



ESCO: Boosting Job Matching in Europe with Semantic Interoperability

Martin le Vrang, *European Commission*

Agis Papantoniou, Erika Pauwels, Pieter Fannes, Dominique Vandenstein, and Johan De Smedt,
TenForce

ESCO—the multilingual European Skills, Competences, Qualifications, and Occupations classification—lets stakeholders in the EU labor market better understand information they exchange. Such semantic interoperability will help address the chronic mismatch between unemployed workers' skills and companies' needs.

The financial crisis of 2007–2008 has had a persistent impact on the EU labor market. Today, most European countries struggle with high unemployment rates—more than 26 million people throughout the continent cannot find a job. The situation is particularly severe for the young. In Greece and Spain, youth unemployment exceeds 50 percent.¹

At the same time, in some economic sectors such as engineering, information and communications technology (ICT), and healthcare, companies cannot find the workforce they need. For instance, the European Commission estimates that through 2015 up to 900,000 job vacancies in the EU will not be filled due to a lack of ICT professionals.²

This concurrence of high unemployment and unfilled job vacancies exposes a mismatch between unemployed

workers' skills and companies' needs. While the education system must provide a long-term solution to Europe's chronic unemployment, greater mobility and better job matching can help address the problem in the short term.

Enabling jobseekers to move and work anywhere in the EU can remedy regional imbalances. However, regional mobility must be accompanied by occupational mobility to have a tangible effect on skills gaps and current unemployment rates. Thus, two goals arise: how to help jobseekers find a suitable job in another European country or region, and how to enable people to refocus their careers on sectors and occupations with a bright outlook.

Communication is fundamental to a well-functioning labor market with regional and occupational mobility. Information must be exchanged among various parties including jobseekers, employers, employment services, job portals, educational institutions, and training providers. Successful recruitment and job placement require an accurate description of both jobseekers' profiles—past, current, and desired occupation, education, training, and work experience—and the skills, competence, and knowledge employers expect from a successful candidate.

Exchanging information accurately is a complex task, especially in a union of 28 member states with different education systems and 24 official languages. Imagine someone who studied in France, lives in Estonia, and wants to work in Portugal. What can we do to make this process easier and more effective? The answer lies in *semantic interoperability*.

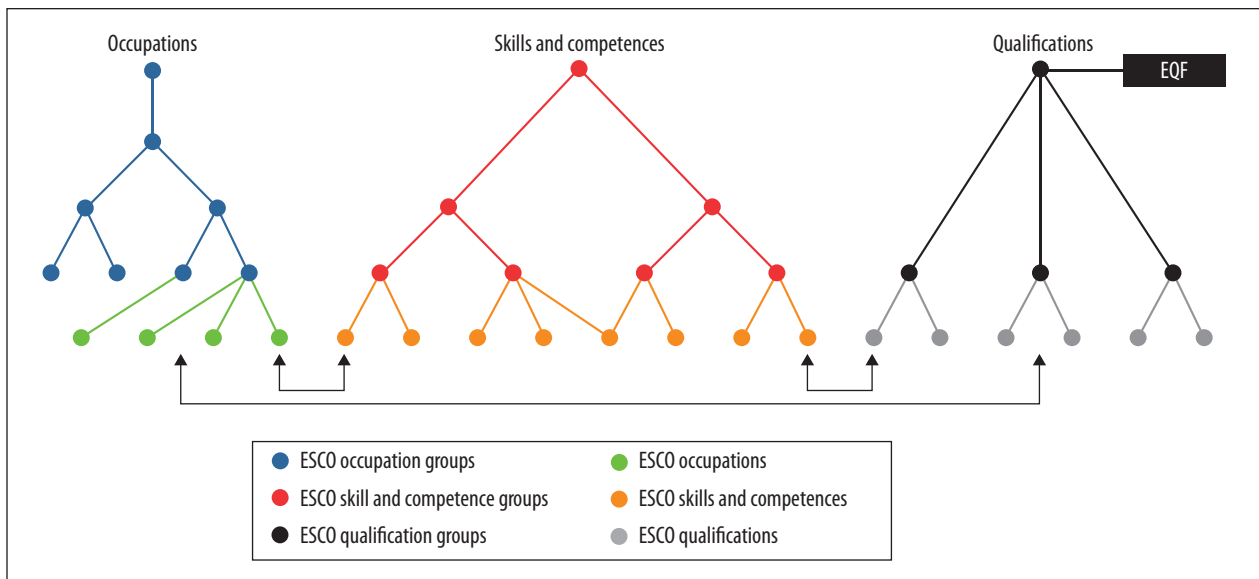


Figure 1. Each of the three pillars of the European Skills, Competences, Qualifications, and Occupations (ESCO) classification has its own hierarchical structure. EQF: European Qualifications Framework.

ACHIEVING SEMANTIC INTEROPERABILITY WITH ESCO

Nowadays, communication about the labor market mainly occurs online. Tools used in e-recruiting include online job boards, curriculum vitae (CV) parsing modules, CV and job vacancy databases, job search engines, and job-matching algorithms. The key challenge is to make the various systems “talk” to one another throughout Europe. The European Interoperability Framework³ provides a set of general recommendations to enable communication between organizations. It distinguishes four layers of interoperability: legal, organizational, semantic, and technical.

To achieve semantic interoperability throughout Europe, the European Commission is developing the multilingual European Skills, Competences, Qualifications, and Occupations (ESCO) classification. ESCO’s goal is to remove communication obstacles, increase transparency, and enable stakeholders to accurately understand exchanged information. Toward this end, it offers a reference vocabulary for the labor market and for the education and training sectors. But ESCO goes one step further: it connects information on occupations and qualifications with skills and competences to promote an in-depth understanding of jobseekers’ capabilities and labor-market needs.

The classification’s first release, ESCO v0, went live in October 2013. It is a fully functional pilot version and can be accessed at <https://ec.europa.eu/esco>. It is free to use for both public and private service providers.

ESCO does not directly provide services to citizens; rather, it is a semantic asset that can be used to improve online tools. In online job portals such as EURES (<https://ec.europa.eu/eures>), which provides information on worker mobility and access to more than two million job vacancies published by European public employment services, ESCO can enable competence-based job matching.

Algorithms compare an individual’s competence profile with an employer’s needs to find the best match. This leads to a better allocation of talents on the labor market, greater workforce satisfaction, and ultimately higher productivity. It also helps people without formal qualifications to find a job, as it focuses on what workers are able to do in practice.

Three-pillar classification

As Figure 1 shows, ESCO organizes available knowledge about the European labor market and the training and education sectors in three pillars: occupations, skills and competences, and qualifications.⁴ Each pillar has its own hierarchical structure, making it easy for users to browse through the classification and find what they are looking for.

ESCO organizes terminology into *concepts* and *terms*. Each occupation, skill, competence, and qualification is a concept and is uniquely identified by a uniform resource identifier (URI). Figure 2 lists some example ESCO concepts.

Each concept comes with at least one *preferred* term in each of ESCO’s 24 languages: Bulgarian, Croatian, Czech, Danish, Dutch, English, Estonian, Finnish, French, German, Greek, Hungarian, Icelandic, Italian, Latvian, Lithuanian, Maltese, Polish, Portuguese, Romanian, Slovak, Slovene, Spanish, and Swedish. The preferred term is the official word or phrase used to refer to the concept.

Synonyms, spelling variants, abbreviations, and other sufficiently equivalent words or phrases are recorded as *non-preferred* terms of a concept. In total, this adds up to more than 250,000 terms in the current version of ESCO. A definition explains the concept in a few sentences, while a scope note clarifies the concept's semantic boundaries in case of ambiguity.

The current pilot version of ESCO contains 4,761 occupations. These are organized according to the International Standard Classification of Occupations (ISCO-08; www.ilo.org/public/english/bureau/stat/isco/isco08), which is managed by the International Labor Organization.

ESCO further defines occupations using 5,096 skills and competences, which are divided into occupation-specific and transversal (cross-occupational). The former are specialized and relate to a limited range of occupations; the latter are relevant to a broad range of jobs and occupations and are often referred to as “key,” “soft,” or “social-communicative.”

In the pilot version of ESCO, qualifications are limited to a small list used for testing and illustration. This list will be further developed and expanded in upcoming releases in consultation with the education community. Partly based on national databases, ESCO will include all kinds of qualifications ranging from university and vocational degrees to industry certificates to driving licenses. The European Qualifications Framework (EQF), which facilitates comparison of qualifications throughout Europe, is an important building block in ESCO's qualification pillar.

Matching jobseekers with job vacancies

Governments worldwide use classifications to provide labor-market services. Almost every country maintains its own classification system for data exchange and job matching on a national level. These national occupational classifications (NOCs) often include skills lists, task descriptions, and other information. Examples of such classifications are

- O*NET OnLine (www.onetonline.org)—US Department of Labor/National Center for O*NET Development;
- Répertoire opérationnel des métiers et des emplois (ROME; www.pole-emploi.fr/candidat/les-fiches-metiers-@/index.jsp?id=681)—Pôle emploi (French public employment service); and

Occupations	Skills and competences	Qualifications
<ul style="list-style-type: none"> • Mail courier • Safety technician • Valet • Automotive designer • Neurologist • Parquet floor layer • Hairdresser • Civil engineer • Bandsaw operator • Flight attendant 	<p><i>Occupation-specific</i></p> <ul style="list-style-type: none"> • Handling complaints • CAD drawing • Car painting • Bacteriology <p><i>Transversal (cross-occupational)</i></p> <ul style="list-style-type: none"> • Editing electronic content • Gathering data • Collaborating on tasks 	<ul style="list-style-type: none"> • European Certificate of Floral Design • Project Management Professional (PMP) • European/International Welding Specialist • Cisco Data Centre Application Services Design Specialist • European Hairdressing Certificate

Figure 2. Example ESCO concepts.

- Klassifikation der Berufe 2010 (<http://statistik.arbeitsagentur.de/Navigation/Statistik/Grundlagen/Klassifikation-der-Berufe/KldB2010/KldB2010-Nav.html>)—Bundesagentur für Arbeit (German public employment service)/Institut für Arbeitsmarkt- und Berufsforschung.

ESCO aims to enable data exchange between private and public employment services that use various NOCs and languages. To achieve this, the NOCs are first *mapped* to the ESCO classification, which serves as a reference vocabulary. Mappings define a correspondence between concepts in two distinct classifications and will serve as a machine-readable translation table when information is converted from one classification to another. Once the mappings are completed, ESCO can function as an exchange hub for services that use different NOCs and languages.

Figure 3 illustrates how this process can help employment services across Europe cooperate and provide better services for EU citizens.

Assume that a surgical nurse in Poland seeks help from the country's employment service to find work in France. The Polish NOC, KZiS-2010 (www.klasyfikacje.gofin.pl/kzis/6,0.html), uses the singular term “pielęgniarka specjalista pielęgniarstwa chirurgicznego” to describe the nurse's occupation, while the French NOC, ROME, has three possible occupational profiles: “soins infirmiers spécialisés en bloc opératoire,” “soins infirmiers spécialisés en anesthésie,” and “coordination de services médicaux ou paramédicaux.”

In this scenario, semantic interoperability between the two countries' systems can be achieved in three steps. First, the NOCs are mapped to the ESCO classification. Second, ESCO uses linked-data technology⁵ to publish the ESCO classification and all mappings (translation tables) as open data. Third, job-matching applications based on ESCO, such as EURES, exploit the data to match

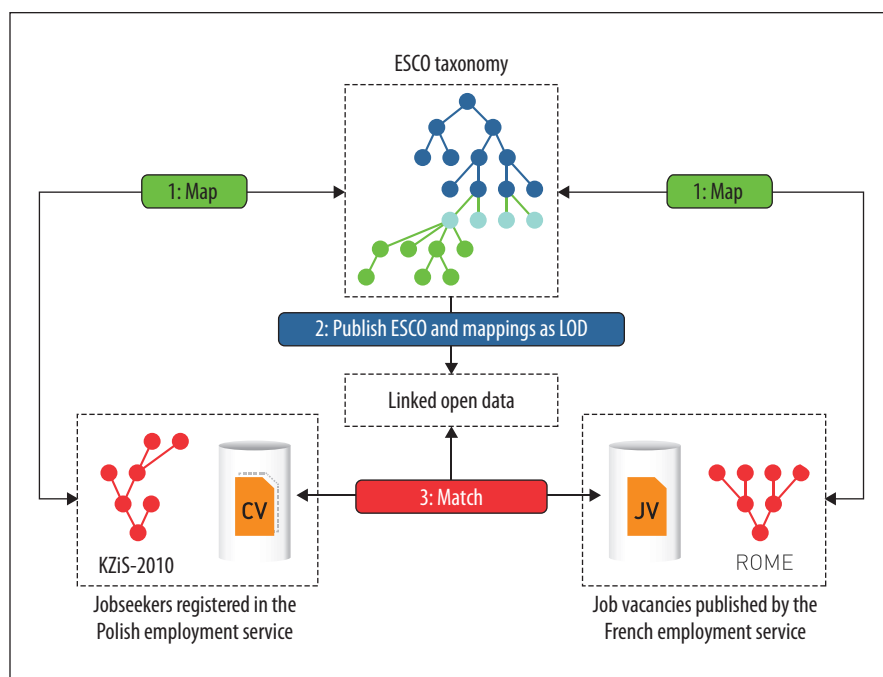


Figure 3. ESCO will serve as an exchange hub for employment services using different national occupational classifications (NOCs) and languages—in this example, to help a surgical nurse in Poland seeking work in France. Semantic interoperability between the two countries' systems is achieved in three steps: (1) NOCs are mapped to the ESCO classification, (2) ESCO publishes the ESCO classification and all mappings as open data using linked-data technology, and (3) job-matching applications exploit the data to match the jobseeker to a job vacancy.

jobseekers to job vacancies. By converting all data into ESCO concepts, these applications can offer services independent of each party's NOC and language.

Fostering semantic interoperability

Google, Bing, and Yahoo jointly provide a common schema (<http://schema.org>) for structured data markup as an annotation of classic HTML Web content. Using such a schema, search engines can process webpage information more efficiently and thereby provide richer results. Schema.org is an ongoing collaborative project that welcomes “participation from major consumers and producers of structured data on the web” (<http://schema.org/docs/faq.html#6>).

It would be useful for developers and webmasters to decide on a markup schema that can be mapped to a multilingual hub vocabulary like ESCO. Suppose, for example, an application such as EURES or Europass (<http://europass.cedefop.europa.eu>) guides a Web user to create a CV online. The application could direct the user to use ESCO concepts for selecting CV elements such as occupations, skills, and qualifications. Once the user has completed and submitted the form, the application would “inject” the ESCO URIs—the formal identifiers of these elements—as annotations in the HTML part of the

page, thus providing structured information. Employers could likewise post job vacancies using ESCO URIs, enabling online job matching to occur.

What about CVs and job vacancies already posted on the Web? Either the developers have used structured schema.org annotation—for example “qualifications” or “skills” found in the JobPosting listing (<http://schema.org/JobPosting>)—or they have not used any annotation. In the former case, mappings between ESCO and the schema.org vocabulary must be in place relating the same context (such as `schema:qualification` with `esco:qualification`), while in the latter case manual or at least semiautomatic annotation is required.

IMPLEMENTING ESCO

Implementing ESCO is a complex task with many interdependencies and actors. The main necessary activities involve

- capturing and organizing knowledge in a consistent manner;
- defining a data model that enables easy reuse and integration with NOCs;
- creating a solid and scalable architecture to support the ongoing development, storage, and dissemination of ESCO and its mappings; and
- communicating ESCO's benefits to stakeholders and supporting pilot applications with information and advice.

Established ontologies serve as the structural framework for capturing and organizing knowledge in ESCO. The data model follows well-known methodological guidelines, like those proposed by Knut Hinkelmann, Barbara Thönssen, and Daniela Wolff,⁶ while its implementation is formalized through the Web Ontology Language (OWL; www.w3.org/TR/owl2-overview).

Joint effort with stakeholders

The European Commission is developing ESCO together with employment services, employer federations, trade unions, and professional associations. This ensures that the expertise of all stakeholders feeds into the project

and that the end result will meet the needs of key actors in the labor market as well as in the education and training sectors.

Project participants can contribute to ESCO in various roles. The ESCO Board includes high-level representatives of the most important stakeholders and provides overall strategic guidance. The ESCO Maintenance Committee is a group of classification experts from numerous companies and organizations who provide technical advice and oversee content creation and quality control. The European Commission supports the effort with the ESCO Secretariat, a small team of experts who help plan, manage, and implement the project.

Content creation based on expert judgment

Actual ESCO content—descriptions of occupations, skills, competences, and qualifications—is developed by the ESCO Reference Groups. Currently, 11 sectoral Reference Groups are operational; another 16 will be established in the coming months.

The Reference Groups bring together experts from different economic sectors and include employers, education and training providers, trade union representatives, job recruiters, and sector skills council members. The experts are volunteers and have in-depth knowledge of the labor market or of education and training programs in the respective sectors. Each Reference Group is supported by taxonomy creation specialists.

The Reference Group's work is complemented by that of the ESCO Cross-sector Reference Group. This group develops vocabulary for transversal skills and competences, which are subsequently applied by the Reference Groups to transferable elements of occupational profiles. The Cross-sector Reference Group also helps develop the qualifications pillar and cross-sectoral occupations such as secretaries, managers, or engineers.

Building on existing standards

ESCO is not being built from scratch entirely. It is based on the EURES taxonomy and makes use of existing standardized classifications that are considered “supporting taxonomies” for ESCO and fulfill different roles.

ISCO-08, NACE—a statistical classification of economic activities in the European Community (http://epp.eurostat.ec.europa.eu/portal/page/portal/nace_rev2/introduction), and FoET (Fields of Education and Training; www.uis.unesco.org/Education/Documents/isc-ed-fos-consultation-draft-2013-en.pdf) provide additional context for ESCO content, facilitate ESCO use in statistical applications, and enhance its compatibility with other classification systems.

NUTS (Nomenclature of Territorial Units for Statistics http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction) and the European Commission's Metadata Registry (<http://publications.europa.eu/>

<http://publications.europa.eu/> mdr) serve as metadata for ESCO concepts or to populate facet groups in ESCO. Faceted classification systems “allow the assignment of multiple classifications to an object, and enable those classifications to be applied by searchers in multiple ways, rather than in a single, predetermined order” (http://en.wikipedia.org/wiki/Faceted_classification).

Frameworks such as EQF (http://ec.europa.eu/eqf/home_en.htm) and the European e-Competence Framework (e-CF; www.e-competences.eu) are important assets for developing the ESCO methodology.

Established ontologies serve as the structural framework for capturing and organizing knowledge in ESCO.

Data model

The ESCO data model is represented in Simple Knowledge Organization System (SKOS).⁷ As of 2009, SKOS is the World Wide Web Consortium's recommendation for representing any type of controlled vocabulary including taxonomies, ontologies, thesauri, classification schemes, and subject-heading systems. As a Semantic Web standard,⁸ SKOS is built on top of the Resource Description Framework (RDF; www.w3.org/TR/rdf-primer). Its main objective is to enable the production, publication, and use of controlled vocabularies as linked data.

Some important vocabularies have been migrated to SKOS format and are available in the public domain, such as Eurovoc (<http://eurovoc.europa.eu>), AGROVOC (<http://aims.fao.org/website/AGROVOC-Thesaurus/sub>), and the Library of Congress Subject Headings (LCSH; <http://id.loc.gov/authorities/subjects.html>).

Technical architecture

The current ESCO architecture consists of four main components: a taxonomy management system (TMS), an object-relational database (ORD) with text indices, an RDF triple store, and a Web portal. As Figure 4 shows, the ORD, RDF triple store, and ESCO portal are deployed in duplicate—in an *acceptance environment* and in a *production environment*—while the TMS is only deployed in the acceptance environment.

The TMS supports the project participants managing the ESCO classification. It allows adding new concepts; merging, updating, or deleting existing concepts; and managing relationships between concepts. Once a new version of ESCO is endorsed for release, the TMS exports the data to the other components in the acceptance environment for testing. Toward this end, a script exports the taxonomy from the TMS to the RDF triple store, and the ORD builds the text indices and downloadable files. The ORD and RDF triple store provide the ESCO data to the

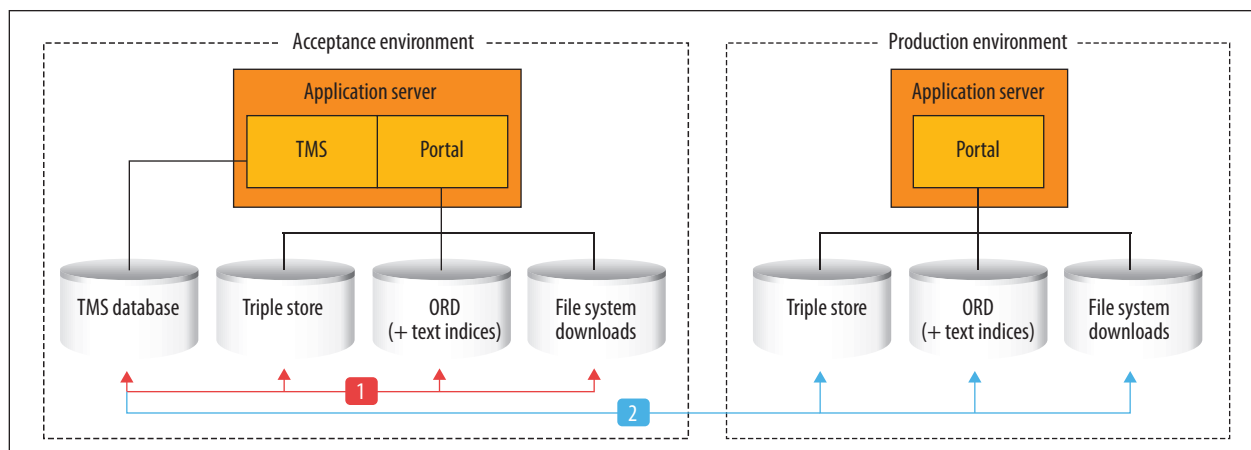


Figure 4. ESCO technical architecture. The taxonomy management system (TMS) exports ESCO data to the other components—an object-relational database (ORD) with text indices, a Resource Description Framework (RDF) triple store, and a Web portal—in the acceptance environment for testing (step 1). The ORD and RDF triple store provide the ESCO data to the portal. Once the ESCO data and portal have been tested, the TMS exports the taxonomy to the production environment so that the new release is publicly accessible via the portal (step 2).

portal. Once the ESCO data and portal have been tested, the script reruns to export the taxonomy to the production environment so that the new release is publicly accessible via the portal.

The multilingual ESCO portal lets users browse, search, and download the ESCO classification. Fuzzy text search of preferred and nonpreferred terms, definition notes, and scope notes makes it easy to find ESCO concepts. Users can also browse through the tree structure of each ESCO pillar and drill down to find relevant concepts.

The portal provides details for each concept. It shows attributes and metadata such as the preferred term, non-preferred terms, URI, definition note, and scope note. It also allows for a cross-language comparison and lists relationships to other ESCO concepts. Figure 5 shows example results for a search of the occupation “flight attendant.”

Through the Web portal, users can download ESCO data, free of charge, in three formats—SKOS, XML, and CSV—as well as access background information, documentation, latest developments, and news about the project.

NEXT STEPS

ESCO is not a standalone tool—it must be mapped to NOCs and applied in labor-market applications such as job portals. Within the EURES network of public employment services, the European Commission is preparing such a system. It foresees all member states cooperating in the field of interoperability and mapping their classifications to a European one.⁹ In a pilot project, the European Commission and four public employment services—of the Czech Republic, France, the Netherlands, and Spain—are testing approaches for mappings between NOCs and ESCO (https://ec.europa.eu/esco/web/guest/escopedia/-/escopedia/ESCO_mapping_pilot).

Using ESCO in pilot applications

At the same time, the test version of ESCO must demonstrate its added value in practical applications. Application programming interfaces will help stimulate early ESCO adoption. Two months after the public release of ESCO, Textkernel presented a new version of its CV parsing component supporting ESCO (www.textkernel.com/2013/12/hr-tech-vendor-textkernel-offers-esco-taxonomy). Euro-pass is likewise preparing an ESCO implementation.

The EURES job mobility portal has already begun the stepwise implementation of ESCO, using the classification to support data input. A jobseeker creating a CV can use typeahead to find ESCO concepts that describe his or her work experience. EURES then annotates this information with language-independent ESCO concepts.

In the near future, EURES will use ESCO as a dictionary to improve semantic job matching by providing synonyms and related terms. This will also enhance search across language barriers: a search request in one language can use the multilingual vocabulary to find content in other languages. Furthermore, ESCO will enable automated and competence-based job matching across borders once interoperability is established. EURES will be able to fully leverage the knowledge represented in the ESCO ontology—for example, skills usually needed for an occupation—and of all mappings with other NOCs. This will obviate the need to formulate search requests: EURES will immediately compare new job offers with client profiles or CVs.

Upcoming releases and versioning

Further ESCO development will follow a pragmatic, step-by-step approach. In the coming months, new releases will gradually increase the pilot version's quality and the terminology's scope. Three important considerations

The screenshot displays the ESCO (European Skills, Competences, Qualifications and Occupations) portal interface. At the top, there is a navigation bar with links for 'Legal notice', 'Cookies', 'Contact', and 'Search on Europa'. Below this is a header section with the ESCO logo and the text 'European Skills, Competences, Qualifications and Occupations'. A secondary navigation bar includes links for 'Home', 'ESCOpedia', 'Browse ESCO', 'Download ESCO', and 'Get involved'. A search bar is located below the navigation bar.

The main content area is titled 'Flight attendant' and 'Occupation'. It features two columns for a cross-language comparison between English (en) and French (fr). The 'Hierarchy' section shows the classification of the occupation within the ESCO structure. The 'Term details' section provides information about the preferred term, URI, and non-preferred terms for the occupation. Below this, there are sections for 'Related facet groups', 'Related skills/competences', and 'Related qualifications'.

At the bottom of the page, there is a footer section with the text 'ESCO is a Europe 2020 initiative.' and 'Current version: ESCO v0 (Last update: 07/05/2014)'. Below this, there is a link to the 'DG Employment, Social Affairs and Inclusion and DG Education and Culture' of the European Commission.

Figure 5. The ESCO portal provides details for each concept—in this case, the occupation “flight attendant.” The portal shows attributes and metadata such as the preferred term, nonpreferred terms, uniform resource identifier (URI), definition note, and scope note. It also allows for a cross-language comparison and lists the relationships to other ESCO concepts.

will determine ESCO’s release strategy. First, each release will be deployable in applications and cover all economic sectors. Second, a versioning strategy will enable backwards compatibility with data that was used in previous releases. Third, an appropriate balance between flexibility and stability will enable ESCO to keep pace with labor-market changes while minimizing implementation costs for applications and mappings.

Continuous updating methodology

The ongoing editorial work of the ESCO Reference Groups is currently the primary method for initial content creation. However, an efficient methodology for continuously updating the classification has yet to be defined.

Crowdsourcing offers one method for stakeholders to support ESCO content creation. The *Merriam-Webster Dictionary* defines crowdsourcing as “the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers” (www.merriam-webster.com/dictionary/

crowdsourcing). Wikipedia demonstrates how crowds of people can be mobilized to find and assemble high-quality content in a cost-efficient manner. However, key questions must be answered when using crowdsourcing to develop a controlled vocabulary:¹⁰ How is quality and consistency to be ensured? Who makes the final decision to include or exclude a concept? What is the best way for contributors to cooperate with experts in ESCO Reference Groups?

A second potential way to enrich ESCO lies in Web mining. This approach could be used to identify new occupations or skills needs and to enhance relationships between concepts. Extensive wordlists of associated terms—an “ESCO term cloud”—would be a valuable asset for natural language processing applications such as CV parsing.

While ESCO is still at an early stage of development, the three-pronged strategy of applying open standards, semantic technologies, and linked open data has proven to be the right one. Stakeholder feedback highlights ESCO’s potential to

become a de facto standard for semantic interoperability in the labor market and education and training sectors. By linking to existing standards, ESCO will quickly find its place in the emerging classification ecosystem. This will enable the creation of new and innovative services that benefit jobseekers and employers alike.

For ESCO to achieve full interoperability, work on the classification's semantic layer must be complemented with progress in legal, organizational, and technical interoperability. What legal arrangements can be found for the exchange of CV and job vacancy data that enable cooperation among partners in the labor market while ensuring data protection? What new partnerships can be formed between public and private actors to support jobseekers and companies during the recruitment process? How can standards such as HR-XML (www.hr-xml.org) best interact with ESCO to allow for an easy exchange of data? Addressing these questions will remove communication obstacles in the labor market and ultimately help get more people jobs throughout Europe. ■

References

1. European Commission, *Labour Market Developments in Europe, 2013*; http://ec.europa.eu/economy_finance/publications/european_economy/2013/pdf/ee6_en.pdf.
2. European Commission, "European Commission launches Grand Coalition for Digital Jobs," press release IP/13/182, 4 Mar. 2013; http://europa.eu/rapid/press-release_IP-13-182_en.htm.
3. European Commission, *Annex 2 to the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of Regions 'Towards interoperability for European public services'*, COM(2010) 744 final, 16 Dec. 2010; http://ec.europa.eu/isa/documents/isa_annex_ii_eif_en.pdf.
4. European Commission, *ESCO: European Classification of Skills/Competences, Qualifications and Occupations*, 2013; <http://bookshop.europa.eu/en/esco-european-classification-of-skills-competences-qualifications-and-occupations-pbKE0313496>.
5. C. Bizer, T. Heath, and T. Berners-Lee, "Linked Data—The Story So Far," *Int'l J. Semantic Web and Information Systems*, vol. 5, no. 3, 2009, pp. 1–22.
6. K. Hinkelmann, B. Thönssen, and D. Wolff, "Ontologies for E-Government," *Theory and Applications of Ontology: Computer Applications*, R. Poli, M. Healy, and A. Kameas, eds., Springer, 2010, pp. 429–462.
7. A. Miles and Bechhofer, *SKOS Simple Knowledge Organization System Reference*, World Wide Web Consortium (W3C) recommendation, 18 Aug. 2009; www.w3.org/TR/skos-reference.
8. T. Berners-Lee, J. Hendler, and O. Lassila, "The Semantic Web," *Scientific Am.*, vol. 284, no. 5, 2001, pp. 34–43.
9. European Commission, *Proposal for a Regulation of the European Parliament and of the Council on a European network of Employment Services, workers' access to mobility services and the further integration of labour markets*, COM(2014) 6 final, 17 Jan. 2014; <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014PC0006>.
10. D.C. Brabham, *Crowdsourcing*, MIT Press, 2013.

Martin le Vrang is project leader for ESCO in the Skills, Mobility, and Employment Services unit of the European Commission's Directorate-General for Employment, Social Affairs & Inclusion. He received a master-level degree in business administration from EBS Universität für Wirtschaft und Recht, Wiesbaden, Germany, a master of computing degree from the Unitec Institute of Technology, Auckland, New Zealand, and a postgraduate degree in European law from the University of Würzburg, Germany. The views expressed in this article are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission. Contact him at martin.le-vrang@ec.europa.eu.

Agis Papantoniou is senior project manager of the SemTech Business Unit of TenForce, a Semantic Web technology company based in Leuven, Belgium, and manages the delivery of products and services for the ESCO project. His research interests involve linked open data and semantic technologies. Papantoniou received a PhD in knowledge engineering from National Technical University of Athens, Greece. Contact him at agis.papantoniou@tenforce.com.

Erika Pauwels is a software developer at TenForce. Her research interests include linked open data and the Semantic Web. Pauwels received an MSc in computer science from KU Leuven. Contact her at erika.pauwels@tenforce.com.

Pieter Fannes is a senior software developer at TenForce. His research interests include the Semantic Web and ontology engineering. Fannes received a diploma in industrial engineering–electronics from KU Leuven. Contact him at pieter.fannes@tenforce.com.

Dominique Vandenstein is a senior software developer at TenForce. His research interests include the Semantic Web and linked open data. Vandenstein received a diploma in industrial engineering–electronics from Erasmus University College, Brussels, Belgium. Contact him at domi.vds@tenforce.com.

Johan De Smedt is CTO of TenForce. His research interests include the Semantic Web, linked open data, and ontology engineering. De Smedt received an MSc in mathematics from Ghent University, Belgium. He is a member of IEEE. Contact him at j.de-smedt@computer.org.