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# Designing dissemination and validation of a framework for teaching cloud fundamentals


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## ABSTRACT

Three previous Working Groups (WGs) met at ITiCSE conferences to explore ways to help educators incorporate cloud computing into their courses and curricula by mapping industry job skills to knowledge areas (KAs). These WGs identified, organized, and grouped together student learning objectives (LOs) and developed these KAs and LOs in a repository of learning materials and course exemplars.

This WG focused on the sustainability of the work of its predecessors through dissemination, community building and validation of the framework of KAs and LOs and its contribution to curriculum development.

Firstly, a case study is presented which analyzed the implementation of a new Masters program which was based on the KAs and LOs. It was found that these provide a useful basis for program development and approval and demonstrate that successful program development of this nature can provide a valuable opportunity to communicate the work of the previous WGs.

Thereafter, a plan was formulated for dissemination of the work done in order to drive adoption and to encourage instructors with an interest in teaching cloud computing to participate and grow the community. While the strategy included a range of dissemination methods, the importance of interaction with users was a guiding principle. Initial pilots of webinar and workshop activities have been implemented.



*Leader

Approaches to validating that a cloud computing course designed around the KAs and LOs can meet the needs of industry have been outlined with further iterations being considered. A research plan has been designed for a study to be implemented over the coming year in order to perform this validation.

## CCS CONCEPTS

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

## KEYWORDS

Cloud computing, education, computer science, curriculum development

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## 1 INTRODUCTION

Skills in cloud computing continue to be in high demand, and there is a shortage of suitably qualified professionals and graduates to support industry's cloud adoption needs [26]. Cloud computing adoption has grown significantly in recent years and is now widely recognized as one of the Industry 4.0 technology pillars, and an enabler of global-scale systems to support high-growth areas: IoT, Cyber Security, Machine Learning, Artificial Intelligence, Data Science and Health Informatics [17]. The growth in cloud computing presents challenges for industry to source cloud skills to support core business activities, with higher education playing a critical role to ensure graduates have the necessary industry-transferable digital skills for the workplace. Embedding LOs mapped to job skills and appropriate certification in an academic program is an optimal approach for sustaining a graduate pipeline that meets the needs of industry making them 'industry ready' [39] and provides an attractive attribute for prospective applicants.

An initial WG in 2018 [28] documented industry needs alongside existing cloud curricula and mapped out a knowledge base consisting of fourteen Knowledge Areas (KAs) and associated Learning Objectives (LOs) applicable to teaching cloud concepts. Building on the KAs, a second WG in 2019 [29] surveyed the existing landscape for publicly available courses and created a mechanism for faculty to share teaching materials. In 2020, the third WG [14] collected existing teaching materials from numerous sources and used it to review and refine the KAs and LOs, create sample syllabi, and update and seed the repository. Additional background on the research conducted in previous working groups can be found in the cited papers.

These previous WGs have laid the groundwork for what is intended to become a catalyst for curriculum development in computing to meet industry needs in relation to cloud computing skills for years to come. The CloudEdRepo, hosted as a repository on GitHub [23], is at the centre of this, providing a community repository of industry-informed cloud learning resources. The KAs and LOs, which we believe provide a good description of the cloud computing domain at this point in time, are embedded within CloudEdRepo. The LOs are mapped within the repository to learning materials which can be incorporated within courses to satisfy the chosen outcomes. There is a wealth of material freely available by the cloud vendors; however, there are so many materials and certifications that it becomes a problem for educators to navigate and determine what meets the needs of their own courses (see Appendix B). We hope that in due course individual educators will contribute to the community in terms of their knowledge and experience of using available materials, and also in terms of contributing their own tried-and-tested materials.

We wish to establish a sustainable community resource that is of significant pedagogical value and is widely adopted by educators. This resource needs to evolve as the domain evolves [25]. Further, it needs to be validated on the basis of evidence [24] in a way that gives educators confidence that using it as a basis for their cloud computing courses will meet the needs of their students, their institutions and the industry that employs their graduates.

The contribution of this current WG is to disseminate and validate our KAs, LOs and mapped curricula to drive community efforts in accessibility and ease of adoption of cloud computing resources by faculty in many disciplines. This work has involved a range of activities related to this contribution: case study analysis of the use of the KAs and LOs in the design of a cloud computing, implementation of pilot dissemination activities, and the design of a research study which will be conducted to validate the KAs and LOs. Another aspect of the WG is to frame and motivate a program of work sustainable outside the lifecycle of the WG. A core of participants throughout the WGs, the continuing interest of previous members, and the addition of new members to each WG shows the dedication of this growing community of cloud educators to the original goals of the WGs.

Members of the WG were recently involved in the process of designing a new postgraduate program in cloud computing in a UK university. The program was taken through the steps required for institutional approval. The design of the program and courses within it involved mapping the KAs and LOs to the program and course outcomes and to the requirements for related vendor certification. We analyzed this process as a case study to better understand how these mappings work and to determine what evidence this approach can provide in validating the KAs and LOs. The course design has also been used as the basis for a webinar, and the case study provides insights that guide plans for further dissemination and validation.

In this work we look at previous research on dissemination of innovations, and formulate a strategy to be followed to promote adoption and build a community. We designed and piloted two dissemination events implemented within the timescale of the WG, and evaluated these in terms of their reach, value to participants and potential for community building.

We want to answer the followings questions: 1) Does our approach map to industry needs and students who will seek employment there? 2) Is our research valid? 3) Does our research and work meet industry needs? To answer these questions, we select one specific aspect of the cloud computing domain and ask the following: "Is a course designed using the KAs and LOs from prior work

Table 1: 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 |

[14, 28] effective at meeting industry's skill demands in the area of Cloud Administration?" If valid, then we would use the future study as a point to seek funding for further research and dissemination to build a sustainable "resource".

# 2 RELATED WORK

## 2.1 Previous cloud Working Groups

This report will make reference throughout to the KAs and LOs defined by the previous cloud WGs. The nature of these is summarised briefly here for the convenience of the reader. Each KA was derived by grouping related LOs which were identified by analysing current cloud computing curricula in CS and similar programs and documenting industry needs for in-demand cloud skills. The set of 14 KAs defined by the first WG [28] is shown in Table 1.

The LOs within the KAs were refined by the most recent WG [14]. These were divided into conceptual and experiential LOs to target, respectively, the foundational topics upon which cloud-based tools and services are built and practical skills that will help learners develop competency. The classification of the LOs in this way altered the curriculum design perspective from a "body of knowledge" approach to incorporate to some extent the "know-how" and "know-why" dimensions of a competency model such as the ACM CC2020 curriculum [22].

The full set of LOs for all 14 KAs is quite extensive and can be found in the WG report [14]. As an example we present in Table 2 the LOs within the Fundamental Cloud Concepts (FCC) KA.

Table 2: LOs within the FCC KA

| Code | Title |
|---|---|
| Conceptual Learning Objectives | |
| FCC-CL1 | Define the cloud computing concept, its history and motivation |
| FCC-CL2 | Name widely-used cloud-based systems and explain the advantages of having the system on the cloud |
| FCC-CL3 | Define virtualization of computing, storage, and networking resources |
| FCC-CL4 | Explain the differences between leasing versus ownership of compute resources and compare the total cost of ownership |
| FCC-CL5 | Discuss some of the advantages and disadvantages of the cloud paradigm when compared to on-premise resources |
| FCC-CL6 | Discuss the implications of utilizing on-premise versus off-premise compute resources |
| FCC-CL7 | Articulate the economic benefits as well as issues/risks of the cloud paradigm for both cloud providers and users |
| FCC-CL8 | Compare and contrast the types of cloud service models |
| FCC-CL9 | Define service level objectives, agreements and their implications on migrating a solution to a cloud service provider |
| FCC-CL10 | Enumerate and explain various threats in cloud security |
| FCC-CL11 | Analyze a case study about a cloud-based system |
| Experiential Learning Objectives | |
| FCC-EL1 | Recognize existing VM templates provided on a particular cloud infrastructure |
| FCC-EL2 | Explain alternative methods of interacting with provisioned resources (e.g., CLI, GUI, API). Browse, identify, and access resources through a GUI and the CLI |
| FCC-EL3 | Create and format virtual storage units |
| FCC-EL4 | Demonstrate attaching virtual storage units to VM instances |
| FCC-EL5 | Copy data from local storage to the cloud |
| FCC-EL6 | Demonstrate creating a VM, and provisioning it with compute, memory and storage options. Demonstrate starting, stopping and deleting a VM instance |

## 2.2 Dissemination strategies

Educational innovations with the potential to be useful to a wide audience are often instead only used within a context local to the originators of the innovation. It is relatively rare for such innovations to be adopted by a wider community of users [48]. An important aim of our work is that resources we have created are useful to a broad community, or better still become the focus of a community related to cloud computing. To achieve this, it will be important to organize and develop a plan for disseminating our work, based on the dissemination approaches reported in the literature.

The term *educational innovation* is a broad one. Much of the literature on adoption is not specific to any particular type of innovation. Taylor et al. [50] identified a set of broad types of innovation, including *curricular innovations* which appears relevant to this WG. However, we argue that the literature relating to education innovations in general is applicable to this work.

Dissemination, or "getting the word out", in itself is not particularly useful. It is possible for an innovation to become widely known without actually being adopted by a significant number of people. *Propagation* is a more useful aim as it involves adoption of an innovation within a community that extends beyond the originators. Plans for propagation, and transferability, are becoming an important requirement for funding for educational innovations, as illustrated by a current NSF program proposal [43].

The literature in this area relates to a wide range of disciplines. Conversely, there is very little evidence specific to disciplines related to computing. For the purposes of this review we focus on STEM education innovations and on work that is not discipline-specific. This will avoid considering disciplines where the community may have distinct characteristics that are quite different from our own.

Taylor et al. [50] conducted an extensive review of scholarship related to the propagation of CS educational innovations. They considered the applicability of literature on other STEM disciplines to CS and found that many of the the findings related to STEM education are applicable to the CS context. They provide a high-level summary of best practices: plan for propagation; plan for adoption and adaptation during development; support faculty during adoption; involve diverse champions; intentionally craft persuasive messages; get institutional buy-in; and consider what resources will be needed.

A number of authors have studied dissemination and propagation of NSF-funded innovations in particular. Khatri [35] derived a model for propagation based on a grounded theory study of successfully propagated innovations. This is based on an understanding of success factors derived from surveys of stakeholders and detailed evaluation of three selected case studies. The key findings were the importance of interaction with potential adopters at all stages of development, and of funding and sustainability.

McMartin et al. [41] surveyed PIs on proposals funded through an NSF program and followed up with detailed case studies of PIs who had been awarded for excellence. They distinguish between traditional methods, such as presenting papers at conferences, and digital methods such as websites, social media and blogs. Interestingly, the methods that PIs perceived as being successful were not always the ones upon which they focused. For example, academics write papers for other reasons in addition to dissemination.

Stanford et al. [48] analyzed propagation strategies articulated in NSF funding proposals, based on a set of factors derived from the literature: (i) identifying potential adopters and articulating a rationale for the choices of potential adopters, (ii) interacting with potential adopters, (iii) addressing propagation from the beginning of the project instead of postponing efforts to reach potential adopters until near the very end of the project, (iv) describing aspects of the instructional system that influence adoption and explaining how the project will work to address these influences, (v) articulating in detail the propagation strategies and activities that will be employed, and (vi) explaining how the propagation activities selected for the project depended on the type of the project. They also used web searches to estimate the success of propagation for specific projects. In a later paper [47] these authors reported on the development of the Designing for Sustained Adoption Assessment Instrument (DSAAI) which is intended to help, for example, investigators or funding agencies to evaluate proposals on the basis of propagation plans. The design of the instrument is founded in the literature, from which it is concluded that developers should adopt multiple strategies, including passive and active strategies, and provide support for new adopters.

Hazen et al. [33] reviewed literature to uncover factors that affect the adoption of educational innovations. Many of the findings related to factors that are intrinsic to the innovation itself, but they identified issues relevant to dissemination: management support, facilitating conditions, logistical issues, and cultural differences.

The following list is a selection of the most commonly used dissemination/propagation methods reported in the above sources. There is no convincing evidence that any of these provide a solution but a propagation strategy can be constructed from a combination of these.

- Hosting website
- Providing community
- Leverage existing community
- Individual support
- Paper presentation at conference
- Poster at conference
- Booth at conference
- Journal paper
- Workshop - on home or visited campus
- Workshop at conference
- Instructional materials - guides, videos, tutorials, FAQs
- Promotional materials
- Video on YouTube
- Social network presence
- Blog posts

Taylor et al. [50] note that the creation of a *community of practice* can encourage adoption of an innovation. Such a community creates opportunities for members to contribute materials, resources, successful case studies and best practices etc.; to collaborate on funding proposals; and share best practices for propagation. Wenger [52] identifies three characteristics that are crucial to the formation of a community of practice and notes that these should be developed in parallel when cultivating such a community:

- the domain—commitment to a shared domain of interest distinguishes members from others;
- the community—members engage in joint activities and build relationships to help each other;
- the practice—members are practitioners and develop a shared body of resources related to their practice.

## 2.3 Curriculum Validation

In this section we review related research on the validation of curriculum, learning outcomes, knowledge areas and job skill alignment. We include work from a wide range of disciplines as the methods may be generally applicable.

There are differing modelling curriculum approaches which we may want to validate. One approach, which we have taken in the cloud WGs, uses learning outcomes or objectives which tend to be expressed in terms of knowledge units and skills. Competency models, on the other hand, place knowledge units and skills within the context of tasks and associated dispositions [22]. For example, the CoLeaF model, which contributed to the Computing Curricula 2020 (CC2020) project, provides a competency-based framework for describing and comparing degree programs. Mulder's [42] ten dimensions of competency provide an overall observation of independence for different views. The ten dimensions are as follows: (i) centrality, (ii) specificity, (iii) definability, (iv) developability, (v) dynamic nature, (vi) knowledge inclusion, (vii) measurability, (viii) masterity, (ix) performativity, and (x) transferability.

Margaritis et al. [40] provide an example of validation of a competency model. They focus on the importance of competencies for teaching pre-service Computing Science teachers. They describe empirical validation of their competency model using qualitative text analysis. Bender et al. [18] discuss the development of a similar model and discuss issues relating to validating the model. Asghar and Luxton-Reilly [16] report a case study of the design of a curriculum informed by a competency based framework proposed by a recent ITiCSE working group on Cybersecurity education [44]. The case study describes the design and development of a Cybersecurity Master's program comprising six courses and a dissertation. The program was mapped to the cybersecurity education competency-based framework and evaluated using institutional quality assurance and student achievement measures. This case study of successful curriculum development provided evidence of the validity of the framework that guided it.

Validation of curricula often involves the participation of domain experts. Lavranou and Tsohou [36] present a common body of knowledge (CBK) for the field of information privacy, titled InfoPrivacy CBK. A CBK categorises the fundamental knowledge of a specific subject area and the proposed framework helps academics to develop the information privacy curriculum. For validation eleven information privacy experts were invited to study the developed CBK and respond to questionnaire with structured and open-ended questions. Hunt et al. [34] determined the perceptions of IT alumni graduates from selected universities, who were deemed to be critical stakeholders, regarding an updated Organisational and End-user Information Systems (OEIS) curriculum. A web-based survey with 117 invitations had 40 responses to a 5-point Likert scale evaluation for the importance of the OEIS curriculum objectives. The ranking of the OEIS curriculum topics was based on the mean values to categorise topics as very important and important. Caskurlu et al. [20] identified that the issue of disconnect between software design knowledge and skills taught in formal education and job needs could be explored through perceptions of faculty, industry and recent graduates. In their study they used a phenomenological approach to explore the perceptions of faculty, although it is not clear whether that approach was to be extended to the other groups.

The Delphi method can be used to distill the collective opinion of the subject experts through a series of rounds to arrive at a consensus solution to any unstructured forecasting problem. Cumyn and Harris [24] proposed a three stage process for curriculum content validation for Obstetric Medicine using Delphi method: (i) initial gathering of the content from textbooks and curricula to develop potential content that was reviewed by two groups of subject matter experts, (ii) surveys involving 25 Obstetric Medicine experts to validate the curriculum content by providing feedback, and justifications on any changes suggested, which after qualitative analysis identified the significant changes, and (iii) the consensus on the suggested modifications were obtained through a two-round Delphi method. The two rounds used a survey with Likert scale (1 to 5) and standard deviation to determine consensus. Leach describes a framework for naturopathic education that was developed and validated using the Delphi method [37]. The framework was based on constructs identified from diverse resources such as institutional websites, and published literature. The outcomes were then refined and validated using the e-Delphi method. A two-round e-Delphi method used a survey comprising of 47 items across the ten domains. A competency framework was developed by Bok et al. [19] based on the analysis of focus group interviews with 54 recently graduated veterinarians and clients and subsequently validated in a Delphi procedure with a panel of 29 experts, representing the full range and diversity of the veterinary profession.

Automated text analysis provides a different approach to curriculum validation. Garscha and Wöhrer report an approach developed for establishing relations between job descriptions and curricula in Austrian universities[30].Using text analysis, job descriptions and curricula were mapped to weighted word vectors to determine the similarity between the two. Mardis et al. [39] used automated text analysis to determine the alignment and extent to which the IT graduates were prepared for their careers. They analyzed the alignment between the curricula, internship postings, job postings and industry certifications with IT programs at a state college and two universities common national IT curriculum KAs. The keywords relating to KAs were extracted and compared for similarity between the syllabi and 2008 ACM/IEEE curriculum guidelines using a Python script. West [53] proposed a natural language programming (NLP) based test that analyzed the data science curriculum to determine if it maintained a multidisciplinary focus.The data science curricula from 320 universities were collected and the processing identified the word frequency, and clustering. This automated test reduced the bias and subjectivity in curriculum validation. Almaleh et al. [15] presented a framework based on a classification model for analysing data on curricula and job websites, and were able to create visualisations of gaps between courses and job datasets.

## 3 CASE STUDY: DEVELOPMENT OF A MASTERS PROGRAM IN CLOUD COMPUTING

In this section, a case study is presented that demonstrates how a UK based higher education institution, the University of Lincoln (UoL), used the findings of the initial WG in 2018 [2], specifically derivatives of the KAs and LOs, to design and develop a Masters in Cloud Computing program. In addition to developing the cloud program, UoL also designed the program to implement Microsoft Certification into some of the core courses. The aim was for students to not only graduate with a Masters degree in Cloud Computing, but also to achieve vendor certification as part of the program outcomes. The case study provides an example of how an institution can directly use, or easily adapt appropriate KAs and LOs from previous WG reports for designing programs with cloud components. In order to achieve this, a newly developed program must go through an approval process. This approval process can be generalised to other institutions in a global context, with differences in practices managed by adhering to the specific institutional guidance and policies. This section includes the wider approval process for the creation of a new program, including the creation of a program proposal document, development of program curricula, and the program approval event itself. This process is presented with examples of the types of program components that are reviewed, with the intention that educators will be able to take the examples and contextualise them to their own program development efforts for KA and LO integration.

## 3.1 Curriculum Design and Approval Process

The development of computer science degree programs follows appropriate academic and quality frameworks that are managed by the host institution and/or any accrediting body requirements. The frameworks are similar from region to region and, therefore, can be discussed from a broader context. Programs usually consist of a collection of related academic courses that provide credit towards the award of a degree. This is the basic approach in the majority of degree programs. In order to create a new degree program, a number of academic approval processes must be completed in order for the new program to be approved and launched.

Broadly, there are four main stages involved to validate and approve a degree program. These are:

- Stage 1 - Planning Academic & Industry Requirements
- Stage 2 - Program Curriculum Development
- Stage 3 - Program Approval Process
- Stage 4 - Program Launch & Co-branding

For stage 2, the UoL used and modified the LOs from previous WG reports to build the program and course learning outcomes. Similarly, other institutions would undertake the development of LOs during the development of the program's curriculum. Stage 4 differs significantly between institutions, and is usually managed by a marketing team. As such it is excluded from the discussion presented here. An overview of the first three approval stages will now be described, with attention to how the previous WG outcomes have contributed.

*3.1.1 Stage 1 - Planning Academic & Industry Requirements.* In this stage, the teaching team stakeholders of the proposed program, including the program leader, develop a program proposal. The proposal identifies the program's academic aims and outcomes. Additionally, the program leader will engage with an industry advisor/expert to align curriculum components to industry requirements. Beyond academic resource planning, the proposal also typically includes resource planning for course costings, library, ICT services, estates, and career services. This stage also includes consultation with student stakeholders on program structure, course topics, and industry transferable skills outcomes. The output from this stage is a formal program proposal document that is reviewed by senior leadership at the host institution. Upon successful approval from senior leadership, particularly on ensuring the proposal is aligned with institutional strategies and satisfies a market need, the program then proceeds to stage 2.

*3.1.2 Stage 2 - Program Curriculum Development.* The program leader manages the process of designing the program and required courses. This involves the production of a set of program documents, which may vary between institutions in form, but includes an overall program structure and list of courses. Central to this process is the development of a set of program-level learning outcomes, which requires a curriculum mapping exercise. This exercise ensures 100% coverage of the program's learning outcomes by mapping each of the program's courses to relevant program outcomes. Each course also has a set of course-level learning outcomes. Students are evaluated for mastery of these outcomes through assessments such as a formal exam or course assignment. A key engagement for the UoL was implementing certification in the program for academic credit. This ensured that program-level and/or course-level learning outcomes aligned with the Microsoft certification objective domains of interest.

The Masters in Cloud Computing was focused on the core areas of cloud for Compute, Storage, and Networking. KAs and LOs were used and adapted from previous WG outcomes as part of the program and course outcomes, focusing on Compute, Storage, and Networking [28]. These main topics were also mapped to suitable vendor certification that students could take as part of targeted courses on the program. When developing computing-related curricula, the ACM Computing Curricula 2020 report states that KAs are not intended to be strictly in one-to-one correspondence with specific courses in a curriculum, and instead a single course can be mapped to multiple KAs [22]. This is also highlighted in the first WG report in that a cloud-specific course can be built out of a combination of KAs. This is the approach followed by the MSc example presented here for some courses.

The Computing Abstractions on the Cloud (CAC) KA has as part of its definition "students will explore different encapsulation mechanisms to abstract computing resources on the cloud." Some of the LOs from this KA, as adapted by UoL, that correspond to the Microsoft AZ-900 and AZ-104 certifications are:

- Discuss compute, network and storage virtualization and outline their role in enabling the cloud computing system model.
- Describe the rationale behind serverless computing and how it enables the running and scaling of applications without the need to manage servers.)
- Describe the advantages of specialized hardware such as GPUs, TPUs, and FPGAs.)
- Build, deploy, manage, and administer containers and container clusters and architect containerized applications using container registries.)
- Develop and deploy a service utilizing FaaS using APIs that are provided as an auto-scaling service.)
- Explore the use of Serverless architectures and components within Cloud based services.)

In addition to the core area of Compute using the CAC KA, the program area of Networking adapted the Networking Resources on the Cloud (NRC) KA and LOs, while the program area of Storage adapted the Storage Resources on the Cloud (SRC) KA and associated LOs. Additional KAs were also used. The SRC KA was complemented by an LO from the Cloud Programming Models and Frameworks (CPMF) KA in the course shown in Table 3. This demonstrates the application of guidance provided by the ACM Computing Curricula Report [22]. For the development of most cloud programs, the CAC, NRC, and SRC KAs and related LOs will be key foundational components to build the program framework.

**Table 3: Example LOs Cloud Data Storage and Tools Course**

| Course Learning Outcomes | DP-900 |
|---|---|
| Critically evaluate and define data concepts for relational, non-relational, and BLOB object data | • Describe core data concepts<br><br>• Describe how to work with relational data on Azure<br>• Describe how to work with non-relational data on Azure |
| Design and deploy core components of a cloud data storage solution | • DP-900 Microsoft Learn pathway |
| Critically evaluate and discuss cloud-based transactional, batch, and streaming data processing approaches | • Describe an analytics workload on Azure |

With the program LOs from the selected KAs defined, a mapping exercise is carried out to map the course-level learning outcomes to the appropriate program LOs. For example, a cloud data course will be mapped to the program LOs that were derived from the SRC KA. This is typically done using a matrix to provide an easy overview of the mapping. The process involves utilising the appropriate academic expertise within the program delivery team, ensuring each course in the program is mapped with the relevant LOs. For the purposes of implementing vendor certification, a further mapping process charts the certification outcomes to the appropriate course LOs. This entire mapping process produces a program→course→certification mapping and ensures both the academic and certification learning resources are mapped at both course and program level. For example, the LOs for the Cloud Data Storage & Tools course are mapped to the Microsoft DP-900 Azure Data Fundamentals certification outcomes as shown in Table 3. This mapping was undertaken as enrolled students would access the DP-900 certification learning materials and sit the certification exam as part of the academic course.

Upon completion of the program documentation, faculty administration, usually the institution's quality assurance team, will approve progression to an institution-led approval event.

*3.1.3 Stage 3 - Program Approval Process.* Following program documentation, the host institution will organize a program approval event where a panel reviews the program. The panel includes senior leadership, such as a Dean or Head of School to chair the meeting, and faculty administrators, generally in quality assurance roles, who support the validation process agenda and document dissemination. Faculty roles that are part of the program approval process vary across institutions and countries. An example of the terminology and roles that are part of the program approval process in the US can be found in the Curriculum Approval Process resource document [46] . An example for a UK university is discussed by the work of Nicol. et al [22]. The panel may also include external industry advisors/specialists to ensure the program aims and content are commensurate with industry developments. During the meeting, the panel reviews the program rationale and development and directs any questions to the program leader and key members of the teaching team. The meeting involves a rigorous review of the program learning outcomes, curriculum, and student outcomes. Upon completion of the validation process, the panel decides whether to approve the program for final development. This decision is normally accompanied by a list of recommendations that will need to be implemented before validating the program. The output from this stage is a validation panel report that includes a decision on program approval and any recommendations or requirements for changes.

## 3.2 Evaluation

In terms of the MSc Cloud Computing program in the case study, in the first instance the program successfully went through the rigors of the approval process. The use of the KAs and LOs derived from previous WG outcomes were deemed to be suitable, after review by academic and industry experts, for the intended audience and award of an MSc degree. Likewise, any new program will be assessed on a range of criteria. From institutions contacted during a UK webinar [27], below are the most common evaluation criteria that were identified:

1. Overall Impression of the provisional course design: is the proposal coherent and well presented?

2. Proposal Rationale Document: has the course got appropriate background detail relating to the development of the program, is the market opportunity and target market clear are the clear entry criteria?

3. Program Outcomes: are these measurable by the assessment activities within the program(s), can interactive hands on labs help support the students learning?

4. Program Structure and Delivery Pattern: is the program structure clear what is the mode of deliver, will part time and full time students be supported?

5. Learning and Teaching: is there an appropriate over-arching Learning and Teaching strategy, how are cloud services and access to services provisioned?

6. Opportunities for work place education activities within the program(s): is there evidence of work place education activities?

7. Employability: do(es) the program(s) prepare students for the world of work?

8. Internationalization: are there opportunities for internationalization and/or international study within the program specifically relating to the content of the curriculum, ensuring it reflects international issues, agenda and legal compliance or regulations.

9. Entrepreneurship: are there opportunities for students to innovate and develop entrepreneurial skills within the program(s)?

10. Digital Education methods/approaches: how do(es) the program(s) utilise cloud technology and blended learning?

From the identified evaluation criteria above, ensuring students are given opportunities to improve their employability was important. To support this area, University College London (UCL) established a National Framework for Industry Exchange Networks (NFIXN) which enables collaboration between universities and their industry partners [8]. The UCL IXN model is being used globally as an example of best practice in this area of higher education. These could take the form of industrial partnerships, capstone projects, industrial individual or team based projects, and work placements. The program is founded on the understanding that experience of real-world interdisciplinary applications, in conjunction with a rigorous program of taught academic modules, is vital to a modern scientific education. Students are, therefore, involved with the IXN program from the very beginning of their undergraduate studies to the end of their specialist MSc programs, with students working with blue chip companies, charities and SMEs [8, 11].

The UoL also focused on enhancing student employability by integrating vendor certification into the MSc Cloud Computing program. Students graduating from the course will not only graduate with their degree certificate, but also a collection of relevant vendor certifications that demonstrate key competencies to support addressing industry skills gaps.

## 3.3 Webinar on best practices

Following the successful approval event for the MSc Cloud Computing program at UoL, a webinar was delivered to disseminate best practices for embedding Microsoft certifications into courses [27]. This provided the opportunity to highlight the contribution of the WG KAs and LOs to the development of the program and how educators could follow a similar approach for their programs, particular to the curricula development and mapping process outlined in stage 2 of the approval process in section 3.1.2. The content of the session is described here, and the webinar, which was part of the Microsoft Education Skills Webinar series, was recorded and can be viewed online.

The webinar content was as follows:

- Certification at UoL
- Academic engagement, including participation in the WG and other ways that academics can get involved with vendor, e.g., focus groups
- Certification implementation approaches - integration inside a course, alongside course, standalone
- UoL program curriculum development, using WG outcomes, certification implementation
- Specific certifications implemented, e.g. DP900
- Program design and structure
- Program learning outcomes
- Program courses/modules and learning outcomes
- Curriculum mapping
- Student experience
- Employability and industry speakers
- Feedback survey

The intention was to demonstrate that educators could generalise the approach UoL used for mapping certification outcomes to their own programs and courses. Regardless of the type of program or where the program is run regionally, there will be an academic mapping process where course outcomes are mapped to the overarching program outcomes. This process where the extra layer of mapping certification outcomes is completed. Large vendors such as Microsoft, Google and others have a significant reach within the CS education community, and events such as this are widely advertised and typically well attended. During this session we had over 335 attendees and over 990 readers of the associated resources. The demographics of the users who attend the session are shown in Figure 1.

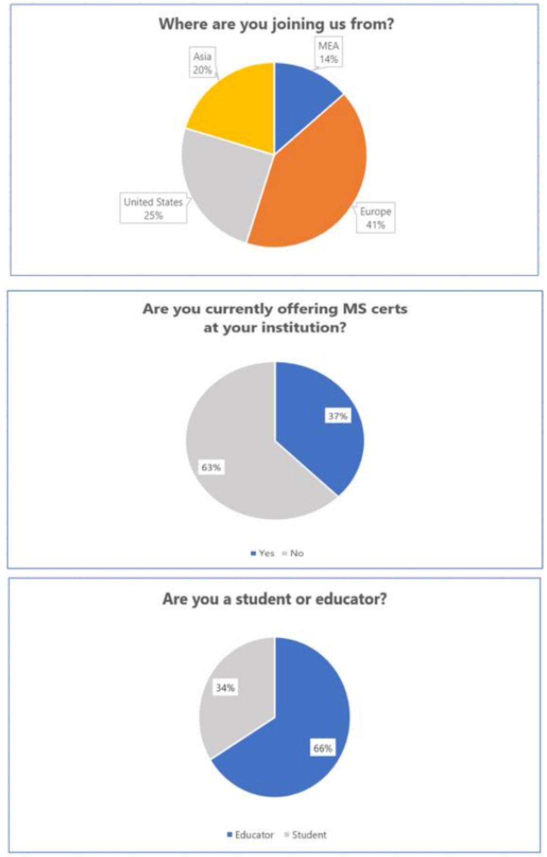


**Figure 1: Demographics of webinar attendees.**

# 4 DISSEMINATION

Dissemination is key to achieving the overall aim of the WG series. In this section, we explore a range of dissemination approaches and describe our current activities and future plans. We discuss open platforms for growing the community which currently consists of past and present WG members. We detail our plans for publications, webinars, individual workshops and a linked series of workshops during which participants create a portfolio relating to their course design. These planned activities will provide a variety of opportunities for reaching out to interested faculty in ways that fit in well with their specific needs and availability.

## 4.1 Community

Community building has been a goal of this WG. The process of recruiting members for and running this series of WGs itself has created a community that has the characteristics of a community of practice: domain, community and practice. A total of 21 members, representing academia engaged in teaching cloud computing related courses and cloud vendors, have contributed to the WGs, including the current one. Eleven of those who have participated have done so in more than one WG, and 6 have been WG leaders.

*4.1.1 CloudEdRepo.* CloudEdRepo [23] is a central supporting resource for this community, and will be the focus of dissemination and propagation activities going forward. Developed initially by a previous WG [29] it is hosted on GitHub and currently includes:

- Core
  - List of KAs, with descriptions of each
  - List of LOs for each KA
  - Details of suggested learning content for each LO
  - Exemplar modules
- Materials
  - Details of large-scale providers, how to access their material, licence terms, etc
  - Details of individual learning objects
- Content
  - Details of other sources of learning content
  - User-generated content
- Community information
- Publications
- Guidance documents for users on contributing

CloudEdRepo is a resource that may be used in support of course design. Since implementation, the WG has been evaluating and enhancing its usability, including:

- adding a way to aggregate information about a provider. Instead of repeating details such as licensing information, users can link to one master document with this;
- creating lists of materials that can be accessed directly instead of through an LO,
- adding the ability to store and browse syllabi.

Feedback obtained from participants who spent some time exploring the CloudEdRepo at an interactive workshop is reported in Section 4.3.2

GitHub was selected, since it is an open platform for collaboration that is free to use and familiar to educators teaching cloud computing. Contributions can be accepted as pull requests, allowing them to be reviewed before being added into the public repository [31]. GitHub provides issue and wiki functionality that can be used for reporting problems with the current material, for requesting new material on a specific topic, or for providing extended documentation related to teaching cloud computing concepts [32]. Documents are written in markdown format, one that is familiar to many educators and that is supported by many tools and development environments [12].

Learning materials are not necessarily individual units of learning, and the repository needs to reflect new learning formats and the way that these can be mapped to our KAs and LOs. For example, many cloud vendors are now developing online MOOC environments to support the learning of these services (see Appendix B) which allow learners to:

- Track progress on learning activities
- Create and share collections of modules
- Save bookmarks
- Accrue points and achievements
- Use free cloud resources
- View personalized recommendations

**Table 4: Citations to Prior WG Reports, By Year**

| Year | Citations | Downloads |
|---|---|---|
| 2018 | 4 | 424 |
| 2019 | 3 | 225 |
| 2020 | 1 | 69 |

Qwiklabs [9], Microsoft Learn [7], and A Cloud Guru [3] are examples of such solutions which offer free, online training platforms providing interactive learning for cloud vendor products and services. Typically the goal of cloud vendors is to provide a service which helps learners become proficient in their technologies and learn more skills. This includes guided, hands-on, interactive content that is specific to Job Role Types and consist of learning units, modules or pathways. They have clearly defined learning objectives and knowledge areas which can be mapped to formal academic curricula allowing these resources to be used as primers or labs.

*4.1.2 Maintainability.* Based on feedback from early participants, we will determine what further information is needed to encourage the community beyond this WG to contribute to the CloudEdRepo. We envision this information taking many possible forms, such as:

- An illustrated page of instructions available as part of CloudEdRepo
- One or more videos walking through the steps of adding or editing contributions
- As part of future workshops, we may add sections (or entire one-hour workshops) on how to contribute and update

Based on early reports from event attendees, it appears increasing the diversity of materials/media that are in the repository is the best first step. As resources are added to CloudEdRepo, these will be reviewed and approved by WG members. Student support may be requested as needed.

## 4.2 Publication plan

The current WG continues a series which started in 2018 [14, 28, 29]. The outcomes of ITiCSE WGs are disseminated through presentation at the ITiCSE conference and publication of the final WG report as a peer-reviewed paper following the conference, which correspond to two commonly-used dissemination methods for educational innovations. The ACM Digital Library metrics for the number of citations and downloads for the three reports to date are shown in Table 4. Google Scholar shows somewhat higher numbers of citations, e.g. 17 for the 2018 report. Analysis of those citations, once self-citations are excluded, indicates that the 2018 report in particular is a useful resource as "related work" for authors reporting on curricular developments related to cloud computing, although there is no evidence of adoption of the KAs and LOs reported in that work.

Publication is widely used as a dissemination method, to some extent, because it is part of the normal activity for academics, and as such it can be valuable as part of a wider strategy [41]. The work plans mapped out by this WG offer a range of opportunities for publication which will serve to raise awareness of the outcomes:

- Informational presentations in conferences which address specific communities, such as [45] which was presented at the Computing Education Practice conference in the UK.
- Case studies of curriculum development in cloud computing
- Research reports based on outcomes of studies within our research framework

### 4.3 Webinar and interactive workshop events

The literature reports consistently on the importance of dissemination methods that actively engage the target audience. We identify two types of events that can be run within a single session, and repeated at different venues or recorded for later viewing.

*4.3.1 Webinars.* As exemplified by the University of Lincoln event described in section 3.3, this format consists of a presentation of approximately 1 hour in length, with Q and A time thereafter. This live event can then be packaged as a video of the presentation. The case study example was hosted by Microsoft and through their community outreach attracted a fairly large audience. A similar workshop was presented to a large audience by other former WG leaders as part of Google Cloud's 2020 Faculty Institute [13].

An additional webinar took place in September 2021 [38], similar in scope to the webinar presented in section 3.3. This webinar was a live broadcast through several media channels, including YouTube, and introduced the outcomes of the WG technical reports, specifically on leveraging the developed KAs and LOs to design new cloud computing programs. It also focused on the role of vendor certifications with two institutions showcasing how they have implemented cloud certifications in their academic programs. Implementing vendor certifications was an area covered in the first WG report. The webinar was advertised on Reactor [6], on Microsoft developer outreach sites,and attracted 1841 views in the few days following its live broadcast.

*4.3.2 Interactive workshop design and implementation.* This event is a more hands-on interactive workshop session for a smaller group of attendees who are expected to participate actively in break-out tasks related to the workshop theme. This format will typically run for 2-3 hours and is suitable for delivery in a variety of contexts. For the moment only online events are under consideration, but these can be standalone events or can be proposed as workshops to be affiliated with conferences such as the SIGCSE Technical Symposium (TS) and Consortium for Computing Sciences in Colleges meetings.

An interactive workshop was held in September 2021. The workshop was titled "Building your Cloud Computing courses on solid foundations: Using evidence-based guidelines and mapped learning resources in the design of your Cloud Computing courses".

This piloted session has lead to the development of further instances to be offered to the community as standalone events and as workshop proposals for community events. The general format is designed to be adaptable to fit into a range of formats up to 3 hours. The workshop can be delivered by different combinations of WG members, suitable for instances purely online or in-person in different geographic areas, for example at conferences. Appendix C documents the general format, describing the significance of the topic, participant requirements, agenda, expertise and expected audience. This information is based on the content required for a workshop proposal at the SIGCSE TS, and can be adapted for other venues as required. For the September workshop we simply extracted and condensed wording from this for the mailing list announcement.

The pilot workshop was an online-only event, using Google Meet, and was promoted on community mailing lists, including the SIGCSE-members list, approximately 1 week before the date of the workshop. Four WG members facilitated the pilot workshop. The time of the workshop was selected to be reasonably suitable for participants in the USA and Europe (and for the workshop facilitators). To make it as simple as possible for attendees, and hence to minimise barriers to participation, pre-registration was not implemented. As a result it was not possible to estimate the number of attendees in advance. The Meet attendance report showed that 16 participants attended for at least 30 minutes during the workshop.

A short (1 hour, no break) format was adopted for the pilot. The intention was to gauge the level of interest in the workshop, the initial reaction of the attendees to the resources presented and the areas that the attendees would be interested in discussing. Based on this information, more in-depth events will be organized in future. The agenda was as follows:

- Introductions
- Four minutes about ITiCSE Working Groups
- Knowledge Areas and Learning Objectives
- Introduction to the repository
- Exploration Time
- Exploration Discussion
- What's next?

For the "exploration time" segment, attendees were able to join one of three breakout rooms each intended to allow active discussion of the KAs and LOs related to one of the areas. Thereafter, everyone returned to the main room for general discussion. Recording activity in breakout rooms on most platforms, including Google Meet, is not possible. The WG session leaders decided not to record the main room segments because such a recording would not capture the full interactive workshop experience.

At the beginning of the workshop, attendees were asked to enter their preferred topic in the meeting chat box, and this information was used to configure the breakout groups.

A post-workshop survey was also administered for evaluation of the workshop, which focused on: overall impressions of the KAs and LOs and their applicability to the attendees' courses; framing of the LOs as conceptual/experiential; repository navigability and usefulness; and ways in which further support can be provided, e.g. more workshops like this, more in-depth workshops.

Eleven responses were received (N=11), and these indicated we had participants based in the USA, UK and Spain, teaching in universities and in one community college. Over 50% are currently teaching a cloud computing course.

Feedback on courses taught and the relevance of the KAs and LOs to those was encouraging and will be further analyzed along with data to be gathered at future events. 55% of respondents agreed that the repository allowed them to explore KAs and LOs easily. While the short workshop format and limited time to explore may have been a factor, there is an indication that the design of the way the KAs, LOs and resources are presented needs to be evaluated further. Feedback regarding the workshop itself indicated that 100% of respondents would be interested in more in-depth hands-on workshops. Respondents and participants during the workshop commented that they would like more time to explore than we allowed in this format; we should revise the timings or adopt a somewhat longer format for future instances.

*4.3.3 Comparison of event types.* These event types have a number of different characteristics:

- Audience size—the webinar format can support a large audience, while the interactive workshop is limited as there is an expectation that all participants will take part in and be involved in reporting on breakout activities.
- Activity—while the webinar format may allow audience members to comment and ask questions, the workshop is significantly more interactive and participants should take away something relevant to their own course.
- Effort—both event types need planning and preparation of content and materials, however, once the webinar has been delivered, it can be available online afterwards for as long as necessary: the demographics of the webinar described in section 3.3 indicate that more people viewed the recording than viewed it "live". The workshop format needs to be organised and presented anew for subsequent groups of participants.

These events were essentially complementary and both formats appear to be useful as part of a dissemination plan. The level of interest in the events provides evidence that there is significant demand to learn about and apply the WG outcomes.

## 4.4 Cohort program plan

Individual events can potentially make a contribution to community building through engaging educators who are looking for resources to help with their cloud computing courses. Moving beyond that, we considered how we could extend the format to provide opportunity for participants to engage in joint activities and build relationships to help each other [50].

The implementation of this aim is clearly beyond the scope of the current WG. However, the WG has prepared the ground for this by designing a format for a program of related workshops. This program will involve recruitment of a cohort of participants who will engage over 8 themed 1 hour sessions. If successful, and provided there is evidence of demand, the format could be repeated with further participants. This recruitment will initially target participants from previous webinars and standalone workshops. The frequency of these meetings is likely to be weekly although more widely spaced sessions will be possible.

The purposes of this program are:

- To provide extended support to participants during the full process of the development of a course using the repository to guide them
- To create a set of curriculum designs that will contribute to the repository as detailed exemplars for others
- To gather data for evaluation of the repository
- To expand our data collection for the developing research study

This program will be considered successful if, as a result of participation, one or more courses based on our KAs and LOs are developed and taught to students, particularly if these become exemplars that can be included in the repository and/or in future dissemination events.

The proposed program will be based on the approach to developing exemplar courses described in the 2020 WG report [14]. It has also been influenced to some extent by the Disciplinary Commons (DC) projects [51] which were successful in facilitating systematic reflection on practice, exchange of ideas, learning of skills and networking. DC participants each documented their teaching practice in a course portfolio which included details on course content and pedagogy along with reflection on the reasons for choosing these. Similarly we expect participants in our program to document their course designs along with reflection on the process that was followed to create these, and eventually on the experience of delivering the course. These exemplars will be of value to the community, not just as exemplars, but as complete artifacts demonstrating the development process.

*4.4.1 Phase 0: Prerequisites.* The prerequisites and requirements for participants are as follows:

- They are designing or redesigning a course scheduled to start at some point in 2022.
- They can commit to a program of 8 one hour workshop sessions, with some “homework.”
- They share the outcomes in the repository (obviously they own all rights to their courses).
- They review and provide feedback on our resources.

*4.4.2 Phase 1: Workshops.* The workshop sessions will be held virtually using one or other of the commonly used videoconferencing platforms because of COVID-19 restrictions. However, video conferencing enables or supports the participation of a potentially geographically diverse cohort without the requirement for significant funding. Course materials such as task instructions and templates will be made available through an area within the GitHub repository. Participants will work with templates under Git and will push their final documentation to the repository. The weekly program activities are briefly described in Table 5. Each week’s task will require participants to do some preparatory work in advance of the session. Structured guidance will be provided for each task.

The participants’ reflections and our notes on the interactions with the cohort will provide data for qualitative analysis to evaluate the participants’ perceptions of the process and the support provided by the KAs/LOs and the way these are presented in the repository.

*4.4.3 Phase 2: During the teaching semester.* Participants will be asked to communicate with us monthly as they teach their course. The arrangement of sessions with the whole cohort may not be possible as the timing of the teaching will differ between participants. Participants will be asked to complete a survey at the end of their course. During this phase we would also attempt to identify a pool of willing participants to contribute to future cycles of our planned research study, which is described in Table 5.

**Table 5: Cohort program schedule**

| Week | Activity and Task |
|---|---|
| Week 1 | introduction, walkthrough of repository, set up template for portfolios including course descriptor document (in GitHub) |
| Week 2 | discuss intended aims of course (e.g. related job role, purpose within broader curriculum) |
| Week 3 | start to map intended aims to KAs/LOs with guidance (1-2 weeks) |
| Week 4 | feedback/discussion of chosen KAs/LOs. (1-2 weeks) |
| Week 5 | start to identify teaching material and build syllabus with guidance. (2-3 weeks) |
| Week 6 | feedback/discussion of syllabus |
| Week 7 | Discuss draft course descriptors. |
| Week 8 | Finalise, wrap up and check in final courses |

*4.4.4 Phase 3: Post teaching.* The aim is that participants will become "champions" and will contribute to further dissemination activities.

# 5 RESEARCH STUDY PROPOSAL FRAMEWORK

## 5.1 Motivation

In our past WG papers, we developed KAs and LOs related to cloud computing, as well as mapped the LOs to job skill needs in industry. We plan to undertake a research study to validate whether a course designed using the KAs and LOs developed will effectively meet industry demands. In this section, we will present the research proposal framework which will guide us as we conduct a proposed WG study next year. This section will outline our research question, method, and three different approaches to validate the outcome of our work.

## 5.2 Research Question

Our proposed research question is: "How and why is a course designed using the KAs and LOs [14, 28, 29] effective at meeting industry's skill demands in Cloud Administration?" Below we will outline the course design using the KAs and LOs, as well as the administration of the course and evaluation of its efficacy.

## 5.3 Course Design

Our intention is to design a course for wider dissemination in the field of CS using the existing KAs and LOs. The course designed here is not an entire single semester, quarter, or term course in the traditional sense. This course is intended as a section that can be included in an existing course. It is important to note that we intend to reevaluate this design approach upon completion to examine how a course can be modified towards non-CS faculty (i.e., Chemistry, English, Sociology, etc.) interested in teaching cloud-computing concepts in their respective courses. This initial course design will serve two goals: one to validate the approach proposed for fast development of effective courses that are well aligned with industry needs; the second goal would be to utilize this course to evaluate the alignment with the tasks, knowledge and skills of an industry position. Given we have 13 KAs and 100+ LOs, we decided to focus on a small segment of our LOs. Based on an analysis of popular entry-level cloud-based positions, we selected the Cloud Administrator as a viable industry position to develop a course. For the cloud administrator position, we have identified the knowledge and skills outlined in Table 6 that are common across multiple job listings that we have identified across the globe.

Given curriculum alignment and design is the current research and standard in the design process [21]. Using the KAs and LOs outlined in [14, 28, 29], we have identified the LOs shown in Table 6 as the best alignment to prepare a learner to understand and up-skill and carry out the tasks in a Cloud Administrator position in industry. Another consideration is the alignment with popular certificates and the Cloud Administrator position. For those, we have developed the alignment between our LOs and the Azure Fundamentals (AZ900), Microsoft Azure Administrator (AZ104), Google Associate Cloud Engineer, CompTIA Cloud Essentials+, and CompTIA Cloud+. Of course, this course can be aligned with other vendor certifications as well. We will also develop a survey that outlines the knowledge, skills, and certifications associated with this job. We plan to administer the survey to validate whether our intended LOs will achieve the desired intent of employing learners that have successfully completed our mapped KAs and LOs and designed course. If certain knowledge or skill gaps are identified by our survey, we will revisit the intended LOs of the cloud administration course to address the gaps.

This alignment between course LOs and certifications has been mapped in Table 7. The cloud administrator job has some variations and specifics in the job requirements across different organizations due to their specific domain, degree of cloud adoption, and size. Some of the skills across Table 6 and 7 may use slightly different terminology or focus. After this alignment analysis, we consider the intended course LOs to be well aligned with the Cloud Administrator position.

Since positions in the cloud computing domain are evolving rapidly, we plan to revisit and update the KAs and LOs for the cloud administration course every two years using the same process outlined above.

For the purpose of the study, we plan to develop the conceptual content and the experiential training modules to achieve the LOs (see Table 8). The conceptual content will include text, images, and potentially short videos along with assessments to evaluate the students' ability to achieve the intended LOs. The experiential content will be in a sequence of hands-on real-world project scenarios. Sá-Pinto et al., [49] assert learning goals and skills required are aligned and developed as part of the curriculum and some goals and skills are considered more important than others leading to variations. We hope to utilize real-world data sets and plan to develop the projects on commercial public cloud providers to give our learners a real-world experience. Our plan is to design, develop, test, and disseminate auto-graded projects that enable iterative exploration by the learner at scale.

**Table 6: LO Mapping to Cloud Administrator Job: Knowledge and Skills Identified**

| Item | Knowledge and Skills | Conceptual | Experiential |
|---|---|---|---|
| 1 | Cloud models: IaaS, PaaS, and SaaS | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |
| 2 | Networking: protocols, VPN, application gateway, subnets | NRC-CL1, NRC-CL3, NRC-CL6 | NRC-EL1, NRC-EL2, NRC-EL3 |
| 3 | Storage: NFS, backup, recovery | SRC-CL1, SRC-CL3, SRC-CL5, SRC-CL7, FTTR-CL8 | FCC-EL3, FTTR-EL2, FCC-EL4 |
| 4 | Compute: Virtual machines, templates, images | FCC-CL3, CAC-CL1 | FCC-EL1, FCC-EL6, CAC-EL2 |
| 5 | Compute: Serverless, FaaS | CAC-CL4, CES-CL8 | CAC-EL3, CAC-EL7 |
| 6 | Security: logging, monitoring, patches, upgrades, user audits, firewall, SSL/TLS, encryption, vulnerability assessment | FCC-CL10, NRC-CL9, NRC-CL10, CMM-CL3, CMM-CL5, CSPPE-CL1, CSPPE-CL5, CSPPE-CL6, CSPPE-CL7, CSPPE-CL9, CSPPE-CL18 | CES-EL9, CSPPE-EL1, CSPPE-EL3, CSPPE-EL4, CSPPE-EL7, CSPPE-EL9, CSPPE-EL10 |
| 7 | Scripting: Automating tasks | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |
| 8 | Performance: Load balancing, identify faults and performance issues | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |
| 9 | DevOps and Configuration Management: Ansible, Chef, Puppet | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |
| 10 | Containers: Micro services, Docker, Kubernetes | CAC-CL2, SOA-CL6 | CAC-EL1, CAC-EL6 |
| 11 | Databases and Webhosting | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |
| 12 | Application and Data Migration | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |
| 13 | Administration: creation and maintenance of existing and new cloud workloads | FCC-CL8, CPMF-CL4 | CES-EL5, CES-EL6, CES-EL7 |

Note: All LO codes can be found in our previous WG paper here: [14].

**Table 7: LO alignment to Administrator Certification Exams**

| Item | Skills | Conceptual | Experiential |
|---|---|---|---|
| 1 | Manage identities and governance | SDCA-CL4 | FCC-EL2, CSPPE-EL11 |
| 2 | Implement and manage storage | SRC-CL1, SRC-CL7 | FCC-EL3, SRC-EL3 |
| 3 | Deploy and manage compute resources | FCC-CL3,CAC-CL2,CAC-CL3,CAC-CL7,CES-CL8,CO-CL11,CO-CL12,CO-CL13,CO-CL8 | FCC-EL6,CAC-EL1,CAC-EL2,CES-EL2,CES-EL4,CES-EL6,FTTR-EL2,CO-EL3,CO-EL4 |
| 4 | Configure and manage virtual networking | FCC-CL6,NRC-CL3,NRC-CL9,NRC-CL10,CES-CL7,FTTR-CL1,CSPPE-CL1,CSPPE-CL7 | NRC-EL2,NRC-EL3,CSPPE-EL6,CSPPE-EL9 |
| 5 | Monitor and backup resources | CES-CL10,FTTR-CL8,CMM-CL2, CMM-CL4 | FCC-EL5,SRC-EL4,CES-EL8,CES-EL9,CMM-EL1,CMM-EL5,CMM-EL6,CSPPE-EL1,CSPPE-EL4 |
| 6 | Security policy and implementation | CSPPE-CL1, CSPPE-CL2, CSPPE-CL3, CSPPE-CL4, CSPPE-CL5, CSPPE-CL6, CSPPE-CL7, FCC-CL10,CSPPE-CL15, CSPPE-CL16, CSPPE-CL17, CSPPE-CL22, CSPPE-CL24 | CSPPE-EL2, CSPPE-EL6, CSPPE-EL9, CSPPE-EL10 |
| 7 | Disaster Recovery and performing standard infrastructure procedures | FTTR-CL8, FTTR-CL9, CO-CL5 | CES-EL1, FTTR-EL3, FTTR-EL4, CO-EL5 |

Note: All LO codes can be found in our previous WG paper here: [14].

**Table 8: Conceptual Content and Experiential Training Module outline**

| Week | Conceptual Content | Experiential Projects |
|---|---|---|
| 1 | Cloud Overview, Quiz and Pre-assessment | Account and Subscription Setup |
| 2 | Provisioning and Managing Cloud Services; Quiz 1 | Subscription and Resource Group Management |
| 3 | Identity Management and Access Control; Quiz 2 | Azure Active Directory |
| 4 | No New Content Week (NNCW) | |
| 5 | Virtualization in the Cloud; Quiz 3 | Resource Provisioning |
| 6 | Elasticity in the Cloud; Quiz 4 | Scalability |
| 7 | NNCW | |
| 8 | Automation, Configuration and Orchestration; Quiz 5 | Infrastructure as Code |
| 9 | Resource Monitoring; Quiz 6 | Monitoring Cloud Services |
| 10 | NNCW | |
| 11 | Cloud Security; Quiz 7 | Cloud Security |
| 12 | Disaster recovery and Backup; Quiz 8 | Backup and Disaster Recovery |
| 13 | Post-assessment, Certification | |
| 14 | NNCW | Capstone Project |

Note: Our course outline is built using the following course outline from SAIL: [10]. All concepts and projects in Table 8 Conceptual Content and Experiential Training Module outline maps to the Conceptual and Experiential LOs in Tables 6 and 7.

## 5.4 Research Design

In this section, we will outline the method utilized to answer our research question. We plan to evaluate whether learners who successfully complete our course as outlined above will meet industry's needs for Cloud Administrator positions using three validation methods. Note, our methodology provides an idealistic high-level overview, however, the specifics of our intervention are subject to evolve based on ethics approval and institutional participation.

*5.4.1 Population.* The Population will focus on Undergraduate students in their 3rd/4th year of study.

*5.4.2 Experimental Controls.* In order to isolate the effects of our experiment, we introduce topic based controls in our course design. In particular, we will identify a set of topics that are taught using the WG LO-aligned materials as well as a set of topics from pre-existing unaligned materials.

*5.4.3 First Experiment.* First, we will validate whether learners who successfully complete the Cloud Administrator course have achieved the intended LOs pre- and post-assessment. This will be helpful since the course will be administered at multiple institutions. The pre-/post-assessments will be developed as part of the course content development process. We plan to identify WG members to participate in developing and delivering the designed course.

Our pre-assessment will cover technical questions aligned with the intended learning objectives. We will also include measures of traits such as self-efficacy and perceived industry-relevance of the module contents. We will compute elements such as time-to completion, results on efficacy and relevance tests as well as overall averages on technical questions. We will also include questions regarding previous experience with course content as this may be a variable of interest to the community. We will stratify students based on past experience to ensure homogeneity among our sample.

Upon the completion of the course, we will provide the students with a post-assessment containing technical questions aligned with the intended learning objectives as well as questions regarding self-efficacy and industry-relevance.

Our primary goal will be to analyze if student performance in topics taught using our experimental materials was similar to, or even surpassed controlled topics. Our preliminary analysis will be an analysis of summary statistics to compare scores in the pre- and post-assessment. Furthermore, we will utilize pre- and post-course **Paired-Samples t-test** to measure whether or not any increase in scores, efficacy ratings or time-to-completion was statistically significant $p < \alpha = 0.05$.

We will conduct an Analysis of Variance (ANOVA) with the intent of deriving and F-statistic to determine if the efficacy of module varies based on past experience.

*5.4.4 Second Experiment.* The second validation process is to collaborate with industry partners who are willing to interview selected students to evaluate their efficacy at performing the tasks for the job description selected relating to the topic groups introduced in the course using our experimental method. The interviews will be conducted immediately after course completion to minimize the impact of external factors. We will normalize the outcomes of the interview process in order to enable the analysis and comparison across the selected groups. The pre-course survey will be drafted this fall with peer-review input as part of validation and reliability process to ensure appropriateness of the survey questions.

We will proceed to use the Delphi Method to collect data on perceived efficacy of our curriculum from industry partners to be evaluated against a designed rubric. We will utilize stratified random sampling to partition our group based on practice area. The strata will correspond to specific industry partners having knowledge, experience and employing students in cloud administrator positions. Each participant will be asked to interview a group of randomly selected students who have completed our module. The interviewers are expected to ask interviewees to perform or describe specific tasks (that may have been completed already) related to an LO defined by the course modules in a cloud administrator role they have completed.

Using the Delphi Method: Before interviews, we will ask interviewers to identify core-competencies expected from students.

Upon completion of interviews, we ask interviewers to rate on a 7-point likert-scale whether or not each student met those core-competency criteria. A **Cronbach's Alpha** $\rho T$ will be computed to measure the internal consistency of the ratings. Furthermore, we will utilize a **Spearmann's correlation** metric to determine whether or not some modules in our course were correlated with higher scores than others to give us a sense of where we may need to improve.

*5.4.5 Third Experiment.* Pending the experimental results of our other experiments, we aim to analyze the scores of students on standardized tests. Though not as rigorous as our other experiments, this will provide some high-level insight into the efficacy of our experiment. This third process will be to randomly select students, who successfully completed the course at their institution and across different efficacies, to attempt the certifications mentioned above. We will secure sponsorship from Azure, GCP, and CompTIA to administer the certification exams for our learners. We speculate that a significant majority, $n > 75\%$ will be able to pass certification exams on the first attempt. We aim to collaborate with industry partners to analyze the breakdown of scores, subject to ethics/IRB approval.

# 6 DISCUSSION

In this section we discuss barriers and limitations relating to our plans for both dissemination (or propagation) and validation of the outcomes of the previous WGs.

## 6.1 Dissemination

Success for propagation depends on the existence of a body of educators who are, or will be, teaching cloud computing courses, are interested in resources to help them design and teach those courses, and who may be willing to participate within a community and possibly contribute to such resources. The level of interest in the events held to date and reported here indicates that at least the first of these is the case. The challenge that the plan laid out by this WG addresses is to target those who fit the remainder of the description.

The cloud vendors have an important role to play. Teaching cloud computing relies heavily on the services provided by the vendors and benefits from the wealth of teaching materials that they can provide. Their education outreach programs have significant reach among communities of educators who are teaching using their specific platform, which has been valuable for this WG. This WG includes representatives from two of the major vendors. There is a challenge in building our community to be inclusive to users of all platforms, and not biased towards any one vendor.

The resources available should be both useful and usable. There is a dependency here between the two aims of this WG. Successful validation of the KAs and LOs will provide reassurance to educators that using our resources and joining our community will benefit their students. Usability is related to the design of the repository and how easy it is for educators to navigate the KAs, LOs and related supporting materials, and to make their own contributions. This is an area that will require further work.

Finally, in terms of dissemination, the sustainability of the planned activities will require a significant effort. The commitment of the existing community of WG members will be important, but there may also be a need to seek further support.

## 6.2 Validation

Our main goal in the research study plan is to design methods for a research study to validate that students obtain the skills that industry needs from taking the designed course (specific to cloud administrator). As part of the design process, there are specific limitations we need to address. 1) our study is limited to Cloud Administrator. 2) Our study is limited to WG members delivering the new designed course. 3) The design and data collected from the study will be limited to our designed course and not comparable to LOs and courses designed by faculty not mapped to our KAs and LOs, and 4) the time scale of the research study.

To address limitation 1, we discussed multiple courses as a potential for the study; however, we realized the difficulty in conducting multiple experiments at the same time. Therefore, based on a consensus within the group on previous courses taught, we agreed on Cloud Administrator.

To address limitation 2, we discussed that we would like to have multiple participating faculty outside the WG faculty group. However, we realize that identifying participants who are willing to teach our course at this stage would not be feasible given the time constraints.

To address limitation 3, we would like to compare the data on performance of students who complete our course to data from students who have completed equivalent courses that were not designed in alignment with our KAs and LOs. However, we recognize that this may not be straightforward in terms of finding suitable participants. There may be potential issues with study design, e.g. how do we find students who have done other courses.

To address limitation 4, it is anticipated that the study will be carried out over a number of iterations. The first iteration is tentatively planned for Spring 2022, so that the study preparation, including IRB approval, will need to be completed by Fall 2021.

Finally, the study outlined in this report addresses a specific research question that is an important aspect of validation of our KAs and LOs and their mapping to job skills and certifications. They may represent a knowledge-based model of curriculum development. We have chosen this particular way of framing our definition of the cloud computing domain in a way that we believe maps well to those skills. However, the way our LOs have been classified reflect aspects of a competence-based perspective. We expect that our study will provide insight into the competencies evidenced by participants in a course based on our model.

# 7 CONCLUSIONS

This WG has taken important steps towards ensuring that the body of work done by previous WGs becomes a widely used resource for addressing the skills gaps, which has been set out as a goal from the inception of the first cloud WG. The outcomes of this work lie within the framework that has been laid out for dissemination and validation of the previous WG outcomes, and which map out a program of ongoing activity to ensure that these have a sustainable impact. These outcomes will be of value to the community of past and present WG members and new collaborators, in framing and providing an evidence base for the program of work to take place over the next year or so. The WG outcomes will benefit the wider cloud computing education community in enhancing awareness of our KAs and LOs and associated resources, and in assuring them that, by adopting these, the skills that their students' gain will be relevant to industry needs. The outcomes will also be of interest to other developers of curricular innovations in defining approaches to building sustainability and community of practice.

We have examined the process of curriculum design and approval for a Masters program in cloud computing as a practical case study of the use of our KAs and LOs. Evidence indicates that KAs and LOs were helpful in the design of the program and individual courses within it and could be mapped successfully to LOs expressed in the preferred institutional form and to vendor certifications. The resulting program was reviewed by experts and was successful in gaining approval for the award of Masters degrees. We noted also that this process provided a valuable opportunity for dissemination of the outcomes of the WGs.

We have developed an understanding of the importance of a range of strategies for propagation of the WG outcomes as an educational innovation, including the benefits of interaction with users and potential users, and on that basis have laid out a plan for a multi-faceted approach to dissemination activities. We have identified the need to evaluate and develop the design of our repository which provides educators with the details of our KAs and LOs and access to associated learning materials, and is at the core of the community which we have established and aim to grow. Webinars and workshops are important aspects of the dissemination plan. We have designed and piloted models for these, and they will form the basis of an ongoing program of similar events and more in-depth activities.

Finally, having demonstrated through the case study that the KAs and LOs are useful in meeting the needs of institutions introducing new programs in cloud computing, we have mapped out a research study. This work will continue beyond the conclusion of this WG, which will aim to validate that the outputs in learner skills and achievements of a course designed using our resources meet industry needs with respect to cloud computing.

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# APPENDIX

## A GLOSSARY

Many concepts have different names in different countries. This glossary defines the terminology of relevance and preferred terms used by the WG. Preferred terms have been used in the paper for consistency and to avoid listing alternatives in each instance.

- **Bachelor's Degree** An undergraduate program of study.
- **Class** A group of students studying the same course, often also called a cohort. Also a period of time when a group of students are taught.
- **Course** An alternative name for a module but also used instead of program/programme.
- **Curriculum** A term with a wide range of definitions such as:
  - What will be taught to the students, defined using learning objectives or Learning outcomes
  - A program of study that allows students to acquire knowledge and skills
  - A teaching plan
  - The teaching practices and student learning experience
  - A set of programs, courses or modules offered
  - A set of subjects and standards used to ensure that students across institutions learn the same things.
  - Specific knowledge to be transferred to the student

  Sometimes considered the same as syllabus.
- **Faculty** University teachers.
- **Graduate Degree** A program of study taken after completing an undergraduate program of study. Used in the US. (Preferred to Postgraduate Degree)
- **Learning Material** Resources such as slide presentations, documents, videos etc. used by academics when delivering a module.

- **Learning Objective** A statement describing knowledge students should have obtained or skills they should have acquired. Expresses the teacher perspective on the intent of a module or program. (Preferred to Learning Outcome)
- **Learning Outcome** Often used interchangeably with Learning Objective. Can also be used to express the student perspective on the intent of a module or program.
- **Level of Study** The academic level a student studies at as they work through a program. A module is typically aimed at a specific level with higher levels being more demanding than lower levels: There are many standards around the world concerned with enumerating the levels and how they correspond to undergraduate and graduate programs. Often the level of study for a module is simply stated as undergraduate or graduate. Some examples are:
  - European Qualifications Framework (EQF)
  - Scottish Credit and Qualification Framework (SCQF)
  - Regulated Qualification Framework (RQF)
- **Master's Degree** A term often used instead of Graduate Degree. Used in the UK and elsewhere.
- **Module** A term used for a block of teaching. A module is of fixed duration with an associated amount of credit. May be elective or compulsory. Features a set of module learning objectives expressing the intent and what must be covered. Often modules are split into smaller blocks of teaching called classes or units to match daily and weekly delivery patterns. Where the term course is used instead of module the smaller blocks are often called modules. (Preferred to Course)
- **Program** A term used for a collection of modules. Is of fixed duration with an associated amount of credit typically determined by the credit from the modules from which it is composed. Features a set of program objectives expressing the intent of the program and what is covered. Used in the US. (Preferred to Programme)
- **Program Approval** An institutional process which is required before a program can be offered to students. Typically requires preparation of documentation of all aspects of the design and proposed delivery of the program, including learning outcomes, curriculum structure, teaching and learning strategy, etc., and a formal panel event which scrutinises the documentation and interviews stakeholders. Sometimes referred to as Validation.
- **Programme** An alternative to program. Used in the UK
- **Postgraduate Degree** A program of study taken after completing an undergraduate program of study. Used in the UK.
- **Undergraduate Degree** A program of study undertaken after secondary education and before graduate level study. (Preferred to Bachelor's Degree)
- **Syllabus** Often the equivalent of a module descriptor but can also just be the module topics.
- **Webinar** An online seminar or presentation. Participants can see and hear the presenter, view slides and other media, ask questions, and sometimes answer polls. Can be live and/or pre-recorded.
- **Workshop** An intensive educational event for a relatively small group of people, focusing on techniques and skills.

## B LEARNING AND CERTIFICATION PATHS

Vendor specific training such as Microsoft curriculum and Grow with Google provides foundational-level to advanced level learning and certification pathways for cloud and business application services. These services have undergone significant changes to now focus on clearly presenting learning objectives and knowledge areas being clearly presented within the content. These material are now becoming ideal for students starting or thinking about a career in technology and ideal for primers for students undertaking academic programs. Many of these vendor resources and courses have been designed for instructor-led and blended learning models and can be delivered remotely or in person which make them applicable to academic and blended learning. These resources also directly align to online learning paths, which are collections of training modules, that are delivered wholesale or via the modular components and many also include cloud provision at no additional cost.

Cloud vendors also have specific programmes for educators including AWS Academy [2], AWS Educate [1], Google Cloud for Faculty [5] and Microsoft Learn for Educators [4]. These programmes provides access to a curriculum. Each course covers knowledge areas and learning objectives through lessons based on real-world scenarios and practice exercises. Supporting resources for these courses include:

- Online training: Self-paced online learning paths and modules via Learn
- Vendor specific Official Curriculum: 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 Learn for Educators takes the best of Microsoft Learn online learning paths and integrated labs with sandbox cloud environments helps you to bring this and the instructor-led training materials from Microsoft into your courses. Eligible educators and faculty members at colleges, universities, community colleges, polytechnics, and secondary schools can access Microsoft ready-to-teach curriculum and teaching materials aligned to industry-recognized Microsoft Certifications. These certifications augment a student's existing degree path and validate the skills needed to be successful across various technical careers.

AWS Educate's Cloud Degree initiative, AWS Educate, has been working around the world to bring cloud opportunities to students from the US to the UK. The AWS Educate Cloud Degree initiative is a collaborative effort between AWS Educate and leading educational institutions to develop degrees and certificates in cloud computing that will prepare students from colleges, vocational schools, and technical academies for in-demand cloud jobs. By working with college faculty – and their high school and four-year university partners – AWS Educate's Cloud Degree initiative allows accredited educational institutions to integrate AWS content into their curriculum and create a cloud computing degree, specialization, or certificate offering.

Google Cloud allows eligible faculty to apply for Google Cloud credits for themselves and their students to use in class, Qwiklabs credits, and more structured learning programmes such as:

- Google Cloud Computing Foundations: curriculum to teach students who have little to no experience in cloud. The 40 hour curriculum contains slides, teacher notes, hands-on labs, and assessments and covers critical concepts to prepare learners.
- Career Readiness: Coursera courses and related materials to allow faculty or other staff to coach students through 16 week on-demand learning programs that prepare them for careers in one of two tracks: Associate Cloud Engineer or Data Analyst.

These programmes are available at no cost to faculty.

## C INTERACTIVE WORKSHOP DESIGN

**Title:** *Building your Cloud Computing courses on solid foundations: using evidence-based guidelines and mapped learning resources in the design of your Cloud Computing courses*

**Abstract:** The CloudEdRepo community has been established to help instructors to define learning goals and identify suitable materials when designing courses which cover topics related to Cloud computing and its applications. Through the efforts of a series of ITiCSE Working Groups, a set of Knowledge Areas (KAs) for Cloud has been defined, and a canonical list of Learning Objectives (LOs) which align with the KAs has been developed. A repository has been created which contains: the definitive set of KAs and LOs; information on available teaching resources and industry certifications that align with the LOs; and exemplar modules that demonstrate the viability of using these to construct units of learning.

The goal of this workshop is to introduce instructors to best practices in designing courses with industry-relevant learning outcomes and designing syllabi which can be delivered with the support of available high quality learning materials. The hands-on session will invite participants to start with a high level aim for a course that they are interested in implementing and access the CloudEdRepo repository to explore the KAs and identify a set of LOs that align to that aim. Participants will then be shown how to find and choose suitable learning materials that map to their LOs and use these to start to define the details of the course syllabus. The presenters have extensive experience of teaching and learning of Cloud computing from academic and cloud vendor viewpoints.

**Significance and Relevance of the Topic:** The increasing adoption of cloud computing is driving a demand for skills which needs to be addressed in higher education. However, the nature of the field presents significant challenges for instructors. The body of knowledge associated with cloud computing is not well established, and many educators may not be comfortable with cloud computing concepts. The body of knowledge associated with cloud computing is not well established, and many educators may not be comfortable with cloud computing concepts. Furthermore the services offered by the major cloud vendors tend to evolve rapidly. On the other hand, there is a wealth of up-to-date teaching and learning material available, much of it supported by the cloud vendors and provided free to students. There are also a range of vendor certifications which are very attractive to students alongside university qualifications. This workshop aims to help instructors implement Cloud courses which address the needs of industry.

**Participant Computer Requirements:** The workshop can be delivered virtually or in-person. In either case, participants will require during the workshop to use a computer with access to the internet and a web browser. In virtual format, the workshop will use Google Meet. In addition to accessing CloudEdRepo, participants will make use of online tools such as Padlet.

**Rough Agenda for the Workshop:** The workshop can be adapted to fit within a 2 hour or 3 hour format with a 15 minute break. The shortened format will have a single breakout session. Agenda:

(1) Introductions
(2) Overview of the Knowledge Areas (KAs) and Learning Objectives (LOs)
(3) Overview of the course materials repository
(4) Breakout groups for course design
(5) Break
(6) Present work from breakout groups
(7) Return to breakout groups to finish course design
(8) Present courses
(9) Final wrap-up

**Expertise of Presenter(s):** The workshop will be delivered by two presenters. One will be an academic with experience in the Cloud computing domain, detailed knowledge of the KAs and LOs and their use in course design. The other presenter will be a Developer Advocate from a cloud vendor with extensive experience in helping faculty incorporate Cloud into the classroom.

**Expected Audience:** The workshop will be of interest to instructors who have an interest in bringing Cloud computing into their curriculum. They will be looking for guidance on how to ensure that their courses have a firm, industry-relevant foundation and on how to evidence this for institutional approval. They will also be looking for guidance on how to find, select and access appropriate learning resources from the vast amount of available content.