GUIDELINES ON HOW ENGINEERING COMPETENCES CAN BE ASSESSED

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1. ABSTRACT

The main focus was on how to obtain a concept for the documentation and validation of non-formal and informal learning, outside education system and activity learning, outcomes of engineers. As engineers are increasingly working on an international level the comparability of job applicants within the European Higher Education Area (EHAE) is important to employers. For that reason it was of the utmost importance to develop an uniform European system that is recognized by engineering stakeholders in Europe. The main goals of the project were:

1. The creation of a system for the documentation and validation of non-formal and informal learning-outcomes;
2. The coordination of the concept with professional engineering organizations;
3. The integration of the concept into the already existing system of the Engineering Card, the professional card for engineers in Europe.

The overarching aim is to give engineers the possibility to have their non-formal and in-formal learning outcomes documented and validated by a system that is recognized throughout Europe. With that system there will be more transparency on the European labour market and may facilitate the mobility of engineers within Europe. This is immensely important before the background of lack of highly qualified personnel on the one hand and high rates of unemployment of highly qualified personnel on the other side. It is intended that the article contributes to the development of a truly European labour market with a systemic approach to recognize all competences of engineers. This system to recognize competences of engineers, acquired outside the formal education and training sector, is the main contribution of this paper

2. USING AN E-PORTFOLIO FOR ENGINEERING COMPETENCE EVALUATION

Several initiatives at European level and worldwide have addressed the engineering competence evaluation. This document is a collection of practices and examples useful for the goal of having a system for recognition of formal and non-formal learning using e-portfolios. Documents and data used in this document are presented at the end for further use and reflection.

The attempt to set out a systematic approach to competency recognition and accreditation of formal and non-formal learning through e-Portfolios has been presented, for instance, by the Europortfolio Network [1]. Some subjects were found to be relevant for the adoption of such a system. The first subject is trust and it emerges as a core dimension to competency recognition and accreditation. It is essential for the exchange of services provided by engineering across society. These accreditation and recognition mechanisms exist (at least in part) to help people make decisions about whom they can trust to supply engineering based goods and services.

The second subject refers to the forms of proof of the engineering competencies [2]. This proof can be direct or indirect. The direct proof may be composed by the exam of a performance or of a proof by the engineer. The indirect form is applied to the cases of some form certification, digital or other, or of a type of qualifications that may be also certified. When using e-portfolios there is mixture of direct and indirect forms combined with different degrees of content and accuracy [3].

The third issue is the level of detail in respect of the competency claimed. Disaggregation of competencies can have beneficial effects on the motivation of engineers since it offers short-term, transparent and more achievable targets [4]. The question of using e-portfolios for the recognition of competencies is related with

the characteristics of these instruments. Some of the benefits of using e-portfolios for non-formal and informal learning are [5]:

a) Encourage engineers to reflect on their learning and training;
b) Helping engineers see how their training relates with real-world practice;
c) Support engineers realize how their non-formal and informal learning is connected with their professional development plan;
d) Offering a flexible yet robust system that provides an assessment of competencies;
e) Providing professional associations, accreditation agencies and engineers a mechanism through which engineers can showcase their knowledge, attitudes and skills acquired through informal and non-formal learning.

The e-portfolio provides an environment where engineers can collect their work in a digital archive; select specific pieces of work (hyperlink or documents) to highlight specific achievements; set goals for future training to improve; sharing this learning work with others; when reviewed by peers can provide formative feedback to engineers on where they could improve; the collection of evidences of what the engineer has learned over time can be used for presentation to different types of professional organizations with the purposed of obtaining validation, recognition or certification.

In terms of digital tools there are specific platforms to produce engineering e-portfolios and generalized tools can be used. For the use of non-specific software of e-portfolios there are simple and accessible tools, such as HTML editors (FrontPage, Dreamweaver) or text editors (Microsoft Word, Microsoft Publisher). Some professional associations have developed platforms to record the e-portfolios of engineers. One example of these platforms is VALORie available for engineers to record their professional development achievements including informal and non-formal learning (http://valore.oern.pt). Another example is “mycareerpath” that allows recording online by engineers to perform and measure their professional achievement (https://www.engc.org.uk/professional-development/mycareerpath).

3. NON-FORMAL AND INFORMAL LEARNING COMPETENCES OF ENGINEERS

The e-portfolios in accreditation processes also support for self-assessment, provide links to external sources requiring competences and qualifications, increase opportunities for evidence validation, use of a variety of evidence forms that support competence and provide content for an assessment dialogue between the assessor and the engineer. Since e-portfolios are commonly used as an electronic space to hold any supporting evidence relevant to learning and achievement that will support the demonstration of competencies. The e-portfolios may provide evidence against criteria, rubrics or competencies with elements of the template structures. This allows the engineer to see progress and gaps where further evidence needs to be generated, cross-referencing the evidence against the standards. The processes of collecting, selecting, reflecting, sharing, collaborating, annotating and presenting evidence of achievement are positive factors to the professional development of the engineer.

Professional competences of engineers are generally established across Europe by professional associations. Therefore, it is not possible to create a common set of competences for different countries and for the different engineering specializations. The European Qualification Framework establishes three groups of competences (knowledge, skills and attitudes) with eight levels of development. This framework is used for lifelong learning and allows progress in levels according to improvement of the competences recognized and validated. There is no equivalent of a qualification framework for engineers that describe non-formal and informal learning competences.

Therefore, it is proposed that there is an e-portfolio system to record evidences of competences acquired in non-formal or informal processes. Each accreditation or professional organization can use these e-portfolios to recognize competences acquired by each engineer. There are some tools for evidencing these types of learning. The two tools that will be presented as examples are from FEANI and from project VALORIe. In both cases templates are used to structure the presentation of evidence and to organise the items to facilitate the assessment process.

FEANI has a system of awarding credits to Continuing Professional Development (CPD) for Engineers [6]. This system is a voluntary system to be used by the FEANI members' professional organizations. CPD activities that can be accounted are classified as follows:

a) In-company training courses or lectures
b) Formal post graduate academic courses
c) External training courses
d) Service in professional engineering organization activities
e) Technical visits or assignments
f) Updating professional development based in individual study
g) Preparation and presentation of a technical paper in a conference
h) Preparation and technical publication in a journal or a book related with the profession
i) Teaching or instructing in CPD related activities with the profession

The VALORIe recording system has a more detailed list of activities that may contribute to the development of competencies. These are:

a) Accredited courses
b) Participation in congress, conferences and conventions
c) Participation in workshops and seminars
d) Development of regulations, codes and norms
e) Registration of brands and patents
f) Communications in congresses, conferences, conventions and seminars
g) Publications (opinion article, technical paper, reviewed technical paper, report of technical work, technical book)
h) Engineering research
i) Design, revision of a project
j) Manufacturing, construction, production
k) Evaluation, inspection, quality control, safety
l) Auditing
m) Coordination and management

In VALORIe the data that is recorded are:

a) Designation of the activity that will be recorded
b) Beginning date and conclusion date
c) Summary
d) Type of CPD associated
e) Other members of technical team (when applicable)
f) Company or organization involved
g) Local
h) List of evidences
i) Evidence(s) submitted

4. SELF-EVALUATION OF COMPETENCIES USING AN E-PORTFOLIO

The assessment can be of two types: self-assessment and external assessment. Concerning the self-evaluation the engineer should have a personal development plan (PDP). PDP is a structured and supported process undertaken by an engineer to reflect upon their own learning, performance and/or achievement and to plan for their personal, educational and career development [7]. The PDP may be created by the engineer taking into account the personal aspirations, employer requirements and professional organizations standards.

The methodology proposed in EuroRecord project [8] is a model that uses a descriptive structure of the key features of professional activity in engineering. EuroRecord employs a professional competence model as a means for ensuring that learning achieved is recorded against a commonly agreed and logical set of headings. The EuroRecord attempts to establish a generic competence model of professional competence that applies across the entire spectrum of engineering. The two concepts that are important for the description of non-formal and informal learning in the EuroRecord are Competences and Body of Knowledge. A generic competence model represents as considerable degree of commonality with other professions, though the fine detail of the relevant Body of Knowledge differs from profession to profession.

4.1. EuroRecord Competence Framework

EURORECORD – EUROPEAN RECORD OF ACHIEVEMENT FOR PROFESSIONALS IN THE ENGINEERING INDUSTRY

A – Reflection, Self-awareness

B – Ethics, Principles and Values
- B1 Follow an accepted code of ethics appropriate to the social and professional context
- B2 Exercise duty of care to clients and the community
- B3 Assume professional responsibility for own actions
- B4 Develop and promote environmental principles

C – Generic Professional Competences
- C1 Maintain and develop own expertise
- C2 Develop new professional knowledge through research and practice
- C3 Develop and mentor others
- C4 Apply self-management principles
- C5 Communicate and represent in the professional role
- C6 Manage people, resources, projects and business affairs
- C7 Work as a member of and lead a team

D – Generic Professional Engineering Competences
- D1 Professional engineering practice skills
  - D1.1 Solve engineering problems, adapting to circumstances
  - D1.2 Apply engineering method
  - D1.3 Apply quality management principles
  - D1.4 Utilise appropriate engineering and technological aids
  - D1.5 Conduct testing, measurement and evaluation
- D2 Professional engineering planning, design and documentation
  - D2.1 Clarify and define engineering design requirements
  - D2.2 Prepare concept proposal to meet requirements
  - D2.3 Perform or arrange for design of selected proposal
  - D2.4 Perform design evaluation
  - D2.5 Prepare supporting documentation
  - D2.6 Maintain integrity of design identification documentation
  - D2.7 Present, report on and advocate engineering ideas
  - D2.8 Prepare, comprehend and communicate engineering documents

E – Engineering Competences Related to Specific Activities:
- E1 Research, development and commercialisation
  - E1.1 Perform research
  - E1.2 Formulate concepts for development
  - E1.3 Identify and seek allocation of resources for development of research outcomes
  - E1.4 Perform market research on research outcomes
  - E1.5 Commercialise research outcomes
- E2 Materials and components
  - E2.1 Define requirements and applications for specific materials or components
  - E2.2 Source raw materials for making engineering materials or components
  - E2.3 Supervise the preparation or manufacture of engineering materials and components
  - E2.4 Assess properties of materials or components
  - E2.5 Select protection against deterioration
- E3 Manufacturing and production
  - E3.1 Plan the manufacturing or production process
  - E3.2 Maintain and supervise a quality assurance programme
  - E3.3 Perform process operations, control and optimisation tasks
  - E3.4 Perform raw materials management tasks
  - E3.5 Measure production performance
- E4 Project implementation
  - E4.1 Perform construction or installation tasks
  - E4.2 Prepare and monitor contracts
  - E4.3 Prepare tenders and meet contract requirements
  - E4.4 Perform site management tasks and activities
  - E4.5 Perform commissioning

E5 Asset management
- E5.1 Perform asset procurement tasks
- E5.2 Perform or supervise maintenance tasks
- E5.3 Perform asset controlling and optimisation tasks
- E5.4 Perform disposal planning

E6 Engineering education and training
- E6.1 Develop engineering education or training plans
- E6.2 Conduct engineering education or training programmes

E7 Other specific activities

4.2. FEANI Credits for Continuing Professional Development (CPD) of Engineers

CPD credits are only an indicator of the commitment of engineers to professional development and to practice improvement. Credits are a numeric appreciation of the CPD activities and may contribute to the assurance of quality improvement of engineering practice. These are procedures approved by FEANI to register and acknowledge CPD performed by engineers. It is based on current practices by national engineers' associations like Engineers Australia (https://www.engineersaustralia.org.au) and Engineers Ireland (http://www.engineersireland.ie). It may be used by any engineering association to record CPD activities of its members. It may be used also by any engineering association to verify CPD periodic requirements of its members.

The CPD activities that can be accounted for engineers learning (formal, non-formal and informal) are registered and should abide by limits for each year. In the FEANI credit based scheme of CPD it is considered that the average of 40 credits per year is the minimum total of CPD for an engineer. One credit is considered, in general, equivalent to one hour of participation in the CPD activity. There are maximum values that can be considered for each type of CPD when calculating the yearly average. The procedures and limits to account the CPD credit values are:

A. In-company training courses or lectures taken in a lecture room or in a virtual environment – no limit of maximum credits.

B. Formal post graduate academic courses that will involve some form of assessment – no maximum limit of credits.

C. External training courses from a recognised institution or training provider – no maximum limit of credits.

D. Service in professional engineering organization activities that may include serving in a volunteer capacity on boards and committees; being a member on higher education accreditation visits; assisting with CPD audits; mentoring a colleague for work experience purposes; contributions to participation in technical standards – limit of 15 credits per year.

E. Technical visits or external assignments where the engineer must be able to demonstrate how it has extended knowledge and skills related with the profession – limit of 5 credits per year.

F. Updating professional development based in individual study for any learning activity undertaken it is necessary to demonstrate how it has extended knowledge and skills related with the profession – limit of 5 credits per year.

G. Preparation and presentation of a technical paper in a conference with papers subject to critical peer review prior to publication – limit of 10 credits per year.

H. Preparation and technical publication in a journal or a book that are related with the profession – limit of 20 credits per year.

I. Teaching or instructing in CPD related activities with the profession when the engineer is not a member of higher education or research institutions – limit of 15 credits per year.

The sum of credits from A., B. and C. has a maximum of 25 per year.

Step by Step Procedure

Concerning the informal and non-formal learning self-evaluation assessment the technologies and platforms described above may be used with e-portfolios. These can support an evidence-based evaluation with inclusion of certificates and other pertinent documents. The self-assessment steps proposed consists of two phases: registering activities and verification of requirements.

Each engineer should provide in a period of one, two or three years its own record of CPD. Validation of formal, non-formal or informal learning can be done by an accreditation agency, professional organization or education or training institution. This can be done by filling a digital e-portfolio template provided, for example, by its national engineering association or by a validation organization. Providing the information about the CPD activities can be done at any

time and it is convenient that it is done when activity is completed. The credits of CPD for each engineer should be reported within the periodicity required by national engineering association or by the validation organization. The digital e-portfolio should have the following fields:

a) Name and contacts
b) National engineering association member
c) Each type of the CPD activities accepted by the validation organization. It should have a description of the CPD activity with the following information:
   - name of CPD activity
   - description of CPD activity
   - duration in hours (or equivalent in hours)
   - maximum credits considered due to the limitation
   - supporting documents of the CPD activity

Engineers should plan their CPD activities preferably in accordance with the identification of competencies required or recommended in a related qualification or job profile. This choice of the competencies required can be based on the engineer's self-assessment against criteria, rubrics or elements within the set of competences required. This definition of competencies required can also be done by the employer. This leads to the development of a personal development plan for next period or stage.

5. EXAMPLE OF APPLICATION OF SELF-ASSESSMENT

Having defined the competences needed for a given year and having registered the CPD activities the engineer may verify if the number of credits was obtained. The following example employs the FEANI CPD credit scheme for the nine types of activities.

In this example the list of activities that were identified are:

- Programming
- Handling meetings
- Project management
- Safety management
- Introduction to nanotechnologies
- Equipment regulations and specifications
- Introduction to cloud computing
- BIM in construction

The accountancy related with the activities according to the FEANI credit system is given by:

1. In-company training courses or lectures.
   a. In-company training – "PLC programming" – 2d (2x7h); "How to use Windows 10" – 1d (7h); "Improve Meeting Efficiency" – 1d (7h)
   b. Sum of hours equals 28.
   c. Consider 28 credits.

2. Formal post graduate academic courses.
   a. Postgraduate course – "Project management" – 150 contact hours; "Safety management training" – 60 contact hours; E-course – "Online course nanotechnology" – 40 hours equivalent
   b. Sum of hours equals 250 credits.
   c. Consider 250 credits

3. External training courses.
   a. Course "Working with Office 2013" – 2d (13h); "EEx equipment class regulations" – 1d (6h); "CE and the new machinery directive" – 3d (20h); Webinar "ERP in the cloud" – 0,5d (3h); E-course "Management for engineers" – 20h equivalent
   b. Sum of hours equals 62 credits
   c. Consider 62 credits

4. Service in professional engineering organization activities.
   a. Attended 3 FEANI EMC meetings in one year – 8 hours each x 3 = 24 hours
   b. Sum of hours equals 24 credits
   c. Consider limit – 15 credits

5. Technical visits or assignments.
   a. Three technical visits to construction sites of one day – 8 hours x 2 = 16 hours
   b. Sum of hours equals 16 credits
   c. Consider limit – 5 credits

6. Updating professional development based in individual study.
   a. Specialization group workshop on BIM in construction – 32 hours
   b. Sum of hours equals 32 credits
   c. Consider limit – 5 credits

7. Preparation and presentation of a technical paper in a conference.
   a. Presentations in three conferences of reviewed papers – 16 hours x 3 = 48 hours
   b. Sum of hours equals 48 credits
   c. Consider limit – 10 credits

8. Preparation and technical publication in a journal or a book related with the profession.

a. Article in the journal “Technical Management” (2 pages) – 30 Hours
b. Sum of hours equals 30 credits as possible
c. Consider limit – 15 credits

9. Teaching or instructing in CPD related activities with the profession.

a. Instructor of course “Machine Safety” – 2d (6h); “Project costs” – 0,5d (3h)
b. Sum of hours equals 9 credits
c. Consider 9 credits

Since activities type 1), 2) and 3) have a sum of 340 credits (28+250+62) only 25 credits can be considered. In this example the engineer presents a total of 74 credits (25 + 15 + 5 + 5 + 10 + 15 + 9) that is well above the average required of 40 credits per year. This case shows that the progress in the professional development of engineers can be considered and accounted. The accountancy results may be used for legal requirements of the profession or for the employer records in terms of qualification.

6. CONCLUSION

The system proposed achieves the outcomes as desired. The e-portfolios and any other digital recording system may be the right tools to facilitate the classification, validation and recognition of the competences acquired through formal learning. A possible advancement can be the establishment of a reference framework that may facilitate the self-evaluation of the development of each engineer and that may help employers and professional organizations to consider the progress of the qualification of the engineers.

The proposed approach requires a combination of steps taken by the engineers, the engineering schools, the engineering professional organizations and quality assurance organizations and agencies. In fact much of the professional development of engineers occurs during activity as professionals and mostly outside the formal teaching and training organizations. Therefore, proposals to recognize, to value and to accredit this type of non-classical learning should be used allowing and promoting the professional qualification of engineers.

7. REFERENCES

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