A new education model in sustainable energy

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Abstract: The European Institute for Innovation and Technology (EIT) has selected knowledge and innovation community (KIC) InnoEnergy as the leading engine for innovation and entrepreneurship in sustainable energy in Europe. Since 2010, KIC InnoEnergy Master School has offered Master’s degree programs, which are directed at a new type of education in the energy field, aimed at mobilising the innovative and entrepreneurial spirit of the students. Seven Master’s programs, accredited by top technical universities in Europe, offer a combination of engineering and entrepreneurship courses. This paper describes a new mechanism for the development of a teaching environment, which creates strong links between education, technology, business and entrepreneurship. The paper also emphasises the main distinguishing features of KIC InnoEnergy education and gives examples of the application of new pedagogical methods.

Keywords: education; master’s programs; sustainable energy; The European Institute for Innovation and Technology; EIT; knowledge triangle; entrepreneurial; challenge-driven education; case teaching method; quality indicators; KPI; key performance indices.


Biographical notes: Wojciech Grega, PhD, DSc, is a Full Professor of AGH – University of Science and Technology in Krakow. His research interests include digital control, optimisation methods, distributed control, industrial control systems and engineering education. He is the author and co-author of more than 150 papers and books. He has been the coordinator or main researcher in 19 national and international projects. He is the Head of the Control Laboratory (since 2000) and the Faculty Commission for Education (2001–2009). He is the elected member of the EAEEIE (European Association for Education in Electrical and Information Engineering) since 2005. He is the European Union Academic Expert and KIC InnoEnergy Poland Plus Educational Director (2011–2015).
1 Introduction

A rapidly developing economy and society requires substantial changes in the education system. Engineering courses especially should be designed in a different way to include not only expert knowledge and behavioural skills, e.g., problem-solving skills together with teamwork capability. Successful contemporary education should be based on a project-based learning and learning-by-doing approach and be closely connected with industrial partners. An attempt to change the educational landscape in engineering MSc programs focused on energy was made by the KIC InnoEnergy (http://www.kic-innoenergy.com/) university partners supported by the EIT.

The EIT is a body of the European Union, established in March 2008. It is the first EU initiative to fully integrate all three sides of the knowledge triangle (higher education, research and business) by way of the so-called KICs. The EIT’s mission is to increase European sustainable growth and competitiveness, reinforce the innovation capacity of the EU Member States and create the entrepreneurs of tomorrow.

To achieve this goal, KIC InnoEnergy operates as a European Company (Societas Europaea (SE)), incorporated in the Netherlands, consisting of 27 formal partners who are all shareholders of KIC InnoEnergy. In addition, KIC InnoEnergy is working with over 150 associate and project partners across Europe, all of them key players in the energy field, including top-ranked industries, research centres and universities. The 27 entities are geographically attached to one of the six co-location centres (Sweden, Poland, Germany, Benelux, France and Iberia). Regarding education, the strategic partners are: KU Leuven, Grenoble Institute of Technology, UPC – Universitat Politècnica de Catalunya, Karlsruhe Institute of Technology, AGH – University of Science and Technology and KTH – Royal Institute of Technology.

KIC InnoEnergy Master School (accredited by the 11 partner universities of KIC InnoEnergy) offers two-year Master’s programs, which are directed at a completely new type of education in the energy field aimed at mobilising the innovative and entrepreneurial spirit of the students. Seven Master’s programs, accredited by the top
technical universities in Europe, offer a combination of engineering and entrepreneurship courses. Major features of the KIC InnoEnergy Master’s education include:

The participation of top-ranked universities: Including the best technical universities and business schools in Europe, several of which rank highly in recognised global ratings – for example, ESADE in Barcelona, where entrepreneurship training for some programs is held. The Financial Times has ranked ESADE as one of the world’s top five business schools (Business Education, http://rankings.ft.com/businessschoolrankings).

Innovative ‘learn-by-doing’ curricula: Based on the assumption (stated over 65 years ago (Tayler, 1949)) that learning takes place through the active behaviour of the students (Figure 1). Several methods of inspiring students to work actively with the course curriculum are implemented. This includes projects with challenging tasks and competition, case studies and the involvement of students in KIC IE innovation projects or writing a business plan for a real start-up.

![Cone of experience (according to the concept of Edgar Dale) (Dale, 1969)](https://example.com/figure1.png)

Special accreditation and assessment: All the Master’s programs are EIT-labelled to meet the high criteria for education, entrepreneurship and innovation set by the EIT. The EIT label is a special accreditation system based on EIT-specific quality criteria and EIT overarching learning outcomes (EIT label, https://eit.europa.eu/activities/education/eit-label). The EIT label accreditation of the programs is supported by KIC key performance indices (KPIs). KIC KPIs provide a means of assessing programs towards learning outcomes.

Industry involvement: Means that significant emphasis is also put on the integration of the concerns and needs of industry into the educational activities. This interest is manifested by the participation of industry representatives on advisory boards, the joint supervision of student projects and the acceptance of students for industrial internships and the offer of scholarships.

Double degree and EIT certificate: Each program involves studies at two KIC InnoEnergy partner universities. After successfully completing a program, the graduate
receives a double degree – one from each university attended – as well as a KIC-EIT certificate, demonstrating that he or she has completed an excellent education fostering innovation and entrepreneurship. The KIC-EIT certificate confirms the extra activities accomplished and special competences acquired by graduates. The EIT certificate (based on EIT label accreditation) has the aim of becoming a recognised brand of KIC graduates.

*International mobility:* a unique mobility program that allows the students to travel and learn during the entire two-year course of studies. In detail, it means that a KIC InnoEnergy student spends his/her first year at one university, the second year at another, and has the possibility to do an internship at a third location. In addition, summer schools are arranged between the first and second year.

*Employment offer for all graduates:* KIC InnoEnergy supports its graduates in finding their first employment in Europe. The Career Centre, part of KIC InnoEnergy’s Education system, assists our students and graduates who are transitioning from education into the European labour market. The purpose of the Career Centre is to provide students with networking opportunities with industry professionals as well as obtain high-quality internships and full-time positions within the energy industry. To support this activity, KIC IE has signed an agreement with one of the leading recruitment agencies in Europe. This organisation assists and guides graduates, helping them to find job opportunities after graduation. Over 93% of KIC InnoEnergy graduates find a job within 6 months of graduating (2014–2015 results).

*Scholarship support for committed students:* The programs of KIC IE Master School require the commitment and hard work of students. In recognition of this, KIC awards scholarships to the best applicants. The educational landscape of Europe is dominated by free education. To attract the best of the best – who usually receive many scholarship offers – KIC InnoEnergy decided to grant scholarships to the best candidates as well. A gradual reduction of the number of scholarships is planned in the future. Table 1 shows the ratio of scholarship students in the programs.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>KIC InnoEnergy Master School: intake statistics</th>
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<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>Available seats</td>
<td>465</td>
</tr>
<tr>
<td>Eligible applicants</td>
<td>459</td>
</tr>
<tr>
<td>Intake</td>
<td>32</td>
</tr>
<tr>
<td>Scholarship holders</td>
<td>0</td>
</tr>
<tr>
<td>Drop-outs</td>
<td>0</td>
</tr>
<tr>
<td>New graduates</td>
<td>0</td>
</tr>
</tbody>
</table>

2 Program structure and learning objectives

Each KIC InnoEnergy Master’s degree program combines ‘classical’ technical training in energy and best practices in innovation. This gives the graduates a very deep understanding of the world’s energy challenges combined with an insight into how
energy businesses are created and into the industrial perspective of the energy systems development. The Master’s degree programs offered are as follows:

- MSc Clean Fossil and Alternative Fuels Energy
- MSc EMINE – European Master’s in Nuclear Energy
- MSc RENE – Renewable Energy
- MSC ENTECH – Energy Technologies
- MSc SENSE – Smart Electrical Networks and Systems
- MSc SELECT – Environomical Pathways to Sustainable Energy Systems
- MSc Energy for Smart Cities.

The programs represent the wide range of energy issues and each program is focused on a specific area. To some extent, the delivered content could be similar, but in each case the program contains all the skills and knowledge essential for a graduate to become a successful professional engineer. Each Master’s program involves at least two European technical universities, a business school and energy-related corporations. The programs are aligned with the objectives of the European SET plan (European Commission, https://setis.ec.europa.eu), including:

- Maintaining EU industrial leadership on low-carbon energy technologies.
- Fostering science for transforming energy technologies to achieve the 2020 Energy and climate change goals.
- Finding the best students for KIC InnoEnergy Education is an important part of the process and a good way to reduce drop-out and enhance the number of top successful graduates. The application process is multistage and competitive and only the very best, most talented students are selected to join KIC InnoEnergy Master’s degree programs. The first stage of the application process is supported by the KIC InnoEnergy Admissions Office. Help is given to candidates in a proper understanding of the procedures and requirements as well as in a good understanding of the mission of the KIC InnoEnergy Master School. Applications are processed in three steps:
  - Document legacy and eligibility control regarding academic background and English proficiency is performed by the KIC InnoEnergy Admissions Office.
  - Home/host universities responsible for the program define the specific admission requirements for each program;
  - The Program Evaluation Committee creates a ranking of the selected applicants.

A common approach is implemented in allocating study places with respect to efficiency and applicability. The competitiveness of the recruitment process is illustrated in Table 1. The learning objectives of KIC InnoEnergy Master School are consistent with the opinions of experts formulated in a document published by the European Commission in 2009 (EU Enterprise and Industry Directorate-General, 2008). The special courses are geared to the acquisition of generic and ‘horizontal’ skills, aiming to make students:
more creative/innovative, highly motivated, pro-active, self-aware, self-confident, willing to challenge

better communicators, decision-makers, leaders, negotiators, networkers, problem-solvers

team players, systematic thinkers

less dependent, less risk averse, capable of recognising opportunities.

This education provides basic business skills and raises awareness of entrepreneurship as a potential career option. It does not relate only to start-ups, but also includes entrepreneurship and the encouragement of enterprising individuals across all walks of life.

First and foremost, KIC InnoEnergy Master School delivers education for high competency and quality engineering skills with a deep understanding of the world’s energy challenges. The teaching methodology of the programs is aligned with several new pedagogical methods (see next section) and implementation of the old concept of ‘learning by doing’.

Each one of the KIC InnoEnergy Master’s degree programs has a clear business and entrepreneurship character, in a way which to date has been seriously under implemented at any of the partner universities. This is achieved not only through specialised courses on business and entrepreneurship in each one of the MSc tracks, but also by special business and entrepreneurship components in individual courses (Figure 2). The major strength of InnoEnergy educational activities is the clear integration of these activities into the day-to-day technical curricula. The successful establishment of a balance between highly specialised thematic areas, a general sustainable energy approach, technologies and entrepreneurship and management modules has been a major challenge for curricula designers.

Figure 2  Mobilising the innovative and entrepreneurial spirit of the students; example of specialised courses on business and entrepreneurship (see online version for colours)

Source: KIC InnoEnergy (http://www.kic-innoenergy.com/)
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All KIC InnoEnergy Master’s degree programs include a strong mobility concept, guaranteed for all students. A typical program includes a number of semesters spent at partner universities, in addition to internships with industrial partners and access to demonstration/experimental platforms.

José Manuel Leceta – EIT Director, said (Leceta, 2014): The (EIT) label flags excellent education programs that put a strong focus on the delivery of entrepreneurship and innovation skills, foster creativity, involve industry in curricula development, try and nurture a ‘game changer’ attitude and value people who dare to think differently.

3 Pedagogical evolution

The KIC InnoEnergy Master School is using the models and techniques that have proven their feasibility and best-possible performance in engineering courses. The key notions are ‘active learning’, ‘learning by doing’ and ‘project-based learning’ (Bonwell and Eison, 1991; Sivan et al., 2000).

A further step is the implementation of challenge-driven education. This means that the Master’s programs should be based on learning experience acquired through identification, analysis and design of a solution to sociotechnical problems. The learning experience is typically multidisciplinary, takes place in an international context and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable.

In each individual program, the challenges are supplied by external stakeholders (mainly industrial partners), and solved by interdisciplinary teams of students. Each student participates in one new challenge per semester, in different teams. The challenges can be linked and have a progression built in. Challenge-driven education in some way redefines the student’s priorities: a diploma is not the goal – the goal is to find a solution to the challenge.

One of the most important elements included in modern pedagogical approaches is the implementation of the case teaching method. This methodology is based on an active learning approach, which uses presentation of case studies as a teaching tool. The case teaching method is an established form of learning in many academic and professional learning contexts, however its use was traditionally strongly focused on law, medicine and business (Yadav et al., 2007). The use of the case teaching method in engineering courses is a new practice.

The pedagogical goals to be achieved by implementing cases in the teaching process include those in the fields of critical thinking, learning, participation and others. The detailed goals are listed here:

**Critical thinking:**
- to improve the student’s ability to view an issue from multiple perspectives
- to develop a deeper understanding of concepts
- to cultivate stronger critical thinking skills
- to improve the student’s ability to make connections across multiple content areas
- to increase the students ability to discuss different issues
Learning:
- to deliver the ability to better grasp the practical application of core course concepts
- to strengthen communication skills
- to provide a challenging format
- to strengthen understanding of ambiguity.

Participation:
- to encourage the student to take a more active part in the learning process
- to make the student more engaged in class
- to develop positive peer-to-peer relationships
- to increase attendance
- to strengthen the ability to work in small groups.

Other:
- to encourage the student to evaluate the teaching more positively.

It is now documented that students can learn more effectively when actively involved in the learning process (Bonwell and Eison, 1991). Apart from its long list of advantages, the case teaching method seems to have some disadvantages. For example, it is more time consuming for teachers and students in comparison with traditional teaching methods.

First, the special preparation of teachers towards these techniques to stimulate discussion is needed. As a fairly new technique, which is not commonly used in engineering courses, its implementation requires time for adjustment on the part of students as well as the teachers. As a result, some problems with covering the full scope of the materials for each semester may appear. It may also require modifications of the pedagogical framework and some formal structures of the universities.

4 Teacher motivation

The implementation of new pedagogical methods requires additional effort from teachers. This means that a special motivating system should be proposed to ensure the success of the implementation of this pedagogical evolution.

The academic staff in any KIC MSc program is an important pillar in achieving the KIC InnoEnergy goals. Lack of motivation and commitment can have a negative impact on the students’ learning. The teachers’ contribution to the development and technological advancement of the KIC MSc programs greatly depends on their motivation and willingness to take the initiative. There are many factors that affect the academician’s motivation, including the class room environment, rewards and incentives, workload stress and administrative policies, etc.

Teaching is considered to be a highly respected and dignified profession and teachers are always taken as role models (Kayuni and Tambulsai, 2007). A well-prepared system involves encouraging teachers to take the trouble to acquire special skills in the
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application of new methods. This seems to be the key issue for the success of the KIC-InnoEnergy-goals-oriented educational process. Unfortunately, the attractiveness and effectiveness of teaching are usually not the most important factors when it comes to the academic staff’s overall performance evaluation. This makes the teacher benefit project the key element in the pedagogical evolution implementation strategy in the KIC InnoEnergy Master School, and a pilot-scale project has already been launched, mainly based on pedagogical grants concept. Teachers who have proposed the best forms of implementation of new pedagogical tools oriented on ‘learning by doing’, ‘project-based learning’ and ‘case teaching’ are awarded grants that can help them in their professional career development.

5 Industry involvement

The hallmark of the EIT educational programs is not only to educate students to know, but also to know what to do and how to solve real-life problems, all framed within an entrepreneurial mindset. To ensure that EIT-labelled educational programs at a Master’s level encourage students to become more creative, innovative and enterprising, some EIT-specific knowledge forms and overarching learning outcomes are applied.

The ‘EIT overarching learning outcomes’ specify that programs should ensure that students achieve skills and competencies in the EIT-specific knowledge forms of creativity, innovation, entrepreneurship, research, intellectual transforming, leadership and making value judgements related to their fields of study.

This means that industry should play a significant role in the pedagogical process. EIT-labelled degrees and diplomas are based on the integration of the three sides of the knowledge triangle: education, research and business/innovation (Adamson and Flodström, 2011; Collaborative Publishing, 2013). Accordingly, they have a strong focus on creativity, innovation and entrepreneurship and build on a set of specific quality criteria and overarching learning outcomes. To implement these criteria and reach learning outcomes, a strong cooperation with all stakeholders, with the special role of industry, is essential. The concept is to involve industrial partners into a complete ‘education chain’ (Table 2).

Table 2 Types of involvement of industrial partners

<table>
<thead>
<tr>
<th>Education chain: activities</th>
<th>Industry contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curricula design</td>
<td>Delivery of the competency models implemented to screen job candidates</td>
</tr>
<tr>
<td></td>
<td>Transformation of the programs</td>
</tr>
<tr>
<td>Teaching</td>
<td>Special lectures</td>
</tr>
<tr>
<td></td>
<td>Subjects for case studies to supplement the program</td>
</tr>
<tr>
<td>Practical knowledge transfer</td>
<td>Summer internships – different in different programs - usually 2 months long</td>
</tr>
<tr>
<td>Transition to labour market</td>
<td>Job proposals</td>
</tr>
<tr>
<td>Industrialisation</td>
<td>Subjects of MSc thesis proposed</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Scholarships for best students</td>
</tr>
<tr>
<td></td>
<td>Promotion of the KIC IE education</td>
</tr>
</tbody>
</table>
The pedagogical process was designed and is continuously improved with cooperation from the industrial partners of KIC InnoEnergy. The syllabuses have been created in a way that secures the transfer of the most important skills that would increase the value of a graduate in the labour market. The whole pedagogical process is constantly supported and supervised by industry. All students can have practical internships in leading European industrial institutions. All Master’s theses are proposed and are supported by the industrial partners. This means that students are part of working groups solving real problems and dealing with the most vital challenges in the present-day power sector. This is a value that cannot be overestimated.

6 Key performance indices: assessing progress

KPIs provide a means of assessing progress towards the objectives of the educational programs; they also create a more direct link between funding and performance. If implemented on a consistent and regular basis, KPIs can be used for several purposes (Schofield, 2009; Michaela and Sauvageot, 2011), including:

- assessing the quality of the education process
- demonstrating the attractiveness of the programs
- assessing progress of the process over time
- measuring the efficiency of the education process
- providing the basis for comparisons between individual institutions of a similar nature.

The KPIs have been used in the education sector of KIC InnoEnergy from the beginning as metrics and indicators around KIC goals and priorities. Initially, they included mostly quantitative indicators, delivered as absolute values (e.g., number of candidates). In this format, the KPIs remained very narrow and did not fully capture the important mission of the EIT education agenda, expressed as integration inside of the knowledge triangle and impact on the university-business cooperation.

The new approach is based on a strategy-following method (Figure 3). Several categories of KPIs and its models (target values) are defined each year. The actual values of the KPIs are scaled (brought to nominal values down to ‘1’) for easier comparison.

Figure 4 and Table 3 demonstrate this approach for MSc Clean Fossil and Alternative Fuels Energy (CFaAFE) for the first KPIs category: education process. Table 3 includes the model (target) values of KPI, while Figure 4 shows how the desired values are followed (time period: 1 year). If the bar is equal to or greater than ‘1’, it indicates that the ‘model KPIs’ are followed well. For example, KPI ‘Attractiveness’ is calculated according to the simple formula

$$\left(\frac{a}{b}\right) \times \frac{1}{c},$$

$$\left(\frac{a}{b}\right) \times \frac{1}{c},$$
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where

\(a\): number of eligible applicants
\(b\): intake
\(c\): Model: candidate per seat.

**Figure 3** KPIs: strategy-following method (see online version for colours)

**Table 3** Example: desired values of KPIs, defined for the ‘education process’ category

<table>
<thead>
<tr>
<th>KPI1: Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Model: graduates &gt;=90% in the cycle</td>
</tr>
<tr>
<td>2 Model: candidate per seat &gt;=5</td>
</tr>
<tr>
<td>3 Model: dropouts in the program (total) &lt;=5%</td>
</tr>
<tr>
<td>4 Model: intake from partner universities &gt;=20%</td>
</tr>
<tr>
<td>5 Model: intake of EU students &gt;=60%</td>
</tr>
<tr>
<td>6 Model: full scholarship holders &lt;=70%</td>
</tr>
<tr>
<td>7 Model: partial scholarship holders &gt;=20%</td>
</tr>
</tbody>
</table>

**Table 4** Example: target values of KPIs defined for KPIs category: education and business

<table>
<thead>
<tr>
<th>KPI2: Education and business</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Model: ECTS delivered in contribution with industrial partners &gt;= 30%</td>
</tr>
<tr>
<td>2 Model: scholarships funded by industry &gt;=20%</td>
</tr>
<tr>
<td>3 Model: thesis executed at industrial sites or for industrial declared needs &gt;=30%</td>
</tr>
<tr>
<td>4 Model: Number of graduates inserted in the labour market in energy sector &gt;=90%</td>
</tr>
<tr>
<td>5 Model: Months/student of internships in industry &gt;=2</td>
</tr>
<tr>
<td>6 Model: average salary related to energy sector – engineers &gt;=105%</td>
</tr>
</tbody>
</table>
Figure 4  KPI 1: the bar plot shows how the desired values were followed for the category education (level 1 is the threshold). The ‘Efficiency teaching process 1’ relates to row 1 in Table 2 (see online version for colours).

Figure 5  KPI 2: education and business (see online version for colours)
Figure 5 and Table 4 demonstrate this approach for MSc Clean Fossil and Alternative Fuels Energy (CFaAFE) for the category: education and business. For example (row no. 1 in Table 4), the target was that 30% of European credit transfer system (ECTS) should be delivered by industrial partners in the form of special courses, training, internships, etc. During the assessed period, only 30 ECTS were delivered, relative to 120 ECTS delivered in total. It means that the goal was reached only in 86% (the first bar in Figure 5).

The proposed method can be considered as a simple and unified approach of providing multiple indicators for each goal, especially for impact assessment. The scaling method provides data for comparison between the Master’s programs. This method can also be used to assess trends and the direction of development of the programs. The results of the operation of this ‘KPIs generator’ are good as far as the data are reliable. The pilot implementation shows that identification of some data related to ‘impact’ might be difficult (e.g., economic impact).

7 Conclusions

Considering global competition in the field of higher education, we should pay special attention to new trends in pedagogy as well as to the efficiency of learning performance. These elements could be the key aspects of the economic efficiency of the system. KIC InnoEnergy Master School, owing to its new and modern model of education, including a high level of knowledge and skills delivered to students, as well as to its implementation of new pedagogical methods combined with mobility components, may be seen as an important step in changing the European educational framework in engineering courses.

The four-year history of the program has proven that KIC InnoEnergy delivers education for high competency and quality engineering skills with a deep understanding of the world’s energy challenges. The current status of KIC InnoEnergy Master School after five years of operation is as follows (Key Facts, http://www.kic-innoenergy.com/about/key-facts/):

- applicants: 9500
- graduates: 352
- employed during the first year after graduation: 93%
- average annual salary earnings over graduates: 15%

The new pedagogy is developed and implemented in KIC InnoEnergy Master’s courses; it is strongly focused on practical skills gained by students as well as solving real problems. The KIC InnoEnergy education could be treated as an important test field for a new pedagogical approach and most advanced solutions created on the basis of the knowledge triangle concept. The KIC InnoEnergy Master School could be the example of a new pedagogical approach to engineering courses. Its efficiency has been verified by the high employment rate of the graduates as well as the number of candidates per place – which is higher than 10, although the promising results are now elaborated on a rather small group of students. The time of the activity of the programs is still rather
short compared with well-established traditional universities and these are the limitation factors of this study. Further research is necessary to find out which element – pedagogical evolution and implemented tools or the close relation with industry – is the causative factors of the KIC InnoEnergy Master’s degree programs.

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