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How to cite:

Ward, Rupert; Philips, Oliver; Bowers, David; Crick, Tom; Davenport, James; Hanna, Paul; Hayes, Alan; Irons, Alastair and Prickett, Tom (2021). Towards a 21st Century Personalised Learning Skills Taxonomy. In: IEEE Global Engineering Education Conference (Educon 2021), 21-23 Apr 2021, [Online] Vienna.

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Version: Accepted Manuscript

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Towards a 21st Century Personalised Learning Skills Taxonomy

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Abstract— There exists a significant gap between the requirements specified within higher education qualifications and the requirements sought by employers. The former, commonly expressed in terms of learning outcomes, provide a measure of capability, of what skills have been learnt (an input measure); the latter, commonly expressed in terms of role descriptions, provide a measure of competency, of what a learner has become skilful in (an output measure). Accreditation traditionally provides a way of translating and embedding industry-relevant content into education programmes but current approaches make fully addressing this requirements gap, referred to here as the Capability-Competency Chasm, very difficult. This paper explores current efforts to address this global challenge, primarily through STEM examples that apply within the United Kingdom and European Union, before proposing a way of bridging this chasm through the use of a 21st Century (C21) skills taxonomy. The concept of C21 Skills Hours as a new input measurement for learning within qualifications is introduced, and an illustrative example is presented to show the C21 skills taxonomy in action. The paper concludes with a discussion of how such a taxonomy can also be used to support a microcredentialing framework that aligns to existing competency frameworks, enabling formal, non-formal and informal learning to all be recognized. A C21 Skills taxonomy can therefore be used to bridge the gap between capability (input) and competency (output), providing a common language both for learning and demonstrating a skill. This approach has profound implications for addressing current and future skills gaps as well as for supporting a transition to more personalised learning within schools, colleges and universities and more lifelong learning both during and outside of employment.

Keywords— Personalised Learning, Skills Taxonomy, Micro-credential, Framework, Accreditation.

I. INTRODUCTION

The first attempt to harmonise the component parts that engineering graduates should gain within higher education (HE) internationally was agreed in 1989 by the signatories of the Washington Accord [1]. The Washington Accord, along with the Sydney [2] and Dublin [3] Accords for shorter programme lengths, provided twelve differentiating characteristics for graduate attributes alongside thirteen differentiating characteristics for professional competency,

mapping these to learning outcomes for professional engineers, engineering technologists and engineering technicians respectively. The success of this common agreement on competencies spawned a similar approach within the computing professional bodies through the Seoul Accord [4] and demonstrated how a broader comparability of qualifications across HE can work using learning outcomes. These memoranda supported the internationalisation of curricula and the global promotion of consistency and parity across engineering education. The organisations that are responsible for defining and executing such accreditation processes vary by jurisdiction. In the United States of America (USA), for example, the Accreditation Board for Engineering and Technology (ABET) [5] is a non-profit organisation that accredits college and university programmes in applied and natural sciences, computing, engineering and engineering technology both within the USA and elsewhere. In the United Kingdom (UK), accreditation to the Washington Accord is coordinated by the Engineering Council [6], but delegated to individual professional bodies.

Irrespective of whether accreditation is completed by a central organisation or individual professional body, the process of accreditation involves confirming whether the exit standards of the programme, as outlined in the programme specification and its underlying module specifications, are appropriate for the level of accreditation sought. This is done in two ways:

i) Programme quality is evaluated by reviewing standards for entry, progression, retention, awards and graduate employability alongside external examiners reports, the most recent internal and external review information, evidence of employer involvement and linkages to research. Together these evidence that a programme is of an appropriate quality to support accreditation.

ii) Programme relevance is evaluated by mapping learning outcomes to the appropriate international memoranda, with exit standards reviewed within the frame of reference of the accrediting body. In the UK, for example, the Institute of Physics would not accredit a computing degree; but both BCS, the Chartered Institute for IT and the Institute

of Physics can accredit courses within their disciplines that align with Chartered Engineer accreditation criteria.

II. CURRENT SITUATION

Within the UK engineering domain, 35 Professional Engineering Institutions (PEIs) are licensed by the Engineering Council for Chartered Engineer accreditation. Originally this approach developed from a lack of industry acceptance of an overly-academic set of Standards and Routes to Registration (SARTOR) [7], but it has subsequently led to the development of a new approach to accreditation through the Accreditation of Higher Education Programmes handbook (AHEP) [8], which has been used by the UK Quality Assurance Agency (QAA) since 2006. AHEP's fourth edition was launched in August 2020, with full implementation, across PEIs, expected by the beginning of 2022. AHEP 4 supports the UK Standard for Professional Engineering Competence (UK-SPEC) [9], which defines Chartered Engineer and other professional standards for registration within engineering professional bodies. AHEP 4 also aligns with the European Network for Accreditation of Engineering Education through the EUR-ACE Framework Standards and Guidance [10].

AHEP 4 focuses on an agreed set of learning outcomes to underpin engineering competence. The number of learning outcomes have been significantly reduced in the latest edition to 18 areas of learning, grouped into 5 themes, namely "*Science and Mathematics*", "*Design and Innovation*", "*The Engineer and Society*", "*Engineering Analysis and Engineering Practice*". There has also been a distinct shift away from demonstrating competence purely in engineering domains to more general transferability in response to employer needs [11].

In terms of qualifications, in the late 1990s the Sorbonne declaration [12] and the Bologna declaration [13] demonstrated a desire within European countries for the establishment of a method of comparison of learning between different countries and qualifications. These declarations led to the establishment of the Bologna Process through which European countries have agreed common qualification structures and transferability between qualifications with the aim of improving mobility, employability and development amongst their citizens. The Bologna declaration, in particular, highlighted a need for easily readable and comparable qualification transcripts between countries and the need to establish a European Credit Transfer System (ECTS), for use both within and outside of HE.

Building on this work, in 2008 the European Qualifications Framework (EQF) [14] was launched providing an eight-level structure that defined qualifications in terms of learning outcomes with knowledge, skills and responsibility, and autonomy descriptors. The EQF provides a mechanism for comparing and translating qualifications between the national qualification frameworks of European countries. It has also since been piloted with Australian, New Zealand and Hong Kong Qualifications Frameworks. UNESCO are also taking steps to agree global qualifications comparability through its Global Convention on the Recognition of Qualifications concerning Higher Education.

Alongside work on agreeing common standards for accreditation and qualifications there has also been significant work in attempting to define the underpinning role competencies and how these relate to specific occupations. In

terms of digital skills, for example, the Skills Framework for the Information Age (SFIA) [15] was launched in 2000 (based on work dating back to the 1980s), and it describes 102 professional skill areas for the computing sector. A range of generic skills, depending on level of responsibility, are also specified. A more universal approach to competencies is provided by the European Skills, Competences and Occupations (ESCO) classification, which describes 13,485 skills and 2,942 occupations [16]. ESCO is meant to be a reference language for education and employment, including aligning with non-formal and informal learning through open badges and digital credentialing, providing a link between qualifications, skills, microcredentialing frameworks and employment. At the European level, the European Skills Agenda [17] highlights twelve actions including developing a new Europass Platform, increasing STEM graduates and fostering entrepreneurial and transversal skills. The Europass framework [18] should support transparency and understanding of formal, non-formal and informal qualifications and skills as identified, for example, through ESCO. The associated Digital Education Action Plan [19] then specifically seeks to incorporate micro-credentials within all educational levels by aligning micro-credentials with the existing Bologna Process tools. In summary then, at a European level there is a strong strategic focus on better aligning what is learnt with what can be used i.e. learning outcomes with skills, capabilities and competencies and through this better aligning formal, non-formal and informal qualifications with occupations.

In terms of the skills themselves, there has long been discussion and debate over the need for, and definition of, 21st Century (C21) skills. These debates tend to focus on sub-categories representing the knowledge, skills and dispositions required to work in the modern world. ATC21S [20], for example, consider ten C21 skills within four main categories (ways of thinking, working and living, plus the tools to work) however many other authors present similar but different combinations of categories [21]. One reason why this discussion persists and is so important is that there is an increasing interest in and emphasise on both lifelong learning and adaptability within the global workforce. Amazon, for example, is set to spend over \$700M to retrain its workforce in response to technological developments [22], and Google is recognising microcredentials as part of its recruitment process [23]. Both examples point to a broader trend to better define credentials and microcredentials, and industry demand for a more cohesive and coherent way to recognise credentials in their broadest sense within employment and careers.

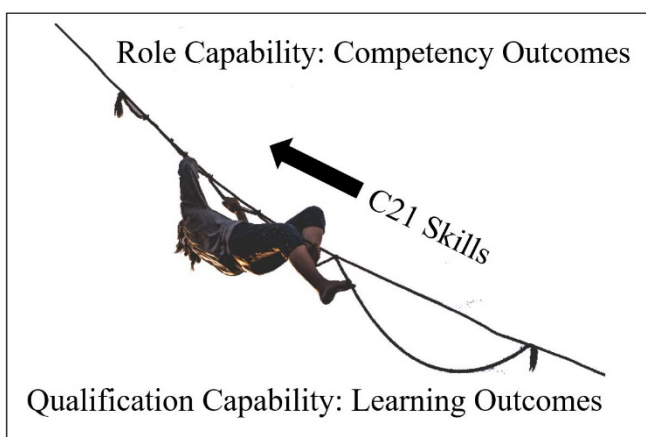
A few key further points need to be emphasised from the above discussion. Firstly, there is clearly a strong need for a common classification system to represent learning, both within Engineering and in other subjects, in order to enable seamless transferability. Secondly, that discussions have focussed on competences, qualifications, skills and learning outcomes. Thirdly, that work is still ongoing in terms of fully aligning skills classifications with competences and qualifications, and that the transferability between formal, non-formal and informal qualifications and skills is yet to be fully specified.

III. STRUCTURAL CHALLENGES

At this critical point in reviewing and hopefully addressing these issues, this paper seeks to highlight two key structural issues with the current direction of travel and to propose a

solution to these issues. At the heart of the discussion that follows are fundamental difficulties with both the input measures used to define learning (learning outcomes) and the output measures sought by occupations (competencies). In particular the role of learning outcomes as the common connection between these systems is called into question. It is argued that the specification of learning outcomes within qualifications is, like the current classifications of skills through frameworks such as SFIA and ESCO, too detailed to be practical in providing a common understanding between HE and employers. The rationalisation of AHEP 4 learning outcomes to a much more manageable number of around twenty clearly demonstrates this. Using learning outcomes to translate between qualifications and skills is unnecessarily complex as different terms, phrases and content can express the same learning requirements and this complexity means it becomes very difficult to match qualifications to competencies. There are very many learning outcomes to match to very many competencies. As a common learning language, therefore, learning outcomes are not the right solution for communicating competencies to employers, or indeed for communicating with learners who then need to be able to communicate their learning to employers. Whilst learning outcomes communicate what is learnt, they do not communicate how well it is learnt. Both learner and employer would therefore be better suited with a more coherent, clearer and simpler approach. In terms of output, qualifications identify graduate attributes as a list of expected capabilities but do not focus on the competencies sought by employers. Furthermore, graduate attributes tend to be individualised to institutions, making them difficult to use as a basis for transferability and common understanding. What exists therefore is a *Capability-Competency Chasm*, a gap between the capabilities learnt within a qualification, as stated in terms of learning outcomes, and the competencies required of job roles, as listed in job specifications. This study proposes a solution to bridge this chasm, as shown in Figure 1. The solution is to develop a more manageable classification system linking learning outcomes and qualifications to skills, competencies and occupations, through using a C21 skills taxonomy linking capabilities to competencies.

Figure 1: The Capability-Competency Chasm



The common learning language underpinning this new C21 skills taxonomy system is a revised input measure known as C21 skills hours i.e. the number of hours spent learning 21st Century skills. C21 skills hours are calculated by dividing the learning hours of a course into the hours spent acquiring

specific 21st Century skills using the number of learning outcomes and the module assessment weightings. Skills hours can be used with any learning (formal, non-formal, informal) that specifies learning hours and learning outcomes. As it can be used to abstract learning outcomes within any discipline it provides a universal learning language enabling seamless transference and comparability between qualifications, credentials and microcredentials.

The skills hours approach also has the added benefit of enabling learning building blocks to be more clearly communicated as output measures to align with competencies and occupations, through frameworks such as ESCO and SFIA. A much simpler skills framework approach can be developed and used, based on this 21st Century skills taxonomy categorisation, enabling better alignment between qualifications and occupations. By focusing on acquisition of learning blocks, rather than learning outcomes, a competency-based rather than capability-based approach can be developed to better summarise graduate attributes.

This study focuses on answering two key questions that underpin a skills hours approach. Firstly, what is the minimum number of C21 skills descriptors that can comprehensively account for all learning outcomes from a variety of HE programmes? Secondly, how are the skills gained from these learning outcomes distributed across a programme? To answer the first of these questions a process of codification and templating was used across a range of disciplines to ensure coverage and to test proof of concept. To answer the second question, a finalised template was applied to a specific programme. Whilst the programme chosen could have represented humanities, health or education, for example, a computing course was chosen as it is also accredited for engineering, and hence subject to the international accords discussed above. This enabled testing across two disciplines that already share some commonality. Indicative learning hours for each skills descriptor were calculated by separately associating each learning outcome with subject specific and transferable skills acquisition. In so doing this approach demonstrates how the subject specific and transferable competencies sought by AHEP 4 and others may be recognised, recorded and communicated for use by different educational stakeholders. Before addressing these issues though, it is important first to understand the role of competency within qualifications and occupations, as this directly impacts on how learning outcomes should be specified and how skills hours may reflect competence.

IV. COMPETENCY

A competency is a behavioural or performance attribute that enables us to be effective, efficient and successful when attempting tasks. The ACM IEEE Computing Curricula 2020 Project (CC2020) [20] highlights the importance of competency as the basis of both learning and effective behaviour and performance within a job role. Competency involves more than simply learning how to do something, it requires us to be able to do something well. Gaining a skill (capability) and being skilful (competency) represent different levels of learning. Professional competence, for example, is often measured through becoming Chartered. This indicates the point at which individuals are deemed “competent” within their discipline. Typically, to be Chartered requires an accredited degree (or equivalent), followed by a period demonstrating their competence in the relevant sector. Indeed, this is at the basis of the CC2020 competency model where

competency is specified in terms of the intersection of knowledge (know-what), skills (know-how) and dispositions (know-why) as observed within a work task. What is learnt is, therefore, best defined in terms of a competency outcome i.e. through its application to a professional practice task. Using learning outcomes to achieve this goal is problematic for the following reasons:

a) *A lack of a common language for specification*

Whilst there are frameworks to help identify the level of a learning outcome (such as Bloom's original Taxonomy [26], and the revised version published in 2001 [27]), the same skill is often specified in different ways. How learning outcomes are expressed varies by institutions, subjects, authors and local quality assurance conventions. In the context of computing, for example, some authors of learning outcomes may use language relating to the use of specialist software whilst others may write about an ability to develop algorithms when both are wanting learners to be able to deliver high quality coding solutions. This lack of specificity in the language of both programme and module learning outcomes is due to a focus on cognition (input) rather than on competence (output). This makes it difficult for employers to understand exactly what a student can do and how well, and also for employers to distinguish between programmes. Couple that with the plethora of titles that exist with very similar content and learning outcomes, plus the difficulties of academics acquiring the in-depth understanding needed to enable them to specify at an appropriate level for employers, and it is no wonder that there is complication and confusion amongst employers. CC2020 highlights the need for a common ontology [24].

b) *Often written at a high level of abstraction*

In the UK, learning outcomes are specified for both individual modules as well as the programme overall. Whilst those at module level may have some degree of detail, even here they are often abstract and perhaps also poorly written, such that their meaning is lost amongst learners, employers and perhaps even fellow academics. When collated to programme level, the level of abstraction increases, making it difficult for employers, or indeed anyone else, to be sure what skills a potential graduate employee is actually offering. Add to this the further level of abstraction that is necessary when defining Professional, Statutory and Regulatory Bodies' (PSRBs) accreditation criteria, that are designed to be applied across a particular sector, and also potentially contextualised within international accords, and the terminology risks becoming so vague as to be devoid of any clearly understandable meaning. When university degree transcripts are provided, they tend only to specify modules and grades, together with an overall degree classification, grade point average or percentage and not include learning outcomes. It is no wonder therefore that employers find it so hard to ascertain what graduates can do and how one graduate is likely to perform compared to another.

c) *Are typically only assessed / demonstrated once*

Given the need to reduce student assessment loads, many module learning outcomes are only assessed once. As discussed below, Bowers, Petre and Howson [28] suggest that this is insufficient to demonstrate competence: a single assessment often covers more than one learning outcome and hence "passing" the assessment does not always guarantee achievement of each learning outcome. How do we then

ensure graduates have developed a particular set of skills? Have repeatedly shown their capability? And have developed their competence?

A potential solution could be through the more widespread adoption of existing skills frameworks, such as the Skills Framework for the Information Age (SFIA) [15]. SFIA, "describes the skills and competencies required by professionals in roles involved in information and communication technologies, digital transformation and software engineering" and claims to have "become the globally accepted common language for the skills and competencies related to information and communication technologies, digital transformation and software engineering" [15]. SFIA underpins, for example, the professional accreditation and registration schemes operated by BCS, The Chartered Institute for IT, and by the Australian Computer Society, and is deployed widely across the public sectors of both countries. SFIA is currently translated into 10 languages, and is used in 180 countries, with some, such as Saudi Arabia, holding a nationwide licence.

Skills frameworks align with discipline areas and identify the range of skills that fit within that discipline. For example, SFIA identifies a number of categories and sub-categories with the skills required within each aspect. Typically, each skill can be demonstrated at different levels but not all skills are defined at all levels. SFIA, for example, defines seven different levels but, data visualisation is only defined at levels 4 and 5, whereas security administration is defined at level 1 through to 6.

As SFIA is structured by categories, sub-categories, skills and levels, it is also possible to use the framework to provide the required levels of abstraction (the second issue with learning outcomes). These are required when moving from specifying modules to programmes to PSRB requirements. Individual modules would develop particular skills at an appropriate level, programmes would abstract these skills to sub-categories or categories within the framework, and PSRBs would select categories or sub-categories, and the specific skills, that are necessary to meet accreditation criteria. Modules and programmes could identify the specific aspects of the framework they intend to deliver and assess, providing a common language, which employers could then use to directly compare programmes and indeed graduates within STEM disciplines, as in the accreditation standard developed by the Institute of Coding [29]. However, it would be problematic to extend a SFIA-based approach more broadly to social science disciplines, for example. SFIA's generic attributes of autonomy, influence, complexity, knowledge and business skills are insufficiently granular to enable accurate competency representation for disciplines outside of the IT industry. ESCO could provide a solution but with more than 13,000 skills listed, directly including ESCO within programme and module specification would be unrealistic.

Bowers, Petre and Howson [28] advocate consideration of competency rather than knowledge, combining Bloom's [26] taxonomy with Simpson's [30] taxonomy for the psychomotor domain as it focuses on practical application of skills. Their comparison is reproduced in Table 1. The apparent gaps in the table arise due to the divergence of the taxonomies. However, it is notable that there is relatively good alignment at lower levels but much less so at higher levels. Bowers, Petre and Howson [28] suggest that their comparison indicates how assessing proficiency (which they equate to unconscious

competence) might differ from assessing capability (the minimal knowledge/cognitive level required to underpin competence), suggesting that, “proficient graduates must have completed appropriate tasks more than once (reproducible), without significant errors (reliable), and ideally with an element of innovation (creative)” [28].

Whilst Bloom’s Taxonomy can be demonstrated by learners in different ways at different levels both within and outside of formal education, traditional university education tends to do a good job of delivering Levels 1-3 in Table 1 i.e. those that underpin capability. Placements and internships are common approaches within universities of moving beyond capability to demonstrate competency. The veterinary profession, who have a clear statement [31] of competencies and proficiencies that they do (and do not) expect a recent graduate to have, provide an example of a professional education with subject-specific competencies within it. This is not trivial, however: the degree is typically five years in England (as opposed to three years for Computing), and requires substantial exposure to “real world” problems, e.g. Cambridge University’s “The Department operates small animal and equine hospitals and equine and farm animal clinical services in order to provide clinical teaching material, as well as using the state of the art 200 cow university dairy herd and sheep flock”.

What should be clear from the above discussions is that to be deemed competent, usually requires a period of practical experience applying the skills that have been developed. During that experience, individuals are likely to develop a deeper understanding of the skills they have gained, a greater ability to apply those skills and make fewer mistakes as a result of practice. This suggests that learners need to be given several opportunities to apply a skill before they can be deemed competent to apply it and that this needs to be visible to programme specifiers. Using a C21 skills framework can provide this visibility when specifying modules and programmes, and it also addresses the issues arising from over-specificity and abstract learning outcomes. A further benefit is that it enables micro-credentialing to be aligned to existing qualification frameworks by supporting a “building block” approach at the right level of granularity. By enabling C21 skills to be demonstrated across several “projects” at several levels to develop competency as learners move from capability to proficiency, from input to output, it can also clearly map to competency frameworks such as ESCO and SFIA. The Institute of Coding [51] is currently developing such an approach for computing through its Flexible Modular Framework, which should enable knowledge gained from different computing courses to be mapped into a degree meeting the IoC standard, which is based on the SFIA framework. A similar approach matching C21 skills gained at a particular competency level with ESCO and the European Qualifications Framework would work in much the same way across disciplines and across European countries.

A competency-based approach also supports better communication between employers and HE institutions, by differentiating where and how competency is developed. This makes it easier for employers to both feed into the curriculum as well as to understand the skills of, and differences between, graduates on a particular programme. This, ultimately, enables skills gaps to be addressed. CC2020, for example, has considered how to visualise and represent competency using appropriate scales, together with discussing the challenges and

the benefits gained from taking such an approach. A C21 skills approach provides a mechanism for addressing these challenges and for providing these standardised scales.

A final benefit of a building block approach, as outlined many years ago in Stephenson and Weil’s discussions regarding records of achievement [32] and more recently in Ward’s discussions of badging and microcredentialing in the context of Personalised Learning [33], is that progression can be easily understood and tracked by the learner. Mastery motivation is a powerful intrinsic driver for acquiring competence. Clearly understanding the steps required to develop capability and to then become proficient enable learners, and indeed educators and employers, to reflect and respond optimising learner progress.

In summary, what is required is a common language that can be used to express learning from capability to competency, and a recognised method for assessing and certifying from capability to competency, from qualifications to job roles. Such an approach should be sufficiently granular to provide transparency but not too granular to make it difficult to use and understand. It should align with existing qualifications structures and the strategic efforts for a better synergy of learning with job roles as outlined above. What is required is a way to codify and specify qualifications by translating learning outcomes into their capabilities and competencies by considering their underpinning knowledge, skills and dispositions. A **C21** skills approach enables this to happen.

TABLE 1: PARTIAL ALIGNMENT BETWEEN A COMPETENCE HIERARCHY, SIMPSON’S HIERARCHY AND BLOOM ENGELHART, FURST, HILL AND KRATHWOHL’S COGNITIVE TAXONOMY [28]

Level	“Competence” Spectrum [28]	Simpson’s Hierarchy [30]	Bloom’s Taxonomy [26]
1			Remember: Recall facts and basic concepts
	Recognition: Knows what the problem is.	Perception: Responds to cues in real world	
2	Understands: Knows how to deal with the problem	Set: Ready to apply a known sequence of steps	Understand: Describe ideas of concepts
3	Capable: Has done it least once	Guided response: Imitation and practice	Apply: Relate information to new situations
4	Consciously competent: Doesn’t make mistakes	Mechanism: Learned responses with confidence and proficiency	
			Analyse: Draw connections among ideas
5			Evaluate: Justify a stand or decision
	Proficient: Reproducible, reliable, creative	Explicit overt response: Quick accurate and coordinated performance	

V. CODIFICATION

In order to demonstrate how qualifications can be codified into competency areas as knowledge, skills and dispositions, a set of cross-disciplinary English HE degree programmes were selected, representing accredited programmes from seven professional bodies. The subjects and bodies were Engineering (IET accredited), Computing (BCS accredited), Accountancy (ICAEW accredited), Marketing (CIM

accredited), Psychology (BPS accredited), Law (Bar Council accredited) and Languages (CIOL accredited).

TABLE 2: TABLE OUTLINING C21 SKILLS, EXAMPLES AND REASONING BEHIND THIS WITH EXAMPLES FROM EACH OF THE DIFFERENT PROFESSIONAL BODIES LEARNING REQUIREMENTS.

	EXAMPLE	REASONING	
LIFE AND CAREER SKILLS	Initiative & Self-Direction	Carry out and record continued professional development (CPD) necessary to maintain and enhance competence in own area of practice. (Engineering)	Skills relating to the continuation of professional development, this encompasses any skills and therefore not subject-specific.
	Leadership & Responsibility	Students should be able to identify and act per the core duties of professional conduct and professional ethics which are relevant to the course. (Law)	Skills which promote leadership and responsibility as either a singular member or as part of a group.
	Flexibility & Adaptability	The ability to challenge the status quo and drive change in a business environment. (Marketing)	Skills relating to the flexibility and adaptability of the application of their other skills.
	Social & Cross-Cultural Skills	Ability and willingness to engage with other cultures, appreciating their distinctive features. (Language)	The ability to effectively interact with others in diverse groups and situations.
	Productivity & accountability	Psychologists should when bringing allegations of misconduct by a colleague, do so without malice and with no breaches of confidentiality other than those necessary to the proper investigatory processes. (Psychology)	Managing own work with ownership by setting and meeting goals, even in the face of obstacles and competing pressures. Prioritise, plan and manage work to achieve the intended result.
LEARNING AND INNOVATION SKILLS	Creativity & Innovation	Develop and apply new technologies. (Computing)	Creativity is creating something new and original, while innovation is the application of creativity.
	Critical thinking & Problem Solving	Be pragmatic, taking a systematic approach and the logical and practical steps necessary for often complex concepts to become a reality. (Engineering)	Problem-solving and critical thinking is the use of logical and rational thoughts, knowledge and facts to effectively solve problems.
	Communication & Collaboration	Effective communication, presentation and interaction (Language)	Collaboration and communication involve being able to effectively as a member of a team or produce documents which express the intended purpose.
INFORMATION, MEDIA AND TECHNOLOGY SKILLS	Information Literacy	location, extraction and analysis of data from multiple sources, including acknowledging and referencing sources. (Accountancy)	Information literacy incorporates a set of skills and abilities which everyone needs to undertake information-related tasks
	ICT Literacy	computational thinking, including its relevance to everyday life. (computing)	The use of digital technology, communications tools to manage, integrate, and create information in order to function in a knowledge society.
CORE SUBJECTS AND 21ST CENTURY THEME SKILLS	Media Literacy	There is no learning outcome which has mapped to media literacy.	Media literacy is the ability to understand the differences in media and understand the messages they represent. which involves knowing how to make appropriate personal economic choices, understanding the role of the economy in society and using entrepreneurial skills to enhance workplace productivity and career options
	Financial, Economic, Business and Entrepreneurial	The ability to think ahead to spot or create opportunities and maximise them. (Marketing)	The knowledge and skills to participate effectively in civic life through knowing how to stay informed.
	Civil Literacy	Have an awareness of the wide range of organisations supporting the administration of justice. (Law)	An individual's understanding, skills and consideration of his or her relationships to natural systems, communities and future generations.
	Environmental Literacy	The ability to work in a way that considers its impact on other people, organisational goals and the wider environment (Marketing)	An understanding of how environmental, social, cultural, economic and political factors impact the world.
	Global Awareness	be aware of the risk, cost and value-conscious, and aware of their ethical, social, cultural, environmental, health and safety, and wider professional responsibilities. (Engineering)	The ability to obtain, process, and understand necessary health information and services needed to make appropriate health decisions
	Health Literacy	There is no learning outcome which has mapped to media literacy.	

A template was developed based on C21 skills areas, collated from existing studies via a systematic review, and organised into six different C21 skills themes that also reflect different levels of learning within the traditional Bloom's taxonomy categorisation. The six C21 skills themes are A) *Understanding*, B) *Context*, C) *Solutions*, D) *Delivery*, E) *Behaviour* and F) *Reporting*. These C21 skills themes were iteratively mapped to both programme and module level learning through the programme and module specifications of the programmes. At programme level, the learning outcomes map to both professional body and QAA requirements and therefore both were included in the codification process. The QAA benchmarks providing an initial list of learning requirements, which were filtered through the professional body requirements before being categorised in terms of C21

skills terms and grouped within the six skills themes. An example of such mapping is shown in Table 2. From this, subject-specific skills could be identified i.e. skills areas that are developed which are specifically aligned to the subject being studied. Examples of these are shown in Table 3.

TABLE 3: TABLE OUTLINING SUBJECT-SPECIFIC SKILLS, EXAMPLES AND REASONING BEHIND THIS.

SUBJECT-SPECIFIC SKILLS	EXAMPLE	REASONING
THEORETICAL KNOWLEDGE	Understanding the principles of managing computing processes (computing)	Understanding of subject knowledge which would not be classed as transferable knowledge.
PROCESS AND PRODUCTION	Use a variety of psychological tools, including specialist software, laboratory equipment and psychometric instruments (Psychology)	A process or activity which requires subject knowledge to complete or a way of doing something unique to a given subject area.
BUSINESS REQUIREMENTS AND APPLICATIONS	The ability to deploy appropriate theory, practices and tools for the specification, design and implementation of computer-based systems according to customer and user needs and use innovation and creativity in a practical and social context. (Computing)	Subject related tasks which require an individual to take into account business needs specifically related to their subject.
CONTEXTUAL ANALYSIS AND EVALUATION	Remain aware of and acknowledge the limits of their methods, as well as the limits of the conclusions that may be derived from such methods under different circumstances and for different purposes. (Psychology)	The subject-specific reflection which requires a good understanding within the field to complete adequately, this could be public perception, your professional actions which relate to the field
TECHNICAL WRITING	be able to communicate orally and in writing and draft and amend documents in a form, style and tone appropriate for the recipients and the context (Law)	Writing which is specific to the subject field and is not a transferable skill such as writing a legal document, engineering diagram/drawings or critically review with the context of the subject at the forefront.
INNOVATION	Contribute to the design and development of engineering solutions (Engineering)	The development of ideas specific to the subject area this could be new ideas, implementations or research processes.

TABLE 4: LIST OF ALL 25 SKILLS, INCLUDING SHORT DESCRIPTIONS FOR EACH. SKILLS THEMES ARE INDICATED BY LETTERS A-F, REPRESENTING UNDERSTANDING, CONTEXT, SOLUTIONS, DELIVERY, BEHAVIOUR AND REPORTING RESPECTIVELY.

SKILLS	SHORT DESCRIPTIONS
Subject-based	
S1A	A - Theory
S2B	B - Business Requirements and Applications
S3C	C - Innovation
S4D	D - Process and Production
S5E	E - Self-Reflection
S6F	F - Technical Writing
Transferable	
T1A	A - Information Literacy
T2B	B - Business Alignment
T3B	B - Entrepreneurship
T4B	B - Numeracy
T5B	B - Analysis
T6C	C - Creativity
T7C	C - Problem Solving
T8D	D - Technical Proficiency
T9D	D - Self-Regulation
T10D	D - Leadership
T11D	D - Management
T12E	E - Professionalism
T13E	E - Ethics
T14E	E - Evaluation
T15E	E - Risk Analysis
T16E	E - Sustainability
T17E	E - Social Learning
T18E	E - Collaboration
T19F	F - Communication

This initial iteration of both subject specific and transferable skills provided a template that could then be applied at module level in a second iteration. Here the entire set of modules from the set of programmes of study were reviewed and codified using a template consisting of the six skills themes, the six subject-specific skills shown in Table 3 and the C21 transferable skills listed in Table 2. This second iteration, as is common with template-based approaches, led to a revised list of transferable skills, consisting of nineteen descriptors that represented all learning outcomes within these programmes of study. The combined set of twenty-five skills are listed in Table 4. The first six are coded S1A to S6F to indicate they are subject-based skills and which of the six

themes they correspond to. The remaining nineteen are coded T1A to T19F to indicate they are transferable skills and again which of the six themes they correspond to.

VI. C21 SKILLS HOURS

The HE programmes studied represented 3,600 learning hours. The HE programme profile provided as an example within this paper consisted of a set of 16 modules studied across three years. Each module contained a different number of learning outcomes. These were codified using the skills listed in Table 4. Knowing the learning hours associated with each module (in this case 200 or 400 hours), together with the number of learning outcomes assessed in each assessment component and their associated assessment weightings, the 3,600 skill hours for the programme were calculated both as subject-specific skills hours and transferable skills hours.

For the six subject-based skills, this calculation was done assuming an equal weighting of learning between the learning outcomes per assessment component. For example, if a 60% assessment component in a 400-hour module covered 2 learning outcomes each of these learning outcomes would equate to 120 hours when allocated to skills. For subject-based skills, learning outcomes were mapped one-to-one to skills. For transferable skills, the mapping was more complex as learning outcomes often mapped to more than one of the nineteen skills. Given this, a further step was required where skills hours associated with a learning outcome would be split amongst the skills areas. So, for the example above, the 120 hours would be allocated equally between the transferable skills associated with the learning outcome. This approach makes the assumptions that learning hours, and therefore skills hours, represent an accurate and consistent amount of learning for all learners and that it is valid to split hours up equally into skills hours. Both assumptions are incidental to the purpose of this study. The point is not at this stage to demonstrate a perfectly accurate representation of skills hours, but rather to show how the translation occurs. It would then be the role of the programme and module specifiers (academics) to review and revise how they actually allocate skills hours. The skills hours approach used here therefore represents the starting point for both these discussions and those regarding a common skills taxonomy itself, providing an alternative input measure as skills are learnt.

Tables 5, 6, 7 and 8 summarise the skills hours calculations by year of study together with the total skills hours for each skill across the degree, the equivalent European Credit Transfer System (ECTS) credits based on learning hours (1 ECTS = 25 learning hours) and the percentage of the degree represented by these skills hours. Reviewing these tables, and Figures 2 – 4, we note that Theory and Process and Production (themes A and D) represent the vast majority of subject-based skills acquisition (70%), with Self-Reflection regarding legal, social, ethical and professional issues making up much of the rest. For transferable skills, Context thematic skills (Business Alignment, Numeracy and Analysis) play a much larger role than for subject-based skills acquisition (28% vs. 7%). As a general pattern the thematic skills distribution is much more even for transferable skills than it is for subject-based skills. This is in part down to the one-to-many mapping of learning outcomes to transferable skills, but is also indicative of transferable skills being less distinctly specified within degrees compared to subject-based skills, and a traditional focus on Theory and Process and Production within many STEM degrees.

TABLE 5 - SUBJECT-BASED SKILLS HOURS BY YEAR OF STUDY

	Subject - Specific (Hrs)			Total
	Year One	Year Two	Year Three	
A - Theory	230	310	461	1001
B - Business Requirements and Applications	30	81	127	238
C - Innovation	0	0	32	32
D - Process and Production	593	602	283	1478
E - Self-Reflection	280	155	163	598
F - Technical Writing	67	53	135	254

TABLE 6 - TRANSFERABLE SKILLS HOURS BY YEAR OF STUDY

Transferable (Hrs)	Year One	Year Two	Year Three	Total
A - Information Literacy	357.0	407.1	443.0	1207.1
B - Business Alignment	108.9	121.1	122.2	352.1
B - Entrepreneurship	0.0	0.0	0.0	0.0
B - Numeracy	114.9	95.6	70.1	280.6
B - Analysis	168.8	124.7	76.4	369.9
C - Creativity	4.3	1.8	0.0	6.1
C - Problem Solving	112.3	46.8	70.7	229.8
D - Technical Proficiency	157.5	193.8	222.2	573.5
D - Self-Regulation	8.0	12.8	0.0	20.8
D - Leadership	0.0	5.8	0.0	5.8
D - Management	4.3	9.2	0.0	13.4
E - Professionalism	0.0	5.8	0.0	5.8
E - Ethics	4.8	24.3	12.6	41.7
E - Evaluation	92.5	70.3	79.8	242.5
E - Risk Analysis	11.4	24.3	58.6	94.4
E - Sustainability	4.8	9.3	0.0	14.1
E - Social Learning	8.0	1.8	0.0	9.8
E - Collaboration	12.3	16.2	0.0	28.4
F - Communication	30.4	29.4	44.4	104.1

TABLE 7 – THEMATIC SKILLS HOURS BY YEAR OF STUDY

		Subject-Specific (Hrs)	Transferable (Hrs)	Subject-Specific (ECTS)	Transferable (ECTS)	Subject-Specific (%)	Transferable (%)
A - Understanding	Year One	230	357	9	14	6%	10%
	Year Two	310	407	12	16	9%	11%
	Year Three	461	443	18	18	13%	12%
	Total	1001	1207	40	48	28%	34%
B - Context	Year One	30	393	1	16	1%	11%
	Year Two	81	341	3	14	2%	9%
	Year Three	127	269	5	11	4%	7%
	Total	238	1003	10	40	7%	28%
C - Solutions	Year One	0	117	0	5	0%	3%
	Year Two	0	49	0	2	0%	1%
	Year Three	32	71	1	3	1%	2%
	Total	32	236	1	9	1%	7%
D - Delivery	Year One	593	170	24	7	16%	5%
	Year Two	602	222	24	9	17%	6%
	Year Three	283	222	11	9	8%	6%
	Total	1478	614	59	25	41%	17%
E - Behaviour	Year One	280	134	11	5	8%	4%
	Year Two	155	152	6	6	4%	4%
	Year Three	163	151	7	6	5%	4%
	Total	598	437	24	17	17%	12%
F - Reporting	Year One	67	30	3	1	2%	1%
	Year Two	53	29	2	1	1%	1%
	Year Three	135	44	5	2	4%	1%
	Total	254	104	10	4	7%	3%

TABLE 8 – THEMATIC SKILLS HOURS SUMMARY

	Subject-Specific (Hrs)	Transferable (Hrs)	Subject-Specific (ECTS)	Transferable (ECTS)	Subject-Specific (%)	Transferable (%)
A - Understanding	1001	1207	40	48	28%	34%
B - Context	238	1003	10	40	7%	28%
C - Solutions	32	236	1	9	1%	7%
D - Delivery	1478	614	59	25	41%	17%
E - Behaviour	598	437	24	17	17%	12%
F - Reporting	254	104	10	4	7%	3%
Total	3600	3600	144	144	100%	100%

Figure 2: Subject-based skills hours within an example degree programme by year of study (calculated using module credits, assessment weightings and learning outcomes).

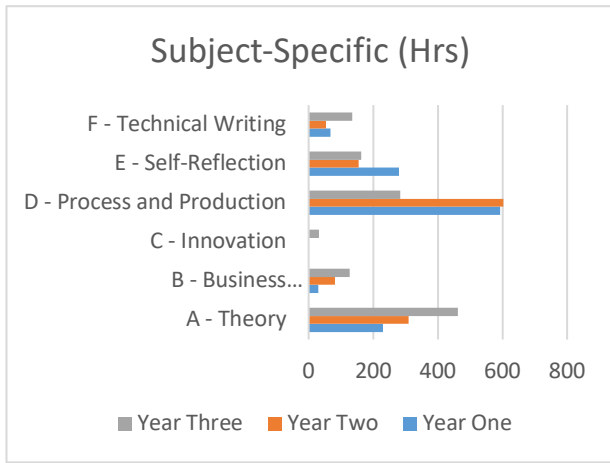


Figure 3: Transferable skills hours within an example degree programme by year of study (calculated using module credits, assessment weightings and learning outcomes).

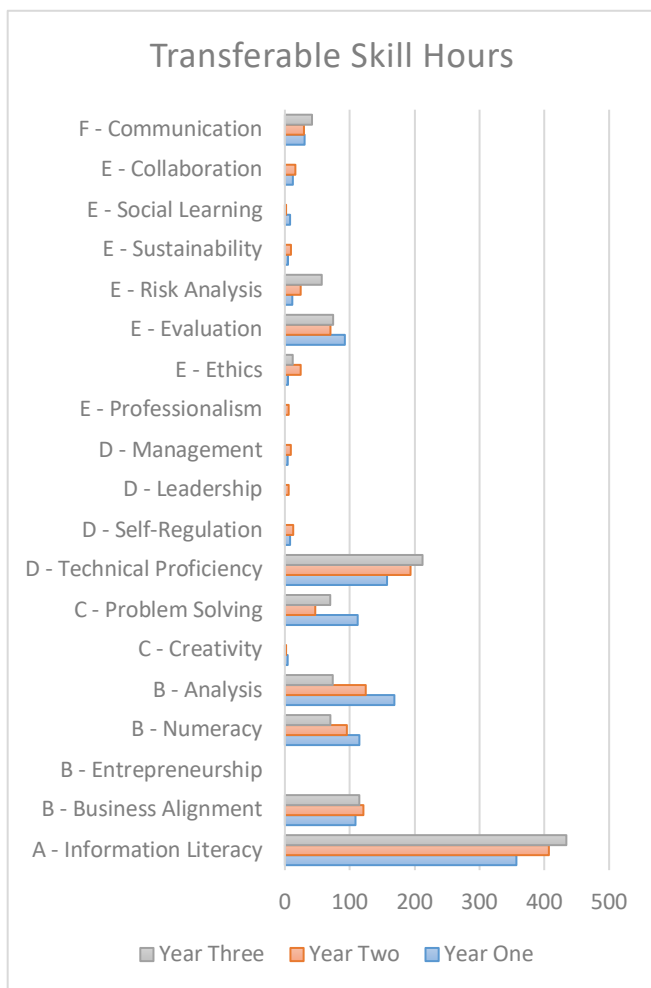
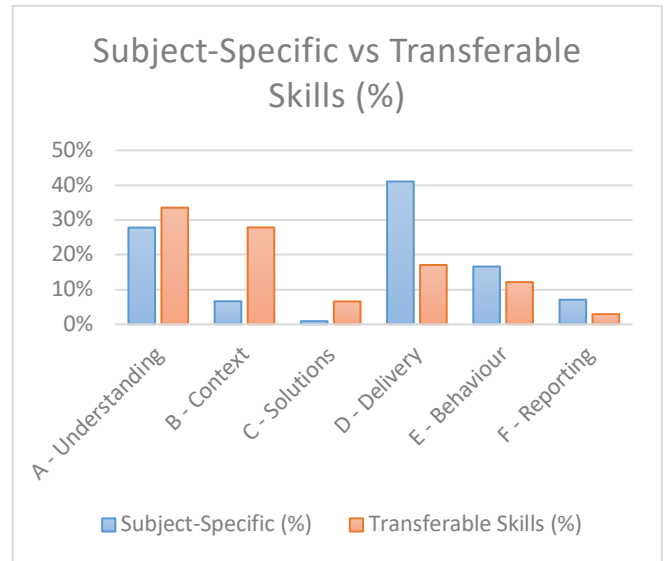


Figure 4: Thematic skills hours within an example degree programme by year of study (calculated using module credits, assessment weightings and learning outcomes) presented in terms of both subject-specific and transferable skills.



VII. IMPACT ON ACCREDITATION

Accreditation is recognised as a kitemarking exercise, supporting a globally portable workforce [32]. Accreditation audits promote internationally recognisable standards, raising output standards, disseminating good practice and ensuring curricula and industry relevance [35]. However, accreditation remains controversial in some quarters; criticisms include that accreditation is unnecessarily bureaucratic and that it constrains rather than fosters innovation [36]; that it generates revenue streams for the accrediting organisation but does not benefit the discipline or wider society [32]; and that it can be colonial and paternalistic if the accreditor is not from the same jurisdiction as the university or college being accredited [37]. Irrespective of individual viewpoints, one commonly agreed limitation of accreditation arises from using a broad set of exit standards based on expected programme learning outcomes. Whilst in many ways this is a strength, there are four consequences from this approach:

Firstly, exit standards handle minimum expectations and hence minimum graduate capabilities that can be evidenced, through programme learning outcomes, regardless of the route learners have taken through a course. Exit standards do not therefore measure specific competences developed within modules, work placements and dissertations. Secondly, accreditation is based on a whole programme of study. Individual elements, minors and majors are not easily accredited within professional body accreditation regimes. Most STEM disciplines suffer from skills shortages, and yet these potential additional skills pipelines are not recognised. Thirdly, accreditation is broad, but not broad enough. Fine-grained learning detail is not captured either within or between disciplines as they only focus on their own subjects. To illustrate this point, programmers and software development professionals remain in high demand from industry [38][39], and good quality graduates can be produced by several related disciplines, such as computer science, electrical engineering and mathematics. A core set of software development skills could be in evidence from graduates from a variety of disciplines, and yet there remains a challenge with accrediting syllabus elements, such as software development

competencies, across a range of subject disciplines. Fourthly, in recent years the range of educational opportunities have extended. There has been a significant growth in Massive Open Online Courses (MOOCs), with more than 900 universities supplying at least one MOOC and over 100 million students having studied one [40]. Alongside MOOCs there has also been significant growth in bite-size learning. Such courses can offer some advantages over a traditional university course such as enabling graduates to strongly evidence soft skills such as teamwork, independent learning, passion and persistence [41].

Vendor-aligned courses have also become more popular, with Coursera, for example, transitioning away from MOOCs to focus on vendor endorsement and certification linked to specific job roles. They join a growing list of companies offering such credentialing [23]. Vendor-aligned courses, and credentialing and microcredentialing more broadly, are not solutions that generally suit HE. Limiting the amount of original course content developed by an institution tends to leave learners questioning the value proposition of their studies. Current professional body accreditation processes can also make accrediting such courses very challenging, limiting their recognition and transferability, but we are starting to see changes to these processes [35, 46, 49, 50, 54].

VIII. CONCLUSIONS AND FUTURE DEVELOPMENTS

Globally, there is significant demand for a more effective and robust way of linking learning with employment in a transferable, integrated and seamless way. Traditional international accreditation and qualification framework approaches have used learning outcomes and graduate attributes to make a connection between learning and job roles, but they have failed to provide the level of clarity required by employers. Vendor certification, credentials and micro-credentials are a growing area, attempting to fill this gap, by recognising learning in more granular and job-related ways.

However, neither approach addresses the fundamental issue which is the need for a common language to translate learning to earning [23]. Skills frameworks provide incredibly granular ways of identifying job-related skills, whilst educational institutions provide learning which is specified by bespoke learning outcomes which are then mapped to standardised quality assurance and professional body specifications. Multiple approaches are being taken currently to try to address this disconnect between many learning outcomes and the competencies required of many job roles, from the analysis of curriculum using learning analytics [43], for example, through to analysing continent-wide qualifications frameworks that can accommodate micro-credentials [44].

This paper highlights two key issues with current structures and proposes a solution to this fundamental educational problem. Firstly, current systems do not provide a simple, understandable language to translate learning to job roles because they use learning outcomes. This shortcoming can be addressed through using a 21st Century (C21) skills taxonomy as an input measure, that can be applied across disciplines to translate learning outcomes to a common standard which can then be mapped to job role competencies. In so doing it enables existing educational providers to maintain their current provision and to undertake simple learning outcome-based calculations to add a C21 skills

profile to their courses. It provides employers with a simple understanding of the C21 skills profiles of graduates, and it enables micro-credentialing to be accommodated within existing education by removing some of the current barriers to the recognition of lifelong and bite-sized learning. Secondly, accreditation and qualifications frameworks focus on capability rather than competency within formal qualifications. A commonly agreed C21 skills taxonomy can also then be used as an output measure, as skilfulness is demonstrated, by mapping to existing competency frameworks. This approach also enables micro-credentials to be mapped to existing national and international qualification frameworks and provides the foundations for a common system accommodating formal, non-formal and informal learning. Such a system can be used to enable greater fluidity of learning and employment as well as greater understanding of national and international competencies for labour organisations, educational providers and governments. Skills gaps can therefore be more easily identified and addressed based on this common learning language, and education can become more responsive to employment needs and, at the same time, better facilitate personalised learning. Through a more personalised approach to learning, overall learning capabilities and competencies can be improved and a more capable, motivated and better aligned workforce developed.

There has been much discussion already regarding developing a global micro-credentialing framework. The European MOOC consortium's Common Microcredentialing Framework [45] unfortunately appears too macro (100-150 hours, 4-6 ECTS) to accommodate learning below MOOC course level. The European University Association MicroBol Project [44] is currently seeking, at the European level at least, to map microcredentials to the Bologna Process for formal qualifications. This paper demonstrates a way in which this mapping can be achieved and a global micro-credentialing framework developed that supports personalised learning and represents employer, vendor, educational provider and learner needs.

Finally, we acknowledge the continued impact of the COVID-19 pandemic to education systems, across all settings and contexts; in particular the challenges of "emergency remote teaching" and the opportunities presented by a shift to online and blended learning modules [47, 53]. Alongside the issues presented in this paper, there are a range of specific challenges across pedagogy and practice for computing and cognate engineering/technology disciplines [48], especially with learning, teaching and assessment [56, 57]; recognition of wider skills [54]; academic and pastoral support [52]; and supporting educational pathways into these disciplines [55].

REFERENCES

- [1] International Engineering Alliance. Washington Accord, 2020 [Online]. Available: <https://www.ieagrements.org/accords/washington/>
- [2] International Engineering Alliance. Sydney Accord, 2020 [Online]. Available: <https://www.ieagrements.org/accords/sydney/>
- [3] International Engineering Alliance. Dublin Accord, 2020 [Online]. Available: <https://www.ieagrements.org/accords/dublin/>
- [4] Seoul Accord. Seoul Accord, 2020 [Online]. Available: <https://www.seoulaccord.org>
- [5] Accreditation Board for Engineering and Technology. ABET, 2020 [Online]. Available: <https://www.abet.org/>
- [6] Engineering Council. 2020 [Online]. Available: <https://www.engc.org.uk/>
- [7] Engineering Council. "The Engineering Council 2002 to 2010": A Review by Andrew Ramsay, 2020. Available:

- <https://www.engc.org.uk/engcdocuments/internet/website/The%20Engineering%20Council%202002%20to%202010.pdf>
- [8] Engineering Council. Accreditation of Higher Education Programmes, 2020 [Online]. Available: <https://www.engc.org.uk/ahep>
- [9] Engineering Council. UK Standard for Professional Engineering Competence (UK-SPEC), 2020 [Online]. Available: <https://www.engc.org.uk/standards-guidance/standards/uk-spec/>
- [10] European Network for Accreditation of Engineering Education. EUR-ACE® Framework Standards and Guidelines, 2020 [Online]. Available: <https://www.enace.eu/eur-ace-system/standards-and-guidelines/>
- [11] S. Wellington. "Accreditation of Higher Education Programmes Edition 4 – Evolution or Revolution?", 2020 (in press)
- [12] C. Allegre, L. Berlinguer, T. Blackstone & J. Rutgers. Joint declaration on harmonisation of the architecture of the European higher education system, 1998 [Online]. Available: http://ehca.info/media/ehca.info/file/1998_Sorbonne/61/2/1998_Sorbonne_Declaration_English_552612.pdf
- [13] Joint declaration of the European Ministers of Education. The Bologna Declaration of 19 June 1999 [Online]. Available: http://ehca.info/Upload/document/ministerial_declarations/1999_Bologna_Declaration_English_553028.pdf
- [14] European Centre for the development of vocational training. European Qualifications Framework (EQF), 2020 [Online]. Available: <https://www.cedefop.europa.eu/en/events-and-projects/projects/european-qualifications-framework-eqf>
- [15] SFIA Foundation. The global skills and competency framework for a digital world, 2020 [Online]. Available: <https://sfia-online.org/en>
- [16] ESCO. 2020 [Online]. Available: <https://ec.europa.eu/esco/portal/>
- [17] European Skills Agenda. 2020 [Online]. Available: https://ec.europa.eu/commission/presscorner/detail/en/ip_20_1196
- [18] Europass. 2020 [Online]. Available: <https://europa.eu/europass/en/what-are-digital-credentials>
- [19] Digital Education Action Plan. 2020 [Online]. Available: https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en
- [20] ATC21S. 2020 [Online]. Available: <http://www.atc21s.org/>
- [21] C. Joynes, S. Rossignoli, & E. F. Amonoo-Kuofi. 21st Century Skills: evidence of issues in definition, demand and delivery for development contexts, 2019.
- [22] G. Marks. "Amazon is spending big to retrain employees – and so should you". The Guardian, 19 July 2019 [Online]. Available: <https://www.theguardian.com/business/2019/jul/19/amazon-retrain-employees-benefits>
- [23] B. Oliver. Coursera Professional Certificates and Google Career Certificates: A snapshot analysis. 2020 [Online]. Available: https://www.edubrief.com.au/uploads/4/5/0/5/45053363/coursera_and_google_professional_certificates_analysis_22_october_2020.pdf
- [24] ACM/IEEE-CS Computing Curricula 2020 [Online]. Available: <https://cc2020.nsparc.msstate.edu/>
- [25] National Committee of Inquiry into Higher Education. Higher education in the Learning Society. Report of the National Committee of Inquiry into Higher Education. HMSO, 1997. Available: <http://www.educationengland.org.uk/documents/dearing1997/dearing1997.html>
- [26] B. S. Bloom, M. D. Engelhart, W. H. Hill, E. J. Furst, D. R. Krathwohl. Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain. New York: David McKay Company, 1956.
- [27] L. W. Anderson, D. R. Krathwohl, eds. A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Allyn and Bacon, 2001.
- [28] D. Bowers, M. Petre, & O. Howson. Aligning Competence Hierarchies with Bloom's Taxonomies: Changing the focus for computing education. In: Proc. of 19th Koli Calling International Conference on Computing Education Research, ACM, 2019.
- [29] Institute of Coding Accreditation Standard. 2020 [Online]. Available: <https://institute-of-coding.github.io/accreditation-standard/>
- [30] E. Simpson. "Educational objectives in the psychomotor domain". Washington, D.C.: Gryphon House, 1972. Available: <https://files.eric.ed.gov/fulltext/ED010368.pdf>
- [31] Royal College of Veterinary Surgeons. Day One Competences, 2020. Available: <https://www.rcvs.org.uk/document-library/day-one-competences/>
- [32] J. Stephenson, & S. Weil. Quality in Higher Education: A Capability Approach in Higher Education, London: Kogan Page, 1992.
- [33] R. Ward. Personalised Learning for the Learning Person, Bingley: Emerald Publishing, 2020.
- [34] J. Knight. The International Race for Accreditation. International Higher Education 40, 2–3, 2015.
- [35] T. Crick, J. H. Davenport, P. Hanna, A. Irons, & T. Prickett. Computer Science Degree Accreditation in the UK: A Post-Shadbolt Review Update. In: Proc. of CEP 2020. ACM, Article 6, 1–4, 2020.
- [36] L. Harvey. The power of accreditation: views of academics. Journal of Higher Education Policy and Management 26, 2, 207–223, 2004.
- [37] S. Mutereko. Analysing the accreditation of engineering education in South Africa through Foucault's panopticon and governmentality lenses. Assessment & Evaluation in Higher Education 4, 235–247., 2017.
- [38] A. Loten. "America's Got Talent, Just Not Enough in IT", Wall Street Journal, 15 October 2019 [Online]. Available: https://www.wsj.com/articles/americas-got-talent-just-not-enough-in-it-11571168626?mod=hp_featst_pos1
- [39] Prospects. "Skills shortages and COVID-19", 2020 [Online]. Available: <https://www.prospects.ac.uk/careers-advice/getting-a-job/skills-shortages-and-covid-19>
- [40] D. Shah. "Massive List of MOOC Providers Around the World — Class Central." Class Central's MOOC Report, 30 July 2019 [Online]. Available: <https://www.class-central.com/report/mooc-providers-list/>
- [41] Q. Burke, C. Bailey, L. A. Lyon, & E. Green. Understanding the Software Development Industry's Perspective on Coding Boot Camps versus Traditional 4-year Colleges. In: Proc. of SIGCSE'18. ACM, 503–508, 2018.
- [42] D. Rajendran. Does Embedding an ICT Certification Help Align Tertiary Programs with Industry A Study of CCNA Workplace Perceptions. Journal of Applied Computing & Information Technology 15, 1, 2011.
- [43] K. Kitto, N. Sarathy, A. Gromov, M. Liu, K. Musial, & S. B. Shum. Towards skills-based curriculum analytics: can we automate the recognition of prior learning?. In: Proc. of 10th International Conference on Learning Analytics & Knowledge. 171-180, 2020.
- [44] MicroBol. 2020 [Online]. Available: <https://microcredentials.eu/about-2/microbol/>
- [45] European MOOC Consortium. 2020 [Online]. Available: https://emc.eadtu.eu/images/EMC_Common_Microcredential_Framework.pdf
- [46] T. Crick, J. H. Davenport, P. Hanna, A. Irons, S. Pearce, & T. Prickett. "Repositioning BCS Degree Accreditation". ITNOW, 62,1, 2020.
- [47] R. Watermeyer, T. Crick, C. Knight, & J. Goodall. COVID-19 and digital disruption in UK universities: afflictions and affordances of emergency online migration. Higher Education, 81, 623-641, 2021.
- [48] T. Crick, C. Knight, R. Watermeyer, & J. Goodall. The Impact of COVID-19 and "Emergency Remote Teaching" on the UK Computer Science Education Community. In: Proc. of UKICER'20. ACM, 2020.
- [49] T. Crick, J. H. Davenport, A. Irons, & T. Prickett. A UK Case Study on Cybersecurity Education and Accreditation. In: Proc. of FIE'19, 2019.
- [50] T. Crick, T. Prickett, J. H. Davenport, & A. Irons. Assessing the Value of Professional Body Accreditation of Computer Science Degree Programmes: A UK Case Study. In Proc. of ITICSE'20. ACM, 2020.
- [51] J. H. Davenport, T. Crick, and R. Hourizi. The Institute of Coding: A University-Industry Collaboration to Address the UK's Digital Skills Crisis. In: Proc. of EDUCON'20. 1400–1408, IEEE, 2020.
- [52] T. Prickett, M. Harvey, J. Walters, L. Yang, and T. Crick. Resilience and Effective Learning in First-Year Undergraduate Computer Science. In: Proc. of ITICSE'20. ACM, 2020.
- [53] T. Crick. COVID-19 and Digital Education: A Catalyst for Change?. ITNOW, 63, 1, 2021.
- [54] A. Irons, T. Crick, J. H. Davenport, P. Hanna, and T. Prickett. Increasing the Value of Professional Body Computer Science Degree Accreditation. In: Proc. of SIGCSE'21. ACM, 2021.
- [55] F. Moller and T. Crick. A University-Based Model for Supporting Computer Science Curriculum Reform. Journal of Computers in Education, 5, 4, 415–434, 2018.
- [56] E. Murphy, T. Crick, & J. H. Davenport. An Analysis of Introductory Programming Courses at UK Universities. The Art, Science, and Engineering of Programming. 1(2), 18, 2017.
- [57] J. H. Davenport, A. Hayes, R. Hourizi, & T. Crick. Innovative Pedagogical Practices in the Craft of Computing. In Proc. of LaTiCE'16, IEEE, 2016.