Towards a Framework for Mapping Authentic Assessment to Competency in University Computing Education in the UK

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***Abstract*—Across various countries and jurisdictions, we have seen reports of a "graduate skills gap", with higher-than-desired graduate unemployment and underemployment, as well as reports from employers that there is a mismatch between the competencies desired by employers and those evidenced by graduates. Graduate employment prospects are related to many complex intersecting factors, including human capital, individual attributes, individual career-building behaviours, labour market factors, and social capital. Alongside the graduate skills gap, there are also reports internationally of a "digital skills gap", with increasing demand for digital skills and a proclaimed shortage of diverse digital skills evidenced by the workforce. These circumstances appear to promote positive employment outcomes for computing graduates. However, there are reports in many jurisdictions, including the UK, of skills-gap-related issues for computing graduates. In response to these concerns, curricula guidance in the computing and engineering disciplines are increasingly promoting competency-based education (CBE) to develop graduates' work readiness better and, hence, reduce the skills gap. Authentic Assessment, i.e. Assessment that addresses important problems or questions that require students to effectively and creatively apply their knowledge and disciplinary and personal skills, mirroring the challenges faced by adults or professionals in the real-world context, has also been advocated to reduce skills gaps between education and professional life. However, the link between CBE and Authentic Assessment in the computing discipline could benefit from further exploration.**

This paper explores the relationship between CBE and authentic assessment. Based on the guiding research question: "How can authentic assessment be employed to promote competency in computing degree programmes?", the paper begins by providing theoretical underpinnings in the form of working definitions for competency and authentic assessment and the link between the two. This paper follows a proof-of-concept research approach conducted by evolutionary prototyping to develop a framework for exploring the relationship between authentic assessment and competency. The paper documents the validation of the framework by applying it to examples of practices from UK universities involved in the study. These illustrative examples show the framework in action. The paper concludes with a discussion of how the framework promotes learner competency development by authentic assessment. This approach has implications for enhancing how computing graduates address digital skills gaps and has the potential to be customised and adopted more broadly across STEM disciplines.

***Index Terms*—Competency, Authentic Assessment, Computing**

I. Introduction

Gaps between the skills sought by the employers of graduates and the skills graduates demonstrate have been reported globally [1], [2]; and specifically in Bangladesh [3], India [4], Turkey [5], the UK [6]–[11], and the USA [12], [13]. Higher-than-ideal graduate unemployment and underemployment, graduates lacking work readiness or differences between the competencies demonstrated by some graduates and those desired by employers are evidence of these skills gaps. [14, p.1] notes that "As the importance of non-technical skills in the software engineering industry increases, the skill sets of graduates match less and less with industry expectations"; [15] also reports various gaps. "Working in teams" is listed as one, which has been addressed in UK computing education for a long time by its explicit inclusion in professional body accreditation criteria [16].

Framed in a post-pandemic context [17]–[20], these issues highlight that it is timely to explore mechanisms to address these skills gaps. The guiding research question: *How can authentic assessment be employed to promote competency in computing degree programmes?* is divided into three sub-questions:

Q1. What types of authentic assessments are effective in developing core competencies in computing degree programs?
Q2. How does authentic assessment enhance practical skills and real-world problem-solving abilities in computing students?
Q3. What role do industry-aligned assessments play in preparing computing students for professional competencies required in the workforce?

This paper develops a prototype framework that can be used to explicate the relationship between assessment in computing education and our current understanding of competency-based education and the real-world skills which it seeks to develop and assess. Section II introduces what is understood by competency and authentic assessment in a computing context. Section III explains how competency on the one hand and authentic assessment on the other were delineated by review and synthesis of existing approaches and then combined, as described in Section IV, to form a prototype framework through which specific authentic assessments or case studies can be described and evaluated. Two such illustrative examples are described in detail in Section V. This is followed in Section VI by a discussion of insights gained, leading to possibilities for further exploration of how competency-based education and related authentic assessment can contribute to addressing the graduate skills gap in computing.

II. Background and Related Work

A. Competency

Competency-based education (CBE) has been employed for at least 50 years. The increasing expectations from policy-makers and education funders of value for money from higher education have encouraged further adoption [21]. There are many definitions of CBE. An operational definition which informs this work is, "CBE is defined as an outcome-based approach to education that incorporates modes of instructional delivery and assessment efforts designed to evaluate mastery of learning by students through their demonstration of the knowledge, attitudes, values, skills, and behaviors required for the degree sought." [22, p. 99]. CBE is an extension of experiential learning [23] and social learning [24], [25]. The definition of the outcomes learners are expected to evidence is pivotal [22].

There have been several attempts to document the expected competency outcomes for computing graduates. Early advocates include the ACM/IEEE-Computer Society's curricular guidelines for Information Technology [26] and European Quality Assurance Network for Informatics Education (EQUANIE) [27]. Both of the organisations defined a collection of competency outcomes that graduates should evidence. It has become a standard recommendation in curricular guidelines in many jurisdictions [12], [28], [29] to adopt CBE. In particular the ACM/IEEE Computing Curricula 2020 Model (CC2020) [12] has done much to promote the adoption of CBE in the computing discipline. Much of this work has been led by academics. At the same time, industrial groups and not-for-profit organisations have developed and published competency and skills frameworks addressing personal, technical, and professional competencies [11], [30], acknowledging wider societal and educational imperatives [10], [31]–[34]; in Europe, the most prominent being Skills for the Information Age (SFIA) [9], [11], [30], [35]–[37]. Other examples of competency frameworks include the European e-Competence Framework (e-CF) [38] and the Japanese i Competency Dictionary [39].

According to CC2020, "A competency specification enumerates knowledge, skills, and dispositions that are observable in the accomplishment of a task, a task that prescribes purpose within a context" [12, p. 47]. Colloquially, Knowledge is "know-what", skills are "know-how", and dispositions are "habitual inclinations that are socio-emotional tendencies, predilections, and attitudes" [12, p. 490]. The elaboration (i.e., doing, following, or acting upon these inclinations) is the actual "personal competency [11]". In the CC2020 model, dispositions, knowledge and skills need to be applied successfully at least *once* in *live or simulated real-world* computing tasks to demonstrate competency. However, considering the industrial SFIA model [35], competency combines generic attributes (i.e. autonomy, influence, complexity, business skills and knowledge) and professional skills. SFIA competence is evidenced by repeatedly employing a professional skill and related attributes in a *real-world context* (i.e. more than once). Arguably, the SFIA definition represents competency (i.e. can do in an ongoing basis in a real-world context). In contrast, the CC2020 definition arguably represents capability (i.e. has been done once, possibly in a simulated and simplified environment) [2]. Either capability or competence would help address the digital skills gap. However, competency would possibly address the digital skills gap more fully than capability. Supervised practice is common before full professional independence is achieved in many other professions (e.g. engineering, law, medicine, nursing, and teaching), and capability commonly proceeds competence. Hence, the CC2020 capability-oriented definition may be sufficient [2]. Equally, in many professions, regulating bodies are responsible for registers of practice rather than universities; e.g. the register of Chartered Engineers in the UK is maintained by the Engineering Council, the General Medical Council (GMC) maintains the list of medical professionals licensed to practice in the UK, etc. Many professionals operate a license to practice (e.g. in the UK, to work as a medical doctor, you have to be licensed to practice by the GMC). Computing does not typically require a license to practice as a general profession, and such licensing is controversial [40]. As such, competency, as discussed in this work (and other works related to CBE in the computing discipline), is closer to the concept of Polanyi's Personal Knowledge [41] i.e. encompasses skills, intuitions, and experiences an individual possesses, in other words, tacit knowledge or notional competence. To use an analogy from driving a vehicle, there is no formal, sector-wide "driving license", so individual organisations need to ensure the competency of their IT/computing staff to practice as professionals and operate within the "rules of the road".

B. Authentic Assessment

Wiggins originally defined *authentic assessment* as "engaging in worthy problems or questions of importance, in which students must use knowledge to fashion performances effectively and creatively. The tasks are either replicas of or analogous to the kinds of problems faced by adult citizens and consumers or professionals in the field" [42, p. 229]. In the last 30 years, there have been multiple attempts to define authenticity, and current practice commonly involves mimicking work tasks [43], the use of portfolios to assess competency [44], [45], and much exploration of team projects e.g. [46]–[48]. It has been argued this approach is too narrow, and the focus should be on the task having social value [49]. Authenticity is broader than simulating workplace tasks, arguably [43] it requires (1) psychological authenticity [50]–[52] i.e. the learner has to perceive the tasks as authentic (which could be perceived to represent a real-world task or have social value); (2) ontological fidelity [53] i.e. the task resonates with the learner's professional aspirations and they identify as being engaged in a meaningful task; and (3) it should address practice-theory perspectives [43] i.e. complexities of the real world, maybe on occasions too complex to support learning (so for example, physics models ignore friction, or CS1 coding problems do not use all available programming syntax etc.). In computing, authentic assessment is commonly seen as assessed tasks which simulate professional workplace activities [51], although it doesn't strictly have to. Research has suggested that the two most significant motivations to study computing are its utility (practical benefits and future career usage) or its intrinsic value (i.e. subject interest) [54]–[56]. These motivations suggest that, whilst mimicking workplace tasks is important in computing education, there is also inherent and possibly sufficient value in many such tasks because learners can readily imagine themselves doing them in a worthwhile context. Frameworks have been developed to steer assessment designers to authentic assessment [57]–[61]. How these frameworks were analysed to inform the prototype framework proposed in this work is discussed in Section III-B.

Authentic assessment and authentic learning can be considered as two sides of the same coin. Authentic learning – learning that is experienced as in the field – will best help reduce any skills gaps between the competencies evidenced by graduates and those desired by the employers of graduates. Authentic assessment can enhance learning in the classroom, authentic learning and its assessment relates to developing competencies and skills in the real-world environment, in other words *work-based learning*. Work-based learning can be seen as "the class of programmes that bring together universities and work organisations to create new learning opportunities in workplaces" [62, p.4]. Alternative work-based learning approaches are possible, ranging on a continuum of integration from live work-based projects, assessed work experience, work placements, work-integrated higher education, and higher education apprenticeships [63]. In addition to work-based learning, *work-related learning* can be seen as "external and embedded aspects of the curriculum that can lead students to an increased awareness of the context of work" [64, p.223], so for example, exploring or completing tasks as related to a work context, that may be real-world or a simulation. Finally, there is also *work-relevant learning* – "learning of a skill or skills, which might be useful in the workplace" [64, p.223]. Work-based learning, work-related learning and work-relevant learning will typically have associated assessments. Competencies as defined by CC2020 [12] and CC2023 [65], and skills as defined by SFIA [35], can help frame these learning opportunities and ensure their "authentic assessment".

The direct relationship between competency and authentic assessment has not been frequently explored, and the relationship between authentic assessment and competency (as defined by CC2020 [12], CS2023 [65] and SFIA [35]) even less frequently. As such, it is timely to explore this space more specifically.

III. Methodology

A. Method

This paper reports proof-of-concept research [66] conducted by evolutionary prototyping [67]. A preliminary framework for authentic assessment was synthesised from the existing authentic assessment frameworks [57]–[61]. Iterative tabular analysis was used to derive a prototype framework to capture authentic assessment in this research. This analysis took place as follows. Firstly, one of the researchers used a table to compare and contrast the commonalities and differences of the five frameworks. A second researcher then analysed the table, noting differences. The second researcher then met with the original researcher and discussed differences, and agreed on a second version. Finally, a third researcher completed the analysis and then met with the other two researchers to compare findings. The information presented in Table I is the consensus outcome from these discussions. The preliminary framework for competency was derived from the SFIA [35] and CC2020 [12] models. For SFIA, skills and levels [68] and related behavioural attributes [69] developed were indicated, together with indication of real-world and repeated successful application. For the CC2020 model, the related ACM Skill, Knowledge (in terms of knowledge units [65]), and dispositions (from [65]), were included. These preliminary frameworks, along with context mappings for university, programme of study, the curricula area(s) addressed (again from [65]), programme-level learning outcomes and module features, were then combined to form a prototype framework for examining authentic assessment.

The prototype framework is applied to two illustrative examples (Section IV). The purpose is to explore the feasibility of employing the framework to illustrate using authentic assessment to develop competency.

B. The Prototype Framework

The framework is derived by the approach in III-A. In the framework, the numbered elements d.1-d.7 are mandatory, and the elements in brackets are provided as a guide for the required content. The derived framework is:

a. Context
1. General context, incl. university, programme and cohort size
2. Curricula area
3. Programme Learning Outcomes (PLOs)
4. Modules/courses involved

b. SFIA expectations derived from [35], [68], [69]
1. SFIA Skill / Level
2. SFIA Behaviour Attribute(s)
3. The task involves real-world application
4. The tasks enable evidence of successful repeated application

c. ACM/IEEE Curricula expecations derived from [12], [65]
1. ACM Skill
2. ACM Knowledge
3. ACM Dispostion

d. Authentic assessment derived from Table I
1. Goal (Your task is to...The goal is to... The problem or challenge is... The obstacles to overcome are... Is the Task is ill-defined or open-ended?)
2. Role (You are... You have been asked to...Your job is... Do the students have autonomy and choice in tasks...)
3. Audience (Your clients are... The target audience is... You need to convince... Has industry had input into the design of the task...)
4. Situation (The context you find yourself in is...The challenge involves dealing with... Is the scenario real world? Or is it a simulation? ....)
5. Product/Performance, and Purpose (You will create a...in order to... You need to develop...so that... Standards and Criteria for Success Your performance needs to... Your work will be judged by... Your product must meet the following standards...)
6. Challenge (To what extent does the assessment activity challenge the student? ... Does the assessment activity require that metacognition is demonstrated? ...)
7. Does task involve reflective practice of the student?
8. Is the task collaborative?

IV. Illustrative Examples

Due to space constraints, we limit ourselves to just two examples to illustrate the use of the framework. The first is the embedded development of software engineering competencies at a research-intensive (Russell Group) UK University. Students in the programmes at this university have a relatively low uptake of the industrial placement year, so curriculum-based opportunities for competency development are essential for them. In contrast, the second example examines the mandatory industrial work placements at a second UK University, which is a more teaching-focused university (post-92), and the assessment of competencies in a "work placement" setting [62], [63].

A. Software Engineering Example

a. Context

1. General context Software engineering is a core component of all undergraduate degrees in computing at this example University, with further depth and specialisation in later years for students on the software engineering specialist pathway. By the end of their second year of study we expect all students (approximately 300 per cohort) to have developed a "good" level of competency in this area – not experts, but on the path to this. Students will then go on to use these skills and develop them further in their third and optional fourth year of study.

2. Curricula area Software Engineering.

3. Programme Learning Outcomes Three key PLOs are achieved by the end of the second year. On successful completion of the programme, students will be able to:

- demonstrate knowledge and understanding of software engineering analysis and design methods and process management.
- apply a software engineering process and take a project through the stages of the software lifecycle, using design notations and software engineering tools selectively.
- work effectively in a team, demonstrating personal responsibility and group management ability, interpersonal skills, leadership and delegation, and plan to meet deadlines.

4. Modules/courses involved Introduction to Software Engineering (year-long, first year), Systems Design and Security (1st semester, second year), Software Hut (2nd semester, second year). Each module includes a team-based software development project, and each builds upon the concepts and skills introduced in the previous module(s). As Software Hut is the culmination of this part of the programme, it is the focus here, but the competencies are developed across the first two years.

b. SFIA expectations

1. SFIA Skill / Level. In terms of the SFIA 8 framework, the following skills are developed to at least level 3, and in some cases level 4: Data modelling and design; Programming/software development; Project management; Quality assurance; Requirements definition and management; Systems design; Systems development management.

2. SFIA Behaviour Attributes On completion of the Software Hut module, we believe that the following behavioural factors have been developed again to at least level 3 and in some cases higher: Collaboration; Communication; Creativity; Decision-making; Delegation; Execution performance; Influence; Learning and professional development; Planning; Problem solving.

3. Does the task involve real-world application? Within

TABLE I
AUTHENTIC ASSESSMENT FRAMEWORKS

GRASPS [57]	Gulikers et al. Five (D)imensions [58]	Ashford-Rowe et al. 8 (Q)uestions [59]	Schultz et al. (F)actors [60]	Villarroel et al. (C)omponents [61]
Goal (Your task is to... The goal is to...The problem or challenge is... The obstacles to overcome are...)	D1) Task D2) Physical Context: How does it resemble a real-world scenario?		F6) Task is ill-defined or open-ended	C2) Cognitive challenge
Role (You are... You have been asked to... Your jobs is...)	D2) Physical Context: How does it resemble a real-world scenario?		F7) Student has autonomy and choice in the tasks	C1) Realism
Audience (Your clients are... The target audience is... You need to convince...)	D3) Social context: With whom do they have to do the task?	Q5) Does the assessment require a product or performance that could be recognised as authentic by a client or stakeholder? (Accuracy)	F1) Activity is realistic / performance-based F8) Industry had input into the design of the task	C1) Realism
Situation (The context you find yourself in is... The challenge involves dealing with...)	D2) Physical Context: How does it resemble a real-world scenario? D3) Social context: With whom do they have to do the task?	Q6) Is fidelity required in the assessment environment? And is the assessment tools actual or simulated?	F3) Context is realistic	C1) Realism
Product/Performance, and Purpose (You will create a...in order to... You need to develop...so that... Standards and Criteria for Success... Your performance needs to... Your work will be judged by... Your product must meet the following standards...)	D4) Result (from student efforts) D5) Criteria (how is it judged)	Q2) Is a performance, or product, required as a final assessment Outcome? Q3) Does the assessment activity require that transfer of learning has occurred, by means of demonstration of skill?	F1) Activity is realistic / performance-based F2) Task requires application of transferable skills	C1) Realism.
		Q1) To what extent does the assessment activity challenge the student? Q4) Does the assessment activity require that metacognition is demonstrated?		C2) Cognitive challenge
		Q7) Does the assessment activity require discussion and feedback?	Q5) Task involves reflective practice?	C5) Evaluative judgement
		Q8) Does the assessment activity require that students collaborate?		
N.B. the numbering in this table is that of the original authors, which is why it does not always start from 1.				

Software Hut teams of students work on real problems, sourced from across the university and external partners. Professionalism in behaviour is at least as important as technical ability.

4. Do the tasks enable evidence of successful repeated application? Tasks are presented with increasing levels of complexity across the three software engineering modules.

c. ACM/IEEE Curricula expectations

1. ACM Skill In the introductory module, students develop the ability to explain and apply software engineering concepts; in the second module they develop skills in evaluating the efficacy of different techniques and frameworks; in the Software Hut module students develop a solution to a real world problem, synthesising their previously-developed knowledge.

2. ACM Knowledge Students will have developed basic (and in many cases advanced) knowledge in the SE knowledge units of: Teamwork; Tools and environments; Product requirements; Software design; Software construction; Software verification and validation; Refactoring and code evolution; Software reliability; Formal methods.

3. ACM Disposition We believe that by the end of the second year of study, these students will have demonstrated the following dispositions: Adaptable; Collaborative; Inventive; Meticulous; Persistent; Proactive; Responsible; Self-directed.

d. Authentic assessment We focus on the final assessment in the series of modules, a 12-week-long team project:

1. Goal The goal is for students to work in teams to move from a rough outline of a problem, through discussion with a client to develop requirements then implement a solution.

The task is very open-ended. Clients volunteer projects for the Software Hut module, and these projects reflect real problems. Academic staff pre-filter the projects, to ensure that they all fit loosely into the same framework (a database-backed website, to be developed using Ruby on Rails), but it is then up to the teams to negotiate the detailed requirements with their client, and to ensure that they are achievable in the limited timeframe.

2. Role Students are taught about team roles and the different tasks required, but it is left to teams to self-organise roles.

3. Audience As above, the clients are varied but the one thing they have in common is that they have a real problem to solve.

We do explicitly tell clients that they should expect a proof-of-concept rather than a production-ready system, and they join the scheme with this understanding.

4. Situation Students are supplied with a brief (single paragraph) outline of the clients' problems, and teams can express ranked interest in these problems. Teams are allocated to problems and it is then their responsibility to develop a wider understanding and develop a solution.

5. Product/Performance, and Purpose Students are told: *Your client has a problem that they want to solve. Each client will have slightly different motivations. Clients come from very different backgrounds, some with detailed technical knowledge, and others with very limited technical knowledge. One of the first things you should be doing as a team is working out where your client is in this spectrum, so that your discussions with them are at the appropriate level. Make sure that you are using a common language, not using the same words to mean quite different things. Your team must determine your client's requirements and develop a solution for them to be delivered at the end of semester. Your client will assess how well they think you have interacted with them and how satisfied they are with your solution. Academic staff will assess your software engineering process, through a combination of a document trace produced by your team and regular meetings with your team.*

6. Challenge This task involves both technical and professional challenges. The technical solutions required are non-trivial, requiring the collaboration of teams of six or more people, and the teamwork itself is often at least as much challenge as the technical requirements. Assessment focuses on software engineering practices, including inclusive teamwork, but there is an underpinning requirement to develop a technical solution.

7. Does the task involve reflective practice of the student? As well as the team assessment in this module, 30% of the assessment in this module is an individual reflective report, focusing on the lessons learned and how these will inform future practice for the individual.

8. Is the task collaborative? Every one of the software engineering modules has an assessment component where collaboration is essential.

B. Year-long Placement Example

a. Context

1. General context Computing at this example University is delivered at two campuses. At the larger campus, current undergraduate provision is through four main programmes: BSc Hons Computing Science (full-time and part-time), BEng/MEng Hons Software Engineering, BSc Hons Computing Technologies and BSc Hons Interactive Computing. For all of the undergraduate full-time programmes, a one year period of industrial work placement is a *mandatory* part of provision. This approach has its origins in the institution's first delivery of undergraduate computing in the 1970s when operating as a polytechnic, reflecting an emphasis on vocational education.

Referring to the QAA's Work-based learning [63][p.6] continuum, the University's approach would be characterized as a "work placement".

Current cohort size is typically 200-250, with the majority undertaking the placement year. Those who do not will have been exempted via accreditation of prior experiential learning, or as direct entrants from an approved foundation degree, or will have an extenuating circumstance. Exempt students do not receive the co-terminus award of a Diploma in Professional Practice.

2. Curricula area All programmes offer a core undergraduate education in computing, with each programme offering specific pathway modules reflecting the programme title. Furthermore, each programme is accredited by the BCS towards Chartered IT Professional and partially towards Chartered Engineer. A core curriculum design theme is to ensure students are "placement ready" by the end of year 2. As well as the inclusion of relevant practical and professional skills within taught modules, this involves collaboration with the institution's employability department and a series of employability student support activities during the first two years. For a number of years, the School have utilized its AWARE framework to focus this approach [70]:

TABLE II
AWARE FRAMEWORK

Letter	Description	Level
A	Awareness	Level 4
W	Work preparation	Level 5
A	Acquire experience	Level 5 Placement
R	Reflect / refine / refocus	Level 6
E	Enhancement / employment	Level 7 / Graduation

3. Programme Learning Outcomes There are three PLOs which are directly related to the placement year:

- Work collaboratively, in physical and remote settings, recognising the different approaches used to effectively organise computing teams and the value of different roles within a team.
- Evaluate and apply contemporary techniques and approaches to solve a range of commercial and societal computing problems.
- Demonstrate and reflect upon core employability competencies, professional standards, ethics and etiquette as well as initiative and innovation in collaborative work environments.

4. Modules/courses involved The work placement year is delivered and assessed through a 60 credit, Level 5 placement module. Successful completion of this module leads to the co-terminus award of a Diploma in Professional Practice.

Given the uniqueness of each student's placement setting, the module level learning outcomes seek to be as generic as possible while focusing on competency both in an academic and industrial context:

- Solve work-based problems underpinned by subject specific related theory and contribute to the employer organisation.

- Demonstrate professional standards, ethics and etiquette in collaborative work environments.
- Critically reflect on the professional learning experience and self-development in the context of career decision making.
- Communicate effectively to a variety of audiences using appropriate written, verbal, or digital delivery methods.

Assessment has two main components: academic visits and development of a reflective report. At least two academic visits to students are undertaken, during which students are assessed on a set of core competencies on a pass/fail basis. By the end of their placement period, all students are expected to have demonstrated each competency. These competencies are:

Independence. Student demonstrates appropriate independence and self-reliance in carrying out their duties. This might include making appropriate use of sources help and support.

Flexibility. Student demonstrates appropriate flexibility in carrying out their duties. This might include transitioning from student life; responding appropriately to changing needs, work patterns, deadlines, etc.

Timekeeping. Student has an appropriate and satisfactory record of attendance and timekeeping.

Teamwork. Student is an effective team member and has good working relationships with colleagues/clients/customers.

Interpersonal Skills. Student demonstrates effective communication & interpersonal skills. This might include: speaking, listening, presenting, writing, use of telephone & email, informing, instructing, training, persuading, demonstrating, etc.

Self-awareness. Student has appropriate awareness of the extent and limits of their own professional competence. This might include: taking appropriate initiative, asking for help, identifying training needs, responding appropriately to performance feedback, etc.

Organisation & planning. Student demonstrates effective planning in managing tasks This might include seeing tasks through to their conclusion, making effective use of own time, avoiding unnecessary work, etc.

Health & Safety Awareness. Student is aware of relevant health & safety issues and, where necessary, adopts appropriate work practices.

Social & Professional Awareness. Student is aware of relevant professional social, legal & ethical issues and responsibilities. This might include awareness of: relevant legislation, impact of organisation's actions on people and the environment, organisation's policy on social responsibility, professional body codes, etc.

Technical Expertise. Student demonstrates appropriate expertise in the use of technology appropriate to the job and their course of study.

b. SFIA expectations

1. SFIA Skill / Level The skills which students apply and develop will vary according to the nature of the placement setting. All positions offered by placement employers are evaluated by the academic team to ensure they will offer meaningful work in one or more of the following areas: Software/hardware analysis, design, development and testing; The use and application of software/hardware tools in the design, development and implementation of problem solutions; Database design, development, implementation and maintenance; Installation and testing of hardware / software systems; Systems maintenance; Customer support; Staff training for new systems; Software support for research projects; Software/Hardware evaluation and re-engineering; Financial systems and application; Statistical/mathematical analysis and modelling. For any one student, their core experience could be described by a SFIA Skills Family such as Software Engineering, Testing, Experience Design or Service Management, to name a few.

Regarding SFIA Levels, over the course of their placement year, the expectation is that students will progress through Levels 1-3 and in exceptional cases, towards the end of their placement year, some students will operate at Level 4.

2. SFIA Behaviour Attributes The placement experience will allow students to exhibit and apply all SFIA generic attributes (Autonomy, Influence, Complexity, Business skills/Behavioural factors and Knowledge), to varying degrees. Within the placement module, assessment against the module's competency list (Independence, Flexibility, Timekeeping, etc) is the assessment element which most closely resembles these attributes. In particular, aspects of SFIA Behavioural Factors (collaboration, security/privacy/ethics, planning, adaptability) are captured by these assessed competencies.

3. Does the task involve real-world application? - Yes.

4. The tasks enable evidence of successful repeated application? - Yes

c. ACM/IEEE Curricula expectations

1. ACM Skill The ACM approach is to frame a competency as a combination of knowledge, skills and dispositions applied in the context of a task. By its nature, work placements provide a rich variety of opportunities to develop and exhibit such competencies. Curriculum design strives for flexibility in order to capture this variety of work experience. The programme level learning outcomes (as introduced above) which are directly linked with the placement year can be understood as high level competency statements along the lines of the ACM approach, with an emphasis on skill and disposition:

- Work collaboratively, in physical and remote settings, recognising the different approaches used to effectively organise computing teams and the value of different roles within a team.
- Evaluate and apply contemporary techniques and approaches to solve a range of commercial and societal computing problems.
- Demonstrate and reflect upon core employability competencies, professional standards, ethics and etiquette as well as initiative and innovation in collaborative work environments.

2. ACM Knowledge - as above.

3. ACM Disposition - as above.

d. Authentic assessment.

1. Goal Since the work placement setting is unique to each student, there is no student assessment brief in this context. The placement module learning outcomes are a meaningful statement of the goal for each placement student, namely

- Solve work-based problems underpinned by subject specific related theory and contribute to the employer organisation.
- Demonstrate professional standards, ethics and etiquette in collaborative work environments.
- Critically reflect on the professional learning experience and self-development in the context of career decision making.
- Communicate effectively to a variety of audiences using appropriate written, verbal, or digital delivery methods

As students progress through their placement period, the interim assessment via the module's competency checklist seeks to ensure that the specific tasks in which a student is engaged are aligned with these "goal statements".

2. Role This could be almost any aspect of being a computing professional, as captured by the SFIA Role Families and as executed at SFIA Levels 1-3.

3. Audience When approving placement settings and roles for students, one aspect is to ensure that students will have the opportunity to engage in meaningful, commercial activity. Depending on the setting, this will translate to collaborative working with one or more of internal team members, employees within the wider organization, and partners or clients external to the employer.

4. Situation This is captured by the range of settings in which a placement student may be employed. In each individual case, the module assessment (via competencies) seeks to ensure that the student has reflected on their specific situation, linked the knowledge and skills required with their previous study, related professional behaviours to their allocated tasks.

5. Product/Performance, and Purpose The academic tutor visit includes a meeting with the student's industrial supervisor. Through this exchange, completion of competencies can be reviewed in the context of actual targets achieved. It is also a requirement of an approved placement that students will be given structured, meaningful and objective targets against which they are expected to perform. This is captured through assessment of the "technical expertise" competency.

6. Challenge Feedback from students consistently demonstrates that they find the work placement experience a challenging, and at times daunting, experience. This is to be expected given the live, real-world nature of the tasks completed. Recognizing this, employers will phase the student into their team or setting through low-risk, sandboxed tasks.

7. Does the task involve reflective practice of the student? Students are encouraged to keep a weekly or monthly log of the work they undertake. This informs the reflective account of their experience which is an assessed component of the module. As well as reflecting on their performance with respect to the competencies above, students are expected to articulate evidence of thoughtful reflection on all aspects of the placement experience, their own learning, including, where appropriate, actively seeking learning opportunities, awareness of their own value and effectiveness as an employee, and awareness of the range of career options arising from their placement experience.

8. Is the task collaborative? Yes.

V. DISCUSSION

The Software Engineering example (Section IV-A) illustrates how authentic assessment can be employed to promote the development of competencies. It shows how the initial course (*Introduction to Software Engineering*) employing work-relevant learning is extended by a further course (*Systems Design and Security*) employing work-related learning, which prepares the students to address the real-world complexities addressed in the work-based learning of the software hut module. The Placement example (Section IV-B) illustrates how year-long industrial placements help promote the development of a broad range of professional competencies [11] by enabling the repeated elaboration of dispositions [12], [65] or SFIA behavioural factors [69]. Additionally, the placements enable the repeated application of skills, again a factor required to evidence SFIA competency [35]. Arguably, the Software Engineering example also enables the development of SFIA competency, as the repeated application of some skills (i.e. some aspects of programming will be required multiple times during the live projects), so this example too represents competency developments during future workplace applications. In both cases, using the prototype framework helps surface the competencies developed and how authentic assessment enables students to evidence those competencies.

During the mapping process, it was apparent that competency and authentic assessment, whilst related concepts, serve a different purpose in the design of the courses. The critical function of competency is at the design stage, helping to promote the desired learning outcomes at the module/programme level, specifically learning outcomes relevant to the workplace. Hence, competency will help reduce the skills gap between the competencies evidenced by graduates and those desired by employers. On the other hand, authentic assessment is more operational. Authentic assessment enables the promotion of the competencies defined via the competency-based approach.

The study did not set out to do so, however, the Software Engineering example, additionally provides insight into how work-relevant learning and work-related learning are valuable in a curriculum-embedded approach to the end goal of competency development. Also, as reported elsewhere [2], SFIA competency may be supplemental or "destination" competencies, compared with the competencies explored in CC2020 [12] and CS2023 [65], which may be considered as "en-route" competencies, emerging prior to those considered by SFIA [35]. The breadth and significance of the competencies developed in the placement example, may help explain why the impact of industrial placements can be so beneficial to graduates [71].

Even on the basis of applying two case studies, the prototype framework seems to provide a lens through which existing assessments can be analyzed for their contribution to "authentic assessment". The framework, suitably refined, could be used to compare and contrast a range of authentic assessment types from a range of contexts, such as we have in this paper, namely curriculum-embedded authentic assessment and work-placement authentic assessment. This leads to opportunities for cross-institutional insights and sharing of lessons learned.

The proposed framework could act as an "aide-memoir" in course design, either by course, teams considering the course and assessment design or by institution course approval panels or professional bodies in the design of their respective assessment and accreditation criteria.

VI. Conclusions and Further Work

This study's research question was "How can authentic assessment be employed to promote competency in computing degree programmes", with three sub-questions (Section I). The Software Engineering example has a layered, curriculum-based progression from introductory work-relevant learning through to real-world applications in a team project assessment, which is a common example of a type of authentic assessment effective for developing core competencies (Q1). In the second example, year-long compulsory placements enhance competency through in-depth professional exposure, enabling them to repeatedly apply and refine skills in real-world contexts (Q2). In both examples, the learning and assessment reinforces SFIA-based skills through repeated application in real-life projects, which nurtures competencies essential for professional practice (Q3). We observe that competencies primarily guide course design and ensure that learning outcomes are relevant to workplace needs, while authentic assessment has an operational role, enabling students to demonstrate and deepen these competencies effectively.

The illustrative examples are two points on the work-based learning continuum [63], representing live work-based projects and work placements. Further examples on the continuum, such as higher education apprenticeships, will help to evaluate and develop the framework. Future research should explore the synergistic relationship between work-relevant, work-related, and work-based learning approaches to assess how these approaches contribute individually and collectively to competency development in computing programs. By exploring how competencies identified in CC2020 and CS2023 curricula align or extend beyond SFIA, new insights can be identified into emerging skills that are increasingly relevant in practice. We also acknowledge wider developments on the future of assessment and comparative judgement [72], as well as the emerging impact of artificial intelligence on education and skills systems globally [73], [74]. Finally, authentic assessment appears to be a potentially significant mechanism for promoting competency development, and this relationship is worthy of further exploration in computing and cognate disciplines.

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