Irish Journal of Academic Practice

Volume 10
Issue 1 *Polytechnic Summit 2021 Special Issue*

Article 9

2022-05-30

HUBLINKED: A Curriculum Mapping Framework for Industry

Paul Doyle PhD
Technological University Dublin, paul.doyle@tudublin.ie

Cathy Ennis
Technological University Dublin, cathy.ennis@tudublin.ie

Anna Becevel
Technological University Dublin, anna.becevel@tudublin.ie

Stephane Maag
Telecom SudParis, stephane.maag@telecom-sudparis.eu

Radu Dobrin PhD
Mälardalens University, radu.dobrin@mdh.se

See next page for additional authors

Recommended Citation

Doyle, Paul PhD; Ennis, Cathy; Becevel, Anna; Maag, Stephane; Dobrin, Radu PhD; Ciglarič, Mojca PhD; Choi, Yunja PhD; Fahey, Alan; and Lillis, Deirdre (2022) "HUBLINKED: A Curriculum Mapping Framework for Industry," *Irish Journal of Academic Practice*: Vol. 10: Iss. 1, Article 9.
doi:https://doi.org/10.21427/a2se-1s03
Available at: https://arrow.tudublin.ie/ijap/vol10/iss1/9

Authors

Paul Doyle PhD, Cathy Ennis, Anna Becevel, Stephane Maag, Radu Dobrin PhD, Mojca Ciglarič PhD, Yunja Choi PhD, Alan Fahey, and Deirdre Lillis

1 INTRODUCTION

SMEs and Enterprise companies are looking for workplace-ready graduates that have already gained a relevant range of skills and knowledge as part of their studies. These include having specific proficiencies as well as a broad understanding of industry, including transferable skills such as self-awareness, critical thinking, teamwork, listening, time management, and leadership (Smith and Reid, 2018). This demand entails a reciprocal relationship between industry and academia, which is one of many aspects that drives the need for solid collaborations between the two sectors (Ankrah and Al-Tabbaa, 2015).

When facing the recruitment process, however, SMEs and Enterprise companies often struggle to match their requirements to the learning outcomes of new graduates applying for positions. Companies are faced with an overwhelming array of degree programmes to engage with, most of which consist of multiple modules and options. Even within the same institute and school, students graduate with the same qualification, but have gone through vastly different pathways and gained a varied experience based on the optional modules they may have taken. Without enough academic knowledge and familiarity and no means to distinguish between these courses and the graduates, the recruitment process for companies must rely heavily on lengthy interview procedures to search for the right graduate with the right experience and transversal skills, a process that can be resource intensive in terms of time and financial cost.

Given that learning trajectories across programmes and curricula are often not visible from an employer perspective some form of mapping of academic curriculum to industry graduate requirements would seem an essential step to help relieve employers, at least partially, from burdensome recruitment procedure (Wijngaards-de Meij and Merx, 2018).

The broad goal of the HubLinked Knowledge Alliance is to strengthen Europe's software innovation capacity by learning from regions of proven Information Computing Technology (ICT) strength in Europe and Asia and sharing that knowledge with all regions. A key goal of the Alliance was to conduct research on the effectiveness of University-Industry (U-I) collaborations between Computer Science faculties and Companies (including non-ICT companies) as U-I collaborations are understood as a core driver of innovation capacity. In recognising that SMEs and Enterprise companies often struggle to match their graduate requirements to the learning outcomes of new graduates, two key challenges (presented here as fundamental questions) emerged:

1. How can SME requirements for graduate recruitment be captured in a way that facilitates matching their requirements to academic programmes?
2. How do you match university programmes from different institution to the industry requirement?

In this paper we present a Curriculum Mapping Framework (CMF) and a Curriculum Mapping Tool (CMT) to address these issues. The CMF encodes the companies' graduate attributes into a virtual curriculum after which the CMT maps the virtual curriculum onto specific educational pathway within an academic programme to determine the level of match between the two.

The CMF and the CMT were both designed within the HubLinked Knowledge Alliance, [1] a partnership of seven large industry-focused Computer Science Faculties and four Industry partners representing large multinationals, SMEs, and start-up companies.

Section two will explore the context that led to the development of the CMF and the CMT. In order to map learning outcomes across different programmes and courses, across different academic award levels and across different institutions, it is necessary to understand the general structure of a programme and how curricula are constructed. Our approach has been strongly inspired by the reports of the Association for Computing Machinery (ACM),[2] Bloom's Taxonomy (Bloom and Krathwohl, 1956) and by the assumption that multiple pathways are possible within each academic programme, meaning individuals undertaking the same programme gain varied skills depending on the optional modules for which they have opted.

Section three describes in the development of the CMF which provides a mechanism for encoding industry requirements into a curriculum. Qualitative data was collected over a three-year period in the form of interviews with 40 Industry professionals and through organised focus groups with academic partners and stakeholders. Data collection was a central theme at each of the quarterly meetings

---

[1] www.hublinked.eu
[2] www.acm.org

hosted by each of the project partners who also facilitated the contribution of additional academic staff from outside of the project.

Section four presents the CMT and demonstrates how the mapping process between ICT programmes and the HubLinked curriculum is achieved. The CMT is available on the HubLinked website for download.[3] Observations on the CMF and the CMT including recommendations on its future use are presented in the last sections of this paper.

2 BACKGROUND

2.1 CURRICULUM DEVELOPMENT

Traditional, higher education programmes are structured around a set of core and option modules taken over a number of years (depending on the level of award and the mode of study, notably full-time, part-time or distance based). Students must complete all core modules, and select a quota of option modules, usually to achieve a specific number of academic credits in order to complete the programme. Each module will prescribe a set of learning outcomes which must be met in order for students to have achieved to pass the module.

Curriculum design is the term used to define the formation of a programme through a set of learning objectives and modules. As a topic subject to extensive research, there are many different models and approaches defined for different disciplines (O'Neill, G., 2015, and Munna and Kalam, 2021). Two main schools of thought exist within these models, the *Process Model* and the *Product Model*. The Product Model is mostly under teacher control, focuses on plans and intentions and has been criticised for having too much emphasis on learning objectives, reflecting the behaviourist approach (Neary, 2003), but is commended for developing clear and transparent outcomes. In contrast, the process model focuses more on the activities and effects and trusts that if the process is right such as, messages and conditions, for example, then the outcomes will follow (Knight, 2001). Variations and alternatives exist such as the backward design model (Wiggins and McTighe, 2010), which is heavily linked to graduate attributes.

[3] www.hublinked.eu/curriculum-mapping-tool/

This model is effective in ICT programmes, where technical curriculums have specific attributes that student must possess upon programme completion, emphasising the importance of learning outcomes.

The ACM published a report on the outcomes of an investigation into Computer Science curricula (ACM and IEEE, 2013) including specific recommendations and core principles to help guide future curriculum development and design. A key recommendation was the provision of flexibility for students to work across disciplines to appreciate the variety of professions in the field of ICT, and to provide flexibility within the curriculum to allow the creation of tailored pathways through a programme to meet the needs of industry. In making their recommendations, they drew inspiration from Bloom's Taxonomy to guide the development of Learning Outcomes. The CMF incorporates both these recommendations in order to develop a HubLinked Curriculum which can help map industry requirements across multiple ICT based programmes across Europe and Asia.

2.2 LEARNING OUTCOMES

Bloom's Taxonomy is a classification system to help define learning outcomes for modules and programmes. The taxonomy describes a number of learning levels with the intention that curricula are designed around these levels. It also provides a set of verbs associated with each level of learning. A deeper learning is associated with each increasing level. This is often used as a basis to map curricula to different learning levels such as undergraduate versus postgraduate (Lau et al, 2018). The original Bloom's Taxonomy published in 1956, was comprised of six levels: Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation. In 2001 a revised edition was published to reflect a more dynamic conception of classification based on cognitive psychology, moving the emphasis to learning outcomes rather than objectives (Anderson and Krathwohl, 2001). In both versions, learning verbs are associated with each learning level to helping define clear action statements which match the desired learning outcome.

2.3 MULTIPLE PATHWAYS

ICT curriculum are, by the nature of the industry, quite diverse in terms of graduate competencies. While there may be a core set of topics considered standard for an ICT programme, such as programming, considerable variability also exists across academic institutes, especially in the final years of the programme where many optional modules are available to students. The ICT undergraduate programmes within the HubLinked academic partner institutes have common year one and two modules but provide a distinctly different focus in later years. Students graduate with a similar qualification, but with considerably varied experience based on the optional modules they may have taken. Multiple pathways (selection of modules within a programme) exist within programmes, so even with a single programme the students may not have achieved the same learning outcomes. Without detailed knowledge of the individual programme curricula, it is challenging for an SME hiring graduates to decipher a graduate's match to their requirements.

3 CURRICULUM MAPPING FRAMEWORK

3.1 METHODOLOGY

The CMF was developed over a three-year period through a series of international conferences held in Ireland, France, Finland, Slovenia, Sweden, Belgium, and South Korea. These conferences were made up of keynote events to stimulate thinking as well as interactive workshops, focus groups, and interviews. These activities involved academics and SME stakeholders representing both Higher Education institutes and companies. Participants were invited for their specific expertise, with academic stakeholders drawing on their experiences of curriculum development and SMEs stakeholders sharing experiences of graduate recruitment and training.

Insights were generated through participatory workshops in which a mixed-methods approach (Hesse-Biber, 2010) was adopted, generating quantitative, qualitative, and visual data sets that could be used to inform and shape the development of the project. Conference delegates were all aware of how conference outputs (recordings, session outputs, and *ad-hoc* diagrams) would be used to support the ongoing development of the project.

Each conference event focused on a unique aspect of the curriculum framework and all the participatory workshops included local participation to ensure that the reach of the project went beyond that of the initial stakeholders.

3.2 HUBLINKED CURRICULUM

The function of the curriculum development framework is to translate the requirements of industry graduate recruitment into a format that can then be mapped to specific and unique pathways through ICT programmes. Thus, with a defined set of criteria from industry, an SME recruitment process could then identify not only the programmes that could supply the required graduates, but the specific set of optional models within the programme that would best meet their needs. In addition to this, the same process could help identify courses in different institutes which were designed to produce graduates who met the same requirements.

The way we encoded the requirements from industry was to create a virtual curriculum. A virtual curriculum is a fictional industry-derived set of learning outcomes which represent the requirements of the industry. Within the HubLinked project we created the HubLinked Curriculum which was an industry-derived set of the learning outcomes they wished graduates to have achieved. Using a facilitated process between academics and industry stakeholders the curriculum was designed within the HubLinked International conference workshops. The process to design the new curriculum can be summarised in four steps (Figure 1).

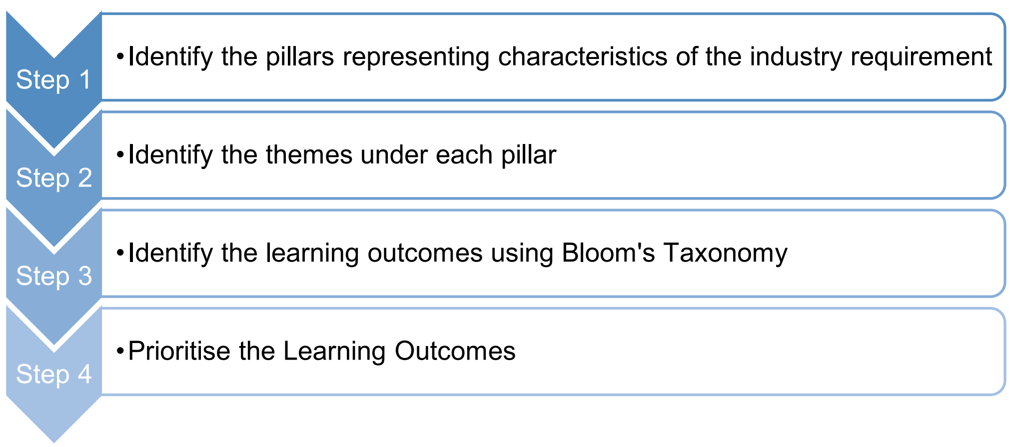

Figure 1. HubLinked steps within the CMF

Table 1. Sample learning outcome requirements datasheet

HubLinked Pillar: Industry		
Theme	**NFQ Level 7 (EQF Level 6, Undergraduate degree)**	**Priority**
Process	Describe standard methodologies and roles within the ICT industry.	P2
Flexibility	Practise multitasking with multiple deadlines in a project development.	P1
Professional Issues	Give examples of professional issues in terms of social, ethical, and legal aspects in software companies.	P3
Implementation	Build a prototype from an industrial project.	P1
Business	Explain the business modules including cost, quality, and management issues involved in the construction of an ICT software project.	P2
Culture	Describe the different work-cultures applied in a large-scale industrial project.	P3
Learning	Illustrate examples of life-long learning practices.	P2
Communication	Present work in a professional manner and show an understanding of key stakeholders such as clients, partners and customer.	P1

The output of this process is a data sheet which defines the requirements for student learning outcomes for each pillar, categorised and prioritised under each theme and academic qualification level. Table 1 show an extract of the data sheet for the industry pillar at NFQ Level 7 (EQF Level 6, Undergraduate degree). Once the curriculum is encoded into the datasheets it can then be used to map against existing ICT programmes using the CMT as described in section 4.

3.3 HUBLINKED PILLARS

The first step in developing the HubLinked curriculum involved the creation of a set of characteristics and categories which represented the high-level topics which were of importance to SMEs during graduate recruitment. These ‘Pillars of Learning’ create a high-level of focus to facilitate the refinement of learning outcomes later the in the process. The following Pillars were defined at the initial meeting of the HubLinked team and are described here.

Table 2. HubLinked Pillars

Pillar	Description
Industry	Students have industry relevant experience such as meeting multiple project deadlines, applying industry standards and methodologies.
Teamwork	Students learn how to work within a team environment, with demonstratable communication and problem solving skills.
International	Students have experience in challenges involving remote collaboration with international students requiring the use of professional and management skills.
Research	Students are familiar with research in the scientific community, and relevant processes such as technology transfer.
Innovation	Students demonstrate an awareness of latest technology trends and have some experience in creative thinking and design thinking.

These collectively defined pillars provide the central supporting narrative for curriculum development and are, as the project demonstrated, recognisable and applicable across all Alliance contexts.

3.4 HUBLINKED THEMES

Within each pillar, a set of themes was defined to help design lower-level curriculum learning outcomes. The themes were defined in the same way pillars were, through a facilitated process between academics and industry stakeholders within the HubLinked International conference workshops. The themes provide a specific focus under the specific pillar. For example, the process theme under the research pillar will lead to different learning outcomes to those under the industry pillar. Each of the themes are summarised as follows in Table 3.

Table 3. HubLinked Themes

Theme	Description
Process	Relating to awareness of and use of common processes, standards and methodologies relevant to a specific pillar
Flexibility	Working to deadlines, conflict resolution, managing collaboration across time zones and consideration of different approaches to tasks
Professional Issues	General professional issues such as ethics, social and legal awareness, time management, requirement elicitation and communication and connection with peers
Implementation	Varies across pillars but can be related to building and assessing prototypes, working within project teams, scientific solutions or writing scientific technical papers
Business	Awareness of business models and perspectives in a technical project such as costs, internationalisation, professional communication, and understanding of research within a business context
Culture	Understanding of culture across the different pillars; within a workplace project, a team project and ethical research
Learning	Staying up to date in the relevant domain, critical thinking and analytical skills, identifying and defining a research problem
Communication	Presenting work in a professional manner, communication skills in multi-cultural/multi-language projects, other team-based skills such as listening, non-verbal communication and communication of skills.

Themes can be described as a number of different perspectives that are needed to achieve the high-level learning outcomes associated to each pillar. To extend the example above, we can look at the differences between the process theme under the research pillar and the industry pillar at NFQ Level 7. The high-level learning outcome associated with the industry pillar requires students to have industry relevant experience such as meeting multiple project deadlines, applying industry standards and methodologies. Accordingly, under the industry pillar, the process theme leads to the learning outcome “Describe standard methodologies and roles within the ICT industry”. Differently, since the high-level learning outcome for the research pillar is to be familiar with research in the scientific community, and relevant processes such as technology transfer, the process theme for this pillar translates to "Describe the basic processes of technology transfer, international patenting and research production”.

3.5 LEARNING OUTCOMES

Within the higher education sector there are multiple award levels which contain increasing levels of complexity in learning outcomes. This means that when developing a learning outcome for a specific award level, the learning outcomes need to be written to reflect the level of knowledge expected of a student at that level. The next step required is the mapping of award levels across each of the academic institutes with the HubLinked project. Of primary interest were graduates from ordinary bachelor’s degrees, honours bachelor’s degrees and master’s degrees in the field of ICT. Within the Irish context, the National Framework of Qualifications (NFQ) defined three levels of awards relevant to HubLinked; undergraduate ordinary degree at NFQ level 7, undergraduate honours degree at NFQ level 8 (EQF Level 7) and postgraduate master’s degree at NFQ level 9. The mapping for these qualification levels to European and South Korean awards is shown in Table 4. This mapping was an essential step in ensuring that programmes across each of the countries were mapped to the correct learning outcomes appropriate for their academic level.

Table 4. Mapping Irish award levels to European and South Korean frameworks

<table>
<tr><th>Framework</th><th colspan="2">Undergraduate</th><th>Postgraduate</th></tr>
<tr><td>Irish</td><td>Level 7

Bachelor’s Degree (Ord)</td><td>Level 8

Bachelor’s Degree (Hon)</td><td>Level 9

Master’s Degree</td></tr>
<tr><td>European</td><td colspan="2">Level 6

Bachelor’s Degree</td><td>Level 7

Master’s Degree</td></tr>
<tr><td>S. Korean</td><td colspan="2">Bachelor’s Degree</td><td>Master’s Degree</td></tr>
</table>

DOI: https://doi.org/10.21427/a2se-1s03

With eight themes in each of the five pillars and three award levels, a total of 120 unique learning outcomes were required to be developed. The process of creating learning outcomes appropriate to the award levels involved the use of the revised Bloom's Taxonomy (Anderson and Bloom, 2001) where the categories within the taxonomy were mapped with award levels as shown in Figure 2. The verbs within these sections were then used to construct the learning outcomes.

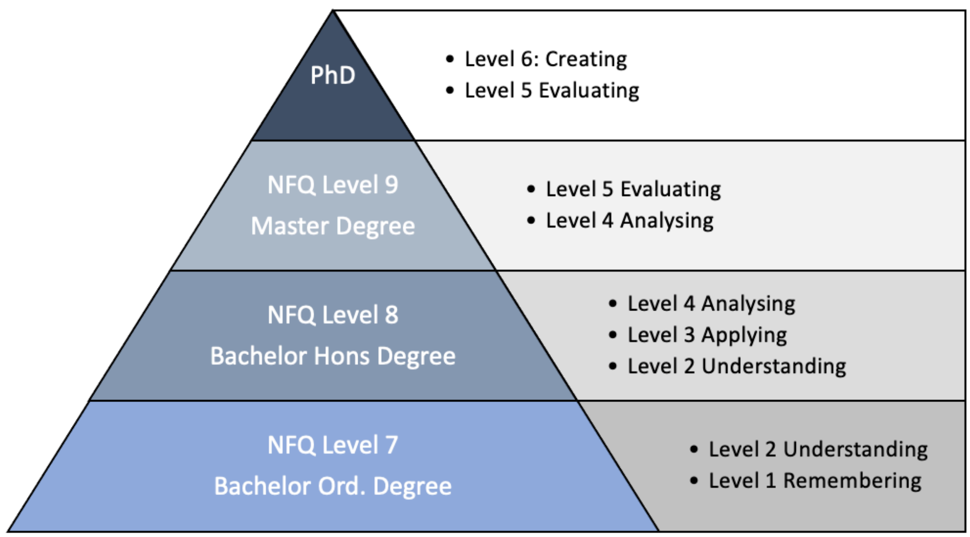

Figure 2. HubLinked Mapping of Revised Bloom's Taxonomy to NFQ Award Levels

3.6 PRIORITISING LEARNING OUTCOMES

Once the learning outcomes were created, a review was performed with HubLinked academic stakeholders to determine if any ICT programme within the partnership could meet all of the defined learning outcomes. In all cases, some percentage of learning outcomes were not achievable within a programme. This led to the question of "are all Learning Outcomes equal?". If a single Learning Outcome was not matched during a mapping exercise then no valid pathway (selection of optional modules) within a programme would be found to meet the HubLinked curriculum requirement. Given that there are 40 Learning Outcomes per award level it did not seem reasonable for a single learning outcome failure to result in an outright failure during the mapping process. This meant that additional tolerance was required in the mapping process. Upon reviewing the learning outcomes in a focus group of all stakeholders, it was reported that relevance of the learning outcomes was very much dependant on the combination of the pillar and that a prioritising exercise was required.

To determine if all learning outcomes are equal, a workshop was run where participants reviewed each of the learning outcomes for each of the levels and then prioritised them using the following scale.

Table 5. Learning outcome priorities

Priority	Requirement	Description
P1	Essential	Essential and core requirement
P2	Highly Desirable	Highly desirable but not essential
P3	Desirable	Nice to have but of lesser importance

This meant that we now have a scoring system which we could use to determine the Learning Outcomes priority. All stakeholder then proceeded to vote on the priority of the learning outcomes. A weighting (w in the equations below) was then assigned to each of the priority scores as shown in *Eq (1)*. The purpose of the weighting was to create clear separation between each priority but to allow consensus on learning outcome priorities to be created.

$$P^1 = w^1 = 10 \quad P^2 = w^2 = 5 \quad P^3 = w^3 = 1$$

(1).

Next, for each learning outcome the number of votes for each priority was counted as follows.

$$nP^1 = numer\ of\ P^1\ votes, \quad nP^2 = numer\ of\ P^2\ votes,$$
$$nP^3 = numer\ of\ P^3\ votes,$$

(2).

A normalised score value (ranging from 0-1) was then calculated for each learning outcomes as shown in *Eq. (3).*

$$\frac{(nP^1 * w^1) + (nP^1 * w^1) + (nP^1 * w^1)}{(nP^1 + nP^2 + nP^3)} \tag{3.}$$

A histogram was generated using the normalised results from all voting to determine how distributed the scoring was. An analysis of the distribution of the votes was required to determine where the thresholds should exist for assigning a final priority. The boundaries were set to ensure that the number of P1s would be approximately 50% of the priorities assigned across all of the learning outcomes. The following thresholds were set ensure that 47% of priorities would be P1, 31% of priorities would be P2, and 22% of priorities would be P3.

$$(P^1 \geq 0.71), \quad (P^2 \geq 0.3,\ P^2 < 0.7) \quad (P^3 < 0.3) \tag{4.}$$

Using these thresholds, the final priority values were determined for each individual learning outcome based on the voting by each of the stakeholders, completing the datasheet. With the curriculum encoded into the data sheet it can then be uploaded to the CMT to begin the process of mapping it against ICT programmes.

4 IMPLEMENTING THE MODEL

4.1 CURRICULUM MAPPING TOOL

The CMT was designed to assist the mapping of a virtual curriculum defined using the CMF. The virtual curriculum represents the industry learning outcomes required, defined under pillars and themes. The tool then assists in identifying pathways within a programme which map to the industry required learning outcomes defined. The virtual curriculum is encoded in the data sheet component of the CMT. In this project the HubLinked Curriculum is an example of a virtual curriculum which was then mapped to ICT programmes in Europe and South Korea.

The tool provides a "what-if" approach by allowing multiple modules to be mapped at the same time and then providing a mechanism for pathways to be easily tested and identified.

With each of the learning outcomes mapped to a priority (P1, P2, P3) the result of the mapping process can have only one of four outcomes as shown in Table 6.

Table 6. Accreditation levels

Accreditation Level	Description
GOLD	All of the P1, P2, P3 learning outcomes are successfully mapped to a set of modules which now define the HubLinked GOLD pathway.
SILVER	All of the P1, P2 and some of the P3 learning outcomes are mapped to a set of modules which now define the HubLinked SILVER pathway.
BRONZE	All of the P1 and some of the P2 and P3 learning outcomes are mapped to a set of modules which now define the HubLinked BRONZE pathway.
Not Accredited	No pathway was found which matched all of the P1, P2 or P3 learning outcomes.

The aim of the CMT is to help identify a pathway which maps to the highest level of accreditation using option modules available within the programme being tested. A successful mapping results in the creation of a specific pathway within a programme, which will ensure that graduates taking that combination of modules will have achieved the specified learning outcomes identified within the framework.

4.2 MAPPING PROCESS

The only prerequisite to using the CMT is that the data sheet is fully populated with the learning outcomes as defined under the pillars and themes identified using the CMF which encodes the requirements from industry against which the mapping is tested. Figure 3 shows the three basic steps in the mapping process using the CMT.

The first step in using the CMT is to identify the award level that is being tested. This will ensure that the correct learning outcomes and priorities are loaded into the system for mapping. Next identify the set of optional modules which will be mapped against the virtual curriculum. The modules selected should contain modules which are a first best guess at the types of modules which fit the profile of the virtual curriculum.

The second step is to identify which learning outcomes match which module. The mapping exercise is performed against all learning objectives covering the five pillars. The accuracy of this step is essential. A mismatch in the mapping of the learning outcomes will lead to a false result at the testing step, causing the virtual curriculum not to be accredited correctly, or not be accredited at all. It is crucial for this step to involve an academic familiar with the details of the selected modules. To improve accuracy, the academics involved should reflect on the activities implemented in each module and whether they lead to the achievement of the learning outcomes in the CMT. If available, module descriptors for each module could be useful. Even though the learning outcomes in the module descriptors and those in the CMT will naturally be phrased differently, extracting the keywords from the descriptors might be a useful exercise to improve the accuracy of the mapping.

In the final step the pathways may be selected interactively. The tool will then automatically check the level of learning outcomes matched between the virtual curriculum and the selected modules. It is essential to ensure that only modules which can be taken together are selected. This knowledge is provided by the academic who should be familiar with the details of the programme being mapped. Valid pathways are then summarised in the final section of the tool identifying the modules within the pathway, the credits associated with them and the level of accreditation (Gold, Silver, Bronze).

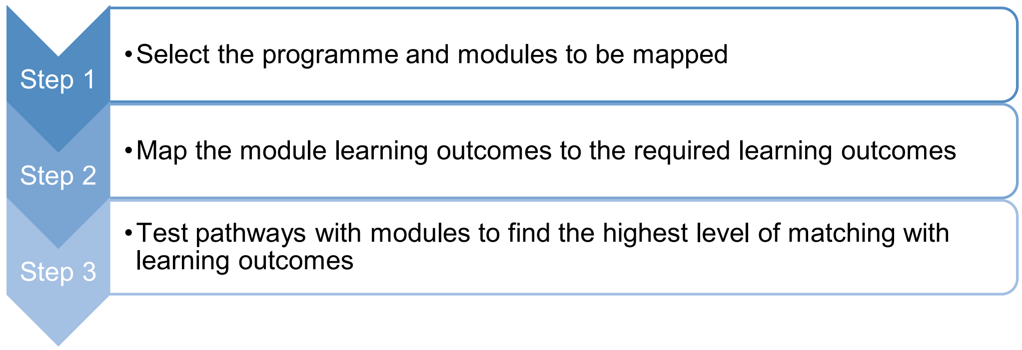

Figure 3. HubLinked steps within the CMT

4.3 TOOL VALIDATION

The HubLinked Curriculum as defined as part of the development of the CMF, was used to test the mapping tool but using programmes run by partners within the project. The programmes selected were existing double degrees programmes with other international universities, or programmes which were being considered for double degree validation. Double degrees are programmes and agreements between institutes where a student receives a degree from two partner universities as part of their study. Students are required to travel to the partner university for two academic semesters and complete the equivalent of 60 ECTS credits of work. As part of the Double Degree validation process, year 1 and year 2 of the degree programmes are mapped to ensure the learning outcomes are compatible and students will be sufficiently prepared for modules in the partner institute. It was on this basis that the programmes selected for mapping were already known to have a compatible curriculum.

4.3.1 NFQ LEVEL 7 TESTING

For this mapping we only considered modules in stage 3 of the undergraduate programme. Table 7 depicts the result of the mapping exercise. Institute-1 achieved mapped all learning outcomes to achieve Gold accreditation, while Institute-2 achieved Bronze and Institute-3 failed to complete the mapping. Where mapping failed to occur the primary learning outcomes which were identified as problematic were around international and research themes. What emerged through review was that not all programmes offered international dimensions to their programmes, and in many cases research was not a core focus in many of modules at this academic award level.

Table 7. Comparing NFQ Level 7 Mappings between partners

Accreditation Level	Institute-1	Institute-2	Institute-3
Gold	☑	☒	☒
Silver	☑	☒	☒
Bronze	☑	☑	☒

4.3.2 NFQ LEVEL 8 TESTING

In Table 8 we can see that two of the programmes achieved a Gold accreditation due to the extent of optional modules focused on business creation, product design and computer ethics. Institute-4 failed to match learning outcomes related to international activities, while Institute-1 only partially matched on research learning outcome in Silver and Bronze.

Table 8. Comparing NFQ Level 8 Mappings between partners

Accreditation Level	Institute-1	Institute-4	Institute-5	Institute-6
Gold	☒	☒	☑	☑
Silver	☒	☒	☑	☑
Bronze	☑	☒	☑	☑

4.3.3 NFQ LEVEL 9 TESTING

In Table 9, Bronze and Silver level accreditation was achieved by Institute 2. One of the issues encountered by the other programmes was that there were relatively fewer optional modules available compared to the undergraduate courses. Another difficulty was that in there is often less focus on Industry and International pillars at this award level. While some modules achieve some Learning Outcomes within the Innovation pillar due to their cutting-edge topics, without a specific module to address the required skills within these pillars, it was very difficult to achieve all of the requirements.

Table 9. Comparing NFQ Level 9 Mappings between partners

Accreditation Level	Institute-1	Institute-4	Institute-2
Gold	☒	☒	☒
Silver	☒	☒	☑
Bronze	☒	☒	☑

5 SUMMARY

In this paper we have shown how industry requirements for graduate recruitment can be encoded into a format based on learning outcomes using the CMF. This process of defining the learning outcomes was based on the revised Bloom's Taxonomy which focuses on the cognitive process which more closely matches the way in which industry express their requirements. Using a series of pillars and themes, the learning outcomes were developed to capture a broad range of transversal skills and applied knowledge. By further refining the learning outcomes through a process of prioritisation, a more nuanced definition of the requirements emerged, allowing ultimately for partial matching to take place in the form of a Gold, Silver and Bronze classification during the mapping process. With each learning outcome further refined to appropriately reflect the learning expectations within levels of academic awards across countries in Europe and in South Korea, a process was created to help industry map their requirements and identify the pathways within academic programmes that match their needs.

The process of mapping and matching requirements to academic programmes was then performed using the CMT. Six of the academic partners engage in a mapping process which demonstrated the capability of the tool which could identify potential gaps in their pathways when compared to the industry requirement. Specifically:

- Many Master's programmes while having a research focus may fail to fully map to learning outcomes related to international and industry activities.
- The International Pillar was often the primary barrier to achieving a valid matching in undergraduate programmes but was of high priority to industry.
- The Research Pillar at NFQ Level 7 was difficult to achieve and required specific modules for matching to occur.

Adopting an approach centered around learning outcomes, allowed us to build a tool that minimizes the impact of differences between the higher education environments of the different partners in their respective countries. Also, while the CMF focused on the creation of a virtual curriculum relevant to the ICT industry call the HubLinked Curriculum, there are no specific aspects of the process which limit it to the ICT industry. The next step in this research will be to identify a non-ICT domain and determine if the pillars and themes identified within this project are generally applicable or if alternatives are required. The process of then defining learning outcomes and using of the CMT are unlikely to require any significant alternation. In sharing the experience of the HubLinked Knowledge Alliance, this paper seeks to facilitate a better interface between the industry and academia and to develop wider dialogue around the ways in which graduate recruitment is performed.

6 ACKNOWLEDGMENTS

The HubLinked Knowledge Alliance is funded by the European Commission. The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

ACM and IEEE, Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science. 2013, ACM, New York.

Anderson, L. W. and Krathwohl, D., A taxonomy for learning, teaching, and assessing, Abridged Edition, 2001, Allyn and Bacon, Boston.

Anderson, L. W. and Bloom. B. S., A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives, 2001, Longman.

Ankrah, S. and Al-Tabbaa, O., Universities–industry collaboration: a systematic review, Scandinavian Journal of Management, 2012, 31(3), pp.387-408.

Bloom, B. S. and Krathwohl, D., Taxonomy of educational objectives: The classification of educational goals, by a committee of college and university examiners, 1956, Longmans, New York.

Hesse-Biber, S., Qualitative Approaches to Mixed Methods Practice, Qualitative, 2010 Enquiry, 16(6), pp.455-468.

Knight, P., Complexity and Curriculum: A process approach to curriculum making, Teaching in Higher Education, 2001, 6(3), pp. 369-381.

Lau, K., Lam, T., Kam, B., Nkhoma, M. and Richardson, J., Benchmarking higher education programs through alignment analysis based on the revised Bloom's taxonomy, Benchmarking: An International Journal, 2018, 25(8), pp. 2828-2849.

Munna, A. S. and Kalam, M. A., Application of Theories, Principles and Models of Curriculum Design: A Literature Review, International Journal of Multidisciplinary and Current Educational Research (IJMCER), 2021, 3(1), pp. 147-153.

Neary, M., Curriculum models and developments in adult education. In Neary, M., Curriculum studies in post-compulsory and adult education: A teacher's and student teacher's study guide, 2003, Nelson Thornes Ltd, Cheltenham, pp. 57-70.

O'Neill, G., Curriculum Design in Higher Education: Theory to Practice, 2015, UCD Teaching & Learning, Dublin.

Smith, E. and Reid, J., Using Curriculum Mapping to Articulate Transferable Skill Development in Science Courses: A Pilot Study, International Journal of Innovation in Science and Mathematics Education, 2018, 26.

Wijngaards-de Meij, L. and Merx, S., Improving curriculum alignment and achieving learning goals by making the curriculum visible, International Journal for

Academic Development, 2018, 23(3), pp. 219-231, DOI: 10.1080/1360144X.2018.1462187.

Wiggins, G. and McTighe, J., Understanding by Design: A brief introduction, 2010, retrieved from www.ASCD.org.