

Redesigning Engineering Curricula: A Learning Outcomes Based Approach

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INTRODUCTION

The expansion of the higher education system in Poland in the 1990's created many problems and challenges. Some of these problems were solved as a result of transformations of degree programmes and other changes at higher education institutions (HEIs) that followed the adoption of the new *Law on Higher Education* in 2005, but some other were still left to be dealt with [1].

In particular, until recently, the autonomy of HEIs in developing and updating their programme portfolio was quite restricted – the universities could in principle offer degree programmes only in the fields selected from the list of 118 fields of study (including 28 fields in engineering), predetermined by the Ministry. Moreover, for each of these fields, the contents of the curriculum was partially defined by means of so-called “standards”. An institution could apply to the Minister for a permission to offer a programme in a field from outside the list, but the lengthy bureaucratic procedure discouraged many HEIs from taking such an initiative.

Degree programmes in engineering were generally overloaded with theory and did not provide graduates with sufficient practical knowledge and skills essential for the labour market. They did not adequately account for the changes taking place in engineering education around the world [2,3].

The analyses done as part of the development of a strategic plan for the modernisation of the Poland's higher education system in 2010-2020 indicated that many of the existing problems could be addressed through the implementation of a national qualifications framework.

In this paper, we show how the development and implementation of the national qualifications framework for higher education has affected engineering education in Poland. In particular, we describe the changes that have taken place at the Warsaw University of Technology.

1 NATIONAL QUALIFICATIONS FRAMEWORK FOR HIGHER EDUCATION

1.1 Development and introduction

The development of the national qualifications framework for higher education in Poland followed a typical scenario recommended by the Bologna Working Group on Qualifications Frameworks [4]. A fundamental assumption was to make it compatible with the overarching qualifications framework for the European Higher Education Area (QF-EHEA) [4], but also with the European Qualifications Framework for lifelong learning (EQF-LLL) [5]. What should be emphasized is the fact that the framework was developed mainly by the academic community; at the late stages of the work almost 200 academic staff members were involved in various projects (most of them supported by the EU funds) aimed at the verification of concepts and drafting parts of legal regulations.

In March 2011, the National Qualifications Framework for Higher Education (NQF-HE) was introduced by means of an amendment to the *Law on Higher Education*. This was followed by lower-level legal acts issued by the Minister (ordinances), including the *Ordinance on the NQF-HE*, containing regulations underlying the NQF-HE implementation.

According to the amended *Law*, all study programmes, including PhD programmes and non-degree postgraduate programmes, offered by HEIs in academic year 2012/13 and later have to comply with the regulations related to the NQF-HE.

1.2 Basic regulations

In Poland, as in many other countries, the NQF-HE has three levels of qualifications, corresponding to the three Bologna cycles. In this paper, we discuss only degree programmes leading to the first- and second-level qualifications, corresponding to the Bachelor's and Master's degrees, respectively.

For these qualifications, the level descriptors that characterise competences of the qualification holder or, in other words, learning outcomes (LOs) he/she achieved at the HEI, are presented at two layers. At the higher layer, the "generic" LOs corresponding to the Bachelor's and Master's degrees are specified. At the lower layer, these LOs are described in more detail. The lower-layer descriptors reflect the concept of qualification profiling, introduced by the Bologna Working Group on Qualifications Frameworks. The Group defined a profile as "*either the specific (subject) field(s) of learning of a qualification or the broader aggregation of clusters of qualifications or programmes from different fields that share a common emphasis or purpose (e.g. an applied vocational as opposed to more theoretical academic studies)*" [4]. Both concepts of qualification profiling presented in this definition are deployed, but the term "profile" is used only in the second sense. Being more specific, the level descriptors are specified (in the *Ordinance on the NQF-HE*) for:

- eight large subject domains, selected based on the OECD/EUROSTAT/UNESCO science and technology classification; one of these eight domains is *Engineering*,
- two profiles, corresponding to more theoretically and more practically oriented studies.

For each subject domain and each profile, the level descriptors are organised into three categories: knowledge, skills, and social competences, similar to those in EQF-LLL [5]. However, they also remain compatible with the Dublin Descriptors used in QF-EHEA [4], and with the descriptions proposed in the Tuning project [6].

The revised *Law on Higher Education* requires that for each degree programme, the intended learning outcomes be developed by the HEI that offers the programme, so

that to comply with the relevant level descriptors. This means that the intended LOs for any programme in engineering and technology must “cover” all the LOs in the level descriptors for the subject domain of *Engineering*, specified in the *Ordinance on the NQF-HE*. In addition, the *Law* states that the intended LOs must be relevant to the labour market and consistent with the mission of the HEI and its strategic plan.

The regulations state also that curricula must be designed so that to guarantee that the student can achieve the intended LOs and that the institution must develop and effectively use appropriate methods to verify that these intended LOs have actually been achieved by each student who receives the degree.

Requirements are also imposed on the minimal number of ECTS points associated with elective courses (curriculum flexibility), on the minimal number of ECTS points associated with curriculum components that aim at the development of skills, etc.

The new legal acts include many regulations intended to strengthen the links of HEIs with the labour market. In particular, HEIs are required:

- to engage external stakeholders, including employers, in the process of developing intended LOs and designing curricula,
- to perform an analysis of the labour market needs as a prerequisite for the development of a new degree programme,
- to track graduates' careers,
- to clearly define and verify LOs for internships and placements,
- to engage practitioners in teaching and to provide the students with opportunities to gain work-relevant experience (for practically oriented programmes).

The new regulations significantly affect the approach to quality assurance. The key task of the Polish Accreditation Committee is now to check whether the intended LOs for the programme comply with the NQF-HE and how effective the internal quality assurance system is. In particular, mechanisms used by the institution for verification whether or not the intended LOs for the programme and its components (individual courses/modules) have been achieved by the students are thoroughly examined.

All these NQF-HE related regulations look quite restrictive, but in fact they have brought a much needed academic autonomy to HEIs. Institutions are now free to decide on the names and the contents of the programmes, as long as intended LOs for these programmes comply with the NQF-HE and the students achieve those LOs.

1.3 Information and training campaign

In parallel with the last phase of the NQF-HE development and after that, an unprecedented effort coordinated by the Ministry of Science and Higher Education took place to inform the academic community about the coming changes and to prepare HEIs for successful implementation of the framework. In particular:

- A dedicated NQF-HE web site, accessible directly from the Ministry home site, was created.
- Two handbooks were published. In the first one, the concept of a qualifications framework is explained and the LOs based approach to design of curricula is presented. In the second one, new legal regulations are thoroughly discussed and procedures for their implementation in HEIs are proposed.
- A comprehensive consultation, information and training campaign was organised by the Ministry and the Foundation for the Development of the Education System (FDES). Members of the national team of Bologna experts and other experts who participated in the NQF-HE development served as instructors for more than 100 conferences, seminars and workshops that took place at HEIs around the country

with an estimated participation of more than 16 000 members of academic and administration staff. One of the biggest events of this type, comprising of a seminar and workshops was organised in September 2010 at the Warsaw University of Technology.

2 LEARNING OUTCOMES FOR PROGRAMMES IN ENGINEERING

A key part of NQF-HE regulations is the specification of level descriptors (learning outcomes) for eight large subject domains. These descriptors were developed based on international „standards”. For *Engineering*, competences of an engineer specified by the following organisations or networks were taken into account:

- EUR-ACE (EUROpean ACcredited Engineer project),
- IEA (International Engineering Alliance),
- ABET (Accreditation Board for Engineering and Technology, USA),
- JABEE (Japan Accreditation Board for Engineering Education),
- SBS (Subject Benchmark Statements, UK) for “Engineering” and “Computing”,
- CDIO (Conceive-Design-Implement-Operate initiative).

The number of learning outcomes statements in level descriptors for *Engineering* (for both profiles and for each category of competences), specified in the *Ordinance on the NQF-HE*, is given in *Table 1*. It should be noted that the same number of LOs in a particular category of LOs for a given level or profile does not mean that these LOs correspond to each other; for example, some of the 19 skills defined for the academically oriented Master’s degree have no counterparts in the description of the practically oriented Master’s degree and vice versa.

Table 1. Number of LOs for *Engineering* in the NQF-HE

	first-level qualification (Bachelor’s degree)		second-level qualification (Master’s degree)	
	academically oriented profile	practically oriented profile	academically oriented profile	practically oriented profile
knowledge	11	11	11	11
skills	16	19	19	19
social competences	7	7	7	7
total	34	37	37	37

The level descriptors for *Engineering* include some LOs that were either ignored or inadequately covered in typical engineering programmes offered by the Polish universities of technology before 2012. Examples are given in *Table 2*.

The level descriptors for *Engineering* form a basis for the development of a degree programme in any specific field of engineering. The first step in this process is the formulation of intended learning outcomes. As stated earlier, the intended LOs defined by the institution (more specifically, by a faculty that offers the programme), should comply with the level descriptors for *Engineering*, for the profile selected by the institution (either academically or practically oriented).

The formulation of intended LOs was a completely new experience for the Polish HEIs. To support HEIs in this process, example LOs for several selected fields of study, including 5 fields in engineering, were defined by teams of experts involved in the NQF-HE development. Some of these examples, including LOs for *Electronics*, became part of the ministerial regulation. It must, however, be clearly stated that institutions are not obliged to adopt the LOs from this regulation; they can adopt only some part of the recommended LOs, modify these LOs, or just ignore them.

Table 2. Selected LOs in level descriptors for academically oriented first-cycle programmes in Engineering

	The graduate has the following competencies:
knowledge	<ul style="list-style-type: none"> - has basic knowledge on management, including quality management, and on running business - knows and understands basic concepts in intellectual property protection; knows how to use sources of information on patents
skills	<ul style="list-style-type: none"> - is able – when formulating and solving engineering problems – to account for their systemic and non-engineering aspects - is able to write a business plan
social competences	<ul style="list-style-type: none"> - correctly identifies and resolves ethical dilemma associated with professional activities - is aware of the role of an engineer in the society; understands the need to inform the society and formulate opinions, in particular through media, on achievements in technology and other aspects of engineering; makes an effort to do that in a commonly understandable way

When developing the intended LOs for a given degree programme an institution can also take into account LOs statements suitable for a group of programmes, proposed by any formal or informal group of experts (for example, LOs for the area of electrical and computer engineering, applicable to programmes in power engineering, industrial electronics, microelectronics, telecommunications, etc., proposed by the deans of relevant faculties). It must, however, be emphasized that such proposals can only serve as guidelines for the interested faculties – they should not lead to imposing “standards”, precluding desirable diversification of the programmes offered by different institutions. The sets of LOs developed in the above described way create an intermediate layer between the level descriptors defined in the NQF-HE and the intended LOs defined by HEIs for specific degree programmes, as illustrated in *Fig. 1*.

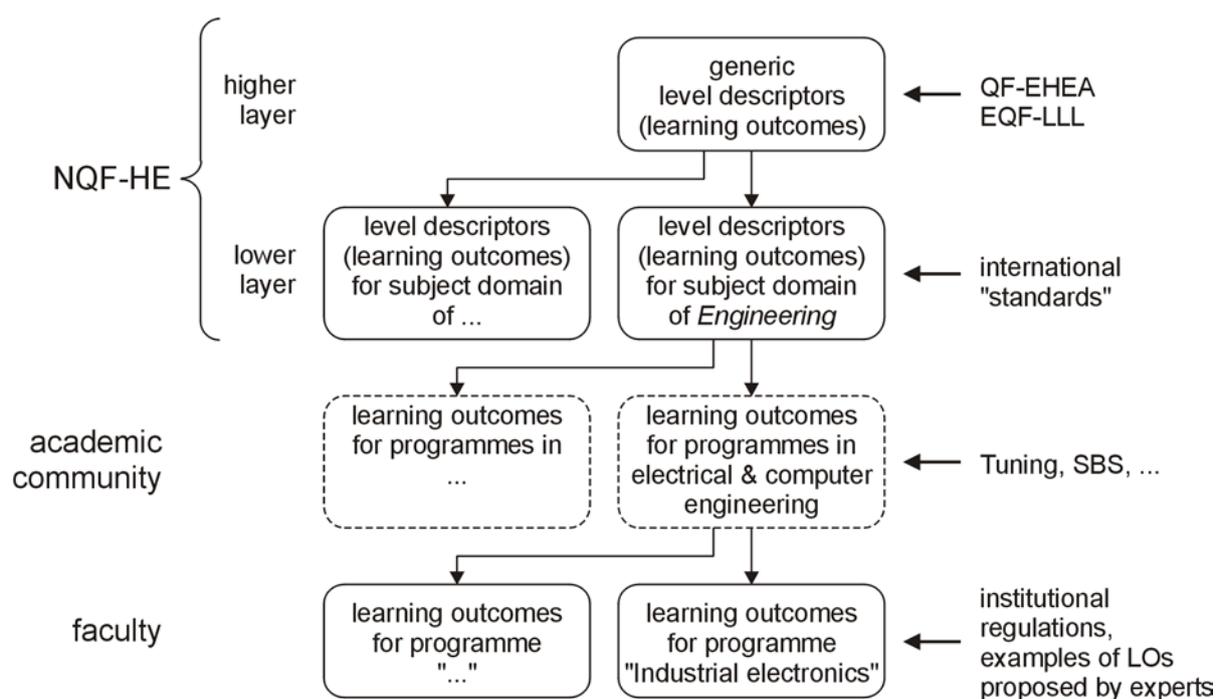


Fig. 1. The hierarchy of learning outcomes (adopted from [7])

3 NQF-HE IMPLEMENTATION AT WUT

As any other Polish HEI, the Warsaw University of Technology (WUT) had to make all the degree programmes offered in academic year 2012/13 compliant with the NQF-HE. A potential threat to the accomplishment of this task was time pressure – some relevant legal acts were issued by the Minister as late as in November 2011.

3.1 Approach

The key step in the process of NQF-HE implementation at WUT was the Resolution of the WUT Senate of 26 October 2011. This resolution specified, *inter alia*:

- the deadlines for actions to be taken by individual and collective bodies at the level of the university and its organisational units (faculties),
- requirements to be satisfied by degree programmes, supplementing the legal regulations; an example would be the specification of the minimal number of ECTS points associated with math and science courses, courses in humanities and social sciences, foreign language training, etc.,
- recommended LOs statements (an interpretation and extension of LOs specified by the ministerial regulation for *Engineering*) for topical areas of math, physics, humanities and social sciences, foreign languages, etc., common for all engineering programmes at WUT,
- the required form for description of a degree programme (programme documentation).

There were also other regulations, issued by the Rector, that defined, *inter alia*, the new form for description of a course (course documentation), with such fields as “intended LOs” and “methods for verification of LOs”.

To support academic staff in the process of redesigning curricula, several seminars, workshops and other forms of training were organised by WUT and individual faculties. The instructors – the earlier trained own staff and invited external speakers – focused on practical aspects of designing curricula and individual courses using the LO-based approach. A special web site dedicated to the NQF-HE implementation was created and regularly updated.

The ICT unit of WUT developed an interactive tool that facilitated the description of the programmes (by coordinators nominated at each faculty) and individual courses (by course coordinators – members of academic staff) in a unified form specified by decisions of the WUT authorities.

The process of redesigning the degree programmes took place at the faculties. For each programme, this process included:

- defining the intended LOs, compliant with the NQF-HE level descriptors for *Engineering* and with the requirements imposed by the WUT Senate,
- redesigning the curriculum; the resulting curriculum must have complied with the legal requirements and internal WUT regulations and, at the same time, must have guaranteed that the student could achieve the intended LOs,
- development of effective methods that would allow the faculty to demonstrate that each student who completed the programme had achieved these LOs.

In most cases, to satisfy these requirements, substantial changes in curricula were necessary – redesign of some existing courses and introduction of new courses. In fact, changes affected all the courses comprising the curriculum, even those whose contents fitted well into the new requirements, as for each course it was required to:

- define the intended LOs,

- develop appropriate teaching methods and techniques that would allow students to achieve these LOs,
- develop appropriate methods to check whether or not the intended LOs have been achieved by the student.

Each programme adopted by the faculty council was subject to a thorough two-level review at the university level. It was first examined by a designated member the special working group composed of experts in NQF-HE, and subsequently by one of the three area coordinators nominated by the Rector.

The reviewing team made a tremendous job to assess within a period of 3 months nearly 100 programmes (*Table 3*). The outcomes of this assessment were discussed at several meetings of the Senate Committee for Education that took place in March-May 2012. After necessary corrections of the programmes having essential deficiencies identified by the reviewers, all the programmes were formally approved by the WUT Senate (at its meetings in April, May and June 2012). Being more specific, the Senate – as required by the *Law* – approved the general concept and the intended LOs for the programmes, leaving the decisions on curricula to the faculties. In particular, it was left to the decision of the faculties how to react to the comments and suggestions made by the reviewers.

Table 3. Degree programmes offered by WUT

	full-time only		part-time only	both full-time and part-time*	total
	taught in Polish	taught in English	(taught in Polish)	(taught in Polish)	
1st cycle	20	7	1	22	50
2nd cycle	20	8		18	46

* according to the Law, a full-time programme and a part-time programme in a given field offered by the same faculty must have the same LOs and the same number of ECTS points assigned, but they may differ with regard to curricula (set of courses, number of contact hours, etc.)

3.2 Outcomes and first experiences

Taking into account the time pressure, it should not be a surprise that the general approach taken by the faculties was to postpone substantial transformations of their programme portfolios and simply adjust the existing programmes to the new regulations which, as discussed above, was by no means a trivial task.

The quality of work done at WUT can be judged by the following fact. As a means of promoting the NQF-HE implementation at HEIs, a special fund was established in the higher education budget for 2012. This fund was used to award – on a competitive basis – grants to faculties that successfully introduced innovations in NQF-HE implementation and in enhancing their internal quality assurance systems, so that to adjust them to the new, LOs oriented approach to teaching. In this competition, WUT was quite successful. Among 62 awarded faculties there were four WUT faculties; each received ca. 250 000 euro for the future reforms.

This success does not mean that the process of the NQF-HE implementation at WUT went without problems. A part of the community, not recognising potential benefits of the reforms or simply having little interest in teaching, perceived the work on the redesign of curricula as an unnecessary burden, jeopardising their other, in particular research related activities. However, as the work was progressing, a shift from an openly demonstrated resistance to at least partial acceptance was observed.

The introduction of redesigned programmes in October 2012 does not mean that the shift towards LOs based curricula is completed. The work on the refinement of teaching techniques and methods for verification of LOs, and also on the reorientation of the internal quality assurance system towards LOs is still in progress.

The WUT academic community has clearly demonstrated the willingness to make improvements – a one-day seminar on experiences in implementing the NQF-HE, including the presentation of good and bad practices by external experts, organised at WUT in April 2013, attracted many members of academic and administrative staff.

4 CONCLUSION

Following the legal regulations that introduced the NQF-HE in Poland, substantial transformations of engineering curricula have taken place at universities of technology, including the Warsaw University of Technology.

There is some evidence that the redesign of degree programmes at WUT so that to make them compliant with the NQF-HE was worth doing. The curricula are now more compatible with the international standards. They also appear more relevant for the labour market, as they focus on the development of skills, including transferable skills, and on raising awareness of non-engineering aspects of engineering work.

How this will affect the quality of education and the employability of WUT graduates is too early to say – and is something to be followed closely in the years to come.

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