Motivation and Strategies for Effective Inclusion of Cloud Solution Provider Certifications in Computing Curricula

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ABSTRACT

A series of Working Groups has met at previous ITiCSE conferences to explore ways of incorporating cloud computing into courses and curricula, including mapping industry job skills to knowledge areas and those areas to student learning objectives. The importance of industry-standard learning content and certification, produced by cloud vendors and others, was apparent throughout this work.

This Working Group has focused on the role of certification within cloud computing curricula, from the viewpoints of a range of stakeholders: students, graduates, institutions, vendors and other certification providers; and employers, with the aim to provide insights and recommendations for educators who are considering whether to integrate cloud certifications into their courses. We reviewed the landscape of certifications provided by the most widely recognised cloud vendors, based on publicly available information and the knowledge embedded within the Working Group through the inclusion of vendor representatives in the membership. An overview is provided of the scope of available certifications and their mapping to our knowledge areas and learning outcomes, and of the influence that standards have or should have on learning design. We then explored the perspectives of stakeholders, through surveys of students on courses with a cloud computing element and of employers who have employed graduates of those courses, drawing conclusions on the awareness of certifications and specific vendors within each of those stakeholder groups, and on differences between the groups on the perceived importance of certifications for employability. Finally we explored approaches to integrating certification in academic cloud curricula, and challenges involved in doing so, through thematic analysis of in-depth interviews with a range of educators who have experience of doing so successfully. A set of recommendations for educators is presented, based on the findings of the Working Group's activities.

CCS CONCEPTS

• **Applied computing** → **Education**; • **Computer systems organization** → *Cloud computing*.

KEYWORDS

Curriculum, cloud computing, cloud certification, cloud objectives, cloud skills

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1 INTRODUCTION

The integration of industry-standard certifications into information technology (IT) curricula in formal education is far from being new [69]. It is, however, a topic of continuing importance. Recent research has focused on the alignment of learning objectives, job-specific skills, and the ability of employees to remain current with ever evolving technologies [47]. Moreover, the growth of micro-credentials, offered by a range of parties including technology vendors, frameworks bodies, independent learning platforms and universities themselves, has expanded the options for learners to demonstrate specific knowledge and skills that employers currently want [72].

Within the broad domain of IT, cloud computing is a high demand, rapidly evolving job skill need. Employers want assurance that selected candidates for cloud-related job roles have some foundational knowledge and maintain more advanced skills. Therefore, certifications related to cloud technology are an increasing point of discourse in higher education curricula to meet job-skill demands [18]. The implementation of cloud computing certifications in curricula has been difficult or challenging at best. One issue is that the rapid evolution of cloud computing from its early inception has and is changing annually [78, 79]. We posit this has led to a shortage of formal industry standards in comparison to fields such as cybersecurity. There is therefore an associated reliance on public/private providers to define what is required by industry from their viewpoint, hence this working group.

In a series of previous Working Groups we focused on aspects of inclusion of cloud computing learning materials within curricula. Starting by mapping out a comprehensive set of knowledge areas (KAs) and learning objectives (LOs), then developing exemplar syllabi and investigating ways of disseminating and validating the outcomes [2, 19, 20, 63]. Evident from this work, certifications can be an important driver in the design of courses which aim to provide their graduates with industry-relevant skills. A next step was then to review the relationship between cloud computing certifications and academic curricula. This Working Group has investigated the perceived value of certification to learners and employers along with current and emerging practice in the delivery of certifications in an academic context. We provide guidance on best practice for academics who are designing cloud computing courses. Our previously proposed KAs and LOs will provide a frame of reference for this and can be viewed in Appendix A.

The report is structured as follows:

- Sections 2 and 3 describe and discuss terminology, related work in certification in IT, and related work currently being done in implementing certifications in cloud computing courses.
- Section 4 discusses a set of stakeholders whose actions may be connected to industry certifications and academic qualifications in cloud computing. Our work is aligned with these stakeholders and their perceptions and experiences.
- Section 5 discusses the nature of certification in relation to industry's needs and industry standards, certifications provided by the most widely recognised vendors as evidenced elsewhere in this report, and the associated support available for educators.
- Section 6 discusses standards, the quality management procedures implemented by vendor certification suppliers and mapped to quality controls as defined by international standards groups.
- Sections 7, 8 and 9 explore the perceptions and experiences of stakeholders and the implications of these for inclusion of certifications in cloud computing curricula.
- Sections 10 and 11 discuss recommendations for educators and conclusions.

2 TERMINOLOGY

At this time, there is still quite a variety of definitions and expectations around what many of the terms in this field actually mean [44, 80]. For the purposes and clarity of this paper, we will use:

Credential: General term for a qualification or achievement

Certification: A process of verification of learning on a specific body of knowledge, which involves an examination.

Certificate: A vendor-provided credential provided to a participant that involves specified body of content, level, and examination passed.

Micro-certification: A vendor-provided credential that includes interactivity and a form of final assessment.

Stackable credentials: A sequence of credentials that are provided independently and individually and can be accumulated over time towards a learning pathway or a career specification.

Learning paths: A range of learning activities taken by an individual that may or may not lead to a credential.

Skill badge: A confirmation of progress in a learning pathway, which may or may not involve examination.

Cloud Solution Provider (CSP): A company which provides public cloud services, and usually provides associated certifications. Also commonly referred to as a vendor.

This paper is primarily focused on the use of certification and the aim of implementing certification courses and exams in academic courses. However, the other types of credentials listed above will be discussed and compared throughout the paper.

3 RELATED WORK

The relationship between industry certification and academic degrees has been an active area of discussion and debate for many years in IT disciplines, with questions raised on the relative importance of these in employability, the beneficiaries of certification within academic settings and a distinction between training and education [9, 35, 69, 71]. The body of literature extends to a wide range of disciplines in which professional certification is significant for employment, for example finance [46]. In this review of related work we limit our scope to evidence within the following areas: certifications and curricula in cloud computing specifically; recent work within the broader context of IT certification to capture current thinking and trends for employability of graduates in the industry; and coverage of issues that are specifically of interest to this working group, for example strategies for embedding certifications with academic delivery and assessment.

The importance of cloud computing certifications reflects a clear deficit of cloud skills in industry [10] with vendors such as Google

[24] and Microsoft [75] offering certification courses aligned to high-growth job areas. With the rapid development of new cloud-based technologies and applications, universities are designing new degrees in cloud computing that are directly supported by industry. As an example Flood and Hall [18] disseminated their experiences of running a BSc program in Cloud Computing at a UK university in partnership with Amazon Web Services (AWS). Interestingly, one of the main selling points of the program is authentic assessment through access to the AWS platform. However, the AWS cloud certifications themselves are not embedded in the curriculum. Additional authors report on the integration of cloud vendor resources in the curriculum, which is a necessary precursor for embedding certifications, but do not consider certifications in detail [15, 33, 74]. While the focus of much of the literature is on AWS, a study by Meyer and Billionière [42] compare the cloud computing learning offerings of AWS, Microsoft and IBM.

Additional work on the outcomes of integrating an Amazon Web Services (AWS) certification into an academic IT course has also been reported by Podeschi and DeBo [67]. The study conducted offers broad insight into the challenges of integrating cloud computing and vendor certification into an academic course, highlighting educator expertise as a particular constraint. Another headline challenge from the work was the inability of educators to have access and oversight of student project spaces on the vendor platform. This can result in support being a labour-intensive one-to-one process and makes troubleshooting particularly cumbersome. In this case, shared access to student projects on the cloud platform is a useful tool for educators to optimise support and something that is touched on later in this paper.

Soltys [76] reports on "cloudifying the curriculum" with AWS as an initiative across a range of subjects within an institution, including computer science, business and mathematics, demonstrating the range of applicability of cloud computing skills. The importance of working in partnership with a vendor such as AWS is emphasised, and a number of key issues are discussed, including instructor training and certification and dealing with curriculum changes. The focus on certification is limited to classes offered to working professionals as a service to the community, demonstrating that through certifications academic institutions can reach beyond the traditional student types.

Such vendors certifications and micro-credentials have gained popularity as diversified educational pathways for keeping skills current [17, 72]. Major cloud providers including Google Cloud [25], the aforementioned Amazon Web Services [8], Microsoft Azure [1], and IBM [38] together provide more than 100 different certificate programs and learning pathways.

In other recent work, Valceschini et al. [77] found that certifications play an essential role in information technology employment decisions, reinforcing the idea that graduate outcomes are improved if students not only graduate with their degree but can do so whilst achieving aligned certifications. This echoes earlier work by Bartlett et al., [9] studied the value of industry certifications in employment of IT professionals. Their findings suggest differences in perspectives of employees with and without credentials on the effect of credentials on the recruitment process.

Ouh and Shim [62] have recently studied trends in IT certifications through analysis of job postings and found that while certifications in areas including project management and software engineering are in high demand, cloud computing, specifically AWS, represents two of the top three certifications. This paper then presents case studies of the authors' own experiences in integrating certification into their courses, and discuss a range of practical issues encountered, including logistics and exam scheduling, concept mapping between academic outcomes and certification and alternative assessments where students have already taken the certifications.

Other work demonstrated that students of Information Systems type degree programs benefit from earning suitably aligned certifications [23]. Gomillion's work [23] framed the benefit to students as being partly down to messaging from potential employers that certification is valuable in the workplace and by default will give graduates an advantage in the job market. Part of this working group will also focus on the employee stakeholder perspective and their relationship to education institutions.

Cybersecurity is an area, like cloud computing, where there is evidence of growing interest in professional certifications, and it is apparent that while degrees are still in high demand for entry level jobs, employers are increasingly looking to augment their requirements with certifications [43, 48].

A concern for educators pursuing the integration of certification in their academic programs is the assessment approach. Saleem et al. discuss the incorporation of IT certification performance into academic grades, and provide a useful set of recommendations on how to approach this [73]. Typical academic assessments comprise coursework and written exams designed by the educator, whilst certification exams are externally managed by the vendor. While some certification exams are purely knowledge based, many are also competency based with practical performance measured. Work in this space by Munson [61] shines a light on the specific performance-based approaches used by Microsoft and other vendors, and is critical for educators to fully understand before offering such competency based certification exams to their students. While the effectiveness of some of these learning paths are not agreed upon [11], improved employment outcomes are associated with getting certified [22].

Prebil and McCarthy [68] describe embedding certifications into degree programs as an "attractive by poorly understood institutional strategy", and report a wide-ranging study of the associated goals and barriers. They present three strategies which focus on maintaining data on in-demand certifications, the funding model and tracking employment outcomes.

Finally, an extensive set of articles has recently been published which provide a wide ranging survey of the state of credential innovations, trends and issues, and models and strategies, including the alignment of undergraduate curricula to industry credentials and the implementation of micro-credentials [36].

The related work discussed in this section clearly highlights that integrating vendor certifications as part of academic programs is a non-trivial undertaking. Full integration will face significant internal policy and regulatory issues that differs from one institution to the next and will likely involve program and module changes at a structural level. It is envisaged the working group outcomes

Stakeholders
Student in Higher Education
Graduate
Employee
Jobseeker
Employer
Recruiter
Cloud vendor
Industry standards body
Higher Education institution
Educator
Products
Learning resources
Certification
Academic course
Academic credits
Credential
Standard

Table 1: Stakeholders and products

presented in this paper will provide educators with robust guidance and insights they can adopt to integrate certifications in their programs.

4 STAKEHOLDERS

There is a range of stakeholders who have an interest in certification and qualifications in cloud computing. This work aims to explore perceptions and/or practice of three groups of stakeholders: candidates who take certification exams; persons involved in hiring decisions; and academics delivering cloud computing courses. In order to understand the perspectives of these stakeholder groups we aim initially to define models which encompasses stakeholders, the products that they provide and/or consume, the transitions that the products may enable for them. These models provide a basis for the design of our instruments in order that these allow us to explore the dimensions within these perspectives that are relevant to the study participants.

A stakeholder in each model defines a role held by an individual or organization at a point in time, rather than the individual or organisation themselves. One individual may at a certain point in their career occupy more than one of these roles, and may transition from one role to another. We also identify products related to learning which will be experienced in different ways by each of the stakeholders. To assist with identifying roles and products, the stakeholders and products are listed in Table 1.

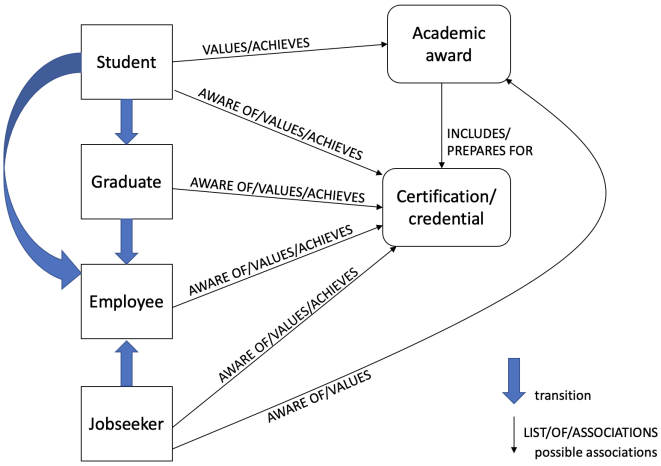
We can model the perspective of each stakeholder type in terms of:

- the **transitions** that they aspire to make
- the **associations** they make with products or other stakeholders

A transition may reflect a change of role or status, for example from student to graduate. Such a transition may be influenced by association with a product - in this example the transition is specifically enabled by the achievement and accumulation of academic credit to a specified value.

Here we will split the stakeholders into sub-groups in order to model these transitions and associations. We can identify a subgroup of stakeholders by considering those with an interest in achieving certification: students, graduates, employees and jobseekers. Note again that an individual may be in more that one of these roles simultaneously. Figure 1 shows a model of the perspective of this sub-group of certification candidates. The jobseeker role represents a person who is seeking employment and does not have any degree level academic qualifications. The transitions represent changes of role that are influenced by the achievement of one or more products. It is possible that a jobseeker may transition to a student, but this transition is not included in the model as it does not depend on the achievement of an award or certification (although in some cases, these might be used as evidence for advanced entry to an academic program). The associations represent the ways in which the stakeholder may experience the product, for example being aware of it, perceiving it as having value to them, and actually achieving it. Based on this, we are interested not only in the achievement of certification but also awareness and perceptions.

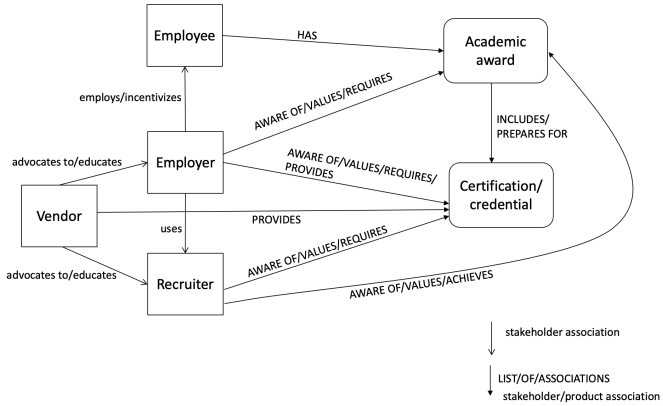
Figure 1: Perspectives - certification candidates



We also identify a sub-group of stakeholders who are associated with candidates who are employed or transitioning to being employees. Figure 2 shows a model of the perspective of this subgroup. Employers and recruiters we take to represent somewhat different roles: employer represents a technical manager or team which the employer works directly for; while recruiter represents a non-technical person who may or may not be within the same company as the employer. The recruiter is involved in the hiring process and may make decisions that filter candidates on the basis of qualifications and certifications but does not make the final hiring decision. The vendors play an significant role here as, in addition to providing the certification framework associated with their platform, they have an interest in working with employers and recruiters to advocate for the importance and value of their own

certification. This may involve a process of educating those stakeholders on the detail of their certification products. Employers and recruiters may be aware of specific certifications and perceive them to be of value when achieved by existing or prospective employees. Employers may incentivize employees to achieve certification, and may provide specific learning paths developed with their organisation, which may or may not be based on vendor learning products.

Figure 2: Perspectives - employment



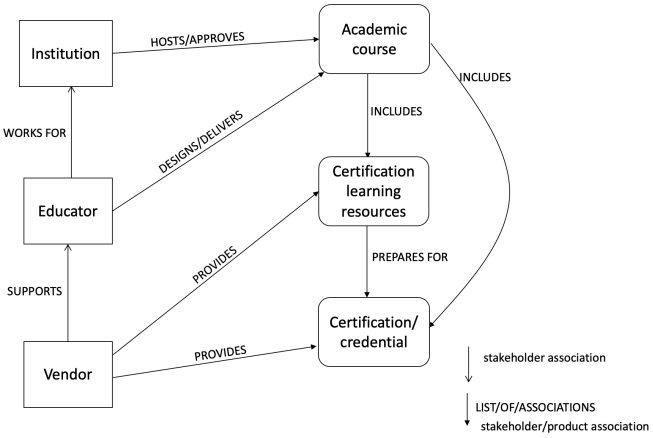
The final sub-group that we model is related to the implementation of certifications within an academic environment. Figure 3 shows a model of the perspective of this sub-group. Students are key stakeholders here, before they transition to becoming graduates. However, it is possible for an individual who is a student to also be an employee if they are studying part-time or on a work-based learning program. We distinguish between an institution and an educator. The latter is involved with designing and delivering a course or program, while the institution, in addition to hosting this may also provide positive direction through policy and vision, but may also introduce constraints through requirement to adhere to assessment regulations and process for approving programs. Vendors play a highly significant role in making it possible to include cloud certifications in the academic context, including provision of resources, cloud credit, as well as in advocating for certification inclusion.

Understanding the set of stakeholders in our model allows us to define the perspectives that we need to explore, to guide the questions that we ask in order to do so and to frame the discussion. This working group includes stakeholders from two of these groups: representatives of two of the major cloud vendors; and educators with an interest in cloud computing, and their input is valuable in exploring these perspectives.

5 CERTIFICATIONS LANDSCAPE

This section presents an overview of the certification landscape most relevant to educators. The information here has been gathered from public sources such as vendor websites, and also from the knowledge of our vendor and educator representatives, and

Figure 3: Perspectives - academic



has also been informed by the outcomes of our previous working groups. We focus on AWS, Google Cloud, and Azure certification. Our selection of the three aforementioned vendors was done based on existing working group members and their currently implemented vendor certifications. As a working group we acknowledge there are additional cloud vendors that were not selected due to lack of participating members utilizing the additional cloud vendor resources. Our initial selection is in line with the perceived importance of vendors suggested by our initial survey results discussed in section 8. We should emphasise that for many of the certifications within this landscape cloud is the underlying context or enabler for techniques and technologies, such as Artificial Intelligence, and is therefore relevant not just in courses which explicitly reference cloud in their title.

The certifications offered by the leading Cloud Solution Providers (CSPs) are becoming increasingly important as the business data and workflows migrate to the public cloud platforms. The services offered by the CSPs are quite similar in terms of addressing the needs of the industry. However, each cloud provider has their own strengths, in terms of the range, adoption, and maturity of the offered services etc. In addition to the certifications offered by the major CSPs, some certifications are offered to validate cloud skills with a vendor-neutral approach, such as, CompTIA Cloud+ certification [14].

Certifications usually require payment of an associated fee and passing a timed exam in accordance with the required qualifying standard. However, variations exist as some certifications might be offered for free, or at a concessionary price. The certifications are valid for a limited time and have to be renewed usually after one or two years. This is inevitable as the fast pace of technology adoption and provision by CSPs is much faster, and newer and better services are being released all the time. Any higher education institutions adopting the certification material as a standalone module or embedded as a training unit for a teaching program, will expect that their students have access to the latest developments and teaching material.

The job market currently requires database, data analytics, networking and security skills within the context of cloud applications. Due to the cost-effective cloud storage and computation resources, the business applications migration to cloud platforms is taking place. The knowledge and experience of the cloud platforms and services has therefore assumed added importance. This is reflected in the range of knowledge areas for certifications related to cloud platforms, which include fundamental cloud computing knowledge and also certifications in more specific areas such as Artificial Intelligence.

The cloud certifications are targeted at both entry and advanced level jobs, and validate the skills and knowledge not only of the relevant cloud services but also the related technology area, such as databases, and machine learning. In general, the certifications have addressed the job demands by creating vertical threads of skills, for example AWS Solutions Architect certification at Associate and professional level requiring a recommended experience of one and two years respectively. The most relevant certifications for computing undergraduates would be the first tier certifications fulfilling the industry job demands for entry level positions.

In the following sections, we provide overviews of the certification programs of each of the main CSPs, including their support for educators.

5.1 AWS

5.1.1 Certifications. The certifications on the AWS platform are organised in Foundational, Associate, and Professional levels. There are also other certifications in specialty domains, such as security, and machine learning [3].

5.1.2 AWS Academy. AWS Academy facilitates the higher education institutions to prepare their students for cloud careers and AWS cloud certifications through providing a cloud curriculum that can be used by institutions. For those courses offered through AWS Academy which are aligned with AWS certifications, a student completing the curriculum will have 85-90 percent of the knowledge and experience to pass the exam [3].

5.1.3 AWS Educate. AWS Educate [4] is a "gateway" that offers free, self-paced training and resources for cloud learners, including university students. The training material is provided free of charge to the registered institutions and includes a credit of 100 US Dollars for each student to access the AWS services for lab and project work. Anyone can join irrespective of their education, career journey, or technical experience.The training is organised for easy access through topics, e.g., Cloud Computing, and Security, and also by levels, foundational, intermediate, and advanced. The advanced level of training is typically 40 hours of content, and addresses topics, such as Cloud Support Engineer, and Data Scientist. AWS Educate provides access to AWS services and other resources including audio, video presentations, demos and reference materials. The performance metrics included are knowledge checks, final assessment, and projects depending on the level of the training.

AWS Skill Builder is the learning centre for building the cloud skills and provides training organised as digital training and learning plans. Some of the learning requires a subscription. The resources for certification exam preparation are also available [5].

5.1.4 Academic credit. The AWS Academy [3] offers training and certifications that do not themselves have any associated academic credit. Training and certification material can, however, be used as part of an academic module, and implemented as considered appropriate by an academic institution.

5.1.5 Employability. AWS educate has a job board, they explicitly say a benefit for students using their platform is to "land a well-paid job in one of the fastest growing industries". The job board can be used by the learners to search and apply for jobs and internships all over the world with all types of organisations [4].

5.2 Google Cloud

5.2.1 Certifications. Google Cloud offers certifications at Foundational, Associate, and Professional levels. The Foundational and Associate certifications are achievable by many students, needing less than a year of experience [28]. The Foundational certification, Cloud Digital Leader, is less technical and aimed at more broad concepts of cloud computing, while the Associate Certification, Associate Cloud Engineer, focuses on the skills necessary to build and deploy cloud solutions.

In addition to these certifications, Google Cloud Skills Boost [31] provides numerous skill badges [32]. These skill badges consist of a related group of interactive labs which lead a student through the activities and a final challenge lab which describes the desired outcome without indicating all of the steps to ensure the student has learned from the previous labs. These skill badges can be used with a class to provide hands-on reinforcement of a variety of concepts. Figure 4 shows the suggested prerequisite structure for these skill badges. Table 2 lists the most appropriate of these skill badges for each of the KAs.

5.2.2 Support for Educators. Google Cloud provides a variety of support programs for educators [30]. These include:

Google Cloud Skills Boost Along with providing labs and skill badges as described above, this program provides on-demand classes, videos, quests (groupings of labs without a final challenge), and learning paths (groups of on-line courses, skill badges, quests, and labs) [31].

Training credits Most of the material at Google Cloud Skills Boost requires payment to use. Faculty in approved schools can get credits for their classes at no charge [26]. Individual students may also receive credits through this program.

Career Readiness Programs This program provides materials including on-demand training modules, professional certificates, self-paced labs and skill badges to faculty who want to prepare students for either the Cloud Digital Leader or Associate Cloud Engineer certifications and provides a discount on the exam for students who complete the training [27]. There is also a Data Analyst track, but it does not correspond to a current certification.

Google Cloud Computing Foundations This is a no cost 10 module, 40 hour curriculum designed to give faculty the tools to teach critical concepts like infrastructure, application development, data, and machine learning to students with little or no cloud computing experience. Faculty may edit

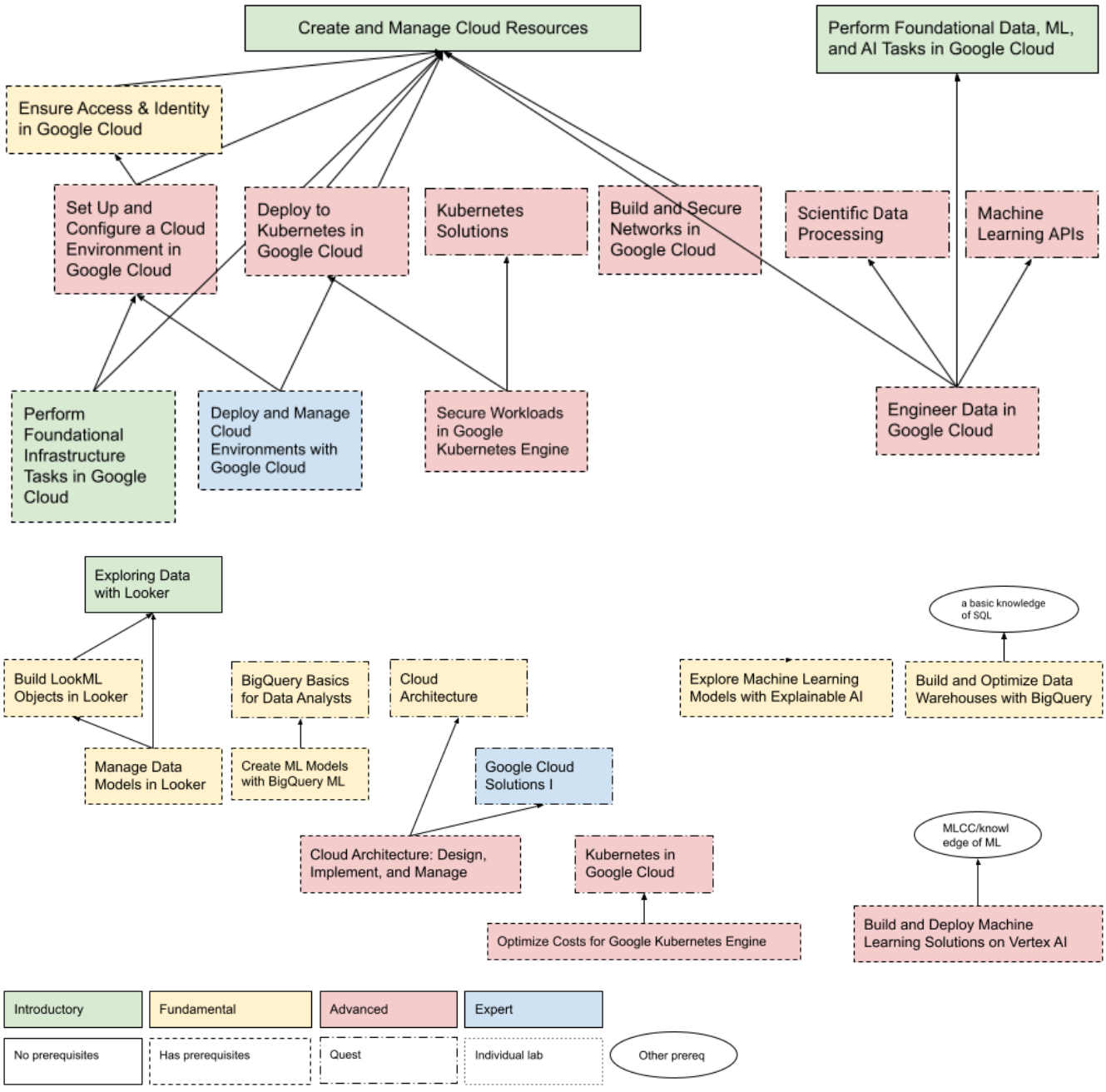


Figure 4: Pre-requisite dependency of Google Cloud Micro-credentials

this curriculum and select just the modules that apply to their classes [29].

Teaching Credits Faculty in approved schools who want students to work on cloud projects outside of the constraints of the labs provided by Google Cloud Skills Boost may request Google Cloud credits for their students [30]. Students typically receive 25 to 50 US Dollars per class and do not need to use a credit card to apply these credits [30].

5.2.3 Academic credit. None of Google Cloud's certifications or micro-credentials currently have academic credit associated with them. However, some of the related Career Certificates in areas such as data analytics, user experience design, and project management[34] have been received as academic credit recommendation in the US from the American Education Council[6] and many colleges and universities do grant transfer credit for these certificates[6].

Table 2: Mapping KAs (KA codes are provided in Appendix A) to Micro-certifications

KA	Micro-credential
FCC	Create and Manage Cloud Resources Perform Foundational Infrastructure Tasks in Google Cloud Build a Website on Google Cloud Integrate with Machine Learning APIs
SRC	Insights from Data with BigQuery
NRC	Build and Secure Networks in Google Cloud Develop and Secure APIs with Apigee X
FTRR	Measure Site Reliability using Cloud Operations Suite
CMM	Deploy and Manage Cloud Environments with Google Cloud Set Up and Configure a Cloud Environment in Google Cloud Monitor and Log with Google Cloud Operations Suite Optimize Costs for Google Kubernetes Engine Monitor Environments with Google Cloud Managed Service for Prometheus
CO	Cloud Architecture: Design, Implement, and Manage Deploy to Kubernetes in Google Cloud Automating Infrastructure on Google Cloud with Terraform Implement DevOps in Google Cloud
SDCA	Build Interactive Apps with Google Assistant Integrate with Machine Learning APIs Build and Optimize Data Warehouses with BigQuery Migrate MySQL data to Cloud SQL using Database Migration Service Manage PostgreSQL Databases on Cloud SQL Serverless Cloud Run Development Serverless Firebase Development Secure and Rate Limit API calls with API Gateway Deploy and Manage Apigee X Automate Data Capture at Scale with Document AI
CSPPE	Secure Workloads in Google Kubernetes Engine Ensure Access & Identity in Google Cloud
CAIML	Perform Foundational Data, ML, and AI Tasks in Google Cloud Engineer Data in Google Cloud Explore Machine Learning Models with Explainable AI Create ML Models with BigQuery ML Build and Deploy Machine Learning Solutions on Vertex AI Create Conversational AI Agents with Dialogflow CX Manage Data Models in Looker Detect Manufacturing Defects using Visual Inspection AI

5.3 Microsoft

5.3.1 Course content offerings and certifications.

- Microsoft fundamentals curriculum. Provides foundational level knowledge of Microsoft cloud and business application services. They are ideal for students starting or thinking about a career in technology and align with fundamentals certifications such as AZ-900. [58]
- Microsoft Advanced Role-Based curriculum. Provides associate level knowledge of Microsoft cloud and business application services. They are ideal for students looking to begin learning valuable job role skills and align with role-based certifications such as AZ-104.[49]
- Microsoft Open Source Curriculum. Provides foundational level of knowledge of technical focus areas. They are ideal for students and educators looking to enhance their technical skills and readiness.[57]

5.3.2 Mirosoft Learn. Microsoft Learn for Educators (MSLE) [54] provides access to a curriculum of official Microsoft learning products. The Microsoft Learn Educator Center, part of MSLE, covers best practices for learning with interactive lessons, earn professional development hours, and acquiring certifications and find programs that help institutions meet their goals.

Each learning pathway and module covers Microsoft Certification exam objectives through lessons based on real-world scenarios and practice exercises and can be used as modular items for assessment, lab or tutorials. Microsoft Official Courseware (MoC) [56] materials have been designed for instructor-led and blended learning models and can be delivered remotely or in person. They directly align to Microsoft Learn online learning paths, which are collections of training modules, that are delivered wholesale or via the modular components

- Online training: Self-paced online learning paths and modules via Learn supported and localized.
- Microsoft Official Courseware: Full course, module content (including lab components where available), and trainer guide
- Course datasheet: Course overview, outline, and learning objectives
- Educator teaching guide: General course information to prepare for teaching delivery
- Assessment guide: Guidance on how to develop formative and summative assessments for students
- Microsoft Open Source curricula: 20+ lessons per subject areas with assignments, Pre- and Post- Quizzes. Made with teachers in mind, for as self paced learning [57]
- Microsoft Learn. Localized hands-on lab exercises for Microsoft course and the self-paced labs which are designed to accompany the learning materials and enable educators [53] and students [55] to practice using the technologies.

5.3.3 Academic credit. The American Council on Education (ACE) is a United States nationally recognized institution in the evaluation of workforce and military training, providing standards, practices, and tools that higher education institutions acknowledge. Most schools in the United States are members of ACE, which represents all U.S. accredited, degree-granting institutions. ACE member

Table 3: Estimated resource costs for Microsoft AI-900

Resource	Est. Cost (€)
x125 candidate exam pack	1900
x125 candidate practice test pack	800
Azure resource costs per candidate	35
Total cost per candidate (based on x125 exam pack)	56

Table 4: Estimated resource costs for Microsoft PL-300

Resource	Est. Cost (€)
x30 candidate exam pack	2200
x30 candidate practice test pack	1150
Azure resource costs per candidate	10
Total cost per candidate (based on x30 exam pack)	121

schools accept some Microsoft certifications for college credit. This includes two-year, four-year, public, and private colleges and universities. ACE has reviewed and established credit recommendations for a range of Microsoft certifications [51].

5.3.4 Microsoft Micro-certification. Micro-credentials in this context are recognized proof of the learning outcomes that a learner have achieved following a short learning experience. The micro-certifications are short, competency-based recognition, issued by Microsoft in the form of badges [16] and transcripts that a students has completed the requirements of the learning experience. These experiences and microcertification are provided by Microsoft Learn with free, interactive, hands-on training and world wide students can receive free Microsoft certification vouchers [59].

Microsoft learning paths, enable students and educators,learn how to implement Microsoft technologies. Academics can blend these resources in new or existing academic degree programs.

There are dedicated educator resources which introduce [53], institutions to different approaches for implementing certification at the course and program level and the benefits it offers students. A real-life case study and contextualized examples are used throughout the learning path to walk through a complete cycle of designing a new technical degree program that implements certification. Microsoft in partnership with a UK university have also developed a learning path title 'Implement Certifications into Academic Programs' [60] to support educators to:

- Understand the benefits of implementing certification in degree programs
- Choose the level of certification that is suitable for your course or program needs
- Identify the academic and industry requirements for implementing certifications
- Describe the processes involved in creating a new program proposal document
- Choose the most suitable learning outcomes for your course or program
- Map certification outcomes to academic learning outcomes
- Understand how to launch a new course or program with certification

5.3.5 Integration Costs. In this section, an overview of estimated costs involved in offering students the opportunity to take two types of Microsoft certification are presented and discussed, specifically AI-900 Microsoft Azure AI Fundamentals (Fundamentals) and PL-300 Microsoft Power BI Data Analyst (Role-based). The costs will cover exam sits and practice tests, as well as costs of cloud services for the practical elements of the certification. Practical elements in this case are Microsoft Learn modules and labs hosted on GitHub. The costs are presented in Tables 3 and 4 which list the core resources required to give students an exam sit, access to a practice test, and access to cloud resources to do the associated practical elements.

It is important to highlight again the costs are estimated and can vary dependent on the exam pack size as generally the unit cost is reduced with larger exam packs and the Microsoft Learn Educator program provides additional discount.[54] For the cloud resources the costs presented are based on best practices of only using the resources when completing the practical tasks, and closing services down when not required.

There are free Azure for student subscriptions [1] which can use to help mitigate costs an institution would incur for running certifications, such as the Azure for Students subscription or institutions can utilize Azure Enterprise subscriptions [52]. Azure for student offers $100 of credit each year a student is enrolled on a suitable course. However, it should be noted that only students have direct access to the subscription with educators unable to have any oversight of the services deployed and credit used.

5.3.6 Digital Badges. Microsoft provides Digital Badges once a candidate has successfully passed the exams requirements for certification. Digital Badges are a symbol of real-world skills and commitment to keeping pace with technology. These can be shared on a LinkedIn profile, career-related social media posts, or embedded in email signature, the digital badge is recognized as a trusted validation of achievement. Certification certificates can be downloaded and printed for the candidate's records [16].

5.3.7 Training and Certification. Academic institutions can also utilise partners and educators can become Microsoft Certified Trainers [50] who deliver instructor led courses on behalf of the academic institution.

Microsoft Learn has created an extensive number of code repositories which contain training, labs, resources and workshops for all Microsoft professional exams [58] these resources are also localized into various languages to support world wide adoption. These repositories contain the hands-on lab exercises for Microsoft course [56] and the self-paced modules on Microsoft Learn [53]. The labs are designed to accompany the learning materials and enable educators and students to practice using the technologies.

Worldwide organisations such as Certiport [65]offers a very broad and comprehensive portfolio of courseware products that are specially crafted from the finest online courses, hardcopy books, and e-books all focused on certification exam success. These resources are designed specifically to help students and workers prepare to take and pass certification exams. They target the areas covered in the certification exams and align directly to exam objectives.

Certiport partners with industry-leading authors, publishers, and instructional technology developers to make these resources easily available to Certiport customers[65].

5.3.8 Institutions becoming certification testing centers. The certification authority Certiport [66] offers institutions the ability to become a Certiport Authorized Testing Center (CATC). A CATC is authorised to run Microsoft exams for Microsoft Fundamentals, Microsoft Certified Educator, and Microsoft Office Specialist certification. Benefits of becoming a CATC, include:

- Educators can use their exam voucher without having to travel to another test center.
- Students will be able to conveniently take their exams onsite or online.
- Institutions are able to buy and offer certification exams to students at a discounted price.

The certification authority for Microsoft's Advanced Role-Based certification exams is Pearson Vue [64].

5.4 Mapping certifications to KAs

Table 5: Certificate Codes and Names

Code	Certificate Name
CLF-C01	AWS Certified Cloud Practitioner
SAA-C02	AWS Certified Solutions Architect - Associate
DVA-C01	AWS Certified Developer - Associate
SOA-C02	AWS Certified SysOps Administrator - Associate
CDL	Google Cloud Digital Leader
ACE	Google Associate Cloud Engineer
AZ-900	Microsoft Azure Fundamentals
DP-900	Microsoft Azure Data Fundamentals
AI-900	Microsoft Azure AI Fundamentals
SC-900	Microsoft Security, Compliance, and Identity Fundamentals
AZ-104	Microsoft Azure Cloud Administrator
AZ-204	Microsoft Developing Solution for Azure
AZ-500	Microsoft Azure Security Technologies
AZ-700	Microsoft Designing and Implementing Microsoft Azure Networking Solutions
DP-203	Microsoft Data Engineering on Microsoft Azure
DP-300	Microsoft Administering Relational Databases on Microsoft Azure
SC-200	Microsoft Security Operations Analyst

Our previous working groups defined cloud computing KAs and LOs and showed how to map these to course content [2]. To extend this we now consider how the certifications map to the KAs. From this, if faculty members cover particular KAs in their courses, they can see which certifications, if any align with their courses. The specific certification programs we examined and the certifications within them are shown in Table 5. We focused specifically on certification programs designed for those who have less than a year experience with cloud computing.

We then mapped the major areas as given by each of the examination descriptions and compared them to the KAs (see Appendix A for the full names of each of these KAs). The resultant mappings can be seen in Table 6, where a check mark indicates that a significant part of the examination is included in the KA. In some cases, examinations have long lists of topics, so we tried to determine what topics would be most heavily covered by reading descriptions, sample problems, and similar materials.

6 STANDARDS OVERVIEW

We argue that a potential issue with the implementation of vendor certifications in university courses is that the quality management procedures are not transparent. Quality management includes policies and procedures related to quality planning, assurance, control and improvement. Universities require transparent and clear quality procedures for all sections of the educational experience. When embedding vendor certificates into a course it is expected that the quality procedures are consistent in all aspects. To this end a review of certificate providers was carried out to establish their quality management procedures. We then reviewed educational quality controls as defined by international standards groups. From this we can establish that quality procedures can be applied in a consistent manner. The rapid pace of change in vendor certificates leads to updates to courses or new course offerings every few weeks. The pace of change in universities is often slower with validation processes taking 6 months or more. It is therefore important for universities considering taking on vendor certificates to use curricula language that is vendor neutral. Is is even better if the curricula defines high level concepts and is linked to a course announcement document that can change regularly, in line with the curricula, without the need for re-validation. For example, the curriculum may refer to Containers as a Service, whilst the course announcement descriptor document may state topics including Google Kubernetes Engine, Amazon Elastic Kubernetes or Azure Kubernetes Service Service as per vendor certification.

When reflecting on whether both the certification and the KAs are appropriate we studied frameworks and standards in the area of education and cloud computing. As cloud computing is a narrow term we had to expand the scope to cloud enabled topics and systems engineering. Our research in this aspect is two-fold. First, we consider standards for education. Secondly, we appraise cloud standards and their application of techniques for knowledge management.

A number of organizations provide guidance for vendors on how to write their curriculum. Professional bodies such as the IEEE and the ACM have done so on a regular basis. However, if the guidance is not written with a view to future proofing the results can be disastrous. As noted in the 2020 report [13], the Computing Curricula from the ACM suggests a competency of "Analyze and compare several networking topologies in terms of robustness, expandability, and throughput used within a cloud enterprise." for Information technology. This leaves much to be desired. Indeed the very limited definition of cloud computing as found in the 2020 Report is an indicator of how poorly many organizations review or define curriculum

The IEEE Standards Association (IEEE SA) work with 175 countries to develop standards in the area of computing. However, a quick search of their standards show little that focus specifically

Table 6: Mapping Certificates to KAs

Certificate	FCC	CAC	SRC	NRC	CES	FTRR	CMM	CO	SDCA	CPMF	SOA	CSPPE	IoTMEC	CAIML
Amazon Web Services														
CLF-C01	✓		✓	✓							✓			
SAA-C02			✓		✓	✓						✓		
DVA-C01				✓			✓		✓			✓		
SOA-C02				✓			✓					✓		
Google Cloud														
CDL	✓						✓		✓			✓		✓
ACE		✓		✓				✓			✓	✓		
Microsoft Azure														
AZ-900	✓	✓	✓	✓										
DP-900									✓					
AI-900														✓
SC-900												✓		
AZ-104	✓	✓	✓	✓								✓		
AZ-204	✓	✓	✓	✓					✓			✓		
AZ-500												✓		
AZ-700				✓										
DP-203			✓						✓			✓		
DP-300									✓					
SC-200												✓		

on cloud computing. Distributed systems of a variety of types are mentioned. Similarly, certification in the area of cloud computing is not specifically called out. Whilst we can argue that some of the existing standards are generic enough to cover educational aspects of cloud computing it would be interesting to see a technical report outlining a mapping of the areas.

6.1 ISO and Knowledge Management

There are a number of standardization bodies but the most notable is the International Standards Organization (ISO). The ISO represents standards bodies from 167 countries worldwide. In this role, they work to create consensus based, market relevant standards. This is important as it represents best practice across market leaders in industry. In 2021 the ISO had over 22,000 standards published [70].

The ISO recognizes the wealth of avenues for learning both formal and informal. The ISO provides standard requirements for services in the area of knowledge management outside of formal settings through ISO 29993 [40]. This set of standards covers both in-house training and outsourced training which is relevant to the cloud based training courses discussed here. The recognition of informal learning by standardisation bodies is relatively new. The recognition of this form or learning by industry has no doubt led to the prevalence of micro certificates such as those discussed here.

Interestingly the ISO 29993 standard [40] on informal learning discusses the needs analysis from the perspective of the learner but not the industry to which the learner may work. It defines the learner needs as a key factor "... in the learning service as it ensures that the objectives, program, content and assessment methods meet those needs". The standard is surprisingly limited given the prevalence of micro certifications. Indeed, references to the parties with vested interest in the outcomes of the learning beyond that of the learner would seem to indicate the tertiary institute in our example. The tertiary institutes are also considered sponsors as they acquire the service on behalf of the learner. A high level of responsibility is placed on the institute in ensuring that quality management practices are put in place.

The work of applying ISO standards to education has been carried out previously in Portuguese vocational schools [21] with respect to ISO 9001. However this work applies standardization in a broad manner to management rather than referring specifically to educational practices. Work in Kenya [7] shows that the work of academic staff correlates with ISO 9001. Whilst not definitive it is an indicator that standards can be applied to quality of learning resources, pedagogy and general teaching practices. Challenges in implementing these standards begins with a lack of awareness of the international standards [37] the are specifically written for the quality management of education whether in formal or informal learning settings.

Further standards and umbrella standard groups include the ISO 21001 management system standard [41]. Although some work exists on presenting a case for adoption within the educational sector [45], case studies could not be found.

A list of some of the standards specifically relevant to education are shown in Table 7.

6.2 Discussion on Certification to Standards

Microsoft notes that they comply with many standards in their service offerings including Cloud Security Alliance and ISO 27001 no specific quality standard is listed for quality control of their courses, whether certified or not. Further investigation into their

Table 7: Sample Relevant Standards

Note: Standards and Technical Reports such as ISO/IEC TR 19759, SWEBOK are not considered in this section as they are too tightly aligned with software engineering.

Organizations	Number	Std. Title	Description	Note
ISO	21001	Educational organizations – Management Systems for educational organizations – requirements with guidance for use	This is applicable where the organization needs to demonstrate their ability to support the acquisition and development of competencies.	This refers to the quality of the knowledge management systems rather than to the KAs themselves.
ISO/IEC	24773	Software and systems engineering — Certification of software and systems engineering professionals	This is an umbrella set of standards regarding certification. It is applicable to systems and software engineering.	This refers to the description of competencies. Given the mismatch in descriptions previously discussed this is a very important standard.
ISO	29993	Learning services outside formal education — Service requirements	This standard presents requirements for informal learning where goals are defined and measured. Interaction with the learner is typical in this form of learning.	It is the combination of micro certificates such as vendor certifications that provide lifelong learning for many in industry. Lifelong learning including in-company training whether outsourced or in-house. This standard is provided to ensure consistency in these pathways.
ISO	29994	Education and learning services — Requirements for distance learning	This standard provides guidance on distance learning.	The certifications we have discussed in this document are primarily provided as distance learning courses. This brings about challenges that are not necessarily encountered during in-person courses.
EN	16234	e-Competence Framework (e-CF)	A Common European Framework for ICT Professionals in all industry sectors. This framework provides high level guidelines on the types of KA needed by all industry sectors.	Whilst primarily targeted at computing, the standard is set at a level too abstract to be of particular interest to this study.
INCOSE	None	Systems Engineering Competency Framework	This Framework covers competencies, knowledge, skills an abilities for systems engineers.	Tailoring of this framework is required to such an extent that it is not considered in depth here.
IEEE	2675	IEEE Standard for DevOps:Building Reliable and Secure Systems Including Application Build, Package, and Deployment	This standard focuses on building systems including those hosted in the cloud. Strong emphasis is placed on communications and collaboration of the team.	This standard has been included due to the shifting nature of cloud computing. The creation of resources through Infrastructure as Code has become important. Knowledge management is prevalent in this standard.

quality controls does show that quality management was carried out within the examination process. The process described in Figure 5 shows that consideration is given to quality checks at multiple stages of exam development. However no such process is described for the development of the course or the course material.

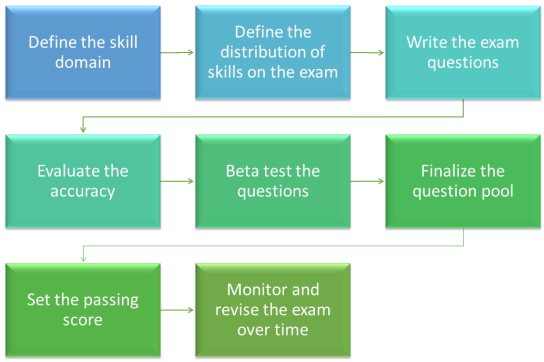
Google mention conformance to the ISO 9001 as part of their quality management system. The authors could not find any specific mention to quality management of courses or related materials. AWS similarly specify that they are ISO 9001, ISO 27001 and Cloud Security Alliance certified. Again, there is no specific mention of compliance to standards specifically regarding training, learning and related areas.

6.3 Standard Case Study

This section provides a discussion on cloud based standards and how they make reference to the importance of knowledge management.

The IEEE 2675 DevOps standard for Building Reliable and Secure Systems Including Application Build, Package, and Deployment was the second standard reviewed in this case study. This standard concerns the creation of infrastructure and systems using services.

Figure 5: Microsoft Examination Quality Process



The 'left-shift' discussed within the standard focuses on the consideration of quality earlier in the life-cycle. Part of this is realized through the description of tasks which need to be carried out more regularly. Another significant component of the standard is the requirement for systems thinking. In the KAs listed here for cloud computing we note the breath of topics that now are considered core. For this reason syllabi must clearly show the relationship with topics not traditionally considered part of cloud computing. The stated KAs map at a conceptual level to the tasks highlighted in IEEE 2675 [39] as shown in Figure 6.

Figure 6: KAs and the IEEE 2675 Standard

	Soft Skills	Technical Skills
Core Activities • Communication (FCC) • Regular tasks (CAC, SRC, NRC) Agility • Scaling (SRC, NRC, CES) • Management (CMM, CO) Business Continuity • Policy (CSPPE, CMM) • Architecture (SOA, CPMF) • FTRR	• Team Oriented • Communication Skills • Work effectively without supervision • Ability to respond to customer requirements • Ability to multi-task, prioritize and take action	• Understand security issues effecting systems or system components • Deploy and manage environments in cloud platforms • Use configuration management tools • Administer and manage operating systems • Configure and maintain CICD • Configure and maintain security • Monitor and maintenance • Perform risk assessment • Review performance and capacity

The second interesting aspect of this standard is the prominence of knowledge management. The standard defines knowledge management as a

> Multi-disciplinary process of obtaining, preserving, sharing, using, and refreshing knowledge.

The standard further goes on to establish the need for support structures from management. This is interesting as it further gives weight to the value of short courses or vendor certificates provided by industry. It specifically mentions the requirement to support micro-learning as part of typical practice. This standard acknowledges alternative paths for learning including embedded learning, mentoring, shadowing and technical exchanges which are often embedded in institutional courses. This works towards the institutional need to validate and encourage lifelong learning through alternative paths as part of continuous professional development. If more standards included such recognition of micro-learning and alternative sources of knowledge it would become significantly easier for institutes to include mechanisms for embedding vendor certificates within the courses.

6.4 Competencies Framework

The Skills Framework for the Information Age (SFIA) is not for profit organisation. SFIA defines the skills and competencies for computing and engineering professionals. It is specifically targeted at people involved in data and technology throughout the systems life-cycle. The purpose of SFIA is to provide a common language for the description of skills and competencies. When mapping vendor certificates to university course requirements the application of a common languages will aid the process. The IEEE 2675 standard [39] defines competence as:

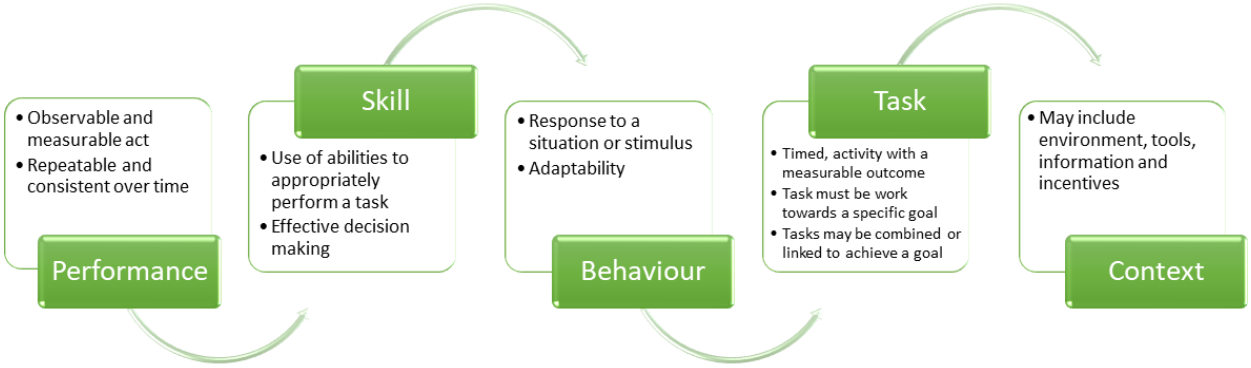
> "Ability to demonstrate and apply the combination of knowledge, formal and informal skills, training, experience, and behavioral attributes to achieve intended organizational and technical results."

In line with the description of competencies in the SFIA Framework, the ISO have described competencies as containing key characteristics of measurable, task oriented, modified behaviours and skills. Considering this further we would suggest that competence in a topic requires consistence in demonstration of skill. Figure 7 describes some of the identifiable characteristics of competency as defined across standards and frameworks such as SFIA.

SFIA goes beyond a common terminology to define a number of skills necessary for computing and engineering professionals not least of which is cloud related skills. Some of the skills listed apply across a range of areas. Quality Management, QUMG, for example is a skill that can apply to the daily framework of processes and practices right through to strategy practices to determine if quality seems meet an organizations needs. We have mapped the knowledge areas previously defined by our working group [2] to the skills listed in SFIA. From this, the knowledge areas from vendor certificates and university courses can be easily aligned together for quality assurance purposes.

SFIA defines seven levels of responsibility and accountability which can also be used to guide the curriculum author as to the level of skill described. This ensures that professional skills are distinct from lower level skills. In considering the quality of goals

Figure 7: Competency Characteristics



and objectives of cloud micro-credentials Levels 3, Apply, to 7, Set Strategy are considered. Of particular interest is that at level 6 requires quality assurance procedures to evaluate that competency is assessed in such a manner as to ensure internal and external consistency in assessment outcomes. Table 8 shows a mapping of KAs to SFAI skills. The levels of responsibility are shown without presenting the detailed tasks at that level. We recommend that institutes look to the current version of SFIA to see the most up to date tasks at each level before mapping to their individual curriculum.

7 METHODS

The previous sections have focused on the perspectives of vendors and to some extent institutions. We now consider other stakeholders and explore their perceptions framed by the three perspectives described in section 4. For the "certification candidates" perspective we were interested in the perceptions of students including their awareness of certifications, the value of academic qualifications and certifications and their expectations of how these enable transition to employment. For the "employment" perspective we wanted to know about the perceptions of employers including their awareness of certifications, the influence of academic qualifications and certifications on their evaluation of potential employees and the importance of certification for their employees once in the workplace. For the "academic" perspective we were interested in perspectives regarding the value of certifications but also in the details of their experience of and strategies for including certification in their courses.

7.1 Data Collection

The data collection process consisted of surveys and semi-structured interviews. Separate surveys were designed and distributed to students and employers. For student perspectives, we invited cohorts of students from within institutions where working group members are based. For employer perspectives we invited persons who were contacts within organisations that had some relationship with the working group members' institutions and were in technical roles related to cloud computing, such as industrial advisory board members.

A different approach was taken from the outset to explore the academic perspective as we were interested in more in-depth information. Through messages distributed to a number of academic organizations via professional messaging boards and referrals we identified a small number (three) of participants based on willingness to participate and the requirement that they had already run at least one course that had implemented cloud certifications as part of the course. These participants were used as case studies, and included educators working with cloud certifications in a range of contexts: different countries, institution types, course levels and vendors. A further two participants were drawn from the working group members who, as a consequence of the nature of the group and its recruiting process met the criteria for inclusion.

Semi-structured interviews were carried out with these participants, and qualitative analysis was done on the interview transcripts. Ethical approval was sought and obtained from the home institution of one of the working group leaders and data collection was carried out under the terms of that approval. Data was securely stored with all participants giving informed consent.

7.2 Threats to validity

Student participants were drawn from courses in the working group members' institutions, hence in which cloud computing played a prominent role in some form. They cannot be considered to be representative of computing or computer science students in general. However, this is appropriate for this work as we wanted to know about students who can be considered as likely to be stakeholders as defined in our model. Further, we are aware that some of the student participants were work-based learners, who are students and employees at the same time, which may affect some of their responses.

As a result of the criteria for inviting students and employers, the number of survey participants is low, which limits the conclusions that can be drawn. While the number of case study interview participants is smaller still, we consider that the in-depth nature of the data gathered provides a sufficient basis to identify commonalities and differences in experience and strategy.

Table 8: Working Group KAs mapped to SFIA Skills

Note: Mapping is subjective and would require further validation.

Knowledge Areas (KAs)	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
Fundamental Cloud Concepts (FCC)	TEST, ITOP	TEST, ITOP, ASUP	TEST, ITOP, ASUP, DESN	TEST, ITOP, ASUP, DESN	TEST, ITOP, ASUP, DESN	TEST, DESN	
Computing Abstractions on the Cloud (CAC)	INCA	INCA	INCA, SYSP	INCA, SYSP	INCA, SYSP	INCA	
Storage Resources on the Cloud (SRC)			STMG	STMG, DATM, CPMG	STMG, DATM, CPMG, POMG	STMG, DATM, CPMG, POMG	POMG
Networking Resources on the Cloud (NRC)			NTDS, SINT, SYSP	NTDS, SINT, SYSP	NTDS, SINT, SYSP, POMG	NTDS, SINT, POMG	POMG
Cloud Elasticity and Scalability (CES)			SYSP	SYSP, CPMP	SYSP, CPMP, POMG	CPMP, POMG	POMG
Fault Tolerance, Resilience and Reliability (FTRR)		COPL	COPL, STMG	COPL, STMG	COPL, STMG, POMG	COPL, POMG	
Cloud Monitoring and Maintenance (CMM)				VURE	VURE, ITSP, POMG	VURE, ITSP, POMG, GOVN	ITSP, POMG, GOVN
Cloud Orchestration (CO)			SYSP	SYSP, ARCH	SYSP, ARCH, POMG	ARCH, POMG, ARCH, ISCO	ARCH, POMG, ISCO
Software Development using Cloud APIs (SDCA)			SYSP	SYSP	SYSP		
Cloud Programming Models and Frameworks (CPMF)			SINT	SINT	SINT, BPRE	SINT, BPRE	BPRE
Service Oriented Architecture (SOA)			SLMO	ARCH, SLMO	ARCH, POMG, SLMO, STPL	ARCH, POMG, SLMO, STPL	POMG, SLMO, STPL
Cloud Security, Privacy, Policy and Ethics (CSPPE)		SUPP	SUPP, ARCH, POMG, ITCM, QUMG	VURE, SUPP, ARCH, POMG, ITCM, QUMG	VURE, SUPP, ARCH, POMG, ITCM, QUMG, STPL	VURE, SUPP, ARCH, POMG, ITCM, QUMG, STPL, GOVN	SUPP, POMG, QUMG, STPL, GOVN
IoT, Mobile, Edge and the Cloud (IoTMEC)				EMRG, INOV, POMG	EMRG, INOV, POMG, INOV	EMRG, INOV, POMG, INOV	INOV, POMG, INOV
Cloud-based Artificial Intelligence and Machine Learning (CAIML)		DENG	DENG, SYSP, DBDS	DENG, SYSP, DBDS, DATM	DENG, SYSP, DBDS, DATM	DENG, DBDS, DATM	Level 7

The inclusion of working group members among the case study participants was a potential concern. We considered that this approach was justified as they met the criteria to be the basis of highly relevant case studies. This is not surprising: it is a distinctive feature of the working group concept that members are typically accepted on the basis of their expertise and experience related to the topic to be addressed, and it was considered to be appropriate to make use of the experience of specific members in this case. To mitigate the risk of bias or other influence on their responses, those participants were not involved in designing or conducting interviews, or in the analysis of the data. They had no sight or knowledge of the other interviews or the outcomes prior to their own interviews. We are confident that their responses accurately represented their experience and strategies.

8 STUDENT AND EMPLOYER PERSPECTIVES

This section describes the main findings from stakeholder survey submissions.

8.1 Survey: Student Perspective

8.1.1 Design and implementation. The relevant model in section 4 identifies associations that students *may* have with certifications and academic credit, and the transitions in their careers that these may enable. The survey questions were designed to elicit information on whether the participants actually did have those associations, for example were they aware of certifications, had they achieved certifications, or if they are planning to achieve certifications. Further questions were included to find out about the scope of their interest within the landscape of certifications, such as which vendors or providers and what knowledge areas were meaningful to them, and their intentions regarding future acquisition of certifications. Finally, ranking questions were included to find out about their motivations and perceptions in relation to certification, including the relative importance for finding a job of certification, experience and academic credit. We included the three main CSPs highlighted in section 5 in options within the survey questions, but also gave the opportunity for students to show awareness of IBM Cloud and others that they might specify. The student survey questions are shown in Appendix C.

The survey was implemented in Microsoft Forms and the URL advertised to our chosen student cohorts. The respondent groups were selected based on anticipated student intention to work in related cloud industry. The URL was advertised in authors' cloud-related classes including junior and senior undergraduate students and professional graduate degrees in Scotland, and Canada. 78 responses had been received from the advertised sources.

44% of the respondents were senior undergraduate students, 36% were junior undergraduate students, and 5% were studying post-graduate degrees and 15% of the respondents have already graduated in a related subject. 40% of the participants were employed in a field related to cloud computing and 9% held jobs in an unrelated area. 51% of the participants consisted of student not currently working, or seeking an employment within a related area.

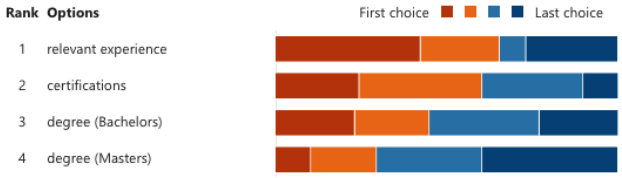
8.1.2 Awareness. All of our student survey participants were aware of at least one cloud computing provider. Familiarity across vendor platforms varied among Microsoft Azure, Amazon Web Services, Google Cloud Platform, IBM Cloud with 96.1%, 94.9%, 80.77%, and 78.72% awareness among the participants respectively. Sources of these awareness varied among students, with 78.08% of the students indicating that they had received information about at least one cloud computing vendor in a course within their degree programs. Amazon Web Services and Microsoft Azure ranked first and second among cloud computing vendors covered in degree courses.

The comparatively lower awareness of platform certifications were still at 91%. These participants were aware of cloud certifications whether generally or aware of specific vendor certification or a certification exam. 23% of the participants had already received at least one cloud computing vendor certification. Only 6% of participants had no intention to pursue any certifications, and 71% of participants were planning (28%) or intend to (43%) receive certification in the future.

8.1.3 Perceptions. 33 out of 78 (42.3%) students assigned the highest factor in employability as relevant experience and 19 students out of 78 (24.4%) indicated the highest factor to be certifications. This ranks certifications higher than both degrees, but lower than relevant experience in student opinion. In totality, Students ranked relevant experience, certifications, Bachelors degrees, and Masters degrees as the most important factors for employments respectively as shown in Figure 8.

We should note to interpretation of data in relevance to our goal and target population. First, for our purposes ordering of masters and bachelors is irrelevant as our goal is analyzing perception of academia in-relation to certifications, regardless of degree level. However, the findings might imply higher tendency to achieve certifications rather than graduate degrees if the participants aim to enter the cloud computing workforce. Second, all of the survey participants were either in a degree program or already had acquired a degree at the time of survey. This might imply the certifications and relevant experience are not considered as a substitute for degree education, but an important fact after degree program for the participating population.

Figure 8: Student Perspectives: Effect on Employability



8.1.4 Intentions. Students were also asked to rank in importance a set of factors which might have influenced their choice of certifications to achieve in future. 34% chose employment prospects or requirements as the most important factor. The answers also indicated that personal interests, cost, availability of a learning path and progression, and having existing knowledge on the certification content rank in their importance in this decision respectively. The relevance or inclusion of a certification in their academic course ranked the last in the participating population's choice to achieve a certification.

Cloud fundamentals, software development, and data were domain areas with the highest number of achieved certifications as well as the domain areas with the highest popularity among the students planning to achieve certifications or further certifications in the future. Microsoft Azure and Amazon Web Services were most popular vendor certifications among the students planning to pursue certifications in the future.

8.1.5 Summary and next steps. In general, it appears that our respondents are well aware of certification and connect it with employability and recognise AWS, Google Cloud, and Azure as the key vendors. They show an interest over a wide range of knowledge areas. There are, however, varied perceptions of the relative importance of experience, academic credit and certification. Further, there is surprisingly little connection made between the content of their academic course and their intentions for future certification.

It should be noted that the respondents were in student cohorts where working group members teach and hence in which we know there is significant cloud content in their courses. Participants were asked if they would be willing to take part in a follow-up interview. Conducting these did not fall within the scope of this working group but there is an opportunity to explore the perceptions in more depth.

8.2 Survey: Employer Perspective

8.2.1 Design and implementation. The relevant model in section 4 identifies associations that employers *may* have with certifications and academic credit and with other stakeholders in relation to certification. As for the employer survey the questions were designed to elicit information on whether the participants actually did have those associations, for example were they aware of certifications, did they value require or incentivize certifications for their employees and candidates, and how often do they require their employees to upgrade their certifications or pursue additional certifications. Further questions were included to find out about the scope of their interest and return on investment within the landscape of certifications. Finally, we asked them to rank the importance of the same factors for employability as the student survey to look for evidence of any mismatch between employer and student perceptions here. The employer survey questions are shown in Appendix D.

The survey was also implemented in Microsoft Forms and the URL advertised to employers with connections to working group members' institutions, for example Industrial Advisory Board members. 20 responses had been received. It was expected that the individuals concerned would mainly be in technical or technical management roles, and this was borne out in the responses.

8.2.2 Awareness. 15 respondents were in technical or technical management roles. All were aware of certifications although only 2 indicated awareness of specific exams. They were mostly aware of specific vendors, however, and like the students place more value on the AWS, Google Cloud and Azure than other vendors.

8.2.3 Perceptions. Out of the 20 responses we have received from employers 80% of our respondents indicated having a role in the hiring process. One respondent believed certifications to be of highest efficacy in hiring decisions. Of the 10 respondents that put certifications at second highest efficacy, 6 put certification ahead of degrees and 4 put a bachelors degree ahead of relevant experience. Regarding the benefits of having employees with certification, the most important was considered by the largest number, 39 percent, to be enhanced job performance, while only one respondent identified no benefit. 27% of respondents indicated a role in employee promotion decisions.

8.2.4 Practice. 14 respondents said they incentivize employees to achieve certification, and 15 provide some kind of certification pathway for employees. A smaller number, 11, said they see a return or significant return on investment for these activities.

8.2.5 Summary and next steps. Firstly, we note that the number of responses is small and we continue to gather data in order to obtain a sample representing a wider range of employers. We know the sectors that these respondents work in, but it would be useful to have richer data to understand more about examples of practice. Again, we have indication of areas that are interesting to explore, such as the details of certification pathways and how they evaluate return on investment.

In general, however, it appears that our respondents are, like the students, well aware of certification and connect it with employability and recognise AWS, Google Cloud and Azure as the key vendors. These findings suggest that it is important to be aware that cloud certifications are an important aspect of the employability of their students. Again there is scope for further in-depth exploration as some participants indicated willingness to take part in follow-up interviews.

9 ACADEMIC PERSPECTIVE

We now explore further stakeholder perspectives, in the case those of educators who have engaged with the certification landscape and are integrating cloud certifications into their courses. Rather than exploring the perceptions of a wide group of educators who are teaching cloud computing, and may or may not have included certifications in their courses, we are interested in in-depth exploration of the experience of educators who have done so in order to identify areas of successful practice along with issues and barriers that need to be overcome. It can be assumed that these educators have been motivated by a positive perception of the value of certifications for their students, although the precise basis for that perception is interesting to explore.

We explore this perspective through a set of five case studies based on educators working with cloud certifications in a range of contexts: different countries, institution types, course levels, vendors. Qualitative interviews were conducted to explore the experience of designing and delivering academic courses with some integration of cloud vendor certifications, within the context of a higher education institution, reflecting the associations in figure 3.

This model informed the design of a semi-structured interview script, which explores the following aspects

- the institutional context and the nature of the course
- the specific cloud certifications included and the reasons for the choice of these
- approach taken to curriculum design and assessment and how these map to certification
- institutional support/barriers

The interview script is shown in Appendix B. This lists the questions to be asked and indications of the kind of information that might need to be elicited with further discussion. All interviews were conducted as Microsoft Teams meetings, by the same interviewer. Interviews were recorded and verbatim transcripts generated automatically from the audio recording. The transcripts were edited for accuracy only, with reference to the audio. The interviews lasted between 33 and 44 minutes.

9.1 Case studies

The educational contexts for the case studies were as follows:

- **Case study 1 - University of Lincoln:** A postgraduate (MSc) program in cloud computing in a UK university which has a focus in the cloud computing space with the recent

launch of its MSc Cloud Computing program. Given the applied nature of the degree program on offer, it was a good fit for offering students vendor certification, with a specific focus on Microsoft Fundamentals and Role-based certification, with the latter being credit-bearing.

- **Case study 2 - Saint Leo University:** A range of courses taught by an educator in a US university that supports education learning for a diversity of student populations. Students range from young learners, diverse student populations, to adult and military veterans. An approach to skill development that is used involves embedding cloud computing curriculum in some form within courses that map to cloud computing certifications, such as Microsoft AZ-900 and various Google Cloud certifications.
- **Case study 3 - VTC Hong Kong:** A diploma program in cloud administration in a Hong Kong vocation education institution that provides valuable credentials for some 200,000 students each year through a full range of pre-employment and in-service programm with internationally recognised qualifications. The Higher Diploma in Cloud and Data Centre Administration is a two year program which is recognised by the Hong Kong Computer Society. Graduates can articulate to a number of local degree programs. Azure and Google Cloud certifications are integrated into courses at VTC.
- **Case study 4 - Miami Dade College:** Two programs taught in a US university which is a Hispanic Serving Institution with eight campuses and outreach centres. The Associate in Science in Networking Services Technology immerses students in the field of network design and administration, with an Enterprise Cloud Computing track delivered through a collaboration with AWS, while the Enterprise Cloud Computing Credit Certificate program focuses on learners who already have a degree or are trying to get back into industry and want to upscale in cloud computing.
- **Case study 5 - University of Cardiff:** A DevOps module which is part of the BSc Applied Software Engineering in a research-intensive UK university. Microsoft's AZ900 certification is integrated in the module. DevOps and the need for cloud and cloud awareness is growing and likely to feature in more programs moving forward.

9.2 Thematic analysis of interview data

A reflexive thematic analysis approach, as described by Braun et al., was used to derive themes from the interview transcripts [12]. This approach was considered to be more appropriate here than a coding reliability approach: the intent was to construct themes through a collaborative and reflexive process rather than seeking consensus on meaning. The transcripts were analysed using descriptive coding process, by two coders, with a second cycle of pattern coding to determine commonalities as well as key differences (important to explore areas where a range of practice occurs).

From this analysis, a set of key themes was identified: benefits of including certification; costs; course design; maintaining currency; testing infrastructure; awarding academic credit for certifications; types of assessments used; teacher preparation; and quality processes. These themes are addressed in turn below. Following each quote from the transcripts there is an indicator of which case study it was drawn from.

9.2.1 Benefits. Participants talked about the factors that motivated them or their institutions to introduce certifications into their programs or courses/modules and of the evidence they have for the benefits realised by doing so. Enhancing the employability of their students was a significant motivation in the first instance, based, for example, on market analysis of job postings for employers likely to hire their graduates: *"And you see that just the job postings alone, all request some level of cloud certification, knowledge or skill. And so we understand that's an important thing for our students to have"* (CS2). Conversations with employers revealed that there is often an expectation that new employees should achieve certification: *"More recently, it seems like most employers are now putting our graduates when they get jobs with them through certification in the first six months of getting those jobs, so it made sense for us as an institution to start embedding them and teaching that material because it is not only aligned with our academic modules anyway, but it really enhances the graduate outcomes for those students for when they go to interview"* (CS1).

Participants' perceptions based on their experience are that their courses perform well in terms of supporting employability. Certification plays a role in this: *"I've had numerous students connect with me. They graduated from university and they've consistently stated that they really appreciated the opportunity to take the certifications. Even if they didn't pass, they appreciated the opportunity to even participate in those activities because according to them, it was a very important part of their interview process or even the job that they're in"* (CS2). It was noted that certifications from one provider were valuable regardless of which platform employers use: *"The ones that I've seen have actually got jobs that are not necessarily with Microsoft, but are very close. Jobs where they're deploying stuff in cloud, whether it's Amazon or Azure"* (CS5).

In one context, certifications were observed to be more important than academic qualifications: *"The basic requirement for the graduate to join the AWS partner Azure partner or Google partner is the certification. Not the degree, not the higher diploma, actually"* (CS3). However, another participant emphasised the importance of the learning achieved through project based assessment in allowing students to demonstrate employable skills: *"I think out of the 14 of my students that were in that class, the ones that finished and passed, the majority of them now have jobs in cloud and the majority said that was because of that project"* (CS4). The inclusion of certifications is also a factor in making a course attractive to students: *"We have two major KPI for courses. First of all, we need to recruit students and then the second KPI is graduate employment"* (CS4). It is apparent that these educators are focused strongly on the other key stakeholders (students and employers) and see the inclusion of certifications in their courses as beneficial to all.

9.2.2 Costs. Teaching cloud computing using public cloud solution providers' platforms involves cost in two main areas:

- platform costs: enabling students to use cloud services to carry out practical activities as part of their learning
- certification costs: charged by test providers for each attempt at a certification exam (whether successful or not)

The current landscape for support from AWS, Google and Microsoft in relation to costs is discussed in section 5. We focus here on certification costs and the approaches that have been taken to enabling students to attempt certification exams through the institution (as opposed to making their own arrangements to sit those exams independently).

Participants have taken advantage of support from the cloud solution providers, to various degrees such as 50% discounts or even completely free exams offered to students: *"The cost point was zero cost to myself or the students. I can understand why they're offering these free certifications, because they want people to come out of universities educated and then available with those certifications to drop straight into jobs"* (CS5). Without that support it would not be possible for some educators to offer certifications within the course: *"There's no way I would've been able to do it because again, I could not justify the budget for my department to cover that. We can't go out and even add on an additional technology charge or testing charge or something like that as part of the course fees because our tuition is already pre-established outside of our control"* (CS3).

In other cases it has been possible to obtain institutional support for certification costs: *"AWS provide the discount, 50% of the price for student. And the second half we covered by our institution"* (CS3). As a strategy for making the case for institutional support, one participant was successful in applying for external funding to support costs, including certification costs, associated with starting up their program: *"We use some of the money from the grant, but then it got institutionalized because it was so good. The student feedback said this is a great tool to improve on the certification and get tested that the school decided to include it in terms of the course"* (CS4).

Exams represent a cost that needs to be met, and when certification is embedded within a course educators need to be clear how this cost can be supported without passing this on to individual students.

9.2.3 Course design. The participants had all designed courses that included cloud solution provider certifications in some form, but were primarily academic courses. Course design was driven by some form of expected outcomes to allow learning to be evidenced: *"So it's, it's based on strictly upon knowledge and skills required to do the job. And then we map that directly to course competency and then map that to a certification"* (CS4). It can be important to ensure that courses are not tied too closely to certification outcomes which may change during the lifetime of the course: *"We did map that out to the specific learning outcome, academic learning outcomes to the certification outcomes. But we also made those module learning outcomes slightly broader as well to capture any changes in that certification, which are absolutely bound to happen"* (CS1). This loose coupling of academic outcomes to certification extends to allowing the flexibility to deliver the same course using different platforms if necessary: *"It's not specific to any cloud platform. So if a faculty wants to use Google Cloud, they can, the competency of the course is not the service provider"* (CS4). There is, however, an alternative approach in which the course is much more closely coupled to certification outcomes:*" We just copy the course content from AWS and put into our syllabus directly, just so we do a direct mapping"* (CS3). The extent of the decoupling that is appropriate may depends on whether the certification content comprises the whole course or just a part of a broader unit of learning.

Regardless of the approach to mapping outcomes, in all cases considered here the syllabus that is delivered contains topics that related directly to one or more certifications. The cloud solution providers play an important role in providing supporting materials that educators can use: *"So that means slide decks. It means practical labs. So there's a huge amount of investment in producing that material and the amount of time that it saves myself as an academic and my colleagues who develop that material is significant"* (CS5). The learning materials which are provided drive the selection of topics in the syllabus, an approach which was described in the creation of exemplar modules by a previous Working Group [2]. The cloud solution providers have developed their offerings for supporting learning in academic contexts significantly in recent years: *"Their (AWS) original training was simply designed ... for people already working in the industry. And they tried to apply that to the college level. And we had to convince them that ... you needed better training, better pedagogy and better materials"* (CS4)

The courses here represent a broad range of contexts, with specific goals and constraints in each case, although there are some common issues. One thing that is common throughout is the value of the learning materials that the cloud solution providers make available and the support they provide for educators.

9.2.4 Maintaining currency. Cloud computing is subject to rapid technological change, and certifications are intended to evidence current industry-relevant knowledge and skills. In terms of providing those within an academic context, three distinct but concurrent lifecycles were identified by the participants:

- Academic program or course - typically validated or approved for a fixed period of a number of years
- Certification - can change or be discontinued or replaced on a much shorter and irregular timescale which is not within the educator's control
- Technology - can also change on a short/irregular timescale, will drive changes in certifications

From the educator's viewpoint the management of technology change is to some extent delegated to the provider: *"the powerpoint slides, the lab material, it will be supported by the vendor. It will keep up to date and then we don't have to"* (CS3). However, the lifecycle for certifications is consequently not within the control of educators and may not align well with the academic lifecycle: *"another concern is that certifications are consistently changing in some respects. The exams themselves are consistently changing so there might be a bit of a difference from one year to the next. There's not some consistency where we as a university or an institution cannot always change or update our courses"* (CS2). Educators need to be aware also that there is a challenge for the providers in aligning the certification and technology lifecycles and may want students to work on projects using technology newer than the certifications can test: *"To be honest, they are not changing fast. Their technology is moving very fast...They are not, they are not teaching student their latest version technology"* (CS3). Similar considerations apply to the providers' learning materials: *"they just need to be on top of them and keep them up to date and make sure that all of what the students see is what's on the worksheet or the lab sheet"* (CS5).

9.2.5 Testing infrastructure. It is in principle possible to support students to sit exams with putting any specific arrangements in place: *"in terms of setting certification exams, there's really only two options to do that. You either give the students a voucher code and they book their own exam..."*(CS1). However, all our participants had put in place the infrastructure to allow students to sit certification exams through their institution becoming a testing center (see section 5.3.8) if it was not already one. The experience of trying to get students to sit exams without that in place was not good: *"We had to go outside of the college. So we had to run buses to take students to take the test, because if you don't take the students, they're not gonna go. I'm just being honest"* (CS4). There is a strong shared opinion among the participants: *"the educator really does need to take ownership of as much of that exam process as possible, because we don't have control over the exam content, but we do have some control over the delivery of that"* (CS1).

An important part of the testing process is finding out students' exam results, and this can be achieved in different ways depending on the specific arrangements of the institutional test center. This can involve students self-reporting their results: *"we can't directly access the system to see the grades. They gave us a PDF copy of their test score... so if they don't report the score, they will get zero for that final grade"* (CS4), or the educator may be able to access the results directly: *"So at the end of exam, you've got access to the student's transcript or score sheet. And it means obviously we can see if the students pass a fail and we can ... also get access to the score sheet for the various objective domains for that exam"* (CS1).

Based on this experience it is clear that the infrastructure for testing is an important consideration in setting up to include certifications.

9.2.6 Academic credit. While it is possible to view certification as an "extra" that students can attempt on their own initiative (and at their own cost) with some alignment between their academic course and the certification learning outcomes, all participants in this study include some academic credit which is based on the results of certification exams. There are different approaches to defining the relationship between certifications and credit, notably the following:

- credit within an individual course can be split between the certification exam and other assessments: *"There's 15 credits in the module and we give them half of those credits, um, for taking that exam ... we adopted the approach in each one of those modules where the certification for academic credit is integrated is that there should always be another academic assessment within that module"* (CS1)
- while the curriculum content may provide preparation for a range of certifications, in some cases the academic credit was only awarded for specific certifications. This included awarding credit for the exams from one cloud solution provider while students could attempt other providers' exams if they wished. Another approach is to select only certifications from one provider for credit that closely match the intended learning outcomes: *"the Microsoft fundamentals are extracurriculum. They're not offered as credit for students as part of the program, and the other two certifications AZ104 and PL300 are offered for academic credit"* (CS1)

Where academic credit is awarded there is a need to consider and potentially mitigate the consequences of students' failing to pass the certification exams as it may not be possible or desirable to support multiple attempts at those exams. One approach is to design the assessment structure for a course so that passing the certification exam is not an absolute requirement in order to pass the course: *"the final exam is, is a certification exam. Um, but there are multitude little projects and stuff that go between the start of the class and the certification, so they can theoretically still pass the class...so it ends up not even being an issue"* (CS4). Another participants described the use of academic reassessments so that the student can pass the course even if they don't achieve the certification: *"we decided that we weren't going to give the students another second sit of the certification exam as part of the program, but we are going to give them a second sit of the exam. If they fail as an extracurricular opportunity. And then in place of that for the resit, they'll be given a standard academic resit assessment to do now"* (CS1).

9.2.7 Types of assessment. Certification exams are generally designed to scale to large numbers of candidates worldwide and to return results immediately, and hence are based on question types, such as multiple-choice questions (MCQs) that can be scored automatically. Academic assessments, on the other hand, can include a wide range of other types of assessment, and while autograding is possible in some cases, marking and feedback are generally provided by instructors. Practical projects and research-based assignments can provide a good balance in assessment types alongside certifications: *"We also got a project there and the project is, somehow it's very practical. It's just a real world problem"* (CS3).

For the certification tests, the style of question encountered and strategies for answering may be unfamiliar to students used to more academic assessments, and it can be necessary to prepare students specifically for this: *"I found that the certification exams and that at least with AWS, uh, there, the style of question they have are nonacademic they're technical...you know, very difficult, you have to understand what all the words mean, you have to be able to parse it and put it in context to then be able to go find the right answer"* (CS4). When assigning academic credit it is important to consider the learning objectives and the part that all types of assessment used in the course contribute to demonstrating that those objectives are met.

9.2.8 Teacher preparation. Should teachers have passed the relevant certification before teaching the content to students? *"So it's really important for students, for faculty to actually sit for the certification. So they know better how to prepare student for the certification"* (CS4). Unlike all the other themes identified in the interviews, this was raised by only one participant. In fact this was flagged up as a concern in light of a recent change whereby AWS no longer require teachers to be certified for the courses they teach: *"I think it's going to reduce the number of people are going to go for certification. Because if you don't pass the certification, you may not understand how to take the AWS test"* (CS4). While there may be an expectation that academic faculty are subject experts, preparedness for teaching in the context of certifications is something that should be considered.

9.2.9 Quality processes. Academic programs are subject to a range of quality processes, from initial approval before the program can

run, to ongoing monitoring and enhancement processes once it is up and running. When including certifications in academic programs educators must work within those processes and may require some inventive thinking in order to manage different sets of constraints.

Participants commented that the institutional approval process for their courses involved academics from other disciplines, and it could not be assumed that these individuals would have an understanding of the nature of certifications within IT and cloud computing in particular: *"It's also a bit difficult to implement some type of certification, because of course you have others outside the computer science field that don't necessarily understand the importance of those. And in those cases they have say over whether the course can be approved or not. And so if we don't provide enough support or justification then that makes it difficult in persuading them to approve"* (CS2).

An interesting observation regarding monitoring and enhancement was made in a UK context. Exam questions papers and other assessment instruments in UK universities are typically required to be moderated by an external examiner who is a peer from a different institution who can give assurance that the standard of assessment is in line with equivalent institutions. However, certification exam questions are closely guarded to protect the integrity of the certifications: *"generally when you're running exams as an academic, you are the person who designed that exam. You created the exam and you run the exam under university conditions and, and rules for your exam policies. But the certification, you're not in control of that as an academic, you don't write the questions, you don't get to see the questions and, and therefore it was a bit of a gray area. So by going through practice tests I was able to pull out a bunch of sample or indicative questions and send it to the external examiner so they could at least have some sort of view of what that exam might look like in terms of what the student will see and the challenge for the student or the rest of it. And the external was happy with that approach"* (CS1).

10 RECOMMENDATIONS FOR EDUCATORS

Based on our findings on stakeholder perceptions, the scope and nature of certifications in cloud computing, and the strategies adopted by educators who have successfully integrated cloud certifications into the academic curriculum, we make the following recommendations:

- While academic curricula and course offerings have different intended outcomes and scope to certifications, we recommend integrating appropriate certifications in courses which aim to provide industry-relevant skills in cloud computing or cloud-enabled computing areas, and that these include at least one of AWS, Google Cloud and Azure.
- We recommend that institutions and vendors comply with global standards of education to ensure consistency of quality management process in developing and managing educational content as the content evolves with technology advancement, and that educators play a role in encouraging this in their interactions with these stakeholders.
- While course announcements should include reference to vendor programs for student interest and perception of skills relevance, we recommend that university curriculum should be vendor-agnostic and cover the targeted knowledge areas regardless of vendor platform or certificates.
- We recommend that institutions and educators discuss their needs with the vendors and develop a clear understanding of the costs of supporting students to obtain their preferred certifications, taking into account the support that is available from vendors and other sources and consider the feasibility of providing support for costs within the institution.
- We recommend that an institution that wants students to sit certifications takes steps to become a test center if it is not one already.
- We recommend that certification exams are included within the academic credit for courses as this will motivate students to achieve certifcations, but that appropriate attention is paid in the assessment strategy to enabling students to have the opportunity to pass the course if they fail the certification exam.
- Finally, we recommend that educators consider the benefits and issues identified here of including certification in a program or course, and include a clear analysis and justification in their proposal for approval from the institution to run the course.

11 CONCLUSIONS

This working group has built on the work of previous groups on the cloud curriculum to explore the integration of industry-recognised vendor certification related to cloud computing into the academic curriculum. We have focused specifically on certifications on the platforms and technologies and related job roles associated with the main cloud solution providers. More specifically, we focused on AWS, Google Cloud and Microsoft Azure certifications even though there are many other providers, and the survey results indicate that those are the most widely recognised. We present an overview of the certification programs of these vendors, including the certifications most likely to be appropriate for the experience level of students in higher education, and the programs that the vendors have established to support educators. This overview indicates considerations that educators should have in mind when deciding on which certifications to include in their courses, and signposts sources of more in-depth information. We also map the certifications to the KAs defined by our previous working groups to support the inclusion of certification in the approach to curriculum development proposed in the previous work. We also present a review of relevant standards that we believe should underpin learning and certification for institutions and vendors.

We have investigated perceptions of stakeholders in academia and industry who have an interest in degree level academic qualifications and cloud certifications, and identified that there currently strong awareness of and value placed on both and that they are important contributors to employability in cloud-related roles. However, we see indications that employer, student and academic perception is not necessarily a singular vision and that students do not necessarily make connections between the content of their academic course and the certification landscape. However, it is difficult to unpick the reasons behind these perceptions based on the data we have, and we intend to explore this further, through

extending the survey to a wider range of students and employers and through conducting interviews or focus groups with survey participants. Our case studies based on successful implementation of this nexus are evidence of successful integration of vendor certifications within an academic context but identify a range of issues that educators should take into account. We conclude that there is significant value for students and employers in the inclusion of certifications as an aspect of industry-relevant courses in cloud computing, but that educators and institutions should consider a range of recommendations based on our findings if they are considering doing so to increase the likelihood of success.

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A KNOWLEDGE AREAS

This report refers to the Knowledge Areas (KAs) defined by previous cloud WGs. They are summarised briefly here for the convenience of the reader. The set of 14 KAs defined by the first WG [19] is shown in Table 9.

Table 9: Knowledge Areas (KAs) defined by previous WG

Code	Title
FCC	Fundamental Cloud Concepts
CAC	Computing Abstractions on the Cloud
SRC	Storage Resources on the Cloud
NRC	Networking Resources on the Cloud
CES	Cloud Elasticity and Scalability
FTRR	Fault Tolerance, Resilience and Reliability
CMM	Cloud Monitoring and Maintenance
CO	Cloud Orchestration
SDCA	Software Development using Cloud APIs
CPMF	Cloud Programming Models and Frameworks
SOA	Service Oriented Architecture
CSPPE	Cloud Security, Privacy, Policy and Ethics
IoTMEC	IoT, Mobile, Edge and the Cloud
CAIML	Cloud-based Artificial Intelligence and Machine Learning

B SEMI-STRUCTURED INTERVIEW SCRIPT

Indicates topics, main questions to lead each discussion point off with, and suggested areas to explore or clarify the question.

I'd like to start by talking generally about your course/ program

1. Please describe the type of institution this course/program is delivered in

e.g. research intensive university, community college, location

2. Please tell me about your course or program

Is it a complete program, a single course/module that is part of a program, or a standalone course?

What is the academic level and duration of your course/program? (use terminology appropriate to your location)

What is the credit value of your course/program? (use terminology appropriate to your location, compare to credit value of a complete academic year)

3. What certification(s) does your course/program include or map to?

Be specific - vendor/provider and exam numbers

4. Why did you choose certifications from this vendor or vendors?

Try to relate to participant's context and needs e.g. learning resources available, faculty support from vendor initiatives/ programs/certification academies, discounted certs/cloud credit, support within your institution, content structure, pre-existing staff skills, industry influence

Now I'd like to talk about the design of your course/program

5. Could you explain how you started your course design?

Involvement of industry in initial course design/concept? Influence from industry to include certification?

Did you start with LOs, or specific projects/certifications in mind?

6. Describe how you mapped academic LOs to certification outcomes?

e.g. Formally documented mapping, or a more informal or no specific mapping

7. How did you design the syllabus or the content that you teach?

Was this based on the content of vendor learning materials? If so were these materials linked to certifications?

Now I'd like to talk about assessment and certification exams

8. Describe how you enable your students to prepare for certification?

e.g. standalone courses specifically aimed at certification or part of an academic syllabus

9. How does certification relate to academic credit in your course?

E.g. certification confers academic credit, or students can optionally attempt certification exams in addition to academic credit

10. (Only ask if academic credit conferred) Describe any issues that arose with this approach?

how do you deal with disparities between academic regulations, e.g. pass mark, and certification? what arrangements are in place for students who do not pass the required certification?

11. Describe any facilities or support you offer to students in sitting certification exams?

E.g. subsidise the cost or provide discounts through the vendor, access to in-house test centre or online exams proctored by program team, or leave students to make their own arrangements

12. Are you able to get feedback on your students' performance in certification assessments?

Ethical aspects of this?

Finally, I'd like to talk about institutional approval and evaluation of your course/program

13. Were there any institutional influences, positive or negative, on your plans for including certification in your course/ program?

e.g. policy on employability, regulations, approval process Describe any steps taken to successfully mitigate any barriers

14. Please describe the outcomes that you are able to share of evaluation of your course/program specifically in relation to certification and/or preparation for certification

C STUDENT SURVEY QUESTIONS

These questions comprised the student survey.

1. Which of the following cloud computing vendors/providers are you currently aware of? Choose all that apply.

Required to answer. Multiple choice.

- Amazon Web Services
- Google Cloud Platform
- Microsoft Azure
- IBM Cloud
- None of the above

2. How would you describe your awareness of industry-recognised certifications in cloud computing?

Required to answer. Single choice.

- not at all aware of these
- aware that industry-recognised certifications are available
- aware of specific vendors/providers of industry recognised certifications in cloud computing
- aware of specific certification exams

3. What is your current education status related to computing or other IT subjects?

Required to answer. Single choice.

- studying - junior undergraduate
- studying - senior undergraduate
- studying - postgraduate
- have graduated in a related subject
- have not studied a related subject academically

4. If you are studying or have completed a degree, which of the following best describes your course?

Required to answer. Single choice.

- Exclusively or predominantly focussed on cloud computing
- Includes content on cloud computing
- Does not include any content on cloud computing

5. If you are studying or have completed a degree, in which of the following ways has your course contributed to your awareness of industry-recognised certifications? Choose all that apply.

Required to answer. Multiple choice.

- has not contributed
- mentioned certifications in general
- mentioned specific certifications
- used learning materials related to specific cloud vendors
- provided preparation for specific certifications
- included certifications as part of the assessment for your course
- supported the cost of achieving certification

6. If you are studying or have completed a degree, which of the following specific vendors' services have you learned about or used in your course? Choose all that apply.

Required to answer. Multiple choice.

- Amazon Web Services
- Google Cloud Platform

- Microsoft Azure
- IBM Cloud
- None of the above

7. What is your current employment status related to cloud computing or other IT areas? Choose all that apply.
Required to answer. Multiple choice.

- employed in a related area
- employed in an unrelated area
- seeking employment in a related area
- not employed

8. How would you describe your intentions in relation to industry-recognised certifications in cloud computing?
Required to answer. Single choice.

- no intention to achieve certification
- intend to achieve some certifications but not sure which ones
- plan to achieve specific certifications
- have achieved certification(s)

9. If you have achieved certifications, which of the following specific vendors'/providers' certifications have you achieved? Choose all that apply.
Required to answer. Multiple choice.

- Amazon Web Services
- Google Cloud Platform
- Microsoft Azure
- IBM Cloud

10. If you have achieved certifications, in which of the following specific domain areas have you achieved certification? Choose all that apply
Required to answer. Multiple choice.

- cloud fundamentals
- software development
- data
- artificial intelligence
- security
- not sure

11. If you plan to achieve certifications, or further certifications, which of the following specific vendors'/providers' certifications are you likely to consider? Choose all that apply.
Required to answer. Multiple choice.

- Amazon Web Services
- Google Cloud Platform
- Microsoft Azure
- IBM Cloud
- not sure

12. If you plan to achieve certifications, or further certifications, which of the following specific domain areas would you consider for certification? Choose all that apply.
Required to answer. Multiple choice.

- cloud fundamentals
- software development
- data
- artificial intelligence
- security
- not sure

13. Please rank how the following factors may influence your choice of certifications to achieve
Required to answer. Ranking.

- cost
- employment prospects or requirements
- personal interest
- learning path/progression
- existing knowledge
- relevance to or inclusion within academic course

14. Please rank how important, in your opinion, the following are as benefits to achieving certification. If you don't consider there to be any benefit, please just rank "no benefit" first.
Required to answer. Ranking.

- different perspective to your academic learning
- alternative to academic learning
- learn industry-relevant skills
- evidence of industry-relevant skills
- help get a job
- help to progress in your job
- no benefit

15. Please rank how valuable, in your opinion, the following are likely to be for you in finding employment related to cloud computing
Required to answer. Ranking.

- degree (Bachelors)
- degree (Masters)
- certifications
- relevant experience

D EMPLOYER SURVEY QUESTIONS

1. What is the primary function of your organisation?
Required to answer. Single choice.

- Technology
- Finance
- Healthcare
- Manufacturing
- Construction
- Retail
- Government
- Education

2. What is your job function?
Required to answer. Single choice.

- Technical
- Human Resources
- Management - Technical
- Management - Other

3. Which of the following best describes your area of employment?
Required to answer. Single choice.

- Exclusively or predominantly focused on cloud computing
- Includes working on cloud computing
- Is not related to cloud computing

4. Do you have a role in hiring and/or promotion decision making?

Required to answer. Multiple choice.

- Yes - hiring
- Yes - promotion
- No

5. How would you describe your awareness of industry-recognised certifications in cloud computing?

Required to answer. Single choice.

- Not at all aware of these
- Aware that industry-recognised certifications are available
- Aware of specific vendors/providers of industry recognised certifications in cloud computing
- Aware of specific certification exams

6. Please rank how important, in your opinion, the following are in hiring decisions?

Ranking.

- degree (Bachelors)
- degree (Masters)
- certifications
- relevant experience

7. How would an applicant's cloud certification in relation to each of the following vendors affect your hiring decision?

Required to answer. Likert.

very positively / positively / neutral / negatively / very negatively

- Amazon
- Microsoft
- Google Cloud
- IBM Cloud
- Other

8. A recent Working Group identified the following as key Knowledge Areas (KAs) in cloud computing. In which of these knowledge areas, and to what degree, would you consider certification as a strength in a job applicant's resume?

Required to answer. Likert.

very strong / strong / neutral / weak / very weak

- Fundamental Cloud Concepts
- Computing Abstractions on the Cloud
- Storage Resources on the Cloud
- Networking Resources on the Cloud
- Cloud Elasticity and Scalability
- Fault Tolerance, Resilience and Reliability
- Cloud Monitoring and Maintenance
- Cloud Orchestration
- Software Development using Cloud APIs
- Cloud Programming Models and Frameworks
- Service Oriented Architecture
- Cloud Security, Privacy, Policy and Ethics
- IoT, Mobile, Edge and the Cloud
- Cloud-based Artificial Intelligence and Machine Learning

9. Does your organization provide incentives for your new employees to get certified on cloud computing?

Required to answer. Single choice.

- Yes
- No
- Sometimes
- Not sure

10. Does your organization provide incentives for your existing employees to get certified on cloud computing?

Required to answer. Single choice.

- Yes
- No
- Sometimes
- Not sure

11. If you encourage cloud certifications, how often do you require your employees to get re-certifications?

Required to answer. Single choice.

- Sometimes, depending on the certificate
- Need employees to obtain the latest certificates
- Yearly
- More often than yearly
- Never
- Not sure

12. What percentage of your employees who attempt cloud certification programs complete the certification?

Required to answer. Single choice.

- 0-20%
- 20-50%
- 50-75%
- 75-100%
- Not sure

13. Does your organization provide cloud certifications or certification pathways that can be achieved by its own employees?

Required to answer. Single choice.

- Yes (in-house)
- Yes (third-party)
- No
- Not sure

14. Do you see a return on investment from getting your employees certified?

Required to answer. Single choice.

- Significant return
- Some return
- No clear return
- Not sure

15. Please rank how important, in your opinion, the following are as benefits to your organisation of employees having certification. If you don't consider there to be any benefit, please just rank "no benefit" first.

Ranking.

- Useful evidence of industry-relevant skills to inform hiring/promotion decisions
- Enhanced job performance of employees
- Increased retention of skilled employees
- Enhanced profile/reputation for team or organisation
- No benefit