How IGIP, the International Society for Engineering Education, intends to tackle the New Pedagogic Challenges in Engineering Education

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Abstract

Never has the speed of development in the area of engineering been as accelerated as it is today, as we observe the enormous and driven growth of the area of engineering. Today's tendencies require well-coordinated new efforts in engineering education - or in other words: The importance of pedagogy in the field of engineering in both, the secondary and the tertiary sectors, is growing enormously. These changes strongly demand new didactic and pedagogic paradigms. The International Society of Engineering Education (IGIP) offers to contribute to the relevance and pedagogical aspects related to developing educational concepts in engineering education.

1. IGIP and Engineering Education

IGIP has had an almost 40-year tradition in contributing to engineering education, its members and many activists have contributed to making IGIP a leading global engineering association, if not a school of thinking. IGIP has presently got a worldwide membership of about 1.750 members (individual, affiliate, institutional). More than 1.100 professionals all over the globe currently bear the title of "IGIP International Engineering Educator - Ing.Paed.IGIP ". IGIP also works in good partnership with international associations as IFEES (International Federation of Engineering Education Societies), IEEE (Institute of Electrical and Electronics Engineers (technology advancement organization)) Education Society, SEFI (European Society for Engineering Education), IELA (International E-Learning Association) and more.

The aims of the International Society for Engineering Education - IGIP are:

- Improving teaching methods in technical subjects
- Developing practice-oriented curricula that correspond to the needs of students and employers
- Encouraging the use of new media in technical teaching
- Integrating languages and the humanities in engineering education
- Fostering management training for engineers
- Promoting environmental awareness
- Supporting the development of engineering education in developing countries

It is important to consider that humankind has never faced such a rapidly changing and dynamic global environment which requires so many engineers as we are witnessing today.
And as our environment changes, it is imperative that we better learn to adapt, which requires us to question and, when necessary, be open to changes in our:

- Educational systems
- Pedagogy & Didactics
- Methods and processes.

Never before have the challenges in education and pedagogy been as challenging as today. Never has so much been demanded of engineers. The work of ASEE (Automated Systems Engineering Environment), IGIP, IEEE (Institute of Electrical and Electronics Engineers), and other associations is focused on high quality in Engineering Education. But what is engineering?
"Engineering is the discipline, art and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize a solution to the needs of society." 1

A short definition of engineering might be: "Exploiting basic principles of science to develop useful tools, objects and processes for society." This means that engineering is the link between science and society, which can include almost anything that people come into contact or experience in real life. The concept of engineering had existed long before recorded history, and has evolved from fundamental inventions such as the lever, wheel and pulley to the complex examples of engineering today. But today, there are two actual tendencies:

Firstly, we can observe an enormous (and accelerated) growth of the area of engineering.
Besides the traditional fields of mechanical engineering, electrical engineering, civil engineering, construction engineering, mechatronics, etc. new engineering disciplines have been created and more are in the process of creation. Some examples of recently created areas of engineering include:

- Software Engineering
- Data engineering
- Medical Engineering
- Neuro Engineering
- Gene Engineering
- Social Requirement Engineering, etc.

And new tasks requiring new competencies within traditional engineering disciplines have grown in number and complexity:

- Online Engineering
- Remote Engineering
- Virtual Engineering
- Reverse Engineering

On the other hand, we can observe a terrific acceleration of the life cycles of technical (or engineering) products (and processes or technologies too!). For example, how many years did it take for the following products to reach a market audience of 50 million?

- Radio 38 years
- TV 13 years
- Internet 4 years
- iPod 3 years

- Facebook 2 years
- Tablet PC (iPad) a little bit more than one year

The field of engineering has never suffered such reduced times to bring its innovations from concept to market. Competition in the field of technology is now measured in weeks.
(Cf.:http://1.bp.blogspot.com/_1UpYFlfWGJo/S_qjHNT0DGI/AAAAAAAADuo/REBZFw_OjK0/s1600/Adoption+rates+in+history-of-products.gif)

Both of these realities require a coordinated effort to develop engineering education into what today's reality is demanding of practicing engineers. In other words, many traditional educational models and practices are no longer functional. For this reason, the importance of pedagogy is growing at an enormous pace. The need to innovate and apply new paradigms to the teaching-learning process is an absolute necessity.

2. New Questions of Today's and Future Engineering Education

There are going to be particularly serious changes in the social position of learning:

- According to some estimates, more than 80% of all learning occurs on the job rather than in secondary, tertiary and post-tertiary education!

Learning in the future has to be an integrated part of the job! Moreover: Learners in the workplace are not only consumers of learning resources, but often also developers or resource providers. Learners are also teachers who participate in the development of content and often in its delivery as well. This new model provides new challenges related to the integration of learning and work. [5]

Data from Australian and Portuguese surveys show: Engineers tend to spend the majority of their working week (around 60%) engaged in activities which involve interaction with others (meetings, supervision, writing reports, etc.), and only around 40% is devoted to technical engineering activity.

- There are also new organizational aspects in engineering education[6]:

On the one hand, engineering issues, either in industrial products or in engineering projects, are quickly becoming increasingly complicated and most of these issues cross disciplinary lines.
On the other hand, the working environment is becoming more and more internationalised due to the globalisation of the world economy. Products are fabricated by worldwide cooperation and manufacturing resources are linked by international supply chains. Nowadays, engineers have to know how to work in multi-cultural environments with people from different countries.
This means the next generation of engineers will need to possess the ability to work seamlessly across cultures, have outstanding communication skills and be familiar with the principles of project management, logistics, and systems integration.

- To face current real-world challenges, higher engineering education has to find innovative ways to quickly respond to the new needs of engineering education, and at low costs.

This means it is necessary to improve the agility of engineering education in the future. One of the approaches in this direction is the creation of virtual educational units.

All these trends result in new questions and the resulting need to evolve educational practices, especially in Engineering Pedagogy. Some of these important questions to consider include:

- What learning approaches have to be used to effectively response to these changes?
- What are the pedagogies that provide the most effective learning experiences for engineering students of the 21st century?
- Which learning skills in engineering education need to be developed and how can engineering teachers succeed in guiding their students to achieve them?
- What pedagogical approaches have been found to support the different phases of the present life-long learning continuum, or is there more research necessary?
- What are the approaches that enable competence in leadership skills in a multi-cultural working environment, and what is the best way for these competencies to be delivered?
- Ambient technology is becoming a reality. What does ambient learning in Engineering Education look like? How can it be designed, delivered and assessed?

These are some of the reasons why the relevance and importance of engineering pedagogy is growing so enormously.

3. IGIP's International Engineering Educator Title

This paper has attempted to show that dramatic changes are necessary in engineering education and that these changes strongly demand a new look at the didactic and pedagogic concepts that presently form the basis of engineering education. IGIP offers a space to look into, debate, and put into practice concepts related to engineering education.

IGIP has established a prototype curriculum for engineering pedagogy which is already used in several countries. In contrast to ABET (Accreditation Board for Engineering and Technology, Inc.), FEANI (Fédération Européenne d'Associations Nationales d'Ingénieurs (French: European Federation of National Engineering Associations)), or EUR-ACE (European Accreditation Engineering Council), IGIP is not an accreditation body for engineering curricula. By passing the curriculum as proposed by IGIP in any accredited or other institution worldwide, IGIP states that a given engineering educator with an Ing.Paed.IGIP title has all the competencies needed to teach to the highest standards with the best available teaching technologies. Interested engineers can continue their education in accordance with the IGIP Curriculum and obtain a diploma that will provide the knowledge necessary for engineers to become better teachers. IGIP already has 46 approved educational centers and more than 1100 approved "International Engineering Educators" (Ing.Paed.IGIP) worldwide.

The IGIP model's point of argumentation is that the individual engineering lecturers initiate and are responsible for the teaching and learning concepts that train engineers and technicians. The quality and success of the engineering studies are decisively influenced by teacher competencies in the area of pedagogy as pedagogical skills represent a network of knowledge and skills that transmit knowledge and experience, much like Web 3.0. For this reason, technology and educational practice must go hand in hand when we are dealing with the education of engineers.

Engineering educators expand their typical engineering subject competence by acquiring teaching and learning skills in theoretical and practical coursework corresponding to the objectives of the Ing.Paed.IGIP model. Students taking engineering education training should acquire the necessary professional skills which technical teachers must have to be able to exercise their profession effectively

and creatively.
The certified IGIP engineering education curriculum is based on the knowledge of traditional pedagogy in philosophy and the liberal arts, but with respect to the particular character of the technician and the analytical-methodological approach in the fields of engineering science.
After many years of experience in industry or research, engineers who are appointed as teachers at a technical school or university are influenced by their professional careers. Their way of thinking is determined by the precision of the technology, by their work with quantifiable and measurable events and objects. The influence of their discipline, the "language" of engineers, must be taken into account in engineering pedagogy education; it must penetrate the engineering education curriculum.

The Ing.Paed.IGIP is a registered program which certifies a certain educational level for teachers, trainers or instructors. Any engineering educator who passes the curriculum at any IGIP accredited training Centre for International Engineering Education, and whose education, training and professional experience meet IGIP standards may apply be registered as an "International Engineering Educator Ing.Paed.IGIP ".
The qualification profile of a specialised engineering pedagogue is based on two pillars:

- Engineering qualification which was earned through a recognized and/or accredited engineering study program followed by relevant professional experience
- Educational qualification in engineering pedagogy acquired in the course of a comprehensive educational program

The engineering pedagogy program is generally an independent course of studies taken after an engineering program. However, it can also form an integral part of engineering degree programs. Already existing educational programs for engineering pedagogues can be accredited by the IGIP. Importantly, to be accredited, they must meet the accreditation criteria defined by IGIP.
The goal of IGIP accreditation is to ensure that graduates of the accredited engineering pedagogical programs are well prepared to perform their teaching duties in engineering subjects and meet the criteria for the registration as International Engineering Educators, Ing.Paed.IGIP. Another goal is to promote quality assurance, quality improvement and modernization of engineering pedagogy programs and to create public awareness of the high quality of the IGIP program for engineering pedagogues. Accreditation is a voluntary process which educational institutions must apply for through the responsible IGIP national monitoring committees.
The accreditation criteria defined by IGIP for the corresponding education processes of a program for engineering educators are:

- Organisation of the program
- Entrance requirements for the first year students
- Skills/abilities of the graduates
- Engineering pedagogical curriculum
- Lecturers and professors
- Institutional resources
- Quality control and feedback

4. Competencies in Engineering Pedagogy

An “ideal“ teacher with a technical background should acquire the necessary professional competencies of an engineering educator. These general professional competencies consist of two main groups:

- Technical expertise
- Specific engineering pedagogical competencies.

Educational theory offers different lists of competencies[7]. The IGIP concept of engineering educational competences is to be summarized as follows:

- Pedagogical, psychological and ethical competencies
- Didactical skills and evaluative competencies
- Organisational (managerial) competencies
- Oral and written communication skills and social competencies
- Reflective and developmental competencies.

Other categorisations might operate with the terms "technical expertise", "pedagogical competencies", and human competencies". Some authors substitute the term "competencies" by "virtues" (Helus, Z.[8]).

4.1. Technical competencies

It is assumed that the candidate has acquired a high level of technical knowledge while studying engineering and has met the requirements as defined by the "Fédération Européenne d'Associations Nationales d'Ingénieurs – FEANI" (Fédération Européenne d'Associations Nationales d'Ingénieurs (French: European Federation of National Engineering Associations)) for registration as a European Engineer – EUR ING. Both an engineering diploma and at least one year of professional experience in engineering are required.

4.2. Pedagogical, Psychological and Ethical Competencies

It is assumed that engineering pedagogues create a positive working and learning atmosphere, see the students as learning partners in a relationship characterised by mutual respect and the use group-dynamics, stimulate a variety of interactions between academics and students[9] as well as within the student groups, use student input and provide students the space necessary to promote creativity, support students in the development of their professional identity, stimulate "value-orientation" in the students and are awareness of their own ethical point of view (within the field of conflicts between humans, society and the environment) that will permit them to better conduct themselves as professionals in the different fields of engineering.

4.3. Didactical skills and subject expertise

Engineering pedagogues use engineering pedagogy models of the teaching process to create their own lessons, develop their own personalized teaching style and strategies to promote the flow of information, and observe the components of the six-dimensional education space in their own teaching and relate these to the selected teaching method. They select the best teaching methods and strategies, e.g. laboratory didactics and project work, and follow up by rethinking and re-evaluating their teaching methods and strategies with their colleagues and students. They set clear teaching goals, select suitable materials, and structure them appropriately. They find illustrative explanations and develop clear manner of communicating content and actions. They integrate new technologies and methodologies into their teaching practices. They are comfortable using what may be called the "classic" teaching media and effectively employ "new" teaching media (e.g. learning platforms, etc), taking into account the individual differences and learning strategies of students in a more personalized learning process (e.g.

intercultural differences). The make effective use student experiences as teaching points, effectively building on these experiences and, therefore, stimulating students to translate personal experiences into practical working theories. They advise students on how to develop their portfolios and stimulate students to include their experiences into the learning process, all the while being responsible for their actions and self-assessing themselves as professional engineers.

4.4. Evaluative Competencies

Engineering pedagogues develop instruments for (self-) assessment of professional engineering skills and evaluate their students using both quantitative and qualitative means to continually monitor, assess and record student progress during the learning process.

4.5. Organizational / Managerial Competencies

Technical teachers (in Austria, for example at the Technical Universities, the Universities of Applied Sciences and the Technical Colleges – HTL) create an adequate physical and virtual learning environment, poses time management skills for their own work, observe relevant laws and are aware of educational policy, administer all relevant data adequately and can work "on the fly" if necessary.

4.6. Communicative and Social Competencies

Engineering pedagogues work as part of trans-disciplinary teams, making their own vision of teaching explicit and effectively relating it to the visions and concepts of their colleagues. They contribute to the development of guidelines and visions of their own profession and to the modernization process of teaching. They have or create relevant regional or (inter)national networks that contribute to knowledge in the field of engineering pedagogy and effectively communicate it to peers. They also communicate satisfactorily both orally and in writing in a variety of contexts and are competent in scientific writing.

4.7. Reflective and Developmental Competencies

Teachers with a technical background appreciate new developments (e.g. new technologies) and readily integrate them into their teaching, systematically rethinking their own teaching strategies and their teaching behaviours, making their own learning process transparent to students and colleagues. They are also willing and in the position to initiate IGIP accreditation and register as an "International Engineering Educator Ing.Paed.IGIP ".
The IGIP Recommendations for Engineering Pedagogy Studies (in short IGIP Curriculum) are described in detail on the IGIP website [10].
Interested institutions and engineers, teachers, and students are welcome to contact one of the 23 IGIP National Monitoring Committees or the IGIP headquarters in Austria.

5. Conclusions

Technical university teaching has often been perceived as a poor cousin to research. Few technical universities require any specific technical teacher education for their academic staff, the only level of learning where this happens. Yet teaching is an art that, at least to some degree, can be taught, if the institutions of higher learning support it as an important element. The International Society for Engineering Education (IGIP) is working to assure that graduates of accredited engineering pedagogical programs are well prepared to perform their teaching duties in engineering subjects and meet the criteria for IGIP registration as International Engineering Educators, Ing.Paed.IGIP. IGIP's ultimate goal,

however, is to promote quality assurance, quality improvement and to modernise engineering pedagogy programs and educational practices. Its intention is also to create public awareness of the high quality of engineering pedagogue programs and to guarantee a future world in which qualified and considerate engineers continue to play an important role.

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