Efficiency of teaching core knowledge and employability competencies in chemical engineering education

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At a (relatively) recent ChemEng Matters workshop we were asked to define ‘why we do this’

“We do this because the world needs people to safely and sustainably create the products and processes that make better stuff, from ordinary stuff without making bad stuff. This is done through continuous improvement that enhances quality of life for all.”
Education challenges

Figure 1: growth in UK student intake by subject

- Chemical engineering (940–2,790)
- Maths (4,006–7,685)
- Mechanical engineering (3,726–7,139)
- Physics (2,612–4,745)
- Civil engineering (2,362–3,863)
- Chemistry (3,059–4,811)
- Electrical/electronic engineering (3,557–4,468)
- Biology (4,697–5,890)
Drivers

- Societal challenges
- Changing character of the industry worldwide
- Rapidly changing technology impacting learning preferences/future work mode of graduates
- UK specific – funding changes

IChemE Technical Roadmap, 2012
Education challenges

- How do we ensure ‘quality experience’ for the increasing student numbers?
- Lab provision, tutorials, placement provision
- Not just doing the ‘same old’ numerous times
- We must start doing ‘smarter’ things
- Students are changing (expectations, education experience, technology ‘savviness’)

Our Happy Moment!
and of course TEF

https://www.heacademy.ac.uk/blog/tef-consultation-implementation-professor-stephanie-marshall-hea
Effectiveness and efficiency

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Luis Miguel Madeira
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16 associate partners formally signed up, representing professional institutions, employers, HEIs
iTeach aim

- develop a framework which will support the assessment of teaching effectiveness (efficiency) in delivering not only core chemical engineering knowledge, but also core employability competencies.

- More detail on www.iteach-chemeng.eu
Project overview

WP1  Management  Oct ‘13 – Sep ‘16

WP2  Data gathering  • Jan ’14 – Dec ‘14

WP3  Assessment framework  • Jan ’15 – Aug ‘15

WP4  Pilot implementation  • May ‘15 – Sep ‘16

WP5  Quality Assurance  Oct ‘13 – Sep ‘16

WP6  Dissemination  Jan ‘14 – Sep ‘16

WP7  Exploitation  Jul ‘15 – Sep ‘16
Effectiveness

- Review of various (inter)national CE accreditation requirements
- List of learning outcomes (LO) collated
- Survey sent to academics, industrialists and graduates on the importance of knowledge, skill and competency areas (> 260 valid responses)
- Clear agreement of all groups on the LO with only minor differences based on geographical or sectoral variations
- Importance of fundamentals, but also core competencies
Predominant methods of delivery

Rembrandt's 'The Anatomy Lecture of Dr. Nicolaes Tulp'
Some examples - flipped lectures

- Growing literature evidence on their effectiveness
- Example of using this approach in Stage 4 Bioreactor engineering module
- Only 4 tutor led lectures
- Groups of students selecting a topic, finding a journal article, learning the principles, critically evaluating the results/research
- 15 min presentation to the whole class
Engagement in lectures

- Expectation raising - ‘Why’ questions at the start
- Use of electronic voting
If activities of two enzymes are:

\[ E_1 = 0.05 \text{ kat} \quad \text{and} \quad E_2 = 500 \text{ U} \]

is the activity:

1. \( E_1 > E_2 \)
2. \( E_1 < E_2 \)
3. \( E_1 = E_2 \)
Given that $10^{-6}$ is the required sterility level and $10^{11}$ initial conc. of contaminants, $D$ at $120 \, ^0C = 1.5 \, min$, $F =$

1. 15 min
2. 25.5 min
3. 16.5 min

- 1. 50%
- 2. 48%
- 3. 2%
The clickers concentrated my attention

1. Yes, I wanted to get the answers right
2. Yes, they broke up the lecture, but I’m not bothered whether I get the answers right
3. No, just a gimmick, I pay attention anyway

n = 63, Stage 3
Seeing the question responses of the rest of the group helps me to gauge my performance.

1. Strongly Agree
2. Agree
3. Disagree
4. Strongly Disagree

n = 136, Stage 1
I would like to see this software used in more of my lectures

1. Strongly Agree
2. Agree
3. Disagree
4. Strongly Disagree

n = 136, Stage 1
Efficiency

- Academics
- Industry
Proposed metrics

Assessment of the efficiency of individual pedagogical approaches:

1. Strategic nature of the course
2. Implementation of the course within the programme
3. Pedagogical relevance of the proposed intervention
4. Student perception of the pedagogical approach
5. Knowledge/skills acquired
6. Ability to apply/transfer the acquired knowledge/skills to professional practice
Proposed pedagogical approaches

P1 (UNEW) – recorded lectures, problem based learning
P2 (UL) – problem based learning, self-instruction delivery
P3 (IBU) – work-based learning, traditional lectures
P4 (FEUP) – recorded lectures, practical instruction via labs
P5 (STU) – traditional lectures, practical instruction via labs
P6 (TUDO) – work-based learning, problem based learning
# Quantification of metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Strategic nature of the course/discipline</td>
<td>((2A+G+2E)/5)</td>
</tr>
<tr>
<td>2. Relevance of the proposed formation</td>
<td>((2A+G+E+S)/5)</td>
</tr>
<tr>
<td>3. Pedagogical relevance of the teaching approach</td>
<td>((2A+2G+S)/5)</td>
</tr>
<tr>
<td>4. Perception of relevance of the pedagogical approach</td>
<td>(S)</td>
</tr>
<tr>
<td>5. Evaluation of the acquisitions</td>
<td>(N.A.)</td>
</tr>
<tr>
<td>6. Evaluation of transfer</td>
<td>((A+2G+2E)/5)</td>
</tr>
</tbody>
</table>

\(A = \text{Academics}, \ G = \text{Graduates}, \ E = \text{Employers}, \ S = \text{Students}\)
Pilot implementation – initial results

Chemical Reaction Engineering (1st Semester) – Total nr. of responses

<table>
<thead>
<tr>
<th></th>
<th>Academi</th>
<th>Graduate</th>
<th>Employe</th>
<th>Student</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invitations</td>
<td>318</td>
<td>1002</td>
<td>899</td>
<td>1441</td>
<td>3660</td>
</tr>
<tr>
<td>Answers</td>
<td>89</td>
<td>101</td>
<td>57</td>
<td>217</td>
<td>464</td>
</tr>
<tr>
<td>A / I</td>
<td>28 %</td>
<td>10 %</td>
<td>6 %</td>
<td>15 %</td>
<td>13 %</td>
</tr>
</tbody>
</table>
Pilot implementation – initial results (2)

Chemical Reaction Engineering (1st Semester)

1. Strategic nature of the course/discipline
2. Relevance of the proposed formation
3. Pedagogical relevance of the teaching approach
4. Perception of relevance of the pedagogical approach
5. Evaluation of transfer

Portugal
Macedonia
Slovakia
France
United Kingdom
Pilot implementation – initial results (3)

Chemical Reaction Engineering (1st Semester)

Reaction Engineering (1st semester);
Metric: 3. Pedagogical relevance of the teaching approach

Stakeholder:
- Academics
- Graduates
- Employers
- Students

Grades:
- IBU (Macedonia) - traditional lectures
- Newcastle (UK) - recorded lectures
- STU (Slovakia) - practical instruction via labs
- TU Dortmund (Germany) -
- Univ. Lorraine (France) - traditional lectures
- FEUP (Portugal) - recorded lectures
Sensitivity analysis

Chemical Reaction Engineering (1st Semester)

<table>
<thead>
<tr>
<th>Metric</th>
<th>I (default)</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>3. Pedagogical relevance of the teaching approach</td>
<td>2 2 0 1</td>
<td>2.5 2.5 0 0</td>
<td>3 2 0 0</td>
<td>2 3 0 0</td>
</tr>
</tbody>
</table>

M3

![Graph showing sensitivity analysis results for different scenarios and institutions]
Chemical Reaction Engineering (1st Semester)

- Reaction Engineering (1st semester);
- Metric: 4. Perception of relevance of the pedagogical approach

Bar chart showing grades for different stakeholders:
- Academics
- Graduates
- Employers
- Students

Institutions and methods:
- IBU (Macedonia) - traditional lectures
- Newcastle (UK) - recorded lectures
- STU (Slovakia) - practical instruction via labs
- TU Dortmund (Germany)
- Univ. Lorraine (France) - traditional lectures
- FEUP (Portugal) - recorded lectures

The chart indicates that students have the highest perception of relevance, followed by employers, with traditional lectures in Macedonia and France showing higher grades compared to recorded lectures elsewhere.
Further work
In-depth analysis
In-depth analysis
Evaluation of whole formation

Pedagogy

Quality

Industry

Employment

Research

Learning Outcomes

Attractiveness
Concluding remarks

- Societal, economic and demographical changes introducing additional challenges to CE education
- Importance of fundamentals and employability competencies
- Need to measure efficiency of pedagogical interventions
- Global professional formation evaluation
- Involvement of all stakeholders throughout the whole process
Acknowledgements

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