Preparation and execution of final year student projects on the cloud

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***Abstract*—Cloud Computing has become an important element of computer science education. This notion is supported by the main cloud service providers that offer resources to facilitate cloud-based module instruction. They focus however on specific topics and do not yet cope with final year projects (or dissertations), a semester or year-long task with particularities: the student works individually and not as part of a class and dives deeper into multiple and diverse technologies. We present a modular methodology to fill in this gap and address the end-to-end delivery of such projects in a way that can be evaluated through a set of assessment criteria and is transferable to other academic institutions. This methodology consists of six phases: from preparing and attracting students to undertake a cloud-based project, through their on-boarding and initial training to monitoring project work and activities beyond the project completion. By addressing this issue, we simplify the upskilling of students (and supervisors) and ease their adaptation to cloud related career pathways.**

Keywords—cloud computing, final year project, dissertation, cloud education, cloud service providers

I. Introduction

The importance of teaching cloud computing for computer science students has been acknowledged by academic departments and supported by the main Cloud Service Providers (CSP). Amazon Web Services (AWS), Google Cloud Platform (GCP) and Azure have initiatives to facilitate the instruction of cloud-related topics and each one avails of a collection of teaching material as well as access to their services. Currently this is still an ongoing effort that aims to address specific topics such as Networking, Virtualisation, Security and Machine Learning. There is no provision yet to accommodate the requirements for a Final Year Project (FYP) or Dissertation or Diploma Thesis undertaken by students in their last semester or year of their studies for BSc or MSc degrees.

Pursing a cloud-based FYP offers several benefits. It enables the student to experiment with different architectures, network configurations and services (e.g. access high performance CPUs for machine learning), evaluate serverless deployments and their costings and exposes them to best practices of software development and information-technology operations (DevOps). Consequently, it represents a firm opportunity to exercise diverse competences and provides an essential foundation for a sound and solid career path in IT.

Despite all these advantages, attracting a student to FYPs with a cloud nature is not straightforward. Within Computing, there are numerous other interesting and trendy domains to focus on. The IT job market is relatively positive in most countries and some students may prioritise securing a job which means finishing their studies in a convenient way rather than choosing a challenging and perplexing project. The FYP is an individual effort- i.e. not a class sharing the same issues- hence any problem must be resolved by the student individually. There may be reluctance or concern over unknown cloud technologies and the learning curve required to master them within the time restrictions of a heavily demanding final year of studies. All the above, build up a contextual situation that needs to be tackled.

The research work presented in this paper aims to facilitate the undertaking and successful execution of cloud-based FYPs thus demonstrating the potential of the synergy between academia and CSPs. We discuss a methodology for managing such FYP projects; from preparatory work to attract students to undertake a project, through their on-boarding and initial training to monitoring their progress during project execution to actions beyond its completion. This methodology reflects on the observations outlined above and tackles the issues deriving from them in order to smooth the adoption and delivery of cloud-based FYPs. The methodology is transferable to other academic institutions and its impact can be evaluated against a set of assessment criteria.

We just outlined the rationale and context of this effort. Section II surveys research works in relevant topics. Sections III and IV list the phases of the methodology and the assessment criteria used to evaluate its success. Section V then illustrates the results of applying this methodology and Section VI closes with conclusions and pointers for further work.

II. Background Work

A. Educational tools on the Cloud

Amongst the available selection of CSPs (e.g. Oracle Cloud, IBM cloud, OpenStack, VMWare), we concentrate our study on the three most popular CSPs, namely AWS, GCP and Microsoft Azure, as they already have educational initiatives whose substance is underlined by the size of the respective corporation.

The purpose of these initiatives is the incorporation of cloud services and technologies in education. AWS Academy [1] and Azure Academy [2] are programmes focusing on respective professional certifications and the preparation of students by academic institutions. AWS Educate [3] congregate cloud-related initiatives on third-level and K-12 teaching and offer virtual teaching spaces (Classroom) with tools to monitor student usage and activity. Google G-Suite for Education [4] is a suite of collaboration and cooperation tools that links to GCP and the Google Cloud Faculty [5] is a scheme to bring together and assist educators that utilise GCP. Azure for Education [6] gives access to learning material and resources in the Azure platform.

The available educational material consists of short (1-2 hours) and long (e.g. 40 hours) introductory or specialised (e.g. Virtual Machines, Security, Machine Learning, Databases) courses, videos and labs with access to tools for hand-on practice.

For the execution of educational activities, CSPs offer free credits for the educational use of their services with a relatively straightforward application and swift approval procedure. A significant issue now resolved was the requirement for the creation of a user account with a credit card. It discouraged students from enrolment and there have been a handful of accidents of improper use that resulted to unexpected huge bills.

Currently, (spring 2020) the academic/CSP educational synergy is still developing [24]. The repositories of material are steadily increasing in size and variety of offerings with contributions from the academic community. However, there is no explicit link to learning outcomes, proposed level of study or recommended audience. There is evidence of quality control on the publicly available resources yet no transparent quality criteria. Overall though, the increasing interest by academics and the existence of these initiatives makes sound the prediction for a sustainable future and expanding communities on cloud education.

For the sake of brevity, the remainder of this paper uses the notations and service names mostly from AWS as it is currently a market leader. It is important to note that GCP and Azure, albeit in different formats, terms or methods of interaction have and are extending similar offerings.

B. Cloud on Education

A review of approaches and open issues for the incorporation of cloud computing in software development exists in [14] which highlights the difference of the coverage of cloud in industry compared to education. Moreover, [16] support the notion that education, especially in computer science should stay close to the state of the art in technology and use the cloud to exemplify the need for upskilling required for students as well as for instructors. This is a complex issue due to the diversity of expertise involved: from user-experience and design to IoT and Big Data.

Such a diversity in skills and technologies drives recommendations for a modular approach. In [8], two short modules are used: the Introductory Module (scalability and other key concepts) and the Intermediate Module (evaluation of techniques and scalable applications). They use qualitative surveys to receive student feedback and report enhanced interest for the cloud by the students thus acknowledging the positive application of a phased approach for cloud education [15]. This conclusion is shared by [19] who used Nielsen heuristics (Learnability, Satisfaction) and identified a set of prerequisites for the induction to cloud education.

C. Tools for monitoring Final Year Projects and Dissertations

A study on the nature of a FYP and how it is defined in different countries exists on [7]. Typically, it contributes 3%-8% of the degree assessment mark, may have a research component and results to a submitted thesis or report. Most of LMSs (Canvas, Moodle, Blackboard) include functionalities to manage the supervision and execution of FYPs. In academic works, [17] specify a FYP management tool with schedule, monitor (by supervisor notes) and logging modules. [16] have integrated FYPs with underlying cloud-based courses and an emphasis on DevOps.

D. Detection of student activity

There is a significant amount of research to consume log data of a Learning Management System (LMS) as patterns of student interaction can be linked to academic performance [9] [21]. Nevertheless, these studies do not yet yield consistent results on the size and effect of interaction [22], hence their results are not mature enough to be portable.

This observation drives the boundaries of our contribution. We utilise cloud log data in two layers of processing, namely Monitoring and Insights, but we stop short of predicting student performance over time and overall grade in the project.

The Monitoring layer collects and visualises metrics of relevant student actions identified [10] such as login frequency, date of last login, length of online sessions, the number and percentage of resource usage, and the number of assignments completed to highlight student interaction. In the area of cloud usage, CloudTrail-Tracker [25] is the first platform that visualises student activity (access, costs, status) for hand-on labs and pinpoints pending tasks giving both the student and the instructor an overall perspective on progress made.

The Insights layer identifies patterns of irregular usage and potential failure. Again, there are numerous efforts reporting promising but non-conclusive results with different machine learning techniques (e.g. multiple regression [23], decision tree classifiers [11] [12]) and data (e.g. discussion groups [13]).

III. METHODOLOGY

Fig.1 illustrates the methodology we have devised to handle all aspects of FYP delivery. In every phase, there exists a set of activities whose completion satisfies a goal and can lead to the next phase.

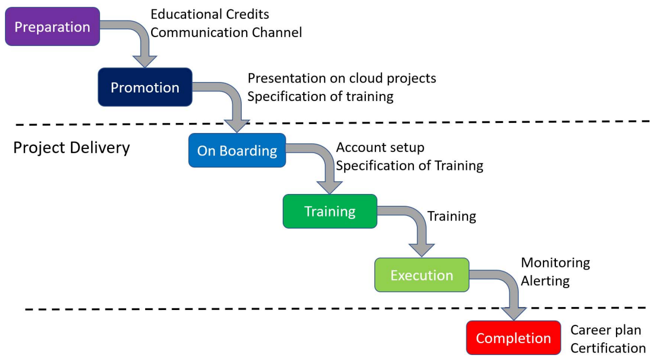

Fig. 1. Project delivery phases

A. *Preparation*

The goal of the first phase is to complete all necessary preparatory actions and establish the environment enabling the efficient delivery of FYPs. It is the responsibility of the supervisor to:

- Apply and receive a sufficient amount of CSP educational credits to deliver projects with access to required services.
- Formulate a list of available educational resources (courses, tutorials) and explicitly link them to skills and career pathways to demonstrate their educational and professional value.
- Establish a "projects on the cloud" communication channel (e.g. Slack, MS Teams, Google discussion group) for students to ask questions, share experiences and access answers.

The FYP is an individual activity. Unlike class assignments, not every student faces the same issues or at the same time. The existence of a communication channel establishes the notion of a community and facilitates dissemination of query answers both by supervisors and fellow students.

B. *Promotion*

The goal is for a student to make an informed decision and undertake either pre-defined cloud-based FYPs or come forward with their relevant own ideas that can be framed into project proposals.

The main activity is a 60-minute lecture that takes place at a period when proposals for FYPs are formulated and is directed to the full class cohort with the following contents:

- Cloud concepts and technologies: Computing, storage, serverless architectures, scalability and high availability, access to super computing devices.
- Supporting educational material: Available online, size of effort required, and badges rewarded.
- Demonstration of previous projects: Aims and objectives, methods of execution, potential issues, ways of tackling them and outcomes.
- Available projects and supervisors: Tools employed, significance of cloud for accomplishment, expertise of supervisor.
- Career pathways on the cloud: either all-purpose (solution architect, DevOps engineer) or technology specific (data analyst, security expert).

Follow-on actions to this lecture are discussions with interested students to resolve any queries, specify any student-initiated project ideas and finalise assignment of a FYP.

C. *On-Boarding*

At this point, the initial FYP paperwork is complete. Before starting work, the student must engage in the following successive steps to establish a sufficient project setup:

- Sign-up for an account with educational CSP credits abiding by step-by-step guides available. There is an ongoing dialogue between CSPs and educators to improve this process as a portion of students face issues completing it.
- Create an IAM account for the supervisor with admin rights enabling them to set monitors and alerts and assist in troubleshooting where necessary and appropriate. Ideally, the supervisor account should have access to the CSP console. If this is not possible, CLI along with remote access tools (e.g. TeamViewer, Remote Desktop) are also viable to use.
- Register to the "projects on cloud" discussion group.
- With respect to the FYP area of interest, have a sprint planning meeting (see training phase below) to agree with the supervisor on a list of online courses to undertake, offered by the CSP's educational programme.

During the last activity, it is critical for the student to be informed of the required learning effort, skills to be obtained and their relevance to the context of the project.

D. *Training*

As most students have no or little experience with the interfaces to cloud services (console, CLI, API) and how to use them effectively, it is of paramount importance to undertake a set of initial training activities to build confidence and expertise. These activities aim to avoid dead-ending and ad-hoc investigations that can lead to frustration and subsequent problems with the FYP. This effort takes the format of:

- One or two (depending on concurrent coursework, complexity of cloud technologies and student prior knowledge), two-week Scrum sprints with the Supervisor acting as the Scrum master and the student as the Product Owner since the "product" (i.e. FYP) is their responsibility. The goal is to undertake and complete upskilling short courses on individual services and obtain training badges by passing upskilling short assessments.
- Bi-weekly tutorial sessions as sprint reviews to assess progress and resolve blockages.
- At the end of the sprint, a sprint retrospective meeting to confirm completion of these tasks.
- A second, one-week sprint to design and develop a short end-to-end exercise on the cloud. Examples of such short projects are also available.

E. Project Execution

The role of the supervisor in a FYP is to assist students to gain a positive experience and deliver tasks that meet agreed performance and functionality criteria. Outside of this paper's context lie the planning, mode of execution and interaction between the supervisor and the student as these vary for each academic institution, staff member and nature of a project.

In the scope of this work, we build on research results in analytics and machine learning (outlined in Section II/D) and define techniques that can be implemented easily on the cloud so as to reveal insights on the interaction of the student with the cloud services. CloudWatch, CloudTrail (AWS) and StackDriver (GCP) are services that log usage and provide interfaces for any log processing through metrics and triggering of events and alerts. This functionality is useful to both the supervisor and the student who convene regularly to ensure detection and settling of issues and compliance with the project plan.

We structure the approach in two layers discussed below:

1) Monitoring student activity on the cloud

The lower level deals with the compilation of analytics on student activity in order to verify one is working resourcefully on their project. We follow the high-level organisation adopted for cloud services into Computing and Storage and we introduce a third category to monitor generic activity.

Computing metrics (Table 1) cater for the supervision of regular, efficient and progressive usage of computing resources and the evaluation of design decisions (e.g. use of suitable VMs).

TABLE I. COMPUTING MONITORING METRICS

Computing Metrics	
Service	***Metric***
VM Instance	Number of connections
	Frequency of Connection
	Length of session
Functions	Number of Invocations
	Timespans of Invocations
	Number of Errors
	Duration of execution
ML models	Number of training invocations distribution over time
	Timespan of invocations
Messaging (Queue, Notification)	Number of messages generated
Internet of Things	Number of devices registered
	Number of data produced and consumed

Fig. 2. Metrics to monitor comupting activity

Storage Metrics (Table II) address the monitoring of usage of the file system and any databases used in a FYP.

Lastly, Table III lists the General Activity metrics on day-to-day activities. These metrics aim to observe regular engagement.

TABLE II. STORAGE MONITORING METRICS

Storage Metrics	
Service	***Metric***
File Storage	Number of objects
	Number of accesses to stored objects
	Origin (IP) of access
Databases	Origin (IP) of access
	Number of queries
	Frequency of queries

Fig. 3. Metrics to monitor storage activity

TABLE III. GENERAL ACTIVITY MONITORING METRICS

General Activity Metrics	
Service	***Metric***
Access to cloud Account	Number of accesses
	Length of session
	Access to irrelevant services
	Generation of resources
DevOps	Number of resource commit/merge/push
	Security Groups and Access lists setup
Contribution to communication channel	Number of sessions
	Number of messages
	Number of replies
	Length of contribution in words

Fig. 4. Metrics to monitor general activity

A practical consideration is that these techniques should be defined in such way so as they can be easily deployed at the cloud. This task may be streamlined by a configuration template (e.g. CloudDeploy) although it is worth noting that each FYP has its own particularities and custom metrics may be required. Part of a template that has been proven useful is a weekly digest email with graphs and tables for every student, an output adding an agenda item in weekly project progress meetings.

2) Insights and Alerts

The upper level deals with the discovery of insights and generation of alerts.

The rationale for these alerts (Table IV) is to establish a baseline for quality control, detect early any issues (student stalled or not using services) and prevent exhaustion of CSP credits.

Alerts are not in place not to police student activity. It is therefore important to inform the student of their existence and include them to any notifications received.

Similarly, to the Monitoring level, templates can be used for their deployment. Generation of these alerts belongs to detailed monitoring (AWS terminology) and it can incur extra costs.

A point to consider is personalization. Raising of an alert should take into account not only the requirements of the FYP but also the student persona (e.g. working hours, duration of working sessions) and external circumstances such as coursework assignments. Thresholds and other parameters for alert should therefore be individualised and open to modification.

TABLE IV. IRREGULAR USE ALERTS

Alert	*Associated Technique*	*Description*
Inactivity	Pattern recognition	Detection of idle activity e.g. no access or limited access for 5 days
Errors	Classification	Repetition of errors (Running function, configuration of resources)
	Pattern recognition	
Billing	Anomaly Detection	Start of Incorrect (and expensive VM)
	Prediction	
Misusage	Ad-hoc usage of services	Detection of usage of services outside project remit
	Pattern recognition	Usage of services in a pattern incompatible to project objectives (e.g. share files, spawn large number of VMs, starting expensive Certificates)

Fig. 5. Alerts for irregular use

F. *Completion*

The final phase of the methodology takes place shortly after submitting the FYP with a two-fold goal: first to evaluate the experience and second for the student to consider and take relevant certification exams. It consists of the following activities.

- An "Exit Interview" with qualitative feedback and emphasis on overall experience- challenges and fears- interest for cloud technologies yielded and skills acquired.
- Schedule certification exams, revise a study plan and access to preparation material.

Successfully undertaking a professional certification exam is an exemplar satisfactory completion of this effort. However, as educators involved in AWS communities informally report, this is far from easy to achieve. Although students acknowledge the importance of such a certification and the closeness to achieve it, the rate of actually sitting in a exam is very low; there is a cost involved (although discount vouchers are available), they are overwhelmed by the effort to complete their studies, delighted to graduate and concentrate on their next step such as acquiring employment and starting a career.

IV. ASSESSMENT CRITERIA

To assess the success of this methodology with regards to the objective of facilitating and expanding cloud-based FYP we have devised the criteria of Table V. These criteria apply to both the student and the supervisor and refer to specific phases of the methodology allowing its assessment throughout the project lifecycle. They have a quantifiable flavour for objective estimation and portability and described below:

1) *FYP Completion:* Although this heavily relies on the student, their previous academic performance and commitment, it is still a decisive criterion as without its satisfaction, the methdology simply cannot be considered successful.

2) *Use of cloud services:* This is examined initially at the On-Boarding phase and mainly at the Execution phase and concerns the type of practice of the student with the cloud environment.

3) *Alerts:* Similarly to the criterion above, this concerns the smooth interaction of the student with the cloud environment. Absence of regular and severe alerts leads to an increased focus on project work and deliverables.

4) *Impact:* Refers to consideration, undertaking and passing certification exams by the student.

5) *Educational material:* The preparation, review and addition to cloud portals by the supervisor.

6) *Sustainability:* Examines the numbers of involved students every semester and the interest by academic staff to join the effort as supervisors.

V. ASESSMENT AND EVALUATION

We have been applying this methodology for two academic years, namely 2018-19 and 2019-20, at the Nimbus Research Centre of Cork Institute of Technology, Ireland. In terms of student interest and engagement with the cloud, numbers have multiplied for the second academic year with triple the number of supervisors involved.

TABLE V. METHODOLOGY ASSESSMENT RUBRIC

Rubric Range						
Assessment Criteria	**Applies[a]**	**Phase**	**Above Expectations**	**Meets Expectations**	**Below Expectations**	**Unsatisfactory**
FYP Result	SV/S	Training, Execution	Completed, average mark >70%	Completed, average mark 50-70%	Completed, average mark <50%	Not completed, average mark <40%
Profile of use of cloud services	S	On-Boarding, Execution	All necessary services used in a professional manner	All necessary services to deliver the project	Some services used, not in the recommended way	Cloud services were not significant project delivery
Alerts of irregular use	S	Execution	No unjustifiable alerts generated	Alerts generated and corrective action taken	Alerts generated and partly addressed by corrective actions	Alerts not generated and feedback ignored
Certification exams	S	Completion	Passed Exam	Scheduled exam	Considered Exam	Not interested
Educational material	SV	Preparation, On-Boarding	Successfully added to cloud portals	Peer-reviewed and submitted to cloud portals	Prepared and used privately but not peer-reviewed	None prepared or incomplete
Number of involved students every semester	SV	Preparation, Completion	Increasing and cloud used in other assessments	Increasing	Stable	Decreasing

Fig. 6. Rubric Table for assesing the methodology

a. SV: Supervisor, S: Student

The areas of delivered FYPs became diverse with the most popular ones being Internet of Things (e.g. smart homes and assisted living), Serverless architectures (e.g. web platforms, processing systems), Machine Learning for (e.g. sentiment analysis, anomaly detection), conversational agents (e.g. industrial training) and cybersecurity.

Moreover, there has been interest by other students to use cloud tools in their projects that started without planning to do so in machine learning, software defined networks and Virtualisation. In those cases, the On-Boarding phase proved very helpful to streamline transition to and adoption of necessary cloud services. Students have mentioned on their feedback that they found the methodology highly helpful, acknowledged the acquisition of DevOps skills beyond the scope of their project and the clarification of cloud-related career pathways.

For the supervisors, the cloud provided the tools to deliver technologically challenging FYPs, presented the opportunity to engage with CSP educational communities and drove research on cloud-based learning analytics. Regarding the production of educational material, it was stated that albeit beneficial, it requires extra workload and as such it needs to be scheduled and accommodated within the academic calendar.

With reference to the Assessment criteria of the Rubric of Table V, our evaluation is as follows:

1) FYP Completion: All students completed sucessfully their FYPs with a mark in line or better to their performance during their studies.

2) Use of cloud services : Students found useful that metrics can be used as tools towards profressional adoption of best practices (i.e. metrics as part of Agile toolbox in a retrospective meeting) and encouraging that these metrics showed progress in this direction.

3) Alerts: Although alerts were tiggered throughout the duration of projects, the majority of them occured in the first six weeks as students get accustomed to the cloud environment.

a) Inactivity: Most were justifiable by course workload, students also reported that these alerts were helpful to keep them in track and remind them of their commitments.

b) Errors: Students were aware of these errors and used these alerts as a reminder to fix them

c) Billing: Raised as a result of students experimenting during On-Boarding with different cloud services.

d) Misusage: The most serious case was one of a suspicion of mining cryptocurrencies using the cloud resources. In another case, a student was sharing large files publicly using the storage system.

4) Impact: All students considered to take a certification exam, a small proportion registered to take one, none though was successfully certified. The main reasons given for this were that their main priorities became their employment or postgraduate studies and there is considerable effort required for certification.

5) Educational material: Material on preparation and On-Boarding, material has been reviewed internally and externally and submitted to AWS Educate. Separate material on Internet of Things, serverless web platforms and anomaly detection is being reviewed externally.

6) Sustainability: Student and supervisor numbers have increased and the impact of the methodology expands beyond cloud-focused FYPs to cater for projects in need of experimentation with the cloud.

VI. Conclusions

We discussed a modular methodology that organises the delivery of final year projects with a cloud nature. It consists of six phases and associated activities that handle all aspects of a FYP: before the project starts (Preparation, Promotion), during its implementation and delivery (On-Boarding, Training, Execution) and beyond its submission (Completion). Our intervention is not a stand-alone effort. On the contrary, it engages and makes use of CSP initiatives, claims educational credits, utilises educational material and contributes to their repository.

We specified a Rubric of assessment criteria to evaluate the impact of this methodology and outlined the highly encouraging results of applying it.

This outcome, along with the fact that the Cloud is consistently among the top sought skills in the last five years [20], enforces the belief that our work fills a significant gap and inspires us to improve and expand it.

Future work includes meeting objectives such as: spreading the context to multidisciplinary projects, the consideration of soft skills (creativity, collaboration, problem solving) in all phases and the involvement of more CSPs. Finally, the expansion of cloud-based projects drives the need (and data required) for formal performance prediction analytics similar to ones that exist for conventional LMSs.

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