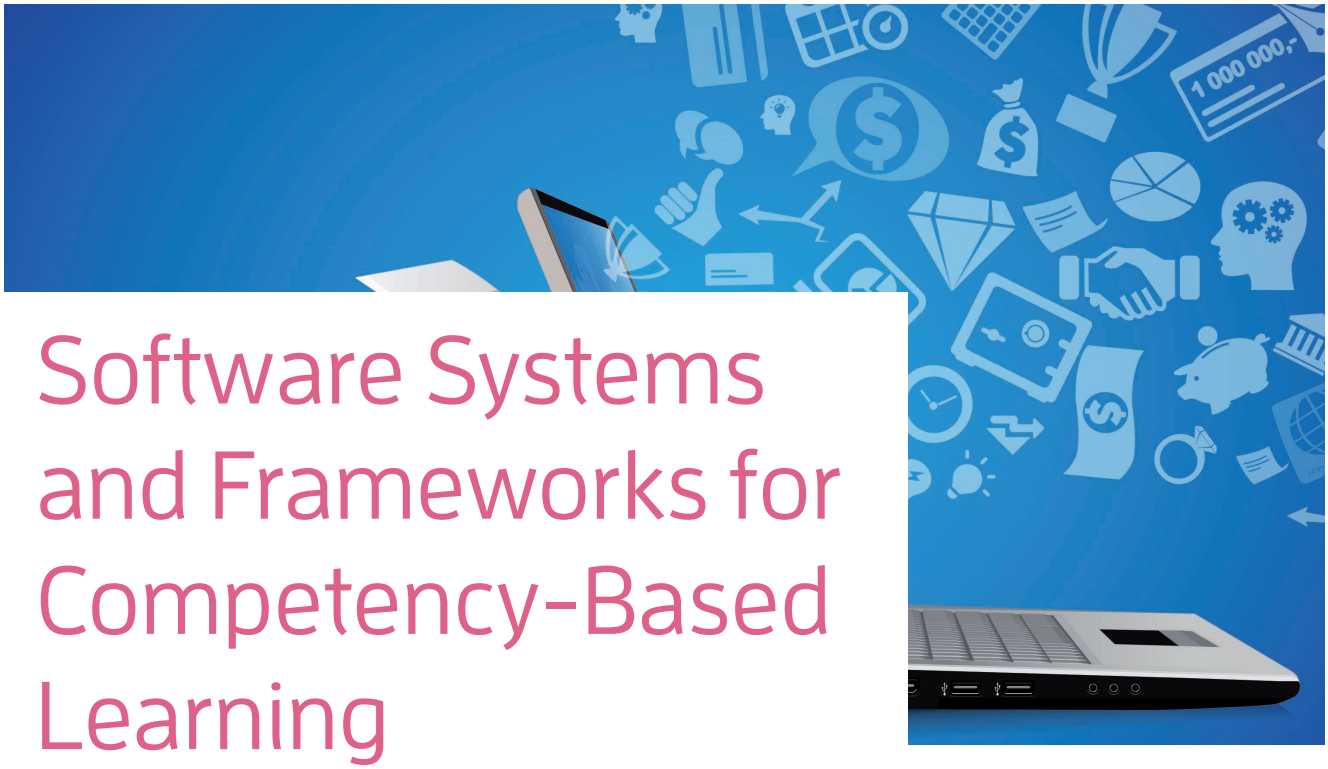

Software Systems and Frameworks for Competency-Based Learning

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There is a major shift today to incorporate competency-based education in all educational systems. This paradigm brings new requirements to software systems used in education. I present some efforts in this direction and show examples and case studies from research projects.

One important trend is the recognition that lifelong learning has become a necessity. It leads to individualized learning.

Another important trend is the need for education to be closely related to real life and to prepare students to participate in the current economy. So, students need to possess new skills and abilities, which will help them start working in any profession without the need of additional training.

The result from these two major trends is called *competency-based education*. This allows both individualized learning and the learning oriented to achieve new skills and abilities. There is a major shift today in all educational systems to incorporate this new form of learning. As a result, there are a lot of pedagogical theories explaining what is competency-based learning, how to be realized in practice, what are the main drawbacks and problems, and how we can try to solve them.

One of the main problems is related to the lack of appropriate software systems and frameworks that are able to support all processes related to competency-based education. There have been many attempts to develop different software tools and instruments to support separate elements and processes related to competency-based evaluation, but the ultimate goal should be to develop a complete software system supporting

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the whole set of processes involved in competency-based learning.

In this article, I will present some of these efforts, propose some important elements for such complex software frameworks, and show some examples and case studies based on my experience from participation in some of the most ambitious research projects funded from the European Commission in past 20 years.

Several researchers[1–4] formulated some of the requirements to new software systems supporting competency-based learning:

- The learner is the center of the system—he or she choose their goals, the forms of learning, the

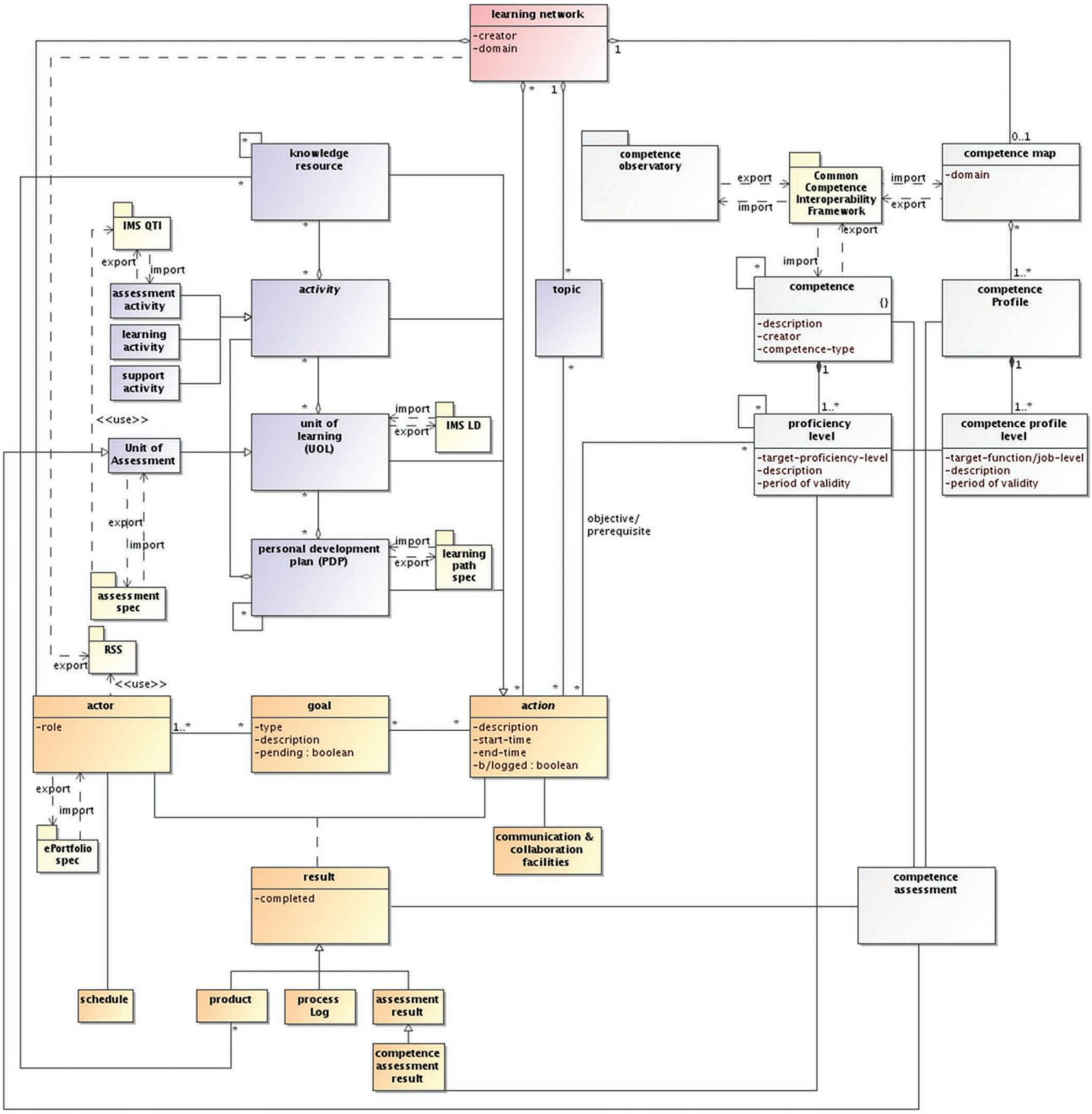

FIGURE 1. The TENCompetence Domain Model.[14]

time and pace for learning, and so forth.
- Different learners have different knowledge and competence levels as well as different goals and learning styles. So, the system should differentiate all these particularities and be able to adapt to match and support all these differences.
- The learning process is oriented to achieving demonstrable competences rather than simply knowledge about some facts and processes. The learner should be able to solve some practical problems in addition to explaining the base of knowledge involved.

In the last 25 years, we have seen a consistent increasing number of experiments and efforts to apply this new method of learning. While competency-based learning is more natural for lifelong learning experiences, we have also seen many efforts to incorporate this process into formal education, first in universities, and later, in K–12 education.[5–7]

Usually, these efforts have been organized around various competence development programs (CDPs). Almost all such CDPs include standard learning units, such as courses, modules, lectures, and so on The main difference is the presence of new standards for competency descriptions, which are used to plan and evaluate the education.[8]

The most used such standards are Instructional Management System Reusable Definition of Competency or Educational Objective,[9] IEEE-Reusable Competency Definitions,[10] and Human Resources Open Standards Consortium-eXtensible Markup Language.[11] Also, the standards for learner modeling and recognition of learner achievements should be centered around these new competency standards or at least in support of them.

The first attempt to create such a complex software system was the main objective of the project TEN-Competence (Figure 1).[12,13] This project proposed theoretical models for competency-based learning, software models for systems supporting competency-based learning, and technical platforms implementing the models, validated through several big pilot experiments across Europe.

The typical implementation of such a software framework involves supporting social networks made up of members from a given domain who are interested in competency-based learning in this domain. Such a network should be distributed, self-organized, and flexible and provide various services. Members share learning resources and experiences, provide different services, and help each other to reach their goals.[15]

The major result of the project was the development of an integrated software platform, including the following main software tools:

- The Personal Competence Manager (PCM)
- LearnWeb 2.0
- The Personal Development Planner (Web PDP)
- The Goal Orientation Tool (GOT)
- The Learning Design editor/player
- The Learning Path editor
- A portfolio manager
- An assessment editor/player.

The PCM[16,17] provides the following functionalities:

- defining a target competence profile
- mapping to a competence development profile
- identification of competence development opportunities
- organizing a competence profile
- building on experience by promoting the development of communities around particular competence development needs.

The simplified architecture of LearnWeb 2.0,[18] including the main elements, is shown on Figure 2.

The main components visualized on the figure are:

- The web server LearnWeb 2.0 provides interactive search, sharing, and exchange of learning resources and knowledge.
- The Knowledge Resources Sharing and Management (KRSM) server provides access

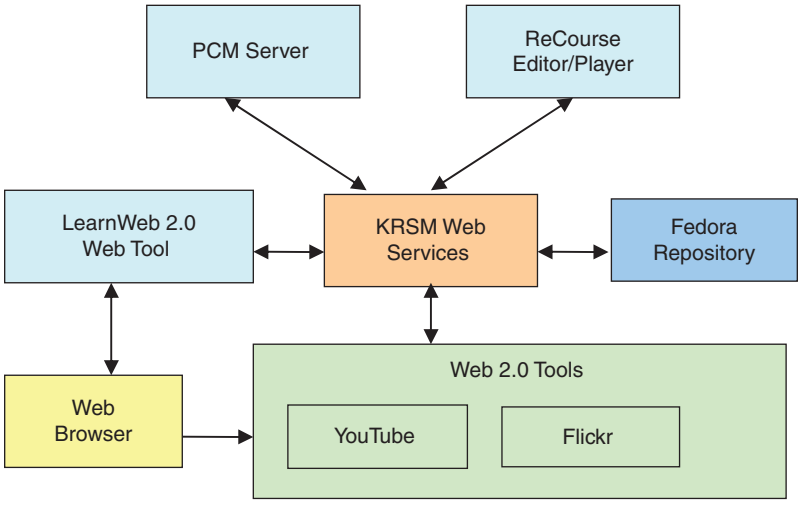

FIGURE 2. The LearnWeb2.0 simplified architecture. KRSM: Knowledge Resources Sharing and Management.

to all knowledge resources in the digital library via Representational State Transfer services. These services can also be used to access many external knowledge resources and social networks.

- The Fedora repository is the digital library that stores learning objects (LOs) and resources.
- The PCM server and ReCourse editor/player provide links between all TENCompetence tools via user management, user modeling, competence development planning, knowledge resource sharing, and so forth.

Web PDP[19] provides learners with the functionality to develop their

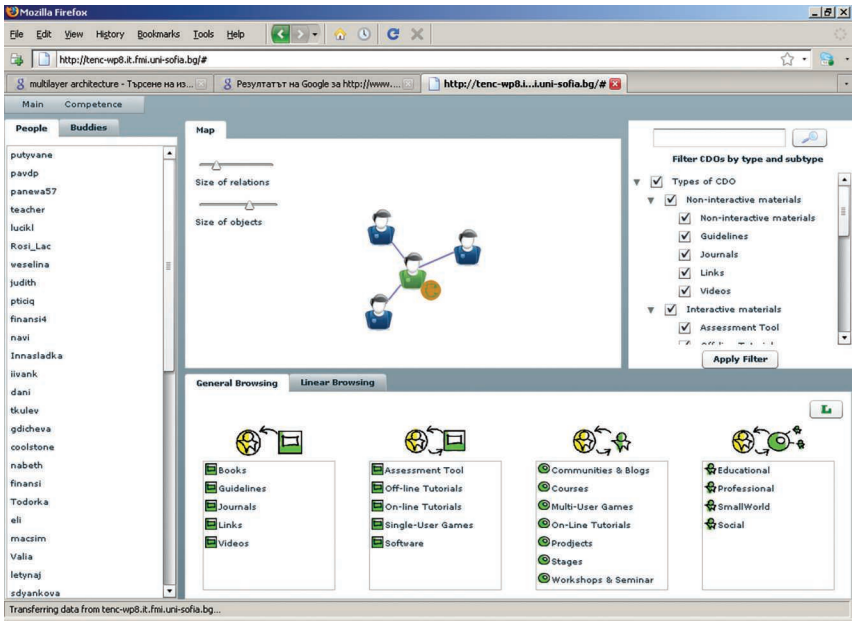

FIGURE 3. The GOT.

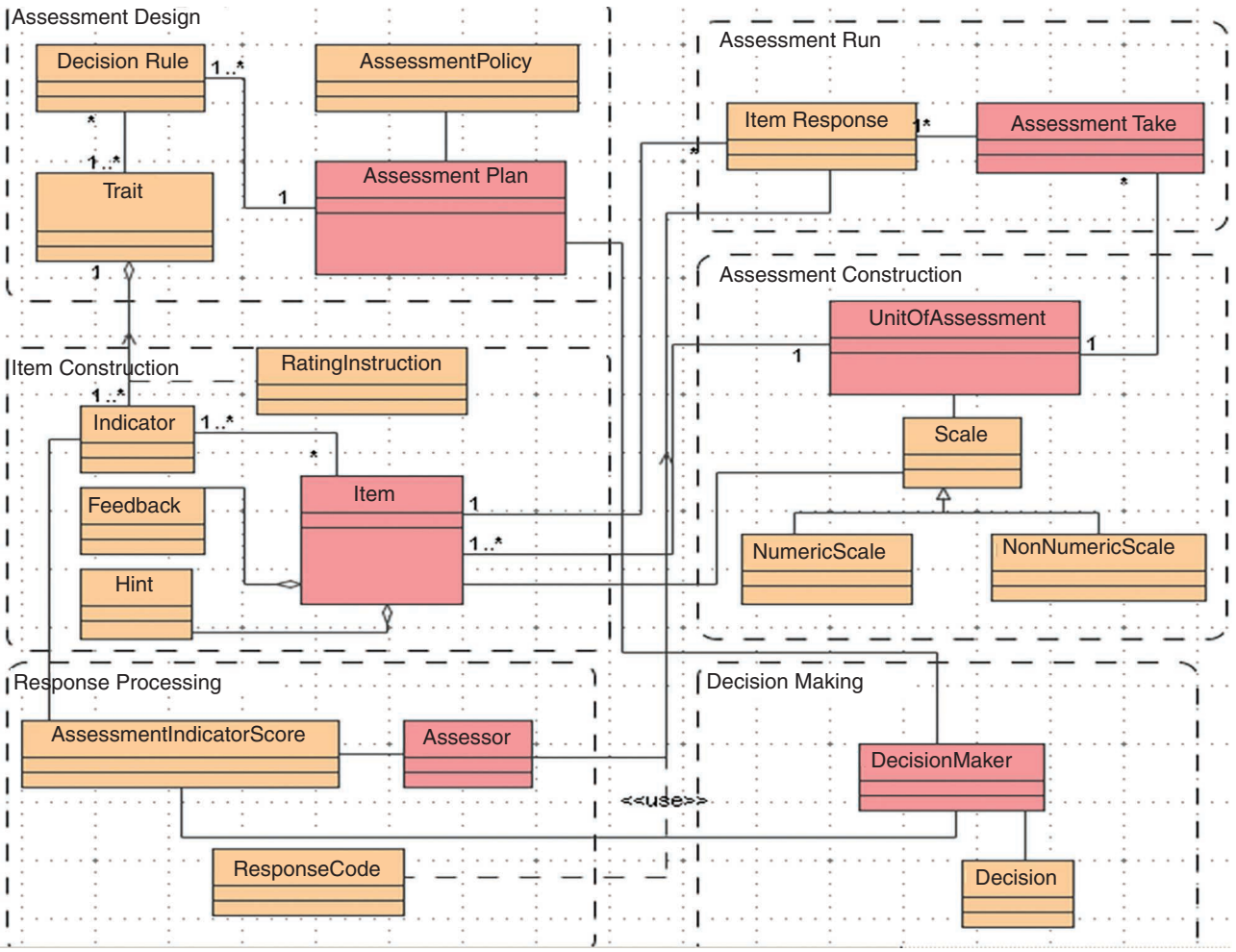

FIGURE 4. A competency-based evaluation model.

own competence development plan (learning plan) by using preliminary created competence profiles. It also enables users to develop a plan to evaluate their competences, adapt the plan on the fly, add useful learning resources, and implement the plan via existing CDPs and other learning activities.

While most of the tools are for experienced users and provide some special services for them, there is one introductory tool for beginners: the GOT.[20] It helps users not only get oriented with the system but also helps them find the relevant social networks for competency-based learning and shows them how to plan further competence development using all other tools and components.

For the classification of all knowledge resources, a taxonomy is used, linked with CDPs (Figure 3). In an evaluation for competency-based education, the crucial question is whether (and at what level) the learner can practice and demonstrate specific competency.[21] As a consequence, the standard evaluation techniques based on tests are not appropriate. Practices in big organizations show that we need new forms of assessment, such as self-assessment, peer assessment, 360° feedback, and portfolio assessment.

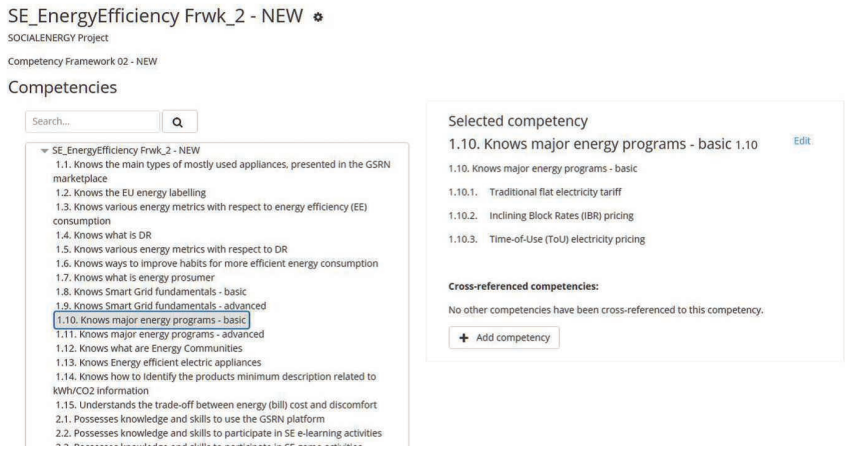

FIGURE 5. The SOCIALENERGY competence framework in Moodle.

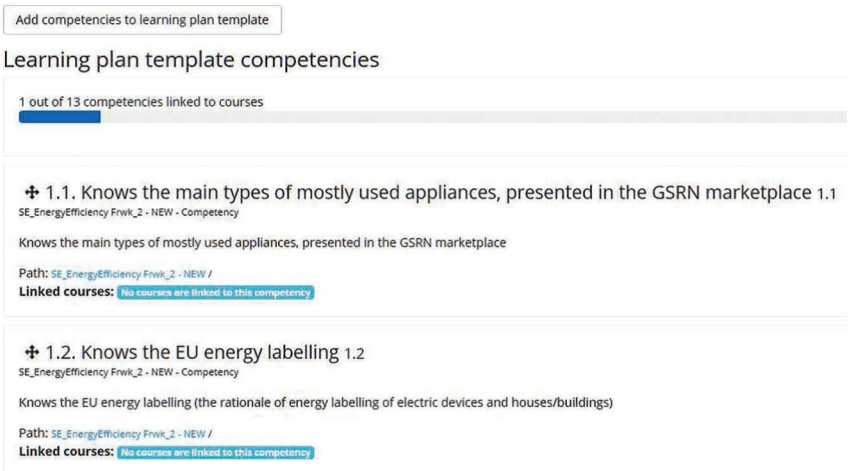

FIGURE 6. The SOCIALENERGY learning plan template.

The competency evaluation model, developed in the TENCompetence project (Figure 4), was based on the Open University at the Netherlands (OUNL)/Cito Institute for Educational Measurement Arnhem (CITO) evaluation model.[22] It was also close to the TENCompetence Domain Model.[14] The model was tested and validated in several pilot experiments [23] and then further developed and described in two Ph.D. degree dissertations.[24,25]

All the tools developed during the project were free and from an open source. Unfortunately, because of the lack of resources, the project team was not able to support and further develop the tools and framework after the project ended in 2009. Some of the tools were used in later projects; for example, PDP was used in the OpenScout project,[19] and most of the evaluation tools were used in big projects in industry, supporting employers in the hiring, planning, and training of workers.[26]

Interestingly, the ideas of the TENCompetence project were implemented in the Moodle[27] Learning Content Management System (LCMS). This was not a surprise as the Moodle technical leaders participated in most of the important technical meetings of the TENCompetence project. So, if somebody wants to apply the TENCompetence approach, the easiest way is to use the Moodle system, which is also free and open source.

The TENCompetence approach using Moodle was implemented in the Project SOCIALENERGY H2020-ICT-24-2016 (A Gaming and Social Network Platform for Evolving Energy Markets' Operation and Educating Virtual Energy Communities), 2017–2019.[28,29] One of the main parts of the software system built in this project was LCMS, which has the following main functionalities:

- receiving personal development plans according to the learners' goals
- organizing the learning process according to personal development plans
- providing learning resources in the form of LOs indexed with

competencies through the use of ontologies and taxonomies that present the main concepts from the energy efficiency domain
- complementing the learning process provided by the serious game.

Software tools for competency-based learning are gaining increasingly more popularity and use. However, we are still waiting for easy-to-use, complete solutions with proven results.

Software tools for competency-based learning are gaining increasingly more popularity and use.

We use Moodle with all the competency support built into the system to implement all the functionalities of the LCMS (Figure 5). Through Moodle, we developed the following competency support features:

- competence frameworks
- individual competences, which are included in competence frameworks
- learning plan templates (Figure 6) and individual learning plans
- individual learning resources and activities
- various competency-based modules/courses.

This is the easiest approach to applying competency-based learning via LCMS. However, the assessment in Moodle still doesn't fully support competency-based learning.

Lately, other developers, such as Coursera, have announced some support for competency-based learning (they use the name *skillset*), but their vision on competency-based learning has still not been made completely clear and open for the public. The Coursera Skills Graph[30] is used to connect the skills (from taxonomy), course content, assessments, career paths, and competencies of learners. They use machine learning algorithms to extract this information from courses and learning programs. They are using a skill taxonomy containing more than 38,000 skills.

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