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# Integration of Information Technology Certifications into Undergraduate Computing Curriculum

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**Abstract**—This innovative practice full paper describes our experiences of integrating information technology certifications into an undergraduate computing curriculum. As the technology landscape evolves, a common challenge for educators in computing programs is designing an industry-relevant curriculum. Over the years, industry practitioners have taken technology certifications to validate themselves against a base level of technical knowledge currently in demand in industry. Information technology (IT) certifications can also offer paths for academic computing programs to stay relevant to industry needs. However, identifying relevant IT certifications and integrating it into an academic curriculum requires a careful design approach as substantial efforts are needed by educators to design and deliver courses. This paper describes our proposed approach and experiences of identifying and mapping IT certifications for an undergraduate Information Systems (IS) curriculum. We first review our IS curriculum with an academic standard and an industry skills framework to identify relevant job roles for students. Next, we perform a web search in the Google Job Search engine for job postings relevant to these job roles and apply text analytics techniques to identify the IT certifications referenced in these job postings. We also share our implementation experiences of integrating two highly referenced IT certifications - Amazon Web Services (AWS) Cloud Practitioner and Solutions Architect - Associate certification exams in two undergraduate computing courses. We learnt that there is a need to allocate efforts for the faculty to manage the logistics matters. Students appreciate the teaching efforts and are motivated to train themselves for the certifications. In the first year of the implementation, we achieved 90% and 96% exam pass rates in AWS Cloud Practitioner certification and Solutions Architect - Associate certification, respectively. We hope that our approach and the lessons learnt can help other educators consider integrating IT certifications into their computing curricula.

**Index Terms**—Computing skills, Undergraduate, Industry demand

## I. INTRODUCTION

Today, technology is at the core of every business. It is no longer a support function but an essential part of every business. Digital transformation using technology is no longer limited to automation, leading to new products and service generation. As the technology landscape rapidly changes, the industry needs skilled individuals in the workforce that are ready to adapt to the evolving technologies and constantly emerging new technologies. A common challenge for educators in institutions of higher learning (IHLs) is how to

produce industry-ready graduates who can join the workforce with the right skills to work on projects right away with minimal onboarding and training.

Preparing students for success in the job market requires a three-pronged approach: education, certification, and experience. Industry certifications offer a way for academic programs to remain current with industry demands [1]. The value of information technology (IT) certifications integrated into an academic curriculum has been studied widely. A study by White [2] with the faculty of an institute indicates that their head of departments and lecturers agreed that certification would help improve students' competencies, skills, employability and raise the institute's profile. Certification may also function as a signal to employers that a potential employee can remain current with a particular technology and is committed to continuing professional and skills development [3].

The results from Wireschen and Zhang [4] show that while IT employers in the academic community do value IT certification, as exemplified by 45% of the respondents indicating that they either require certifications or expect their employees to work towards certifications, an overwhelming endorsement is not evident. This research also validates that there is value in industry certifications for many employers, other than just additional hiring criteria. These benefits include providing a base level of technical knowledge that results in earlier productivity gains, heightened employee value leading to increased retention, and increased awareness for technology skills maintenance. For academics, this research can help establish a justification for the inclusion of certification training as part of academic curricula.

By providing certification training, students would have credentials that employers have identified as necessary, resulting in increased chances of getting hired. From the student's perspective, Hunsinger's study [5] found that Affect (how students "feel" about certification) is more influential on Attitude than Cognition (what students "think" about certification). Job and salary benefits are important to students; information about these benefits should be presented to them. It is important to note that certifications are certainly not the only way to document that individuals have sufficient knowledge of a specific area. A study by Reinicke and Janicki

[6] shows a wide variation across different job areas with IT professionals with industry certifications. Students who are considering a career in those areas where certifications are well-recognized or even required (for example, cloud-related technologies and cyber-security) are encouraged to take up those certifications, but it may not necessarily be the case for other areas.

There are earlier attempts to integrate IT certifications into the undergraduate computing curriculum. A previous study by Nelson and Rice [7] describes some of the third-party certifications available in the mid-2000s and how various third-party certifications are being integrated into their Computer Information Technology (CIT) curriculum. Previous studies by Al-Rawi [8, 9] propose a comprehensive model IS curriculum based on well-recognized academic standards ABET (Accreditation Board for Engineering and Technology) while integrating the objectives of key IT certificates.

Technology has evolved tremendously in the last decade, so are the types of IT certifications. This paper describes our design approach to identify an updated list of IT certifications and map these IT certifications into our curriculum in Sections II and III. We then describe case studies to integrate specific IT certifications in our courses in Section VI and V. Lastly, we describe our future directions in Section VI and the conclusion in Section VII.

## II. DESIGN APPROACH

Our design approach to identify and map IT certifications into our IS curriculum is based on three process steps:

- S1: Review an IS academic standard and map the objectives of this standard to each of the course categories in our IS curriculum.
- S2: Review an industry skills framework and select job roles relevant to the course categories and IS academic objectives identified during S1.
- S3: Review job postings to determine IT certifications referenced and map key IT certifications to each set of job roles identified during S2.

In this section, we first provide a background review of the widely recognized ACM IS 2010 [10] as an IS academic standard and the SkillsFuture Framework [11] as the industry skills framework to map to our IS curriculum in our study. We describe how we identify relevant IT certifications in Section III and summarize this list in Table II. We also describe the mapping of our IS curriculum to the academic objectives of the ACM IS 2010, relevant industry job roles in SkillsFuture Framework and possible IT certifications. This mapping is summarized in Table III.

### A. ACM IS 2010

ACM IS 2010 is a series of model curricula for undergraduate degrees in Information Systems (IS). The high-level IS capabilities that the curriculum specifies are as follows:

- 1) Improving organizational processes
- 2) Exploiting opportunities created by technology innovations
- 3) Understanding and addressing information requirements
- 4) Designing and managing enterprise architecture
- 5) Identifying and evaluating solution and sourcing alternatives
- 6) Securing data and infrastructure
- 7) Understanding, managing and controlling IT risks

Courses in Curriculum Model are:

- 1) IS 2010.1 Foundations of Information Systems
- 2) IS 2010.2 Data and Information Management
- 3) IS 2010.3 Enterprise Architecture
- 4) IS 2010.7 IS Strategy, Management, and Acquisition
- 5) IS 2010.4 IS Project Management
- 6) IS 2010.5 IT Infrastructure
- 7) IS 2010.6 Systems Analysis & Design

### B. SkillsFuture

Skills Framework (SFw) is an initiative developed for the Singapore workforce to promote skills mastery and lifelong learning. The SFw for Infocomm Technology contains information on trends, career pathways, occupations, job roles, skills, competencies, and training programmes. There are seven tracks and a total of 104 job roles. The tracks are (1) Cyber Security, (2) Operations and Support, (3) Infrastructure, (4) Data and Artificial Intelligence, (5) Strategy and Governance, (6) Software and Applications and (7) Sales and Marketing.

A set of skills and competencies are documented for each job role with proficiency levels from 1-6 in varying degrees of responsibility, autonomy, complexity, knowledge, and abilities. Table I shows an example of the job role, skills, and competencies relevant to IS students.

### C. IS Curriculum

Our school's undergraduate Information Systems (IS) curriculum is categorized into the following two IS Core areas:

- Business Solutioning and Management (5 Credit Units)
- Software Design and Development (7 Credit Units)

The **Business Solutioning and Management** category aims to equip our students with business process-related and enterprise management skills. The **Software Design and Development** category is a set of courses designed to equip students with skills in programming, data management, web development, enterprise development, and project management. Students typically take these courses in their first two years of study. On top of the core IS curriculum courses, our students can choose an area of specialization from the following IS Tracks:

- Business Analytics
- Digitalisation and Cloud Solutions
- Financial Technology

The **Business Analytics** track helps students deepen their knowledge and practical skills in data analysis and data engineering. The **Digitalisation and Cloud Solutions** track trains students in concepts and hands-on knowledge of engineering digital solutions on the cloud. The **Financial Technology** track focuses on the solutioning for banking and financial technology ("FinTech") sectors. Students are required to take 4 courses from their chosen track that accounts for 4 credit units. Students can also go for their preferred courses counted as IS and free electives to make up another 8 credit units. University level core courses make up the rest of the 36 credit units of the program requirements.

### III. IT CERTIFICATIONS

IT certifications can help boost students' portfolios [12], and many undergraduates students are actively seeking to become certified outside of their academic programs in preparation for the job market. Integrating IT certifications into education curricula requires a careful design approach whereby relevant certifications are selected such that the selected IT certifications support the existing direction of the education program. Further, for the IT certifications to be well "woven" into courses (*instead of being treated as a separate component independent of other learning components in the courses*), a well thought-through integration approach must involve all stakeholders (course designer, track/program-level curriculum designer, certification expert, and the learner). To this end, the integration of IT certifications must ensure that all aspects of teaching and learning are sufficiently addressed in the design. We describe our approach to identifying this list of IT certifications in the next section.

#### A. Trends in IT Certifications

To identify the list of IT certifications, we search on the Google Job Search engine that localizes the job search based on a set of relevant job roles to identify job postings that indicate IT certification(s) within the job description. For searching trends in IT certifications, we use two key search terms "certified" and "certification", and selected job roles to retrieve a list of job postings on the Google Job Search engine. We select these job roles based on the industry skills framework and our past graduate employment outcomes, where a majority of our graduates start their career in one of these roles. During the initial search, we realise that if we combine all roles in the search criteria in one search (e.g. "software developer" — "system analyst" — other roles), the number of results is limited as compared to multiple searches using one role at a time. A possible reason is that the Google Job Search engine may have limited the number of results for a single search. To maximise the initial number of results, we performed the search by each role separately.

There are challenges to identify the IT certifications mentioned in the job postings. One challenge is the large number of job postings as it takes time to manually analyse

each job descriptions and error-prone. We decide to develop Python scripts to automate our search and analysis. This approach allows us to retrieve and process the results in a reliable and repeatable manner. Our scripts invoke the Google Job Search engine based on the following search criteria.

("certified" or "certification") (<job role>)

where <job role> can be one of the following "software developer", "system analyst", "IT analyst", "software engineer", "solution architect", "project manager", "product manager", "programmer", "consultant", "data analyst", and "data scientist".

The engine returns job postings in JavaScript Object Notation (JSON) format with information on the title, company, job description, and job id. This format is human-readable and programming language independent. We combine the results retrieved per role into a single job data dictionary in JSON format. As we search each role separately, there are potential duplicates of job postings across multiple searches. We first process the job data dictionary to remove duplicates based on the job id. However, upon manual review of some postings, we realize there are job postings with different job ids but similar job descriptions. These happen when the Google Job Search engine retrieves these similar job postings via different sources (e.g., LinkedIn, Monster, JobsCentral). We further automate our scripts to detect these cases by comparing the similarity ratio between the job postings. We only include one of the job postings in our subsequent analysis if the similarity ratio is above 95%.

Another challenge is the inconsistencies of certification names used across job postings. While it is easy to identify a certification based on the exact match of the certification title or its acronyms, there exist job postings that indicate subsets of the certification title (e.g., "AWS Solutions Architect" instead of "AWS Certified Solutions Architect") or infer using generalized words (e.g., "AWS Certified or Google Cloud Certified", "AWS certification(s) (DevOps or architect)", "Certification in Java, J2EE would be an added advantage", "Certification or formal training in project management") to denote a set of possible certifications. We perform fuzzy searches on the job descriptions using the natural language toolkit (NLTK) to address this issue.

We first preprocess the job data dictionary to remove stop words and punctuation, convert all characters into lowercase, and tokenize the results. For comparison, we prepare another certification data dictionary to represent each of the IT certifications that contains the certification title, its acronyms, and a list of possible keywords to represent this IT certification. We first attempt to detect each certification in the certification data dictionary with all the job postings in the job data dictionary based on the exact match of the certification title or its acronyms. If the certification is found within a job posting based on an exact match, the search stops for this certification and this job posting. If the certification is not found within a job posting based on an exact match, we perform fuzzy searches to capture the scenarios of generalized

TABLE I  
SKILLS FRAMEWORK – AN EXAMPLE OF JOB ROLES, SKILLS AND COMPETENCIES

Track	Job Role	Skills and Competencies (Proficiency Level)
Data and Artificial Intelligence	Data Engineer	Data Engineering (level 3) - Implement data management processes and systems to map data sources, processes and relationships, and transform and process multiple streams of data
		Data Design (level 3) - Identify data requirements and support the design of database models, incorporating parameters, fields, and mechanisms for the maintenance, storage, and retrieval of data
Software and Applications	Software Engineer	Software Design (level 4) - Create a software design blueprint based on a broad design concept, and business and user requirements
Strategy and Governance	Business Analyst	Business Process Re-engineering (level 4) - Evaluate business processes and workflows, and develop a business process reengineering plan
		Process Improvement and Optimisation (level 4) - Analyse and develop, review of plans for process improvement and optimisation
	Solution Architect	Business Process Re-engineering (level 5) - Establish a business process re-engineering strategy, determining the processes to be reengineered and significantly redefining process flows
		Solution Architecture (level 5) - Establish frameworks and determine relevant tools and techniques to guide the development IT solutions

TABLE II  
TRENDS IN IT CERTIFICATIONS IN JOB POSTINGS

Category	Sample list of IT Certifications - Number of Job Postings
Business Solutioning and Management	Certified Agile Product Owner - 80 Certified Scrum Master - 115 IT Infrastructure Library(ITIL) - 130 Project Management Professional(PMP) - 325 Certified IT Project Management - <50 Certified Business Analysis Professional - <50
Software Design and Development	AWS Certified Developer - 133 AWS Certified Solutions Architect - 158 Certified Agile Developer - 100 Microsoft Azure Solutions Architect - 89 AWS Certified Cloud Practitioner - <50 Google Professional Cloud Architect - <50 Google Professional Cloud Developer - <50 Microsoft Certified Solution Developer Associate - <50 Google Associate Cloud Engineer - <50 Oracle Certified Java Architect - <50 Oracle Certified Java Developer - <50 Oracle Certified Java Programmer - <50
Data Science and Business Analytics	AWS Certified Data Analytics - <50 AWS Certified Machine Learning - <50 Microsoft Certified Azure AI Engineer Associate - <50 Microsoft Certified Azure Data Engineer - <50

words being used. This fuzzy search is based on scanning a sliding window of six grams (words) to determine if this job posting contains the certification or not. For example, in the case of "AWS certification(s) (DevOps or architect)", an exact match of "AWS Certified Solutions Architect" will not happen but a fuzzy match of "AWS", "Certification", and "Architect" can be found within the grams. Many of the IT certification titles are 3-4 words, and we find that using six grams is reasonable. This configuration setting can be adjusted when necessary.

With this automated approach, we can execute the analysis consistently and be easily extended to other IT certifications and job roles. The results of our automated approach are then exported into an HTML file per job role with matched words (exact or fuzzy) highlighted for manual validation when necessary. A job posting may mention multiple IT

certifications and may also mention a specific IT certification more than once. Our approach loops each specific IT certification search through all the job postings. If an exact or fuzzy match occurs more than once, we still count the IT certification under this job posting only once.

Based on our searches performed, a total of 2,291 job postings are retrieved. After removing duplicates, the number is reduced to 1368. Within this reduced set, our program identified 60 unique IT certifications with a total of 2105 mentions of these certifications across all job postings.

Compared to earlier works that examined IT certifications prior to 2010 [8, 9], the IT certifications we identified focus more on the latest skills in cloud, project management, and data science. This insight aligns with the technology advancements in the last decade, where many companies are seeking to migrate their business functions to the cloud or

TABLE III  
IS CURRICULUM AND PROPOSED IT CERTIFICATIONS

Category	ACM IS 2010	Relevant Job Roles	Relevant IT Certifications
Business Solutioning and Management (IS Core)	IS 2010.1 IS 2010.3 IS 2010.7	Business Analyst Software Engineer	AWS Certified Cloud Practitioner Google Associate Cloud Engineer Project Management Professional Certified Scrum Master
Software Design and Development (IS Core)	IS 2010.1 IS 2010.2 IS 2010.4 IS 2010.6	Data Engineer Software Engineer Product Manager Project Manager	
Business Analytics (IS Track)	IS 2010.2	Data Engineer Artificial Intelligence Engineer	AWS Certified Data Analytics AWS Certified Machine Learning Certified Business Analysis Professional Microsoft Certified Azure AI Engineer Associate Microsoft Certified Azure Data Engineer
Digital and Cloud Solutions (IS Track)	IS 2010.3 IS 2010.7 IS 2010.5 IS 2010.6	Data Engineer Software Engineer Software Architect Solution Architect	AWS Certified Developer AWS Certified Solutions Architect Google Professional Cloud Architect Google Professional Cloud Developer Microsoft Certified Azure Developer Associate Microsoft Certified Azure Solutions Architect Oracle Certified Java Programmer Oracle Certified Java Developer Oracle Certified Java Architect
Financial Technology (IS Track)	IS 2010.3 IS 2010.5	Data Engineer Software Engineer Solution Architect	AWS Certified Developer AWS Certified Solutions Architect Google Professional Cloud Architect Google Professional Cloud Developer Microsoft Certified Azure Developer Associate Microsoft Certified Azure Solutions Architect

develop cloud-native applications and analytics systems.

The top 5 IT certifications are (1) Project Management Professional, (2) AWS Certified Solutions Architect, (3) AWS Certified Developer, (4) IT Infrastructure Library, and (5) Certified Scrum Master. We also analyse the organizations that offer these IT certifications in terms of the number of job postings.

The top 3 organizations with the most number of job postings are (1) Project Management Institute (PMI), (2) Amazon Web Services (AWS), (3) Microsoft. PMI stands out primarily due to the PMP certification, while AWS and Microsoft have a number of cloud certifications that are widely mentioned in job postings.

For IT certifications related to data science and business analytics, we notice that there are many job postings mentioned in a generalized approach (e.g., "Possess certification in Data Science will be highly favored", "Certification in Data Engineering or Business Analytics", "Professional Certification (Big Data)"). We do capture specific products related to this area, but the number of job postings is not substantial (e.g., Qlik, Tableau, PowerBI). We infer that certifications in this area may still be maturing. Networking and system administration related certifications such as Cisco Certified Network Associate (CCNA) is mentioned in many job postings. These networking and system administration certifications are not on our list as we do not consider job roles related to those certifications. However, we may have to review our courses for that in the future. We highlight a set of IT certifications in Table III that we consider

for each category of IS courses. The Python scripts and search results are also available in our GitHub repository [13].

### B. Mapping of IT Certifications

Students taking the three categories of IS Core courses in their initial year of study are exposed to software development, programming, and essential project management in these courses. Developer certification from Google Associate Certified Engineer is a potential certification they can take at this level. Project Management Professional (PMP) and Certified Scrum Master are well-recognized certifications if one wishes to embark on the project manager role. However, PMP certification requires project management working experiences as a prerequisite. There is a related associate-level certification, which we will consider in the future for our undergraduate IS students. Another certification to be considered is the AWS Certified Cloud Practitioner. This certification gives the student a grasp of cloud computing fundamentals in the Amazon Web Services (AWS) cloud environment.

The Business Analytics Track courses are taken by students who pursue in-depth data analysis and data engineering skills. In this case, data analytics and engineering certifications such as AWS Certified Data Analytics, AWS Certified Machine Learning, Microsoft Certified Azure Data Engineer, and Microsoft Certified Azure AI Engineer Associate are relevant. The emergence of new cloud and data-related IT certifications in recent years is in alignment with the increasing demand for skilled professionals in analytics and cloud computing. As more organizations are undergoing digital transformation

with technology as the core enabler, we expect to see more job postings in the cloud and data-related areas and more companies will look at IT certifications as a form of accreditation of their employees' skills.

The Digitalisation and Cloud Solutions Track courses are taken by students who pursue in-depth business solutioning, software engineering, and cloud engineering skills. In this case, certifications related to architecting roles are most relevant such as Oracle Certified Professional (Programmer, Developer, Architect), AWS Certified (Developer and Solutions Architect), Google Cloud Professional (Developer and Architect), and Microsoft Certified Azure (Developer and Solutions Architect).

The Financial Technology Track courses are taken by students who pursue in-depth skills in financial and FinTech domains. To the best of our knowledge, there is no domain-specific certification in these areas, but the certifications related to business solutions and architecting are still relevant.

#### IV. CASE STUDIES

In this section, we share our experiences of integrating Amazon Web Services (AWS) Cloud Practitioner and Solutions Architect - Associate certification exams in two undergraduate computing courses at our school. We first describe each course, followed by how we evolve the course to integrate the IT certification.

##### A. IT Solution Architecture

This case illustrates our experiences of integrating **AWS Certified Solutions Architect – Associate (CSA)** into a **Digitalisation and Cloud Solutions** track course.

###### 1) High-level Course Description (ITSA):

IT Solution Architecture (ITSA) course integrates design concepts and methods to develop IT solutions from both the software and system-level perspectives. It focuses on analysing, designing, and implementing an IT solution through which business requirements, software qualities, and solution elements are transformed into implementable artefacts. ITSA is initially designed for students to appreciate architectural concepts to take on the role of software or solution architect. The topics involve architectural thinking concepts, design patterns and styles, and quality attributes - similar to these existing works [14, 15]. The quality attributes emphasised in this course are performance, security, maintainability and availability.

###### 2) AWS Certified Solutions Architect – Associate (CSA):

AWS Certified Solutions Architect - Associate (CSA) certification is intended for individuals who perform a solutions architect role and have one or more years of hands-on experience designing available, cost-efficient, fault-tolerant, and scalable distributed systems on AWS. It validates a student's ability to define a solution using architectural design principles based on customer requirements. The student

should also be able to provide implementation guidance based on best practices according to a set of certification domains. These domains are covered in the modules of an online AWS CSA course in AWS Academy's Canvas (Learning Management System) which is available for students to review.

###### 3) Course Conduct and Assessment:

ITSA is offered as a track elective under the "Digitalisation and Cloud Solutions" track and conducted in two terms a year. Each term is 13 weeks, including the recess week. Students are required to attend a 3-hour seminar-style lesson each week. This case study involves 48 students. ITSA is designed with a mid-term assessment and a final term assessment. Students are also assessed on a project where they design solution architecture for given project requirements. The project assessments emphasise the students' competencies to make design decisions that achieve the quality attributes required. The students can fulfil the project requirements based on cloud or on-premises design. Students are also assessed weekly on graded assignments and class participation.

###### 4) Integration Design:

We first map ITSA weekly topics to the modules provided by the AWS CSA course. We took the approach to cover the concepts and theory in the 3-hour class session and students are also exposed to tutorials and labs that are non-vendor specific. Once the students understand the key concepts, they are required to continue their learning by accessing the relevant modules of the AWS CSA course. They will then be exposed to additional videos and labs that utilize AWS services with the related concepts covered in class.

The design of the course project also evolved to allow students to have hands-on experiences using AWS services. In this case, students are required to design and develop their solution architecture on AWS. We managed to keep the project requirements similar to the earlier ones with minimum modifications. As the AWS CSA course also provides case studies, we allow the students to choose from these multiple projects.

We also need to evolve the ITSA course design to incorporate the assessments. We have both mid-term and final term assessments. The decision is to convert the final term assessment component from an internal written examination to an external AWS CSA examination. While the mid-term assessment covers ITSA topics only, the final term assessment will now cover the AWS CSA domains. AWS CSA examination is being graded with a score of up to 1000. This score is converted as part of the grade for the student. The final term assessment takes up 20% of the total grades of the course.

##### B. Social Analytics & Applications

This case illustrates our experiences of integrating **AWS Certified Cloud Practitioner** into a **Business Analytics** track course.

### 1) High-level Course Description (SAA):

The Social Analytics & Applications (SAA) course explores emerging methods and applications for understanding online user behavior on popular social media platforms. Students in SAA will examine a variety of real-world business cases of social media analytics. Through weekly hands-on lab exercises, students will learn how to connect to social media APIs for data crawling, perform web scraping, and mine insights from the data by using social network analysis, text mining, and other machine learning algorithms. The course includes a term-long experiential group project in which a group of 4 to 6 students works with an industry sponsor to build an end-to-end social analytics pipeline in AWS cloud environment.

### 2) AWS Certified Cloud Practitioner:

The AWS Certified Cloud Practitioner examination is for individuals with the knowledge and skills for effective demonstration of an overall understanding of the AWS Cloud. When SAA first launched a few years ago, it lacked data engineering component - where students built social analytics scripts locally on their own computer using Python. At maximum, the scripts were "weaved" together to build a partial analytics pipeline via shell scripts and crontab in Linux OS. Only in the last two years, SAA has gradually introduced data engineering concepts and hands-on lab exercises to students - in response to an increasing demand for graduates equipped with data engineering skills. However, SAA is not a full-fledged data engineering course - its main focus is still on the concepts and applications of social media analytics for deriving meaningful actionable insights for business, society, and people.

As an AWS Academy institution, our university's faculty and students receive numerous benefits such as access to AWS Academy and Certification Training courses and exam vouchers. In SAA, we received very positive feedback from many students about AWS learning. At the same time, there were inquiries from students about becoming AWS certified. In the Fall 2019 term, SAA included AWS Cloud Practitioner as a graded course component for the first time. Since then, SAA continues to train students towards their AWS Cloud Practitioner certification goal.

### 3) Integration Design:

At the start of a term, faculty must enroll students in AWS Academy Cloud Foundations course in AWS Academy's Canvas (Learning Management System). With this, students will have free access to all certification training materials (slides, videos, hands-on labs via Vocareum, and knowledge quizzes). Similar to ITSA, SAA lessons span 13 weeks including a recess during Week 8 followed by a group proposal presentation in Week 9 (no lesson). Typically, there are two to three sections of SAA per term where each section is joined by 48 students.

Each lesson is 3 hours long, and short lecture bits and hands-on lab exercises are interwoven throughout the lesson.

Each week's SAA lab exercises are carefully designed to map to the corresponding AWS concepts. For example, in *Week 3*, students develop Python scripts for connecting to social media APIs for data crawling and deploy the scripts to EC2 instances ("compute" service). Students learn about different EC2 instance types. In *Week 4*, students learn how to store crawled social media data in S3, and they also learn about different S3 classes and how S3 differs from EBS and EFS. Students also learn how to use Athena to query S3 objects. By *Week 12*, all AWS concepts in scope for the certification exam are sufficiently covered. Students learn to build an end-to-end social analytics pipeline combining all AWS services and concepts they learned so far. SageMaker and Rekognition are AWS services that are outside the scope of the certification exam, but it is relevant to the SAA course - hence faculty created lab exercises on this. Finally, by *Week 16*, all students complete the certification exam. Over four academic terms, over 90% of the students (a total of 287) successfully passed the **AWS Cloud Practitioner** certification exam.

Students are assessed on a weekly basis on both SAA concepts and AWS concepts. While weekly hands-on lab exercises and 'knowledge quiz' (*in the AWS Academy course*) reinforce regular practice and training for exam preparation, continuous assessments provide students with a constant stream of opportunities to evaluate their mastery of the concepts learned in class. Continuous assessments also provide faculty with early indications of the performance of students, and this allows faculty to adopt appropriate interventions - for example, faculty can provide extra revisions on selected concepts that many students indicated as confusing and difficult.

### V. FINDINGS, OBSERVATIONS, LESSONS LEARNT, & FUTURE DIRECTIONS

- 1) Although ITSA and AWS CSA modules overlap on a high level, there are some significant differences. While ITSA focuses on vendor-neutral offerings to illustrate key architectural concepts, CSA specifically targets AWS services and platform. Most CSA best practices align with general architecture design best practices; there are subtle differences. For example, a proxy server is common in tiered architecture but not widely practised on the AWS platform.
- 2) Some students might have already taken the certifications. Faculty can consider using their examination scores. Or, faculty can prepare a replacement exam in-house.
- 3) The concept mapping between academic courses and certifications exams may not be one-to-one, resulting in students having to study certain certification concepts not in scope for the academic curriculum. Faculty have to provide support such as practice MCQs for those concepts.
- 4) Cost of the examination remains a concern. Though most students can fork out the outstanding amount after initial subsidy with AWS exam vouchers, some students require further financial support. In our case, to address this concern, faculty arrange for a further subsidy if students



pass the examination and meet specific criteria (e.g. citizenship).

- 5) Besides the need to evolve the course design and conduct, there are also logistics efforts that faculty and students have to take on. Faculty has to set up the AWS and subsequent subsidies to be readily available for students to sign on. Students who wish to enjoy the subsidy have to follow specific instructions to sign up for the examination, pay and claim for the examination.
- 6) The scheduling of the actual examination is another concern. If students are unable to schedule an examination in time for grading, the faculty cannot include their score for course grading. Faculty reminds students to schedule their examination by Week 8 - despite that, students may not comply or reschedule it. Due to the COVID-19 pandemic, many students chose virtual examination. Some students encountered issues such as missing invigilator or other technical issues, resulting in postponement.
- 7) Students feel that preparing for the certification examination is useful; one such feedback is "The certification portion and project allows me to apply what I had learnt in theory during class". However, some students are concerned about passing the examination, which affects their course grade. Faculty and TAs diligently provide the necessary support. We are glad that over 96% of the ITSA students and 90% of the SAA students have passed.

## VI. FUTURE DIRECTIONS

In the next phase of our IT certification integration plan, we plan to map IT certifications to more courses in our undergraduate IS program and also *realign* the existing mapping. As shown in Table III, the *AWS Certified Cloud Practitioner* certification best suits the IS core courses. In particular, we plan to realign the *AWS Certified Cloud Practitioner* certification to a year 2 IS core course "Enterprise Solution Management" (ESM) under the Business Solutioning and Management category. This change is motivated by the recent trend of the industry-wide emphasis on cloud computing, which has created a new focus in computing programs worldwide. It is no longer a specialized knowledge area but an essential element in computing curricula. By situating the *AWS Certified Cloud Practitioner* certification in ESM, all of our computing graduates will be equipped with the knowledge and skills necessary to effectively demonstrate an overall understanding of the cloud. SAA will integrate *AWS Certified Data Analytics - Specialty* certification in place of the current *AWS Certified Cloud Practitioner* exam. Another *Business Analytics* track course "Introduction to Machine Learning" will integrate *AWS Certified Machine Learning - Specialty* certification into its curriculum. It is worth noting that while the certifications are vendor-specific, the crux of each of our academic courses is really teaching *transferable* knowledge and skills for problem-solving.

## VII. CONCLUSION

This article describes our experiences of identifying and integrating information technology certifications into an undergraduate computing curriculum. IT certifications allow students to validate their knowledge in a specific domain, and it provides an accreditation channel for employers to evaluate prospective students. We describe our approach to align IS academic standard ACM IS 2010 and industry Singapore SkillsFuture framework to select relevant job roles, search job postings using Google Job Search engine for these job roles, and apply text analytics to identify in-demand industry certifications within these job postings. We also present case studies of our implementation of integrating AWS Cloud Practitioner and Solutions Architect - Associate certifications into two courses. We observed that the faculty require additional efforts to manage the logistics of examination matters and by students to prepare themselves for vendor-specific MCQ-based examinations. Besides designing the course evolution, faculty need to manage logistics matters related to external certification examinations. Students also have to target their efforts to prepare for vendor-specific technologies and services. On the other hand, students appreciate the effort and are motivated to do the certification. We hope the proposed approach, implementation and lessons learnt can help other educators to consider integrating IT certifications into their computing curricula.

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