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### Outcome 02-A3 – Competency Directory – Final Report

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Executive summary

This document proposes an approach towards the technical interoperability of OpenBadges with unambiguous definitions of competencies based on semantic web meta-data (using the JSON-LD linked data format). The overall goal is to allow systems to detect similarity of defined badges and graph-based dependencies of the competencies linked to the OpenBadges. This could be achieved by using the unique IRI identifiers of JSON-LD defined competencies for the criteria and alignment fields in BadgeClasses.

Based on the desired functionalities from the community the major problems to address were identified. Beside the resolving of ambiguities (mentioned above) to allow earners and displayers to display similarity of badges, find badges that amend each other or contain others, a major needed first step is to assist issuers in defining badges with competency alignment. For this use case, the OBN first influenced the improved OpenBadge Specification for the BadgeClass to allow better alignment to competency frameworks. Second, based on this, an easy-to-use web directory is proposed that is automatically filled by crawling decentrally defined competency definitions. The directory then provides searching, updating and traversal of the graph-like structure of defined competencies (and competency frameworks) to use the JSON-LD format search results to be used in OpenBadge definitions. Additionally, the prototypical implementation offers a REST-API to later create tools, like plugins, for integration in OpenBadge creation editors.

Finally, it can be stated that basically none of the manifold existing competency frameworks by now is available in a machine-readable semantic-web format (only ESCO will soon be available in such a format). Thus a strong recommendation exists to increase the effort in future projects that framework definitions must as well provide their results in a semantic format like RDF or JSON-LD using a proper semantic vocabulary like InLOC or ESCO. Based on this fact, the proposal suggests as well an end-user application. This application could assist in creating a JSON-LD formatted, ESCO specification of existing competency frameworks that later could be used by referencing them from OpenBadges (and adding them to the directory).

0 Aims and Objectives

The intellectual output O2A3 aims at:
Investigating and aggregating the desired functionality of Open Badges (OB) concerning their relation to (official) standardised Competency Frameworks (CF) (e.g. ESCO framework or EQF aligned-ones like e-Competences)

This document is a successor to the O3A2 proposal document, dated 01.03.2016, which was published on the Open Badge Network Web Portal, via Social Media, as scientific publications and discussed at Open Badge community events (mainly Mozilla Festival 2016 in London).

This document summarizes the achieved results, which include
- collected information about the development of open badges by issuers, and the needs by issuers and earners, and resulting open problems
conceptual solutions for better alignment of Open Badges to competency frameworks to address the identified problems
- standardizations of the Open Badge Specification, as influenced by the Open Badge Network initiative to address the before mentioned problems
- and prototypical implementation description to illustrate the path to better alignment

Glossary

**CF**: Competency Framework. A scheme and logical structure of different competencies, e.g. with dimensions, levels and skill/knowledge examples aligned to them.

**ESCO**: European Skills, Competencies and Occupations framework (still under construction in 2017)

**InLoC**: Integrating Learning Outcomes and Competences. A semantic standard defined in the EU project InLOC (finished 2013)

**JSON**: JavaScript Object Notation. An exchange format for hierarchical key:value data

**JSON-LD**: A JSON format specification especially for linked data (LD)

**LD**: Linked Data. A distributed approach to semantic web that allows machine readable resolving of ambiguities and meaningful (typed) links among semantic concepts

**LO**: Learning outcome. An observable individual’s action as example and indicator of the presence of one (or more) competencies

**OB**: Open Badge

**OBSpec**: Open Badge Specification, the standardization of OpenBadge BadgeClass, AssertionClass, and Profiles in JSON-LD format to allow machine-processing of Open Badges

Beside the glossary, each abbreviation is introduced at first occurrence with the full expression.

Terms used in this document

**Badge, Open Badge**: This document focuses on competence badges¹ (demonstration of knowledge, skills, competence) if not otherwise explicitly mentioned. Still, the approach is feasible for other open badge types likewise.

**Alignment**: Badges can be aligned to existing standards of which they represent a part of all of the learning outcomes, skills, knowledge, attitude (in general: competencies) defined there. The Open Badge Specification (OBSec) v2.0 has the criteria-field and alignment-field of a BadgeClass². If generally writing about aligning badges to competencies both possibilities are meant, if not otherwise explicitly mentioned.

**Competency**: For the discussion and definitions in this document it seems suitable to reduce the concept of a competency to some measurable (observable) ability of an individual. Such a competency is

² [http://openbadgespec.org/#BadgeClass](http://openbadgespec.org/#BadgeClass)
evidenced by exemplary actions that indicate the presence of such a competency with an individual, and they can be called observable learning outcomes (LO). This document does not discuss several dimensions, interdependencies and measures based on skills and knowledge, but it is the aim to find a technical approach that allows representation of all different competency framework structures. Likewise, LO and competencies are seen quite interconnected and if this document writes of competencies to be represented technically, it includes the aligned learning outcomes as well, if not otherwise stated.

1 Requirement Analysis and Results
All project partners were asked to contribute their input to the following questions

a) Is there anything you think is of relevance from project history about competencies in open badges?
b) What requirements do you have for a support of competencies in open badges?
c) What do you think is definitely too much (or too complex) and should not be considered in our approach to connect OB to competencies?

The received answers from seven project partner employees and two external associated partners from OB community were qualitatively analysed, grouped and aggregated into requirement lists and non-desired functionality (listed below). From this list definitions of existing problems with OB and competency alignment are derived from which some are proposed to be addressed in this final report of O2A3.

Desired Functionality
Note: The order and numbering has been changed compared to first draft due to dependencies

DF1. Decentralized solution
DF2. The alignment of OB to competencies remains optional (and backwards compatible)
DF3. Support for a community wide directory of competency frameworks (CF) to add, search and update existing CFs. Ability to export the found competencies to be used in OB directly
DF4. Provide some standardized vocabulary (multi-language support)
DF5. Plugins for Learning Management Systems (LMS)/frontends to allow direct usage of competency catalogues (frameworks) on badge definition
DF6. Computational detection of badges that relate to the same competencies (unambiguous)
DF7. Computational detection of alignments and similarity of competences between several existing CFs

Functionality out of scope of O2A3

NF1. Realize an unambiguous relation of OB to Credit Point Systems (CP) like ECVET

---

3 Formulation was slightly changed for report clarity
4 http://openbadgenetwork.com/
NF2. Create a centralized solution to host/list all possible competencies
NF3. Create a structure (e.g. taxonomy) to represent/suit all possible CFs into it
NF4. Abstract or translate existing CF defined competency IRIs into a new schema
NF5. Find a complete mapping to LRMI or xAPI or Schema.org eduAlignment

List of problems in alignment of OB to competencies

In relation to the defined use cases (O2A1) of badge issuers, earners and displayers (viewers, audience) the following problems emerge from the desired functionalities (DF*) and functionalities expected to be out of scope (NF*):

P1. An issuer wants to make clear which officially defined competencies are certified by the OB
P2. An earner wants to see for desired badges which competencies have to be evidenced to earn a badge
P3. An earner (or consumer) wants to compare badges, identify similar ones (or identical concerning the competencies aligned to it), or wants to identify badges he/she can apply for due to earlier earned badges that proof all needed competencies
P4. A displayer wants to calculate some weight/importance of badges based on competencies the badge is aligned to
P5. A displayer wants to aggregate badges and identify badges that summarize/contain all the competencies of a subset of other badges
P6. A displayer wants to display the similarity and overlapping of badges concerning aligned competencies

For the project outcome O2A3 the focus is on proposing solutions for P1 and P2 (bold in list) as it can be argued that a solution for resolving the ambiguities in aligning badges to competencies will also contribute to solutions for detecting similarity (P3, P5, P6). If possible, the proposed solution will consider the information about competency level/grade and weight as well to support P4 solutions even though in NF1 it is clearly stated that an alignment to credit values is not a focus.

2 Relevant related work

Categorization of badges

To support earners as well as issuers to find out about existing badges, the OpenBadgeAlliance started an initiative to collect existing badges in a directory in 2015. If information about the alignment-field or criteria-field of BadgeClasses is compared, the directory could assist in finding similarity between

---

5 http://lrmi.net/
6 http://experienceapi.com/
7 http://schema.org/educationalAlignment
8 Named in alignment to the three activities EARN, ISSUE, and DISPLAY of Open Badges, http://openbadges.org/
9 https://badgealliance.github.io/openbadges-directory/
badges. This is not yet part of the directory due to the free text format allowed in the mentioned badge fields.

The problem increases as more and more badge issuers offer badges and more badges are earned. It is imaginable that soon earners will have collected hundreds of badges which are not any more easily to overview. Thus, badges need to be comparable to group them automatically and hide Open Badges that are covered by more weighted other Open Badges (e.g. all competencies certified by lighter Open Badges are covered by the more advanced, higher level competencies of a heavy-weighted Open Badge. This could be the case with some steps in a curriculum which are later certified by a final course badge or a degree badge).

**Competency Frameworks and Standardized Competencies**

The problem of comparability gains more and more attention in a globalized world where students and employees move across borders and need credit for their certificates, skills and knowledge or competencies gained somewhere else. Thus, for education and business sectors several specific competency frameworks evolved and equality (or at least similarities) between some of them (but far from all) have been defined. Compare e.g. EQF\(^{10}\), eCompetencies\(^{11}\), ECVET\(^{12}\), CGMA\(^{13}\), UK CCCF\(^{14}\), SUNY GLQF\(^{16}\), ESCO\(^{17}\), Tuning Reference Points\(^{18}\), DigiComp\(^{19}\), ..

While the discussion is moving on whether one standardized framework (taxonomy) can be defined where all possible competencies of all educational sectors and businesses can be defined (see discussion of the OpenBadgeAlliance Taxonomies Working Group\(^{20}\)), it can be concluded that a OB alignment to competencies need to be flexible enough to support several CFs in parallel and even detect/support the cross-linkage between similar (or same) competencies from different CFs.

**Resolving ambiguity by semantic metadata**

Ever since the world wide web existed, mankind worked hard to define machine readable linked structures that are still manageable (and readable) by human beings at the same time (cf. Tim Berners-Lee talk about the next web and linked data\(^{21}\)). Standards like Standard Generalized Markup Language (SGML), the subset eXtensible Markup Language (XML), Resource Description Framework (RDF) and its derivative for web

\(^{10}\)https://ec.europa.eu/ploteus/en/compare

\(^{11}\)http://www.esc.edu/suny-real/global-learning-qualifications-framework/

\(^{12}\)http://www.ecvet-team.eu

\(^{13}\)http://www.cgma.org/Resources/Tools/Pages/cgma-competency-framework.aspx

\(^{14}\)https://www.gov.uk/government/publications/civil-service-competency-framework


\(^{16}\)http://www.esc.edu/suny-real/global-learning-qualifications-framework/

\(^{17}\)https://ec.europa.eu/esco/portal/home

\(^{18}\)http://www.unideusto.org/tuningeu/

\(^{19}\)https://ec.europa.eu/jrc/en/digcomp/governance

\(^{20}\)http://etherpad.badgealliance.org/taxonomy-wg-10-8-2105

\(^{21}\)https://www.ted.com/talks/tim_berners_lee_on_the_next_web?language=en
usage RDFa\textsuperscript{22}, Web Ontology Language (OWL) and recently JavaScript Object Notation Linked Data (JSON-LD\textsuperscript{23}) to name a few. The general problem is to find a balance between being too generic (and thus the concepts expressed by semantic annotation are too simple to be of use) and too specific (then the solution is not usable in manifold application fields).

The recent movement towards linked data (LD) with a distributed design (using the formats RDF or JSON-LD) is based on unique resource identifiers (IRI\textsuperscript{24}). IRIs allow explicit unambiguous reference to a concept or instance defined in a different context (domain). As such it is easy to cross-reference meaning. Linked data is decentralized and in each namespace new concepts can be defined. Thus, it is easy to create a vocabulary and a valid schema for one’s own scope. Still, with IRIs it is possible to reference concepts (and data) outside the own scope, e.g. by using standardized LD attributes like isSimilarTo\textsuperscript{25} or educationalAlignment\textsuperscript{26}.

The linked data approach can be used to link OBs to competencies defined somewhere else. Concerning the most popular formats, RDFa is for augmentation of HTML by semantic means, while JSON-LD is the suitable format for (computer) systems exchange and interoperability for linked data. This format is to favour currently, especially since OpenBadges are committed to JSON-LD support since version 1.1\textsuperscript{27} (released May 2015). Still, RDFa and JSON-LD can be converted into each other.

Beside the format, a discussion is necessary about the vocabulary used within the competency specification expressed in such a format. The vocabulary is the set of noun terms and relations used to express the competency definitions and their structure. Competency frameworks need to be written in a machine-readable format (e.g. JSON-LD) and expressed in a standardized, machine-understandable vocabulary. This is discussed in the next section.

**Semantic definition of competency frameworks**

The remaining problem is a machine readable and web exchangeable version of the (manifold) competency frameworks mentioned above. After intensive research none of the above mentioned frameworks was found to be exportable in an OWL, RDF or JSON-LD format. Thus, to the best of our knowledge no such solution exists yet. Still, efforts towards such solutions exist.

The problem of ambiguities in terms, keywords, tags and their relation is addressed by the SOKOS Simple Knowledge Organization System (SOKOS)\textsuperscript{28}, a RDF standard of the W3C Semantic Web Working Group\textsuperscript{29}. SOKOS allows the standardized semantic linkage of terms, e.g. in thesauri or folksonomies. It’s applicability to the competency alignment problem is of less value as it does not explicitly distinguish evidences (LO) and their links to competencies.

\textsuperscript{22} http://rdfa.info/
\textsuperscript{23} http://json-ld.org/
\textsuperscript{24} Formerly only based on ASCII characters (URI), extended by international characters (IRI)
\textsuperscript{25} https://schema.org/isSimilarTo
\textsuperscript{26} https://schema.org/educationalAlignment
\textsuperscript{27} http://openbadgespec.org/
\textsuperscript{28} https://www.w3.org/2004/02/skos/
\textsuperscript{29} https://www.w3.org/TR/2009/REC-skos-reference-20090818/#L879
In the project InLOC ELM 2.0\textsuperscript{30}: \textit{Integrating Learning Outcomes and Competences}, from the ICT Standardisation Work Programme of the European Commission’s DG Enterprise and Industry\textsuperscript{31}, the problem of semantic meta-data for learning outcomes and competencies was addressed. With Integrating Learning outcomes and competencies (InLOC) the project committee released a European standard which is able to express all existing CFs in a semantic and machine readable form. They provide suggestions on representations in XML, RDF and more recently in JSON-LD.

InLOC provides several examples on how to apply InLOC to CFs. The EU CF eCompetence Framework 2.0 for occupations in ICT contains five responsibility areas (PLAN; BUILD; RUN; ENABLE; MANAGE), each with several dimensions. One dimension (3) defines the competency levels while another (4) defines the knowledge and skill examples for a specific competency.

\textsuperscript{30} http://www.cetis.org.uk/inloc/Home
\textsuperscript{31} http://ec.europa.eu/growth/sectors/digital-economy/
Figure 1 illustrates the mapping of a part of it (competency A.2) to InLOC definitions (red), InLOC associations (orange), and InLOC structure (yellow). Basically the structure is most of the time one (full) document to be mapped to InLOC. Figure 2 illustrates the InLOC associations (relations) resulting from the table as a graph. InLOC has as well a defined multi-language support which allows translations of text-labels and descriptions of LO or competencies. For details refer to the source.

32 Source: http://www.cetis.org.uk/inloc/attachments/A-2_LOCrels.png
33 http://www.cetis.org.uk/inloc/InLOC%2bexplained%2bthrough%2bexample#InLOCexplainedthroughexample-ThedistinctionbetweendefinitionsandstructuresofLOCs
While InLoc has its strength in the semantic definition with more specific constructs than a pure RDF triple, it lacks an implementation. A much smaller, but more recent project, is conducted by University of Potsdam\textsuperscript{35}. Based in the Neo4j\textsuperscript{36} GraphDB they created an implementation that is a RDF compatible

\textsuperscript{34} Source: http://www.cetis.org.uk/inloc/attachments/e-CF.png
\textsuperscript{35} https://github.com/uzuzjmd/Wissensmodellierung
competency database. Currently the project heads towards implementing similarity detection based on language processing. While the text based approach can be criticised, it is definitely a good assisting approach to help humans in defining competency similarities (e.g. made explicit with InLOC semantics). Moreover, the project implementation of a working server infrastructure with REST conform interfaces may be a valid base for the anticipated competency directory of the OBN O3A2 (see below).

Recently, the European ESCO CF offers a machine-readable download in RDFa or CSV\(^37\). The aim of ESCO is provision of semantic information that allows computational comparability of qualification certificates like diplomas, work experience, recommendation letters and certifications, like OpenBadges, with job requirements to match offers and demands. It would be of much benefit for the interoperability of educational, occupational, and voluntary work systems in Europe. ESCO is an ambiguous project whose key advantages are:

1. Its definition of a vocabulary to express competencies, skills, occupations, and their relation among each other
2. Its expression of thousands of existing occupations (jobs) in several sectors as well as competencies that are job specific and uniform 21\(^{st}\) century skills\(^38\)
3. Its translation into manifold languages of Europe (even though the first set is primarily available in English only).

Like InLOC, ESCO allows the expression of semantic relations among competencies within ESCO, but as well to reference similarities to competency frameworks other than ESCO. As this is a core aspect to allow a decentralized, inter-linked web of competency framework definitions that reference each other, InLOC and ESCO remain as candidates for vocabulary. It remains an open question, whether these two are of same flexibility and can be transformed into each other easily.

Note: For the further course of the O3A2 the decision was first made in favour to InLOC as a finalized, properly defined vocabulary until January 2017. Based on discussions in the Open Badge Network Europe project and with officials from ESCO and the pen Badge community, the ESCO vocabulary was then favoured for future use.

### 3 Update of the Open Badge Specification in version v2.0

While the before mentioned problems of alignment became clear within the Open Badge Network project and our first proposal for addressing this problem was published and discussed, other initiatives became aware of the need to improve the possibilities to align Open Badges with competency frameworks.

As a result, members of Open Badge Network Europe discussed their current solution proposal and open problems with members of the Open Badge Alliance, namely Nate Otto and Tim Cook. These discussions

\(^{36}\) [http://neo4j.com/](http://neo4j.com/)

\(^{37}\) [https://ec.europa.eu/esco/portal/download/](https://ec.europa.eu/esco/portal/download/), since March 2017 first competencies are accessible as. Additionally, an API is offered to access ESCO as linked-data (see [https://ec.europa.eu/esco/portal/escopedia/ESCO_API](https://ec.europa.eu/esco/portal/escopedia/ESCO_API))

\(^{38}\) As of 01. March 2017 more than 5000 competencies were available via ESCO API in RDFa format. ESCO want to release the final first set in September 2017.
lead to the naming and specification of the alignment field in Open Badge Specification 2.0, which was released in December 2016 and is briefly discussed here.

When designing an Open Badge, a badge issuer will create a BadgeClass, which can contain the following fields (here shown as JSON-LD code):

```json
{
   "@context": "https://w3id.org/openbadges/v2",
   "type": "BadgeClass",
   "id": "https://example.org/robotics-badge.json",
   "name": "Awesome Robotics Badge",
   "description": "..",
   "image": "https://example.org/robotics-badge.png",
   "criterias": "https://example.org/robotics-badge.html",
   "issuer": "https://example.org/organization.json",
   "alignment": [
      { "targetName": "CCSS.ELA-Literacy.RST.11-12.3",
        "targetUrl": "http://www.corestandards.org/ELA-Literacy/RST/11-12/3",
        "targetDescription": "Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.",
        "targetCode": "CCSS.ELA-Literacy.RST.11-12.3"
      },
      { "targetName": "Problem-Solving",
        "targetDescription": "Using research, analysis, rapid prototyping, and feedback to formulate a problem and develop, test, and refine the solution/plan.",
        "targetFramework": "Mozilla 21st Century Skills"
      }
   ]
}
```

Listing 1: Example of a Badge Class in v2.0, based on https://www.imsglobal.org/sites/default/files/Badges/OBv2p0/examples/index.html#BadgeClass

As shown in Listing 1, the alignment-field of a BadgeClass now contains an array of AlignmentObjects which contain a targetUrl and a targetCode as the most important fields. targetUrl is per specification now meant to be an JSON-LD containing target which can be read (and parsed) by a machine. If the targetUrl contains several competency definitions, the targetCode identifies the ID of the targeted competency in its competency framework. This specification is a major advancement and allows now pointing to semantic definitions of competencies this badge stands for. Ideally, the used targetUrl is a unique and permanent IRI for the competency, but in case several are behind this address, the targetCode identifies it without ambiguity.

Listing 1 as well illustrated that unfortunately the criteria-field still contains only one URL pointing to a “document”. The specification 2.0 now allows a criteria-object as well to be used (see Listing 2), but the major problem remains that criteria are not properly defined semantic skill definitions. Even though OBN members emphasized the criteria-field to be compatible and of same semantic strength like the alignment-field, open badges are used for manifold, not only credentialing, badges. Thus, the criteria field still does not allow a well-expressed semantic definition of skills one must evidence to get the badge.
"criteria": {
  "id": "https://example.org/robotics-badge.html",
  "narrative": "To earn the **Awesome Robotics Badge**, students must construct a basic robot.

  * Move forward and backwards [1](https://example.org/robot-skills/1).
  * Pick up a bucket by its handle [2](https://example.org/robot-skills/2)."
}

Listing 2: Example of a criteria-field with more details in v2.0, based on https://www.imsglobal.org/sites/default/files/Badges/OBv2p0/examples/index.html#BadgeClass

In summary, alignment to specifications from competency frameworks and comparison of OpenBadge BadgeClass elements can be done primarily based on AlignmentObjects used in the alignment-field.

### 3 Proposed solution concept

Note: the following proposal does not mention any more an extension to the Open Badge Specification (as discussed on the O3A2 proposal 2016) as the specification now includes semantic alignment.

To address the problems P1 and P2 of clarifying which officially stated competencies a badge is aligned to, may be addressed by two separate solutions.

**S1.** ESCO-Dir: Community directory for ESCO JSON-LD defined competency frameworks  
**S2.** ESCO-App: Assisting (web) application (or service) to create a ESCO JSON-LD representation of existing competency frameworks

The solutions use the ESCO vocabulary for competency definition as exchange language (or a similar semantic one). As format, JSON-LD was decided (see discussion above). If other formats or vocabulary become popular, it is possible (with reasonable effort) to write adapters that convert from these formats into JSON-LD and from these vocabularies to ESCO and vice versa (e.g. see converting examples of InLOC\(^{39}\)). Possibilities for implementation are discussed in the next section. First, a brief description of the solution components and their interoperability is given.

\(^{39}\) [http://www.cetis.org.uk/inloc/RDF](http://www.cetis.org.uk/inloc/RDF)
Figure 3: Schematic Illustration of the three proposed components

S1: ESCO-Dir

The directory is strongly inspired by the OpenBadgeDirectory. It will allow registration of ESCO schema IRIs by community members. The directory can then crawl all connected ESCO definitions by itself and add them to the index. The directory can update the definitions by re-crawling the IRIs to stay up to date. Users of the (web) frontend of the directory will have the ability to search for entries by e.g. text similarity, issuer, popularity, similarity, competency level, prerequisites ..etc. An essential feature of the directory is the direct export of ESCO JSON-LD format to be used in the targetUrl and targetCode field(s) for OBs.

While the directory provides a central and easy way for issuers to find competency definitions to be used in their BadgeClass, the competency definitions themselves can be distributed decentralized and are maintained by each competency framework institution itself. To unleash the whole power of this decentralized graph the competency frameworks need to cross-reference their definitions for similarity and containment. This can be assisted by S2 component as described next.

S2. ESCO-App (optional)

The application (app) will assist issuers and/or competency framework providers to define existing CFs in ESCO vocabulary and JSON-LD format. The assistant will allow a graphical setting of (object) definitions and associations. Whether or not the application itself allows storage of the result under a public available IRI or offers download to publish the file(s) on one’s own IRI seems to be of equal practice. Such an application

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40 https://badgealliance.github.io/openbadges-directory/
(or several of it) are expected to be optional for the scope of the project as our main goal is the proposal of a structural solution. For a proof of concept such an app is not absolutely necessary.

# 4 Implementation alternatives

## S1: ESCO-Directory Implementation

### Table 1: Approaches to ESCO directory implementation

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<tr>
<td>The OpenSource MediaWiki(^{41}) can be used to allow all community-members to create pages and sub-structures to document existing CFs and competency/LO definitions. The representation as ESCO JSON-LD are added as links to the IRIs.</td>
<td>The existing GitHub project code for OpenBadgeDirectory(^{42}) is released under MLP 2.0 licence. The code could be forked, adapted to list and crawl ESCO JSON-LD entries instead of badges.</td>
<td>Based on modern Single Web Application frameworks and components (node.js, hapi.js, AngularJS, REACT, ..) a REST API could be developed that allows several clients to add and request the directory. A web-fronted could offer search (and graph traversal) features suitable for ESCO data.</td>
</tr>
<tr>
<td><strong>Advantage:</strong> lowest implementation effort, open for any further requirements/directory structures</td>
<td><strong>Advantage:</strong> basic features already exist, both projects might benefit from future code improvements</td>
<td><strong>Advantage:</strong> most elaborate solution approach with an independent API to be used by further systems, least overhead as no code is written for other purposes</td>
</tr>
<tr>
<td><strong>Drawback:</strong> missing auto-update of data, no easy filter and search functions beyond text-matching</td>
<td><strong>Drawback:</strong> Code structure does not suit needs for graph-based data structure of ESCO. (and is more implementation effort)</td>
<td><strong>Drawback:</strong> most effort to code and maintain</td>
</tr>
</tbody>
</table>

## S2: ESCO-Application (for conversion of CFs to ESCO JSON-LD) Implementation

### Table 2: Approaches toward editing/creating ESCO vocabulary enriched documents

<table>
<thead>
<tr>
<th>Proposal A: web-based application with direct hosting</th>
<th>Proposal B: Configuration of existing RDFa editor</th>
</tr>
</thead>
<tbody>
<tr>
<td>For node.js there exists a module for JSON-LD parsing (and creation). This can be used to write a more restrictive module that only creates (and validates) ESCO JSON-LD format. A web-fronted could be created responsive to be usable with mobile clients as</td>
<td>Semantic data editing with a WYSIWYG editor is a well-known aspect for semantic web in general. As RDFa is convertible in JSON-LD a common RDFa editor, like RDFaCE(^{43}) can be used and guidelines could be written to use this</td>
</tr>
</tbody>
</table>

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\(^{41}\) [https://www.mediawiki.org/](https://www.mediawiki.org/)

\(^{42}\) [https://github.com/badgealliance/openbadges-directory](https://github.com/badgealliance/openbadges-directory)

\(^{43}\) [http://aksw.org/Projects/RDFaCE.html](http://aksw.org/Projects/RDFaCE.html)
well, even though it is expected that most users will be desktop-based as definition of a competency structure in ESCO will require a lot of copy&paste as well as definition of objects (properties). Afterwards resulting data needs to be converted by existing converters from RDFa to JSON-LD.

**Advantages:** An assisting application with a graphical interface is expected to strongly support the acceptance and spread of ESCO for competency definition, not only for OpenBadges, but as well all other systems that need competency definitions without ambiguities for machine based processing. 

**Drawbacks:** The effort for a generic ESCO definition assistant is not to underestimate and appears to be far beyond the scope of the projects O2A3 scope.

**Advantages:** Existing applications are rich in features and more stable. Guidelines and community already exist. 

**Drawbacks:** The editors can be overwhelming and do not restrict the use properly to ESCO vocabulary. The step of converting RDFa then to JSON-LD is overhead that reveals disadvantages in case changes from JSON-LD need to be edited or written back as well.

### 5 Implementation of prototypical competency directory

Based on the specification, discussion of alternatives and the current state of the art, the OBN members decided to first favour a prototypical implementation of the competency directory (S1) that addresses P1 and P2 primarily. The proposal variant C with own implementation was preferred.

In early 2016 the prototype was developed and its pre-final version was presented at Mozilla Festival in London, November 2016. Due to the discussion above, the InLOC vocabulary was used for implementation. The change to ESCO, which is reflected in this final document, is not yet reflected in the implementation due to resource restrictions. Still, the project consortium is since 2017 continuously working on an updated implementation using ESCO. The implementation and documentation is publicly available under [https://github.com/openbadgenetwork/](https://github.com/openbadgenetwork/).

### Web Stack components

For implementation a modern single-page application (SPA) web stack was used. As mentioned earlier it is of desire to separate backend and frontend. The backend is implemented as a REST-Level 2 conform API using node.js/express framework. The backend builds on top of the available JSON-LD processor\(^{44}\) and JSON-LD parser\(^{45}\) to process the data found by the crawler in the URLs added to the directory.

For data storage first a neo4j database was considered and tested for object-related semantic data storage, but then replaced by a simple MongoDB that can store JSON objects directly.

The frontend is implemented with AngularJS 1, as at the moment of implementation the newer versions where still under development. AngularJS was amended by a modal Service\(^{46}\) for popup of details for found competencies.

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\(^{44}\) [https://github.com/digitalbazaar/jsonld.js](https://github.com/digitalbazaar/jsonld.js)

\(^{45}\) [https://github.com/scienceai/jsonld-rdfa-parser](https://github.com/scienceai/jsonld-rdfa-parser)

\(^{46}\) [https://github.com/dwmkerr/angular-modal-service](https://github.com/dwmkerr/angular-modal-service)
Supported competency frameworks

As no existing competency framework was available in InLOC vocabulary, the OBN project decided to encode only parts of one competency framework exemplary in InLOC using JSON-LD and RDFa format for comparison of practicability. JSON-LD was then decided to be more compact and easy to maintain, while RDFa has the advantage to add the semantic definitions directly into the displayed HTML-document (viewed by humans). This lowers the risk of inconsistencies between semantic definition(s) and displayed information for human visitors of the URL. Still, the semantic definitions will be maintained probably by using an editor (see S2) or automatically generated and JSON-LD is the recommended standard format for Open Badge alignment. A detailed comparison of parts of the e-competency framework expressed in RDFa or JSON-LD (both InLOC vocabulary) can be seen in Listing 3 and Listing 4.
improvement of organisational process efficiency and ...

Listing 3: excerpt of the implementation of e-Competency framework with InLoc vocabulary using RDFa extensions directly mixed with HTML in the website. For complete file see https://github.com/openbadgenetwork/competence-directory/blob/master/resources/RDFa_Websites/e-CF.html

```json
{
    "@context": {
        "abbr": {
            "@id": "http://purl.org/net/inloc/abbr",
            "@container": "@language"
        },
        "combinationRules": {
            "@id": "http://purl.org/net/inloc/combinationRules",
            "@container": "@language"
        },
        "created": {
            "@id": "http://purl.org/net/inloc/created",
            "@type": "http://www.w3.org/2001/XMLSchema#dateTime"
        },
        "description": {
            "@id": "http://purl.org/net/inloc/description",
            "@container": "@language"
        },
        "hasLOCpart": {
            "@id": "http://purl.org/net/inloc/hasLOCpart",
            "@type": "@id"
        },
        "hasExample": {
            "@id": "http://www.cetis.org.uk/inloc/hasExample",
            "@type": "@id"
        }
    }
}
```
Listing 4: excerpt of the implementation of e-Competency framework with InLoc vocabulary using JSON-LD. For complete file see https://github.com/openbadgenetwork/competence-directory/blob/master/resources/JSON-LD/e-CF/e-CF.jsonld
As one can conclude, the JSON-LD format is more concise and better readable as well as machine-parsable as no HTML-based content is mixed between. The crawler component of the prototype is searching for JSON-LD information in the targeted URLs.

**Resulting functionality**

The described document of e-Competency framework in JSON-LD format using InLOC is used for the prototype functionality. The following functionality is implemented.

**Crawler component**

The crawler can be fed with URLs to lookup, parse and add to the directory index. For demonstration purposes a web-frontend for the crawler was created that allows easy pasting of URLs to crawl (see Figure 4).

![Figure 4: Web frontend of prototype to allow easy adding of new URLs to be parsed for semantic competency definitions](image)

**Directory lookup**

The directory lookup is a AngularJS based frontend with Twitter Bootstrap responsive design to adapt to screen size. It allows the entering of a search term in a simple search interface (inspired by Google). Future version may allow the restriction to certain languages and global regions of competency framework origin. Figure 5 shows the easy interface structure.
Modal service for competency details

The modal opens on click of one of the search results. The details are displayed with a copy-paste field for the unique URL pointing to the competency specification. This URL can be used in Open Badge BadgeClass AlignmentObjects’ targetUrl field. Currently, no additional ID as targetCode is displayed for a competency in case the URL is not unique (due to the fact that all InLOC specified e-Competency elements are identified by their hastag in the URLs, see example in Figure 6).
Figure 6: With a click on one of the competency search results the modal displays all associated InLOC concepts (K1-K4, S1-S4) and offers the URL to be copied to the BadgeClass specification for Competency alignment.

Outlook

To bring the competency directory into wide practical application, the Open Badge Network Europe has already started continuing activities. Next major goals are

1. Adding ESCO as supported vocabulary beside the InLOC vocabulary. This would be a strong improvement as discussed earlier in this document. Unfortunately, ESCO was not ready for use during the major phase of definition and implementation of O3A2 (Competency Directory for Alignment). The internal database-representation could then as well be changed to ESCO, while maybe supporting InLOC still by an converting adapter implementation. Currently the project team is already working on an advanced implementation supporting ESCO.
2. Whatever vocabulary is used, it is advised to define the vocabulary as well as an extension to schema.org semantic concept definitions. This allows easier cross-referencing from other vocabularies and supports further use. ESCO, as well as InLOC, need to be defined this way.
3. The competency directory will not be accepted in practice, if only few competencies are listed in the directory. Thus the support for ESCO will at once increase the available definitions by
thousands (from ESCO to be released in 2017). But the major power of the central directory listing all decentrally defined competencies comes from two next steps:

a. Other competency framework maintainers need to be encouraged to define their framework in ESCO vocabulary as well and provide a public URL that can be crawled by the competency directory to list all these additional competencies

b. The competency framework maintainers (or the community) need to define cross-references between competency frameworks in order to allow machine-based search of similarities through the graph of inter-lined competency definitions. Currently, even well defined cross-referencing competency frameworks only cross-reference within their own framework.

References

References are made directly in the text as footnotes. Due to the novelty of the issue no scientific publications concerning the cited standard and systems were found. Last access date is in all cases the date of submission mentioned in the document header, if not otherwise stated.