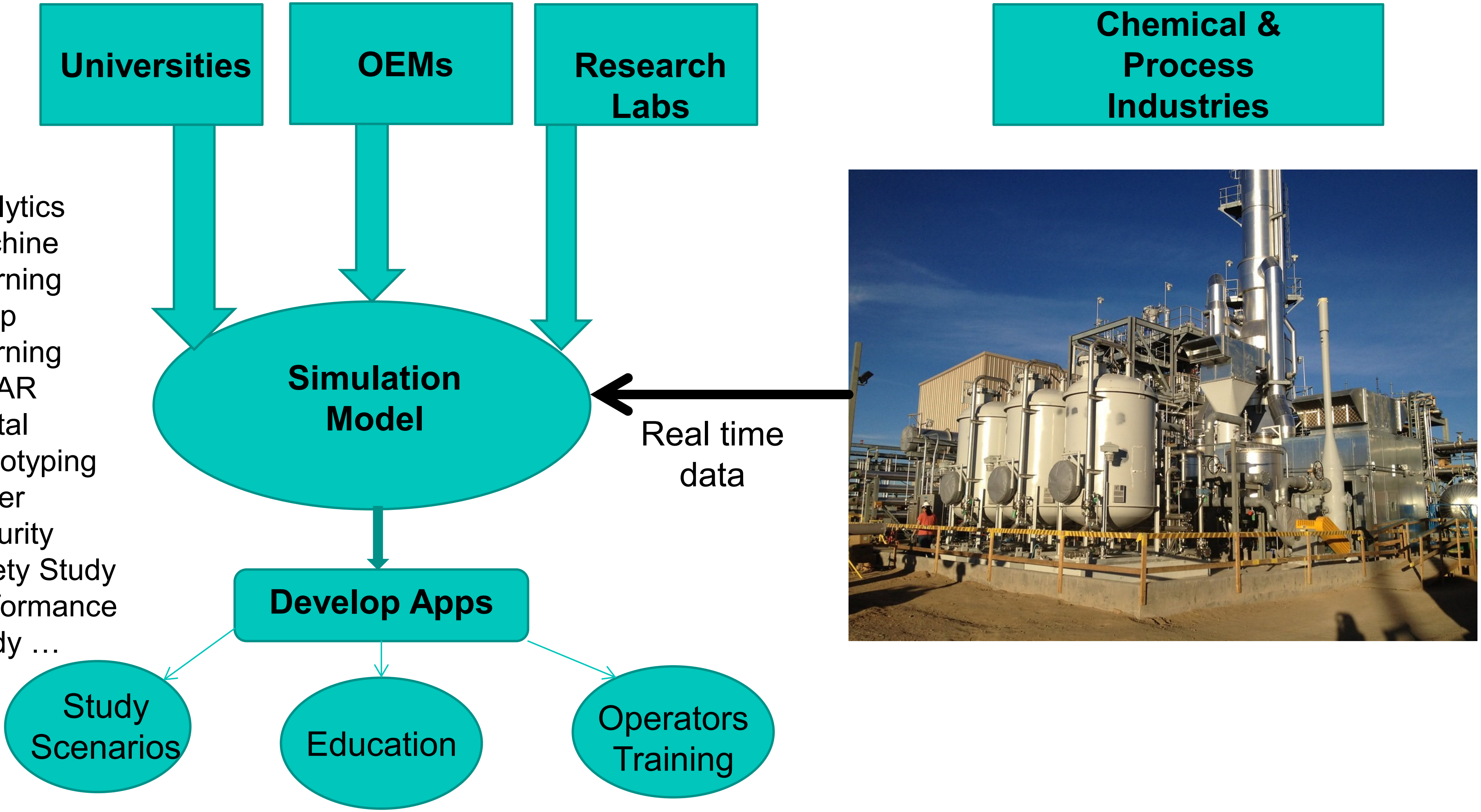
Carbon Capture Pilot Plant

Source: ABB

Internship & Start-up incubator

- A well-structured internship of 3-6 months with joint evaluation of institutional lecturer and industry supervisor .
- Expose students to live projects and how engineering theories are applied in real life situations and progressively the student will gain skills in project management, planning, software skills, design, site visits, evaluation and reporting to senior management.
- Start-up incubator and cohort programs are excellent process of bridging industry practices and higher education in the area of innovation, product development, digital business model etc.

- AI
- Analytics
- Machine Learning
- Deep Learning
- VR/AR
- Digital Prototyping
- Cyber Security
- Safety Study
- Performance Study …



Conclusion

- **Increase Academia-Industry Collaboration:** Employability skills, Innovation and demand-oriented education system.
- **Digital Curriculum Design & Pedagogy:** Digitization, Digitalization, and Digital Transformation.
- **Higher order thinking:** Studio/ Problem/ Inquiry based learning, Agile methods, Design thinking, Digital communication and Soft skills.
- **Lifelong learning**

Thank You Gracias Merci Danke

Teşekkürler Спасибо 谢谢 감사합니다

Σας ευχαριστώ! धन्यवाद ありがとうございます

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شكرا תודה

Questions ?

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