Developing a Competence Assessment which References a Student Portfolio to a Professional Skills Framework

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Abstract. As part of the UK Institute of Coding (IoC), established to address the perceived skills gap between computing graduate capabilities and employer needs, a degree accreditation standard was developed which focused on the demonstration of real-world computing competence rather than on traditional academic knowledge. A graduate's competence was to be assessed by using a portfolio recording their achievements in a real-world setting to map those achievements to the skills descriptors of a global skills framework for IT professionals. This paper explores the decisions made as the accreditation standard was developed, and the range of tests and checks that were required to ensure that the standard would both confirm graduates' specific competence and meet national regulatory frameworks for degrees. Although the specific accreditation standard was for computing degrees, the design approach and subsequent validations would apply also to competence-based standards for other subjects.

Keywords Graduate competence, professional skills framework, portfolio assessment, degree accreditation standard, SFIA

1. Introduction

There is growing acceptance across many academic disciplines that graduates need more than content knowledge to succeed as practitioners in the "real world". Although knowledge enables graduates to know *what* particular activities entail, they need also to know how to do them *in the real world*, and – fundamentally – actually to *do* them, successfully and reproducibly. While completing such activities, they need also to demonstrate behavioural and professional characteristics appropriate for their discipline. The combination of knowledge (what and how), skills (do) and appropriate behaviours in a real-world context constitute *professional competence* [1].

Universities have long sought to broaden students' educational experience through work placements, internships or employer-based projects. For medicine, internships have been fundamental to the development of future professionals since the 19th Century [2]; in computing, internships and work placements are (necessarily) a more recent development. Internships and work placements complement the cognitive learning and content knowledge gained in the classroom with practical application of that knowledge in the real world, and also develop requisite professional behaviours. With suitable guidance, this should lead to the development of professional competence: "*the repeated, successful application of knowledge and skills to complete tasks, in a professional manner, and reproducibly over a period of time*" [1].

The challenge is how to *assess* students' achievements during an internship/ placement. Students are not managed by educators during placements/internships, but by workplace supervisors, whose primary interest is 'getting the work done'. Furthermore, every student's experience is unique, distinguished by the characteristics of their working environment, their tasks and level of support they are given by their supervisors. The only common factor is that they have worked in the real world. Students may not even succeed in all – or even most – of the tasks they are assigned.

Given such diverse experiences, a common practice can be for students simply to submit a reflective report on their experiences – but reflection is purely cognitive, so such reports can miss completely the potential value of a placement/internship.

Students can compile a portfolio recording their experiences: what they have done, how they did it, whether it worked and so on. The assessment then evaluates the portfolio for evidence of competence, rather than marking a post-hoc reflective report.

This paper presents an approach to assessing one aspect of competence, technical achievement, – the "*repeated, successful application of knowledge and skills to complete tasks*" – recorded in a portfolio, by mapping its content to a professional skills framework. "Competence" also requires the assessment of behavioural characteristics constituting "*a professional manner*"; [3] describes this in detail.

The design and implementation of the approach are discussed in Section 3, and its validation in Section4. Section 5 presents a worked example showing the feasibility of the approach. Section 6 concludes by reflecting on the process of developing and validating an approach to assessing a student portfolio by mapping it to a professional skills framework, and notes that these processes have general applicability.

2. Related Work

The idea of competence was formalized by the emergence of crafts guilds in Medieval Europe and the associated notion of apprenticeship [4]. Many professions, such as teaching [5], medicine [6] and law [7], have a well-developed understanding of competence. Competence combines personal qualities and characteristics with the technical knowledge, practical skills and experience that underpin job expertise.

2.1 Personal Competencies

The emergence of the "knowledge economy" in the final decade of the 20th century led to a growing perception of a need to prepare children better for employment in this new environment. Several projects evolved independently and proposed 21st Century Skills frameworks (C21 skills) in international, national, and regional contexts. Not only is there no single definition of what C21 skills should comprise, there is also no consensus on how to develop and, crucially, to assess C21 skills. We reserve the term, "*competencies*" for these generic, discipline-independent skills.

Several authors have tried to integrate the disparate C21 skills frameworks, with only limited success [8, 9]. Voogt and Roblin [10] compared eight popular frameworks, noting both considerable overlaps and significant differences. However, C21 skills transcended disciplines across a wide range of professions and levels of education, and so were relevant to students in both schools and higher education.

More recently, international organisations such as the OECD, UNESCO [11] and the European Union (EU) [12] have sought to develop harmonized sets of "key competencies". The EU suggests that these key competencies – although effectively personal – should embody knowledge, skills and attitudes, which is a small step towards professional competence. But there is still no advice on how to assess them.

2.2 Professional Competence

Professional competence, which we refer to as *competence*, comprises more than personal competencies in isolation. Competence is about being able and equipped to do something *in the real world*. ISO [1] describes competence as, *"the repeated, successful application of knowledge and skills to complete tasks, in a professional manner and reproducibly over a period of time"*. Thus, competence requires the ability to complete particular tasks, whilst demonstrating an appropriate "professional manner". [1] also defines skills (the *performance* of tasks) as the application of knowledge, and competence therefore requires repeated application of knowledge and (practical) skills. It follows that Bloom's classical taxonomy of educational objectives [13] is insufficient for the demonstration and assessment of professional competence. Even the change from concepts to verbs, and the substitution of "create" for "synthesis", in the updated Bloom's taxonomy [14] does not address the need to complete real-world tasks, in a real-world context, expected for competence in [1].

It is argued in [15] that, rather than Bloom's cognitive taxonomy, Simpson's psychomotor hierarchy [16] could provide a better model for the development and assessment of professional competence. Alternatively, in medical and allied fields, clinical competence is usually measured and assessed using Miller's hierarchy [17]. The essence of both hierarchies is that, to demonstrate the higher levels, repeated practice of tasks, leading to their repeated successful demonstration, is required. Miller's hierarchy is something of a hybrid, with the two "lower" levels being aligned with Bloom's cognitive taxonomy, building toward the two "higher" levels, where competence is demonstrated by the repeated application of knowledge and skill.

Furthermore, with Miller's hierarchy, clinical competence is assessed on tasks completed *in the real world* rather than in the classroom. This has implications for the kind of evidence needed to assess professional competence in other disciplines.

2.3 Competence Development in Computing Higher Education

Compared with medicine, teaching, and engineering, computing is a young discipline. Nevertheless, accreditation bodies, particularly in the UK and Europe, have long required graduates from accredited Computing degrees to demonstrate personal competencies – such as communication and collaboration – alongside content knowledge [18]. This is required also by UK regulatory frameworks for degrees [19].

In the US, the ACM and IEEE regularly update their curricular recommendations for computing degrees. The 2017 Information Technology report (IT2017) [20, 21] proposed a new focus for degrees on developing "competence", with competence defined as the intersection of knowledge, skills and "dispositions"; the term disposition capturing the, "socio-emotional skills, behaviours, and attitudes that characterize the inclination to carry out tasks and the sensitivity to know when and how to engage in those tasks" [22]. This shift in curriculum emphasis, from content knowledge to competence was consolidated in the overarching ACM/IEEE curricular recommendations in 2020 (CC2020) [23]. CC2020 retains the model of competence as knowledge ∩ skills ∩ dispositions, in the context of a task, identifying 11 specific dispositions to be developed by students in their degree. Curricular recommendations for Information Systems [24] and Data Science [25] have embraced this competence focus. However, the "context" proposed in this model for competence is simply a task – there is no requirement for a real-world context, and nor is there an expectation of *repeated successful application of knowledge, skills (and dispositions).*

Alongside this shift to a focus on "competence", there has been a growing interest in "competence-based learning" (CBL) [26]. The majority of approaches to CBL focus on personal competencies and skills rather than overall (professional) competence [27]. Typically, these approaches seek to combine the acquisition of knowledge and the development of cognitive skills with the development of "professional" behaviours and characteristics, but usually within the confines of the classroom [28]. Two prominent examples are the 2012 report of the National Research Council [29] and Fink's Significant Learning Model [30]. Each identifies intra- and inter-personal competencies that are valuable in the "real world", and can be developed in the educational domain, but neither indicates how even this limited version of competence should be assessed. Recent approaches to *authentic assessment* – that is, assessing tasks in as authentic a setting as is practical – such as [31, 32], and *problem-based learning* [33, 34] do suggest possible modalities for assessing this kind of competence within computing educational contexts.

It follows that, despite the emerging focus on "competence" for computing degree curricula, there is still a need to support the development of *real-world* competence, as defined in [1], and ways of assessing such competence. Assessing portfolios compiled by students on work placements offers a valuable opportunity in this regard.

2.4 Portfolios and Work-Based Learning

Internships and work placements have long been recognised as helping students to prepare for employment [35, 36]. Since competence requires the repeated, successful completion of tasks in the real world, it follows that competence *assessment* should be based on the real-world completion of multiple tasks; and students are most likely to have opportunities to complete multiple relevant tasks while undertaking an internship or on a work placement [37]. An appropriate medium for the collation of required evidence is an individual portfolio. The requirement is not for detailed evidence of how each particular task has been completed, but for evidence of a *pattern* of completion of similar tasks.

Portfolio development and management in educational contexts have been studied extensively. A simple portfolio might be a laboratory notebook, diary, or professional logbook, as used for engineers' continuing professional development (CPD) [38]. Digital "e-portfolios" [39] have gained popularity across higher education as both learning and assessment tools [40, 41]. Students undertaking an internship or placement should maintain a contemporaneous record of their achievements (and failures!) and interactions with colleagues in some form of e-portfolio, which would provide evidence enabling an assessment of their level of competence.

Issues that have arisen with portfolios in medical education [42], where their compilation is compulsory in support of continuous professional development (CPD), suggest that portfolio entries should focus on what has been achieved, not merely on what the student has attempted, or the events or activities in which they have participated. Portfolio content should be evaluative and reflective [43], since both (self)-evaluation and reflection are key "professional" attributes. For experience captured away from the learning environment, independent validation is needed of the portfolio contents, most likely by verification by a workplace supervisor.

2.5 Professional Skills Frameworks and Assessment

Employers have for many years articulated their expectations for competence, both for recruiting and internal staff management, and these expectations are often collated in sectoral competence frameworks. There are three established general competence frameworks for computing/IT: the Skills Framework for the Information Age (SFIA) [44], the European e-Competency Framework (e-CF) [45] and the Japanese i-competency dictionary (iCD) [46], alongside several more focused frameworks for areas such as data science and cybersecurity. Uniquely among these frameworks, SFIA was developed, and is maintained by its users, who are primarily employers.

Skills frameworks such as SFIA set out the skills and personal competencies important to employers. They specify technical activities and expectations for professional behaviours: both are required to be "competent". Furthermore, employer-led skills frameworks specify actionable and measurable descriptions of required activities and behaviours, rather than the abstract dispositions identified in CC2020.

SFIA has become the "global […] common language for skills and competencies for the digital world" [47]. It was selected for assessing portfolios because: it covers the whole of the computing/IT sector; behaviours are characterised separately from technical skills; so behaviours appropriate for new graduates can be identified [3].

SFIA is a two-dimensional matrix, with seven levels of responsibility orthogonal to 121 technical skills. The seven levels range from *Follow* (1), through *Apply* (3), to *Set Strategy* (7). At each level, a set of "responsibility characteristics" is grouped under five generic attributes of *autonomy*, *influence*, *complexity*, *knowledge* and *business skills*, all of which are needed alongside a technical skill to achieve competence [48].

At each level for which a technical skill is defined, SFIA sets out expectations for "competence" as between two and six generic activities. For a user to be "competent", they need to demonstrate successful completion of at least 85% of the activities (50%

for “partial competence”), multiple times over an extended period, and also demonstrate most of the responsibility characteristics for the relevant level.

The portfolio assessment approach presented in this paper uses SFIA as a reference framework against which the contents of a portfolio are benchmarked. SFIA Level 3 (apply) is the most appropriate level for a new graduate, or for students completing a work placement between their second and final years of study.

3. A Competence-Based Assessment Approach

This section presents an overview of the design and operation of a criterion-based assessment approach for *technical* competence, based on mapping the content of a student portfolio to the SFIA professional skills framework. Competence at a specific level in SFIA requires demonstration of both a skill and the corresponding responsibility characteristics, but we focus on assessing a portfolio for evidence demonstrating a single technical skill. Assessing evidence for the personal competencies corresponding to the responsibility requirements is described in [3].

Assessing technical competence is more challenging than assessing personal competencies because of the large number of technical skills from which students can choose. Since SFIA technical skills and responsibility characteristics are defined separately, they can be assessed separately. This paper offers a consistent mechanism for assessing the technical aspect of competence, whichever skill is chosen.

The criterion-based assessment approach is based on a marking rubric deployed by Bowers for a university work-based learning module. With five markers, portfolios were blind double-marked, and a sample audited to ensure consistency. The markers found the scheme straightforward, with no significant issues of consistency, and it led to an appropriate distribution of grades. It was reproducible, scalable, and, as references to portfolio entries used for assessment were recorded, it was auditable.[1]

The design, development and marking scheme of the approach are described in this section.[2] Validation criteria with corresponding test cases are presented in Section 4, and the approach is demonstrated, for a fictitious student portfolio, in Section 5.

3.1 Design, Development and Refinement

The assessment approach was developed as a component of a novel degree accreditation standard by the UK Institute of Coding [49] to address a perceived gap between the skills of computing graduates and those sought by employers. The development approach adopted was evolutionary prototyping [50], informed by expert review. Expert review of the increasingly complete draft standards was provided by an “accreditation panel”, which included academics and employers,

[1] The distributions of marks for the module were confidential and therefore not published, but Bowers is happy to discuss their general characteristics should you contact him directly.

[2] Technical reports on the development, validation and demonstration of the approach are available from https://institute-of-coding.github.io/accreditation-standard/

representatives from the relevant professional body (BCS, the Chartered Institute for IT) and – since the standard was to focus on professional computing and IT skills – skills professionals from the SFIA community. Leadership of the panel was shared between an academic and an industrial co-chair. The academic panel members – representing those who would implement curricula to meet the accreditation standard – were drawn from five UK universities; the employer members included a sole trader consultant, SME directors and senior staff from multinationals. The panel met monthly over two years. Proposals for refinements to the draft accreditation standard were circulated in advance of panel meetings, in which the proposals were subject to joint critical reviews. The critical reviews confirmed the thrust of the initial proposals and guided and modified incremental details as they were added.

The initial requirements, developed in workshops involving a wider audience of academics, employers and skills professionals, were for *a scalable, reliable means of assessing, from a student portfolio compiled during an extended period of work experience, and verified by their workplace supervisor, whether the student had demonstrated competence in one or more SFIA skills.* Formal assessment of SFIA competence had hitherto been conducted in-person by a handful of SFIA consultants; this was not scalable into an educational context. The required assessment approach was to retain the consultants' threshold for competence: *repeated successful completion of the bulk (85%) of the components of a skill at a particular SFIA level, and demonstration of most of the responsibility characteristics for that SFIA level.*

For the use of the scheme as part of a degree accreditation standard, any accredited degrees should also be shown to meet the appropriate regulatory frameworks [51].

As an example of the prototyping approach, the expert review of an early prototype of the scheme confirmed the initial design, including the weights for *technical achievement* and *reflection*. However, three additional requirements were added:

- Two new pieces of evidence were added to the "reflection" section – evidence of personal development, and of professional accountability;
- A threshold for "partial competence", was added;
- The assessment record was required to be traceable, for audit purposes.

3.2 The Portfolio of Evidence

The evidence to be assessed should be assembled in a portfolio; the format is irrelevant, beyond that it should be possible to reference individual portfolio entries (perhaps by date) so that an assessment can be reconstructed for audit. The portfolio should include (near) contemporaneous notes of the student's accomplishments (and failures), as well as in-context reflection by the student as a developing professional, highlighting any insights gained.

Given that competence is evidenced by the *repeated* completion of tasks i*n the real world*, rather than by merely participating in or attempting them, completion should be the focus of the majority of the entries: what the student has *done.* Furthermore, to allow for the required repetition, the portfolio should cover an extended period of real-world experience – not just a short "taster" period of "work experience".

It could be challenging to include detail in a portfolio; for example, a student rebuilding a lab-full of PCs would be unwise to include a separate build-log for each

PC. Nevertheless, some idea of volume (how many PCs, over what period, problems encountered, and challenges faced) helps to transform a *narrative* into *evidence*.

There could also be issues around commercial sensitivity, so students would be likely to need support to abstract the entries to maintain confidentiality.

Finally, an essential requirement would be that the evidence should be verified, by a workplace supervisor or senior colleague, confirming the stated achievements.

3.3 The Assessment Process

The first step of the (technical skill) assessment is to identify one SFIA skill against which to map the content of a portfolio. The 121 skills described in SFIA cover the whole spectrum of professional computing and IT, ranging from high-performance computing and data science, through information- and security-strategy, to service- and project-management. Not all skills are appropriate for every level of responsibility; only 81 are defined at level 3. Identifying an appropriate skill requires assessors to be sufficiently aware of the computing and IT profession so that they can identify, from an initial scan of the portfolio, the most appropriate skill; this should not be a problem in a university department of computing.

The assessment is criterion-based: the only judgement needed is whether or not a portfolio entry demonstrates completion of one (or more) component(s) of a skill.

Table 1. Assessment criteria for technical comptetence.

(a) **Technical Achievement Evidence** **Weight:16**

Item of evidence	*Quality criteria*
• Portfolio entries showing completion of components from a SFIA skill in a real-world environment	• There is more than one portfolio entry for at least 85% of the skill components
• Supervisor comments confirming the accuracy of the portfolio entries	• There is more than one portfolio entry for at least 50% of the skill components • Supervisor comments evaluate achievements against their context • Portfolio entries present evidence rather than assertion

(b) **Reflection Evidence** *may be in a separate document* **Weight: 9**

Item of evidence	*Quality criteria*
• Reflective ad-hoc portfolio entries for achievements across skill	• The style of portfolio entries is appropriately professional
• Portfolio identifies area(s) of personal development	• Reflection is based on evidence rather than assertion
• Portfolio identifies instances of personal/professional accountability for achievements	• Personal development claims supported by comparison of achievements across period of experience • Recognition of accountability related to (potentially) customer-facing achievements

3.4 Scoring – Technical Skill

Each skill description at a particular SFIA level is composed of between 2 and 5 sentences, the "components" of the skill. The contents of the portfolio are evaluated for evidence of successful application or completion of the components. The goal is to find multiple portfolio entries containing evidence of the application/completion of each skill component, together with appropriate reflection and insight.

The portfolio is assessed against a required set of items of evidence, and those items are measured further against a set of quality criteria. The items of evidence required and the quality criteria for *Technical Achievement* and *Reflection* are shown in Table 1. The scoring scheme for both aspects of competence is set out in Table 2.

The scores for each aspect are added together, weighted by the factor ('weight') set for each aspect. The weights are integral to the design of the scoring scheme, and reflect a professional perspective on the relative importance of the two aspects.

The scoring scheme measures how well a portfolio demonstrates technical competence in a skill. The overall score is measured against two thresholds: 85% for "competence", and 65% for "partial competence".

Table 2. Scoring scheme for Technical Achievement and Reflection evidence.

Evidence present	*Quality criteria satisfied*	*Score*
All items	100% (4)	4
	75% (3)	3
	50% (2)	2
	< 50% (0 or 1)	1
1 item missing	100% (4)	2
	> 50% (3)	1
2+ items missing	-	0

3.5 Scoring - Responsibility (Professional) Characteristics

To be *competent* in a skill at SFIA Level 3, a student's portfolio must both satisfy the requirements for one or more technical skills *and* provide evidence of the demonstration of the responsibility characteristics for SFIA Level 3.

A SFIA skill may have up to 5 or so components in its description, but there are 24 responsibility characteristics defined at SFIA Level 3, grouped under five broad attributes of *autonomy*, *influence*, *complexity*, *business skills* and *knowledge*. In [52], these characteristics are shown to be equivalent to a large proportion of C21 skills [10] and to the CC2020 dispositions [23].

As for technical skills, the approach maps portfolio entries to any characteristics that an entry shows the student has demonstrated. However, there is no requirement for "successful completion" – it is about demonstrating the characteristics repeatedly, so the assessment simply counts the portfolio entries for each characteristic.

The minimum number of portfolio entries required to demonstrate a characteristic, $I_{Min.}$ is defined, and a maximum so that the outcome cannot be distorted by continuous demonstration of just one or two characteristics. Thresholds are set for the number of characteristics that must be demonstrated and for the total number of mappings between portfolio items and characteristics. Both thresholds must be met for the portfolio to "demonstrate" the responsibility characteristics for SFIA level 3 [3].

4. Validation

The purpose of validating an assessment scheme is to ensure both that it leads to the required outcomes and that those required outcomes are appropriate. Hence, validation should first challenge the requirements, perhaps (as in this case) through expert review, to ensure that they are complete, and then specify test cases to be considered that ensure that the assessment satisfies the agreed requirements. Validation is neither an optional extra, nor is it completely separate from the design process – it is an essential aspect of that design process. Whilst this paper focusses on the assessment scheme for technical competence: a similar approach was required for the demonstration of SFIA responsibility characteristics.

4.2 Test Cases

The following test cases were identified.

- It should not be possible to achieve "competence" or "partial competence" without *verified* portfolio entries;
- At least basic reflection should be necessary to achieve "partial competence";
- "Competence" should in most cases correspond to the 85% threshold;
- It should not be possible to achieve "competence" without all three items of evidence for "reflection";
- It should be possible to achieve "partial competence" with a bare minimum of verified portfolio entries.

Evaluation of these test cases is illustrated by considering the first in detail.

It should not be possible to achieve "competence" or "partial competence" without verified portfolio entries:

- The maximum score available from *reflection* is 36. A further 29 is required to achieve "partial competence", and 49 for "competence".
- To gain at least 29 marks from the Achievement section, needs at least one item of evidence and all four quality attributes, or both items of evidence and at least two quality attributes (weighted score of 32 in either case).
- Zero portfolio entries imply zero confirming comments, giving a score of zero.
- Absence of supervisor's confirmation (evidence) implies absence of the third quality criterion (contextualising experience), giving a weighted score of 16.

Thus, however good the portfolio itself, in the absence of supervisor's confirmation, it is not possible to score sufficiently to achieve competence or partial competence.

A similar approach was applied to each test case, leading to overall outcomes of:

- An unverified portfolio is insufficient to achieve either "competence" or "partial competence".

- It is possible to achieve "partial competence" with a minimal validated portfolio and at least basic reflection.
- To achieve "competence", the portfolio must be verified, and the reflection component must demonstrate basic reflection, recognition of personal development and appreciation of personal/professional responsibility.
- Covering 85% of the components of a skill does not on its own guarantee "competence" or even "partial competence".

4.3 Comments on Validation

The outcomes from the test cases are slightly stricter than the then-current approach of focusing purely on completion of the components of a technical skill. The outcomes were deemed appropriate, and were endorsed by the expert panel.

It should be noted that altering the balance of marks (weights) between "technical achievement" and "reflection" could change the test case outcomes significantly. Any such re-balancing should be accompanied by reworking of the thresholds to ensure the desired outcomes are met.

A similar exercise was completed for the demonstration of SFIA responsibility characteristics which, given the extreme variety of student placement environments, would be the only common element for all students. That validation, however, is somewhat more straightforward, since the algorithm involved is simpler.

5. A Worked Example

Jo Garcia's portfolio, shown in the Appendix, is fictitious, but based on the kind of student experience observed when supervising work placement students. For brevity, the portfolio is somewhat shorter than would be expected for a realistic portfolio from an extended work placement, but it is sufficient to demonstrate the process.

Garcia's portfolio has a high proportion of data modelling and design activities, for which an appropriate SFIA skill would be "Data Modelling and Design". At SFIA Level 3, this skill has three components, shown in Table 3. Hence, the quality criteria "more than 50%" and "more than 85%" refer to 2 and 3 components, respectively.

5.1 Score for Technical Achievement

Entries from the portfolio are considered in turn to determine whether they provide evidence of *successful completion* of one or more skill components; links to relevant entries are recorded as in Table 3. For example, the entry for 30th September:

> *I've reverse engineered a model for one Small Fry database – customers – but it leaves several questions. For example, Whale Sports allows people to be members of more than one gym; but, in Small Fry, a person who is a member of two branches is treated as two different people. This became clear when I compared the two data models and found that "customer_id" in Whale Sports's database corresponded to*

the compound value (pn, bc) in Small Fry's database. After talking to the IT guys from Small Fry who had stayed after the merger, I found that "pn" stood for "person number" and "bc" was "branch code" ...

describes the application of "*standard data modelling ... techniques ... understanding of requirements*", indicating completion of activities for the first component.

Further examination of the portfolio locates entries on 11th Nov and 2nd Dec for the first component, 13th Sep, 14th Oct and 18th Nov for the second, and 14th Oct, 11th Nov and 2nd Dec for the third. The entry on 2nd Dec shows successful engagement across the skill description, but there are sufficient entries already for the second component.

It is important that the entries identified demonstrate completion of the bulk of at least one component of the skill description. Furthermore, they should describe separate achievements, and not small increments on achievements counted already.

Table 3. Recording table for *Data modelling and design, Level 3*

Component	*Entry 1*	*Entry 2*	*Entry 3*
Applies standard data modelling and design techniques based upon a detailed understanding of requirements.	30 Sep	11 Nov	02 Dec
Establishes, modifies and maintains data structures and associated components.	13 Sep	14 Oct	18 Nov
Communicates the details of data structures and associated components to others using the data structures and associated components.	14 Oct	11 Nov	02 Dec

There are brief, but comprehensive, supervisor's comments accompanying Garcia's portfolio in the Appendix. These are needed alongside the completed map of achievements to generate a score for technical achievement.

There are multiple entries for each component of the skill. Supervisor comments verify the accuracy of the entries. So, both items of evidence (Table 1(a)) are present.

Since there are multiple items of evidence for each component, the first two quality criteria are satisfied – more than 85% of the components, and also more than 50%. The portfolio entries show the kind of evidence possible in a portfolio – such as the discussion of the ambiguities between databases (30th Sep), and the loyalty scheme (11th Nov). This is "evidence", because it provides explicit examples of the challenges encountered. Other examples might be the number of classes or entity types designed, or the volume of data imported: anything that shows that achievements are real. It is unrealistic to expect "real" evidence, such as entity models or designs – such things may be both large and confidential!

The supervisor comments emphasize that the achievements were particularly challenging, and that the company is very happy with the students' contribution.

Summarizing, for the items required in Table 1(a)

- Portfolio entries describe successful completion of components of the skill;
- These entries are confirmed by the supervisor;
- The entries cover more than 85% (and therefore 50%) of the components;
- The entries include realistic evidence rather than just assertion;
- And the supervisor has contextualised the achievements and their challenges.

Thus, both items of evidence are present, and all four quality criteria satisfied. This gives an unweighted score for technical achievement of 4.

5.2 Score for Reflection

The portfolio contains reflective entries (e.g., 13th Sep, 11th Nov), in addition to the reflection at the end. Hence, for Table 1(b), the first item of evidence is present.

There are entries (e.g. 23rd Sep) that identify personal development opportunities, and the value of that development is noted in the entry for 11th Nov.

The reflection shows that the student was aware how important the database merger project was to the company; so, "professional accountability" is also present.

For the quality criteria in Table 1(b), it would be reasonable to deem the first two to be satisfied. Personal development opportunities are identified, and there is mention of their impact; however, even the overall reflection is focused on internal company requirements, rather than on the potential impact on customers. Thus, the second and third quality criteria are not satisfied for this portfolio.

From the scoring scheme, this gives an unweighted score for "reflection" of 3.

5.3 Overall Outcome

Using the weights in Table 1, (16 and 9), the total score for technical skill is $4 \times 16 + 3 \times 9$, giving 91. This exceeds the threshold for "competence", provided that Garcia has also demonstrated the SFIA Level 3 responsibility characteristics.

There is insufficient space in this paper to demonstrate the scoring for responsibility characteristics, but an exposition can be found in [3]. In summary, with I_{Min} set to 2, Garcia's portfolio meets the required thresholds easily.

Having achieved the competence threshold and demonstrated the responsibility characteristics, Garcia is "competent" in data modelling and design at SFIA Level 3.

6. Discussion

The assessment approach described in this paper addresses the challenge that every student on placement is likely to work in a different environment and complete different tasks. Choosing a professional skills framework that covers the full range of such environments enables appropriate expectations to be set for students regardless of their working context. The assessors do not need to have a deep professional knowledge of every possible working environment, but merely sufficient awareness of the sector to understand the task descriptions in the skills framework.

A key issue is the quality of evidence possible in a portfolio. An assessor should not need to scan detailed data such as build reports or work tickets; so students need to provide sufficient detail – subject to any confidentiality requirements of their employer – that the achievements recorded in the portfolio are convincing. For example, quantifying achievements – how many, how large, how often – and commenting on exceptions or challenges will help. Since "competence" requires repeated successful *completion* of tasks, rather than merely assisting or participating, it follows that the portfolio entries should emphasize this. Crucial to the value of the evidence is verification by the workplace supervisor, who will be able to spot over-optimistic claims "supported" by such a level of detail.

The assessment scheme we have presented allows for one of three outcomes – *competent*, *partially competent* or *not yet either*. The information collated to reach this judgement can be used in formative feedback to students, as it indicates where they could develop their skills and competence further.

Developing a scheme for a different discipline would require both an appropriate skills framework and a clear idea of the evidence needed to demonstrate competence. The skills framework should set out the activities expected of a competent person at the appropriate level; the evidence expectations should be agreed with discipline professionals. Whether a distinction between technical achievement and reflection, presented in this paper, would be appropriate for another discipline should be apparent from the evidence expectations. It may also be possible to simplify the "evidence items" and "quality criteria", but the more the scheme is simplified, the greater the level of professional expertise needed by assessors.

Whatever the scheme's design, test cases and validation are essential to ensure both fitness for purpose and fitness for use.

7. Conclusions

We have demonstrated that it is possible to develop a criterion-based assessment scheme for mapping a student portfolio to a skills / competence framework, and to score the mapping to determine the student's level of competence. This addresses a major challenge for the assessment of student achievements during a work placement. There is no *a priori* reason why a similar approach should not be adopted for a discipline other than computing, or indeed for a different level of education, such as high school. Whatever the target domain, the decisions involved in developing such a scheme and the need for comprehensive testing will be essentially the same.

One observation that led to the formation of the Institute of Coding [49] was that the current higher education system appeared not to be serving all computing students well. A particular issue was that purely academic curricula seemed not to prepare all students sufficiently for employment, and one possible interpretation of this was that some students might be better at *doing* work-related tasks that *thinking* (or writing) *about* them. Building on the observation in [53], *inter alia*, that the expectations of employers providing student placements may differ from those of the institution – and indeed of the students – this was the justification for the development of the IoC accreditation standard, focusing on a skills framework, in which the portfolio assessment presented in this paper is a key component. This suggests several avenues for future work, including measuring the extent to which outcomes resulting from this assessment scheme would differ from those resulting from a more traditional reflective placement report and, more broadly, whether portfolio assessment outcomes would differ significantly from those for traditional, "academic" modules [54]. In both cases, the crucial issue for exploration would be the underlying reasons for any such differences.

Any portfolio-submission system will be vulnerable to the creation of fraudulent (as distinct from linguistically improved) portfolios using generative AI [55]. On the one hand, for the scheme described in this paper, the risk may be significant, since the target is well-defined by the assessment rubric (Tables 1 and 2), and the SFIA skills are openly available online. The primary defences are the requirements for supervisor confirmation and contextualization; but exploration of the issues surrounding the authentication of such verification suggests a further area for investigation.

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Appendix: Extracts from Fictional Portfolio for Jo Garcia

6th September My placement employer, Whale Sports, operates a large national chain of gyms. In the weeks before my placement, they had completed the purchase of a much smaller local chain, Small Fry Fitness. My role is to merge Small Fry's records into Whale Sport's main customer, financial and operations databases.

I'm expecting to draw on my second year data management module – it should be quite straightforward, as both companies use standard relational database software. So, it should just be a question of writing a few scripts to transfer the data.

My initial estimate is that this should take no more than a week or two.

Back to data recording table

13th September This is not going to be as simple as I expected. The database structures for Small Fry are completely different from those of Whale Sports. They claim to serve the same purposes, with similar scope and operations. But there are so many differences – ranging from different field names for the same things to completely different sets of foreign keys.

What's more, the two databases run on different DBMSs which, although they both use SQL, seem to do quite a lot of things – particularly scripts! - in different ways. This will just make the job even more challenging…!

Back to data recording table

20th September My supervisor told me that I was supposed to understand databases, so why couldn't I just sort it all out? Fortunately, my university tutor reminded me of the data modelling we did in the data management (DM) module. So, I'm going to compare the data models, and match the structures rather than the field names.

Back to data recording table

23rd September At least there are full specs – including data models! – for Whale Sports's database. They use an unfamiliar notation – but, as we were taught in the DM module, the basic concepts represented in all notations are essentially the same.

Small Fry, however, is more of a problem. There's not even a data dictionary. Nor is there any security on any of the Small Fry databases - even for customer data! That seems odd, and won't be tolerated in Whale Sports. I'll have to reverse-engineer the data structures from Small Fry's three separate databases and then ensure that the imported data "fits" the Whale Sports security schema.

I also need to understand better the idiosyncrasies of both DBMSs, so I've found some online learning material. I'm focusing on the Small Fry system, as that has virtually no documentation – so I'll need to work out what's going on from the code!

So much for a simple job of a few SQL scripts…

Back to data recording table

30th September I've reverse engineered a model for one Small Fry database – customers – but it raises several questions. For example, Whale Sports allows people to be members of more than one gym; but, in Small Fry, someone who is a member of two branches is treated as two different people. When I compared the two data models, I found that "customer_id" in Whale Sports's database corresponded to the compound value (pn, bc) in Small Fry's database. After talking to the IT guys from Small Fry who had stayed after the merger, I found that "pn" stood for "person number" and "bc" was "branch code"…

I need now to list all the ambiguities and oddities in the data model for Small Fry, and spend some time with their former IT guys…

Back to data recording table

14th October My supervisor is really impressed that I've managed to resolve the differences between the two customer databases, but she's getting worried about how long it is taking, as the deadline to have the merged systems running is January. And we've not even started on the applications around Small Fry's customer database!

She's asked me to brief a developer – Phil – on Small Fry's database, so that he can export, clean and import the data into Whale Sport's main database.

She's also given me someone to help – another placement student, Andrea. She wants me to brief Andrea on the approach I took for the customer database, so that she can tackle the financial database while I focus on the operations database. Her parting comment was that the operations database was likely to be the trickiest, as it is in the way they run their operations that companies seek to distinguish themselves…

Back to data recording table

11th November Phil has more or less completed the transfer of the customer data, and has even replicated most of Small Fry's distinctive customer functionality – such as the loyalty scheme – within Whale Sports's systems. The loyalty scheme was a bit of a challenge, as Whale Sports had nothing like it, and the scheme's use of personal data now has to be consistent with Whale Sports's data protection expectations. Once Phil and I really understood what it was doing, and what data security we needed, we checked our understanding with some of the Small Fry managers who now work for Whale Sports. We presented our findings to a meeting of Business Managers; who really liked the idea of the scheme, and plan to use it across Whale Sports.

I would never have understood Small Fry's loyalty scheme if I hadn't been able to follow the code. It's a good job I learned about their DBMS a couple of months ago!

Andrea has also made good progress. Having two people working on different aspects of the problem has made it much easier to check our understanding, to validate each other's assumptions, and review our respective models. It works better, too, when we are meeting with the ex-Small Fry staff – it seems to run much more positively with two of us talking with the three or four guys who used to run their IT.

Back to data recording table

18th November We've completed formal model reviews with my supervisor for the second and third data models and the additions to the security schemas, and they have all been signed off. Andrea and I are now working with Phil to get the data transferred by the end of this month – so that there is plenty of time for testing.
Back to data recording table
2nd December The data transfer and merge project has been signed off as complete.

My supervisor seems very happy – in fact, she has asked Andrea and me to trawl through the data models and specs for the main Whale Sports database, to find any anomalies or odd assumptions. She's also asked me to present a talk to the development team on how I approached the modelling, so that other people can do the job after Andrea and I go back to University.
Back to data recording table
Reflection on placement portfolio One thing that kept striking me was how much of the boring detail in my university modules was useful. I hadn't paid much attention to data modelling – it's easy to prototype a database, so there didn't seem any point in "designing" it…. And, until I encountered a "real" database holding personal data, I never appreciated the importance of security schemas and data protection policies.

In my placement, I found time and again that I was using aspects of that modelling to resolve issues. What's more, it was because I could do so that my supervisor was impressed – particularly when I found some howlers in Whale Sport's main systems!

It was an eye-opener working with real colleagues in a team, to achieve something important. I suppose I was the team leader, but it was very collaborative – what really mattered was that we documented decisions, rather than any one being "in charge".

It was quite scary to realize that the work I was leading really mattered to Whale Sports. If we hadn't got it right, their investment in Small Fry could have fallen over!
Back to data recording table
Supervisor comments Jo came to us as an "ordinary" placement student, to work in the data migration team. We had just acquired a small company, Small Fry Fitness, and I asked Jo to transfer Small Fry's data into our corporate database.

Their commentary shows that they were optimistic about how simple it would be. I knew that there would be problems, but, frankly, I had no idea how challenging it would turn out to be. Jo rose to the challenge superbly. They took it upon themself to learn about the systems involved, and now understand more about the Small Fry systems than their colleagues who used to run Small Fry's IT department!

Their work was so thoroughly professional and well-documented that it became the team benchmark. They even reminded us of our responsibilities regarding personal data - adding three apparently unsecured databases from Small Fry gave us a good opportunity to revisit our internal standards.

As they comment, I asked Jo to give a seminar, with the two other members of their team, so that we would retain at least some of their knowledge after they left.

I am very happy to confirm the content and detail of Jo's portfolio. If anything, they sell themself short – this really was a difficult project. Moreover, they hardly mention how effective they became as a mentor and team leader to Andrea and Phil.
Back to data recording table