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Transforming CS Curricula into EU-Standardized Micro-Credentials

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Micro-credentials are a way to integrate flexible learning pathways into the classic forms of education defined in the European Qualification Framework (EQF). They allow members of the workforce to get necessary skills described, certified, and recognized in a transparent and portable way. One way for universities to enter this market for lifelong learning is to convert existing study programs into smaller units, namely, micro-credentials. This process of converting a study program consisting of modules into small, independent pieces is called unbundling. When unbundling a program, the existing modules have to be converted to a standard EU-wide recognizable form. In this paper, we will describe the process we used to convert modules from our study program at DHBW. The first step converts the skill descriptions into a standard form. Since there is no common accepted formal standard, we use the Dublin descriptors as a way to structure the skills on the different abstraction levels, and ESCO-terms as a widely used standardized vocabulary. The second step breaks down modules of 3-12 ECTS into smaller constituents (each ECTS corresponds to a workload of around 30 hours). Typical micro-credentials have a size of 1 to 3 ECTS, a group or stack of micro-credentials corresponds to one module.

Keywords: *micro-credentials, curriculum design, internationalization, computer science, learning outcomes, standardization*

Introduction

The European skills agenda from 2020 names micro-credentials (MC) as an important tool for citizens to develop future skills demanded by employers. They serve the purpose of supporting life-long learning and international validity of certificates for distributed learning in time and space. To document this personal record, platforms like Europass[1] are developed and rolled out. To enable the recognition of courses including their assessments, it is essential to define outcomes, competences and skills in a standardized manner that everyone can interpret at an international level. In the EU, qualification frameworks define levels of achievement in the different Bologna cycles. Dublin Descriptors[2] define one such framework by describing levels of learning through "generic statements of typical expectations of achievements and abilities associated with qualifications

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[1]https://europa.eu/europass/en.
[2]https://www.aqu.cat/doc/doc_24496811_1.pdf.

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that represent the end of each of a Bologna cycle". These levels can be used to structure the learning outcomes within module descriptions from basic facts, their application, or critical reflection and communication on the given topics. A significant component of the standardization of learning outcomes is a controlled vocabulary that defines the different skills. The ESCO classification provides such terms for some areas (ESCO)[3].

In addition to providing personalized learning paths, such a standardized structure forms the basis of learning data that can support comparative studies as well as best practices. Open educational resources can be indexed uniformly as a function of best practices. Any such comparative study is very difficult without these standards. In particular, these MCs pave the way for learning path definitions that will be multidisciplinary in future. One such example is "Data Science" that combines domain knowledge, technology, and mathematics. Such a degree is highly personalized and enabled through MCs. Using EU-standards for MCs supports unification of module descriptions on several levels: (1) Learning outcomes formulation (skills) sorted by level (Dublin Descriptors) (2) Teaching content formulation (knowledge) (3) groupings into smaller, modular, and stackable components, and finally (4) assessment and activities. Especially, transversal and interdisciplinary skills can be described for MCs with ESCO. A more detailed discussion of this aspect can be found in section 4.

Currently, most universities do not follow common standards when describing competences and skills in module descriptions. "Traditionally higher education was relatively explicit about the knowledge (outcomes) to be achieved, or at least the knowledge covered by the curriculum. It was however somewhat less explicit on the skills or competences required for the award of a given qualification. Competences, such as those of critical evaluation, were and are embedded or implicit in the assessment values and practices." (Bologna Working Group 2005, p. 63) The same goes for ethics, security, or sustainability. Principally, module descriptions are difficult to standardize across modules and even more so across majors as their authors differ and are often untrained in this matter. The current process, therefore, frequently leads to inconsistencies.

This problem is even more complicated than usual with DHBW (our university) because of size and history, from our website: "Baden-Wuerttemberg Cooperative State University (Duale Hochschule Baden-Württemberg/DHBW) is the first higher education institution in Germany which combines on-the-job training and academic studies and, therefore, achieves a close integration of theory and practice, both being components of cooperative education. With around 34,000 enrolled students, over 9,000 partner companies and more than 145,000 graduates, DHBW counts as one of the largest higher education institutions in the German Federal State of Baden-Wuerttemberg."[4] Being large and distributed over 10 campuses, running study programs in parallel, makes coordination difficult and slow. As a result, a change to our (many) module descriptions to adapt EU standards requires a prolonged change-process.

[3]https://esco.ec.europa.eu/en/classification/skill_main.
[4]https://www.dhbw.de/english/dhbw/about-us.

In this paper, the authors present representative examples of learning outcomes from very simple to highly complex. We will show the process of converting from the existing more or less "free form" definition into a standardized form using Dublin Descriptors and ESCO-terms. The process is designed to be generalizable into a methodology for others in order to follow guiding steps during conversion of new modules. We will point out lessons learned and pitfalls to avoid along the way, and elaborate on the following steps:

1. Analysing learning outcomes in modules
2. Assigning Dublin Descriptors to learning outcomes
3. Associating standard formulations
4. Creating stackable sub-modules (micro-credentials)
5. Editing the online micro-credentials

Micro-credentials

Although there is no global consensus about the term MC the indication is always the same: MCs are usually short, flexible, and modular learning programs that can be stacked and completed in much less time than the traditional degree programs. In the last years there was a significant push towards the interest for these small units but as the relevance of MC increased, the lack of definitions and processes towards creating MC has become evident (Brown et al. 2021).

The European Union started an approach to support lifelong learning and employability through short, flexible, and modular learning programs with their Council Recommendation in 2022[5]. This recommendation aims to establish a common understanding and recognition of MCs across the EU to reach their full potential. According to this resolution, the EU describes a MC as follows:

> "'Micro-credential' means the record of the learning outcomes that a learner has acquired following a small volume of learning. These learning outcomes will have been assessed against transparent and clearly defined criteria. Learning experiences leading to micro-credentials are designed to provide the learner with specific knowledge, skills and competences that respond to societal, personal, cultural or labour market needs. Micro-credentials are owned by the learner, can be shared and are portable. They may be stand-alone or combined into larger credentials. They are underpinned by quality assurance following agreed standards in the relevant sector or area of activity." (Council of the European Union 2022, p. 5)

This definition already gives an idea of the enormous advantages offered by MCs. They are an attractive option for professional development as they allow individuals to acquire new skills quickly and individually. On the one hand, they help individuals to stay competitive in the job market by demonstrating their expertise in a particular area and on the other hand, employers can identify and recruit individuals with specific skills as well as provide a way to train and upskill

[5]https://eur-lex.europa.eu/legal-ontent/EN/TXT/?uri=uriserv:OJ.C_.2022.243.01.0010.01.ENG

current employees. So overall, MCs are a valuable tool for both individuals and organizations providing a flexible and accessible way to acquire and validate specific skills or competences (European Commission 2020).

According to the definition of the EU, there are still two main issues that need to be solved: First, the "transparent and clearly defined criteria" for the learning outcomes to achieve a well-defined set of knowledge, skills and competences have to be defined. Additionally, there must be a recognized standard that validates this set to ensure the quality of those small units (Council of the European Union 2022).

Since MCs are gaining popularity and the use continues to grow, it is important to quickly establish common standards and recognized frameworks that ensure the value and credibility of MCs in the education and employment sectors (UNESCO 2022).

Dublin Descriptors

The European MOOC Consortium (massive open online courses) collaborates on a Common Microcredential Framework (CMF) which aims to combine the learning outcomes in higher education and professional training. Those programs consist of 4 to 6 ECTS and can be certificated to fit into Europass. To assure the quality of the programs the ENQA Guidelines are used as a reference framework. The CMF uses the qualification levels taken from EFQ to be fully compatible with the qualifications under the Bologna Process (European MOOC Consortium 2019).

While the EQF defines skill levels that allow comparison between qualification systems, its definition of skill levels is too abstract to be used to classify learning outcomes (European Commission 2008). This level of detail is possible using Dublin Descriptors, that are compatible with the EQF:

> "In the QF-EHEA [Dublin Descriptors being adopted in EHEA], learning outcomes are understood as descriptions of what a learner is expected to know, to understand and to do at the end of the respective cycle" (ibid, p. 10). That is precisely what is needed in a module description or a definition of the outcomes of a MC. "The Dublin descriptors refer to the following five dimensions: 'knowledge and understanding', 'applying knowledge and understanding', 'making judgements', 'communication' and 'learning skills'. Whereas the first three dimensions are mainly covered by the knowledge and skills dimensions in the EQF, the EQF does not explicitly refer to key competences such as communication, or meta-competences, such as learning to learn" (ibid). Those are the transversal skills also needed in defining learning outcomes of a module or a MC. The ESCO[6] terms provide a standard vocabulary for these skills.

[6]https://esco.ec.europa.eu/.

Table 1. *Overview of the Five Levels of the Dublin Descriptors Including Their Description (Taken from Joint Quality Initiative Informal Group 2004) Supplemented by Exemplary Keywords and Sentences*

Level	Title	Description: The students …
Keywords		*Example*
1	knowledge & understanding	have demonstrated knowledge and understanding in a field of study that builds upon and their general secondary education, and is typically at a level that, whilst supported by advanced textbooks, includes some aspects that will be informed by knowledge of the forefront of their field of study;
know, understand, describe, comprehend, …		*The students know the software devlopment process with scrum.*
2	applying knowledge & understanding	can apply their knowledge and understanding in a manner that indicates a professional approach to their work or vocation, and have competences typically demonstrated through devising and sustaining arguments and solving problems within their field of
apply, implement, develop, utilize, execute, …		*The students can use the scrum process for their project management.*
3	making judgements	have the ability to gather and interpret relevant data (usually within their field of study) to inform judgements that include reflection on relevant social, scientific or ethical issues;
analyse, choose, argue, reason about, improve, …		*The students can improve the scrum process so that it fits best to their project.*
4	communication	can communicate information, ideas, problems and solutions to both specialist and non-specialist audiences;
communicate, discuss, exchange ideas, cooperate, present, mediate, debate, …		*The students can discuss the scrum process and exchange ideas for improvement.*
5	learning skills	have developed those learning skills that are necessary for them to continue to undertake further study with a high degree of autonomy.
acquire knowledge, deepen knowledge, transfer finding, generalise, teach, …		*The students can transfer their knowledge about scrum to other software development processes.*

Table 1 provides an overview of the five dimensions of the Dublin Descriptors and associated examples for possible formulations. Of course, Dublin Descriptors are only one way to define skill levels. The well-known Blooms Taxonomy could also be used. So, Dublin Descriptors and Blooms Taxonomy are pretty much exchangeable and serve the purpose of sorting things nicely. It has no relationship with standardizing the formulation through ESCO, which is the more important standard that serves to unify the description on an EU (or international) basis. But

since the Dublin Descriptors are accepted by the EU (see above) and provide an easily understandable layering with each level built on top of the next lower one, we use that.

Converting the Module Description

Step 1: Analysing Learning Outcomes in Modules

The first step in the conversion analyzes the curriculum description, especially the learning outcomes, to apply the Dublin Descriptor framework. In our case this includes translating the text to (at least) the English language. The next step is to reduce complex sentences and enumerations into simple, single topic sentences like "Students can apply X", "They can implement Y" or "They can develop Z". Sometimes it was necessary to combine sentences, but only in very few cases. Learning outcomes on a higher abstraction level have to be phrased accordingly like "Students can … (analyze, choose, argue, reason about, improve, …)" (see Table 1). This process repeats for all skills of the module description and will lead to a list of statements sorted by Dublin Descriptor levels.

Example Transformation of Learning Outcomes

In the following sections we will show only selected examples from a first cycle module in Software Engineering. The complete module description, before and after conversion, can be found on github[7].

Let's start with the German original "Die Studierenden kennen die Grundlagen des Softwareerstellungsprozesses". In Step 1 we translate that to English and split it up (not necessary for this example) in simple sentences. We get "The students know the basics of the software development process."

Step 2: Assigning Dublin Descriptors to Learning Outcomes

In step 2 we associate a Dublin Descriptor level: When analyzing the verbs we find "The students know …" This corresponds to level 1. In the next step, we try to find a corresponding ESCO skill or a corresponding ISCED category. In this case we get an appropriate ESCO skill (knowledge): "ICT project management methodologies".

The next example is a bit more complex:

> "Sie können eine vorgegebene Problemstellung analysieren und rechnergestützt Lösungen entwerfen, umsetzen, qualitätssichern und dokumentieren."

Translated to English we get: "They are able to analyze a given problem and can use computer based tools to design, develop, assure quality and document solutions." Split this up in simple parts gives (step 1): "They can analyze a given

[7]https://github.com/TillHaenisch2/MicroCred.

problem. They can use computer based tools for communication and problem solving. They can design and develop a solution for a given problem. They can assure the quality of the solution. They can document solutions." Based on the vocabulary used, we order these learning outcomes by Dublin Descriptor levels (step 2):

> DD2: "They can design and develop a solution for a given problem.", "They can document solutions.", "They can use computer based tools for communication and problem solving."
> DD3: "They can analyze a given problem."

Step 3: Associating Standard Formulations

Now we have to associate standard terms for the skills and competences. We won't do that for all the skills given in the example but only for some edge cases, see Table 2.

Table 2. *Corresponding ESCO-Terms for Given Skills and Competences*

"They can analyze a given problem"	S2.7.4 analyze business requirements
"They can design and develop a solution for a given problem"	S1.11.1 designing ICT systems or applications
"They can use computer based tools for communication and problem solving"	S5.6 using digital tools for collaboration, content creation and problem solving.

But that doesn't work always: "Sie können korrigierende Anpassungen an Lösungsvorschlägen vornehmen". In English: "They can correct design decisions" doesn't exist in ESCO yet. In this case we need to propose a new term S4.9+ "correcting design decisions" as the ESCO criteria are incomplete and don't offer a corresponding term.

> Or: "Sie können für konkrete Problemstellungen angemessene Methoden auswählen."
> In English: "The students can choose appropriate methods to solve a given problem."

That would correspond to level 2 or 3 in the Dublin Descriptors.

In ESCO there are either broader or narrower terms, so we need a new skill "Software development lifecycle models" as a generic term for the subcategories under "ICT project management methodologies".

To modify or add ESCO categories one has to differentiate between two types of changes: There are small and large changes.

An amendment to the given text is a small change, that can be done quickly. Adding a new skill is a major change that has a larger delay in implementation as it goes through a central consortium and needs to be translated to several languages.

Figure 1 shows the mapping of the German free text version to groups of skills structured according to the Dublin Descriptors, but still in the original competency framework. It would be nice to change that to a standard form too, but this is something which should be addressed in the long run since it requires

changing the competence framework used for accreditation and probably will take years to be accepted.

Trying to convert the topics covered in a course and defined in the module description is a bit different than skills. These document the knowledge gained during the course.

Classifying knowledge on a high level is easier. The relevant knowledge of the example module (software engineering) is:

- Project Management Methods
- Phases of Software Engineering Process
- Requirements-Engineering and Management
- Analyses and Modelling (for example UML)
- Software architecture, APIs, Class-Diagram, DB Design
- Code quality, Reviews, Testing
- Continuous Integration
- Versioning
- Lifecycle Management
- Documentation
- Implementation of a full project

On a high level, these topics are classified by the ISCED-F (International Standard Classification of Education) classification (ISCED[8]), but the level of detail given there might not be sufficient. The relevant category for our example is ISCED-F/613 "Software and applications development and analysis" with the following subcategories (ISCED-F 613).[9]

Computer programming, Computer science, Computer systems analysis, Computer systems design, Informatics (computer science), Operating systems, Programming (computer), Programming languages development, Software development, Software localisation, Software programming, Software testing

This might not be as fine grained as needed for a module description. So, the broad topic of a course can be defined in standardized way using ISCED but probably has to be complemented with (non-standard) terms to make clear, what the course content really is. Depending on the topic, existing ESCO-terms can be used, in other areas they have to be defined. Whether this is acceptable for the recognition of MCs remains to be seen.

The output of this rather mechanical process is given in Figure 1 in the form of our standard module descriptions.

[8]https://ec.europa.eu/eurostat/statistics-explained/index.php?title=International_Standard_Classification_of_Education_(ISCED).
[9]http://data.europa.eu/esco/isced-f/06 (example for Computing).

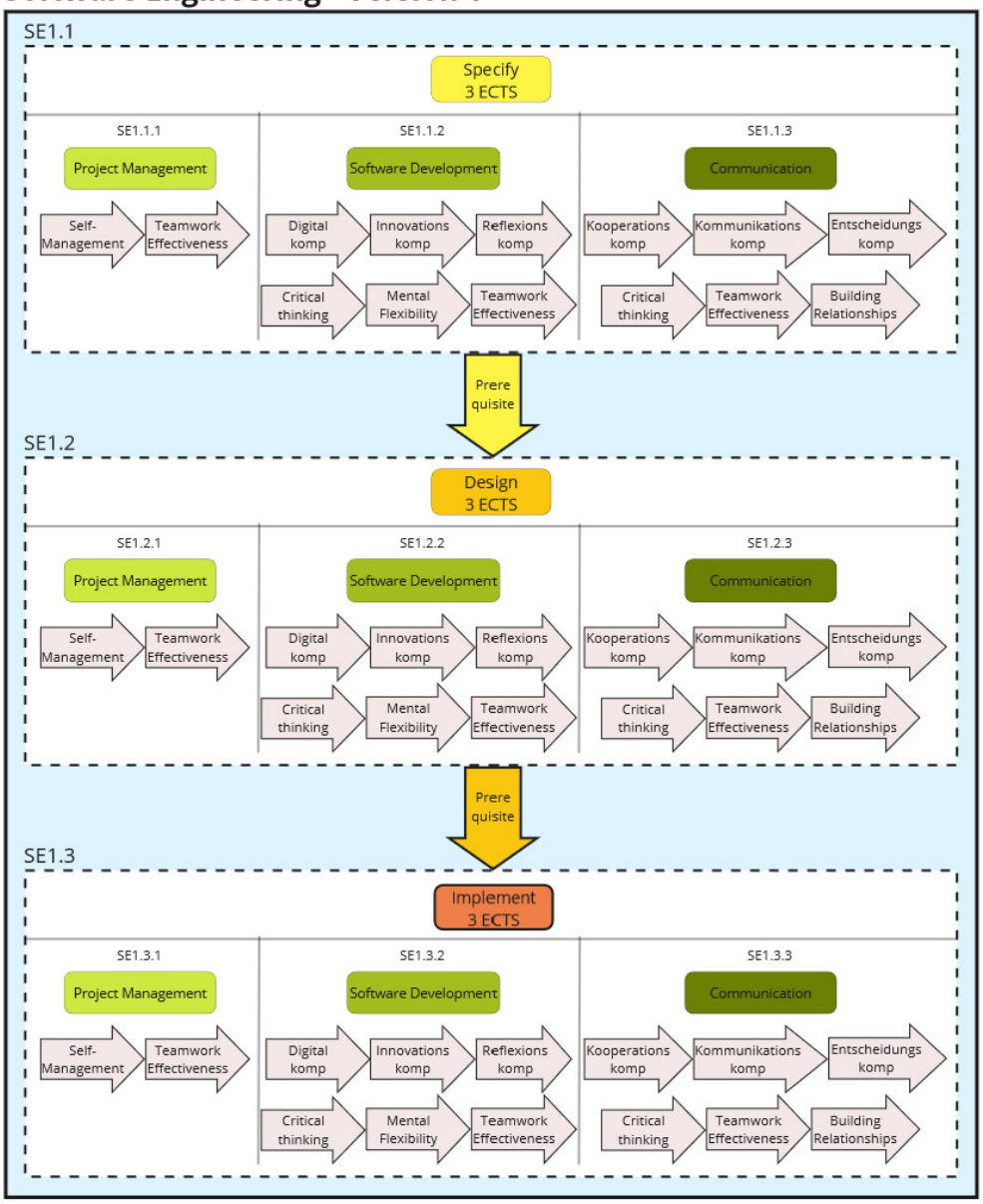
Figure 1. *Skills and Knowledges Converted to Standard Terms*

QUALIFIKATIONSZIELE UND KOMPETENZEN
FACHKOMPETENZ (DD1)
know technical designs, procedures, methods, tools or activities
METHODENKOMPETENZ (DD2 + DD3)
analyse business requirements organising, planning and scheduling work and activities designing ICT systems or applications correcting design decisions using digital tools for collaboration, content creation and problem solving
PERSONALE UND SOZIALE KOMPETENZ (DD3 + DD4)
analysing and evaluating ICT systems and solutions negotiating presenting information working with others building and developing teams
ÜBERGREIFENDE HANDLUNGSKOMPETENZ (DD5)
thinking skills and competences planning and organising thinking creatively and innovatively working efficiently taking a proactive approach accept criticism and guidance communicating supporting others collaborating in teams and networks

Step 4: Creating Stackable Sub-Modules (Micro-Credentials)

As it can be seen in Figure 2 modules might often have a huge size, so it is necessary to break up modules into smaller “micro” units.

Figure 2. *Example Module Separated into Three Stackable Micro-Credentials*



Since MCs are defined as small units, a typical size for existing MCs is 1 to 3 ECTS, so about 3 ECTS looks like an acceptable maximum size. In our programs most modules have a size of 5 ECTS. Our example (Software Engineering I) has a size of 9 ECTS which is too big for a MC. In this case it makes sense to divide the 9 ECTS into 3 parts: design, specification, and implementation. Each of them can stand alone and be taken since each unit has individual skills and competences defined. Of course, these three MCs can be stacked if desired.

That makes sense for a first cycle computer science degree (which the module is intended and accredited for), but in other cases not. For someone working in business or health care, it might make perfect sense to acquire the skills necessary

for analyzing and specifying the (business) requirements of a system while the skills to design or implement it are not needed, so they only need the first part.

When splitting a module into several parts, a few interesting questions will arise, especially with transversal skills. While assigning the skill to one (and only one) of the three parts of our sample module is easy for some skills - typically more technical skills - it might become difficult for others. We must consider three edge cases:

1. skills, which are used equally in all parts. Example: "using digital tools for collaboration, content creation and problem solving"
2. skills, which are used to some extent in more than one part but with a clear focus in one part. Example: "Requirements management" focused in part two
3. skills, which are only acquired in one part. Example: "S2.7.4 analyze business requirements" only in part one or "Code quality, review, testing" only in part three.

Case number 3 is obviously the easiest: the skill (knowledge in the example above) can be assigned to one of the parts. Case number 1 is easy from the viewpoint of assigning the skill: it must be assigned to all parts. But that is not without semantic problems:

Consider the case of two students, one takes and completes only part one, the other one all three parts. Do both have the same set of skills afterwards? Probably student number two spent more time learning "using digital tools for collaboration, content creation and problem solving". But how do we know that, looking only at the certificate? Especially in the case, that she didn't take three MCs but completes the module as originally intended and got only one certificate. Should the skills be weighted with the size of the course? Probably not, since several skills could be acquired in a course, not all equally important/deep. So, we cannot distinguish the two.

There is (as far as known to the authors) no standard way of handling this. Maybe we could assign points or badges or some other quantitative attribute to the skill for each MC. But that would be hard to get consistent across platforms/ universities. Maybe that only makes sense in one ecosystem to express things like: "To get the skill 'using digital tools for collaboration, content creation and problem solving' you need to take all three parts together or maybe take only one of these but then you need other MCs which give the missing amount of that skill."

In the future, student administration systems in universities must be capable of handling not only lecture-names, grades and granting university. A student must have a set of MCs shown but in addition the skills must be extracted into a skill-profile. Out of such a profile, we can then determine, if a student is able to register for a new MC, without taking a specific pre-requisite. Instead, a pre-requisite is expressed by pre-required skillset. Today, moodle and most student management systems in universities are not enabled for this requirement of new learning.

Step 5: Editing the Online Micro-Credentials

The format of MC certificates is defined by the EU[10] as an XML-format. There are (web-) tools to create certificates manually, but in the long run, any XML editor can take given module descriptions and highlight problems with the texts and allow editors to change texts into sentences, looking for autocomplete that matches the current ESCO criteria and ISCED classification of knowledge. In our (DHBW) current project portfolio we have MicroCredX and EU4Dual, that work on such interfaces for MC design and future work will publish on how these ideas are implemented and integrated with our student management systems at DHBW. We plan to leverage open-source projects here and cooperate with other universities that have similar requirements.

Teachers will have to adapt their way of grading by adopting more detailed skill descriptions and using a more granular grading system. Additionally, transversal skills must be made visible within the grading scheme. The online editor or digital credential issuer uses the MC format to provide an XCEL to enter grades for each of the students based on their ID, which consists of the EU-ID or an email. After uploading the grades, all students receive a notification and can share their credentials publicly.

Conclusion and Further Research

The more or less unstructured format of our module descriptions is not adequate to capture the complexity of mapping different competence frameworks (especially in more than one language). While the visual representation we used for our work[11] has proven to be a valuable tool for structuring sample module descriptions during the process, a much more powerful way of representing the content (the learning outcomes, skills and knowledge, achievements and all the other metadata) is needed. Graph databases can be used to represent complex structures and dependencies and have been applied to capture dependencies between modules in university contexts, see for example (Samaranayake 2022). So, it should be evaluated, if a graph database is the right way to solve these problems.

MCs require reforms by universities with respect to their basic student management systems. These need to be extended to view students as life-long learners instead of full-time clients for a couple of years. A new student should be able to enter a university with all past certifications immediately accessible to the student management system. Based on this model, that includes a skill-profile, specific coursework should automatically be accredited by the current institution, outlining the remaining curricular options that are open to the student given their profile. Additionally, for dual education, skills gained during any practical phase should be taken into account. Finally, a match between employers and employees

[10]https://europa.eu/europass/digital-credentials/issuer/#/home.
[11]https://github.com/TillHaenisch2/MicroCred.

can now be based on skill-profile matching, revolutionizing future job market in a world that seeks their employees in a worldwide international market.

References

Bologna Working Group (2005) *A framework for qualifications of the European higher education area. Bologna Working Group Report on Qualifications Frameworks.* Denmark: Danish Ministry of Science, Technology and Innovation. Available at: http://ehea.info/ media.ehea.info/file/WG_Frameworks_qualification/71/0/050218_QF_EHEA_580710.pdf.

Brown M, Mhichíl MNG, Beirne E, Mac Lochlainn C (2021) The global microcredential landscape: charting a new credential ecology for lifelong learning. *Journal of Learning for Development* 8(2): 228–254.

Council of the European Union (2022) Council Recommendation of 16 June 2022 on a European approach to micro-credentials for lifelong learning and employability. *Official Journal of the European Union* C 243: 10–25. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2022.243.01.0010.01.ENG.

European Commission (2008) *Explaining the European qualifications framework for lifelong learning.* Luxembourg: Office for Official Publications of the European Communities. Available at: https://europa.eu/europass/system/files/2020-05/EQF-Archives-EN.pdf.

European Commission (2020) *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on achieving the European Education Area by 2025*. COM (2020) 625 final, Brussels, 30.9.2020. Available at: https://eur-lex.europa.eu/le gal-content/EN/TXT/?uri=CELEX%3A52020DC0625.

European MOOC Consortium (2019) *EMC Common microcredential framework*. Available at: https://emc.eadtu.eu/images/EMC_Common_Microcredential_Frame work_.pdf.

Joint Quality Initiative informal group (2004) Shared 'Dublin' descriptors for Short Cycle, First Cycle, Second Cycle and Third Cycle Awards. In *JQI Meeting in Dublin on 23/03/2004*. Available at: https://www.aqu.cat/doc/doc_24496811_1.pdf.

Samaranayake (2022). Dependency visualization tool for decision support systems with preferential dependencies. *Athens Journal of Technology & Engineering* 9(4): 267–280.

United Nations Educational, Scientific and Cultural Organization – UNESCO (2022) *towards a common definition of micro-credentials*. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000381668.