

# Investigating the Impact of Organised Technology-driven Orchestration on Teaching

by

Lighton Phiri

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This work is dedicated to “Me from the past” [...]

# Abstract

## Investigating the Impact of Organised Technology-driven Orchestration on Teaching

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Orchestration of learning involves the real-time management of activities performed by educators in learning environments, with a particular focus on the effective use of technology. While different educational settings present unique problems, the common challenges have been noted to primarily be as a result of multiple heterogeneous activities and their associated intrinsic and extrinsic constraints. In addition to these challenges, this thesis argues that the complexities of orchestration are further amplified due to the ad hoc nature of the approaches and techniques used to orchestrate learning activities. The thesis proposes a streamlined approach to technology-driven orchestration of learning, in order to address these challenges and complexities. Specifically, the thesis proposes an organised approach that focuses on three core aspects of orchestration: activity management, resource management and sequencing of learning activities. Orchestration was comprehensively explored in order to identify the core aspects essential for streamlining technology-driven orchestration. Proof-of-concept orchestration toolkits, based on the proposed orchestration approach, were implemented and evaluated in order to assess the feasibility of the approach, its effectiveness and its potential impact on the teaching experience. Comparative analysis and guided orchestration controlled studies were conducted to compare the effectiveness of ad hoc orchestration with streamlined orchestration and to measure the orchestration load, respectively. In addition, a case study of a course that employed a flipped classroom strategy was conducted to assess the feasibility of the proposed approach. The feasibility was further assessed by integrating a workflow, based on the proposed approach, that facilitates the sharing of reusable orchestration packages. The results from the studies suggest that the streamlined approach is more effective when compared to ad hoc orchestration and has a potential to provide a positive user experience. The results also indicate that the approach imposes acceptable orchestration load during scripting of learning activities. Case studies conducted in authentic educational settings suggest that the approach is feasible, and potentially applicable to useful practical usage scenarios. The long-term implications are that streamlining of technology-driven orchestration could potentially improve the effectiveness of educators when orchestrating learning activities.

# List of publications

The proof of concept toolkits, studies, data, experimental results, images and plots in some of the manuscript chapters appear in the following scholarly publications<sup>1,2</sup> authored or co-authored by the author.

- [1] Parker, N., Valentyn, M., Phiri, L., Christoph, M., and Suleman, H. *Complex Orchestration Packages as Open Education Resources*. Tech. rep. University of Cape Town, 2018. url: <http://pubs.cs.uct.ac.za/archive/00001261>
- [2] Phiri, L., Meinel, C., and Suleman, H. Peer Tutoring Orchestration: Streamlined Technology-driven Orchestration for Peer Tutoring. In: *Proceedings of the 9<sup>th</sup> International Conference on Computer Supported Education*. Vol. 1. CSEDU '17. INSTICC. ScitePress, 2017, 434–441. isbn: 978-989-758-239-4. doi: [10.5220/0006339104340441](https://doi.org/10.5220/0006339104340441)
- [3] Phiri, L., Meinel, C., and Suleman, H. Ad hoc vs. Organised Orchestration: A Comparative Analysis of Technology-driven Orchestration Approaches. In: *Proceedings of the 8<sup>th</sup> IEEE International Conference on Technology for Education*. Ed. by Kumar, V., Murthy, S., and Kinshuk. T4E '16. IEEE Computer Society, Washington, DC, USA, 2016, 200–203. doi: [10.1109/T4E.2016.48](https://doi.org/10.1109/T4E.2016.48)
- [4] Phiri, L., Meinel, C., and Suleman, H. Streamlined Orchestration: An Orchestration Workbench Framework for Effective Teaching. *Computers & Education* 95 (2016), 231–238. issn: 03601315. doi: [10.1016/j.compedu.2016.01.011](https://doi.org/10.1016/j.compedu.2016.01.011)

In addition, the work presented in the “[Reusable orchestration packages as Open Education Resources](#)” chapter of the manuscript was conducted as part of the “rVOA” Project, and some details in the chapter are also described in the following project reports submitted by honours students supervised by the author.

- [–] Parker, N. *Feasibility of Seamless Integration of Reusable Virtual Orchestrated Appliances and Open Educational Resources*. Tech. rep. University of Cape Town, 2016. url: [http://projects.cs.uct.ac.za/honsproj/cgi-bin/view/2016/parker\\_valentyn.zip/deliverables/PRKNAB003\\_-\\_Final\\_Report.pdf](http://projects.cs.uct.ac.za/honsproj/cgi-bin/view/2016/parker_valentyn.zip/deliverables/PRKNAB003_-_Final_Report.pdf)
- [–] Valentyn, M. *Reusable Virtual Orchestration Appliances: Are Such Applications Feasible?* Tech. rep. University of Cape Town, 2016. url: [http://projects.cs.uct.ac.za/honsproj/cgi-bin/view/2016/parker\\_valentyn.zip/deliverables/Final\\_-\\_VLNMOR001.pdf](http://projects.cs.uct.ac.za/honsproj/cgi-bin/view/2016/parker_valentyn.zip/deliverables/Final_-_VLNMOR001.pdf)

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<sup>1</sup><https://scholar.google.co.za/citations?user=UTb4aEsAAAAJ&hl=en>

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# List of abbreviations

ATT	Attractiveness
BPEL	Business Process Execution Language
BPM	Business Processing Modeling
COML	Classroom Orchestration Modeling Language
CPUT	Cape Peninsula University of Technology
CSCL	Computer-Supported Collaborative Learning
CWPT-LMS	Classwide Peer Tutoring Learning Management System
DL	Digital Library
DLE	Distributed Learning Environment
DLS	Digital Libray System
EF	Effort
EML	Educational Modeling Language
FR	Frustration
GET	General Education Training
HQ	Hedonic Quality
HQ-I	Hedonic Quality – Identity
HQ-S	Hedonic Quality – Stimulation
IDE	Integrated Development Environment
ISP	Intermediate and Senior Phase

LMS	Learning Management System
MD	Mental Demand
MOOC	Massively Open Online Course
NASA-TLX	NASA Task Load Index
OAI-PMH	Open Archives Initiative Protocol for Metadata Harvesting
OCW	OpenCourseWare
OER	Open Education Resource
OP	Performance
PAL	Peer Assisted Learning
PD	Physical Demand
PEU	Perceived Ease of Use
PQ	Pragmatic Quality
PU	Perceived Usefulness
rVOA	Reusable Virtual Orchestration Appliances
SUS	System Usability Scale
TAM	Technology Acceptance Model
TD	Temporal Demand
TEL	Technology Enhanced Learning
UCT	University of Cape Town

# **Part I**

## **Background**

# Chapter 1

## Introduction

### 1.1 Contextualising orchestration of learning

Formal learning spaces are continuously evolving into complex learning environments as the demand for advanced and specialised skills increases [10]. The demand for new skills from learners has subsequently resulted in the introduction of various student-centric teaching models [76] such as flipped classroom teaching models [115, 160] and, the adoption of technology-rich learning environments [175]. This, coupled with rapid technological advances, has resulted in the increasing use and adoption of educational technology with the goal of improving the effectiveness, user experience and quality of teaching and learning. These educational technologies fall within the broad spectrum of hardware and software solutions. Furthermore, the educational technologies are either aimed at solving student-centric challenges, educator-centric challenges or a combination of both.

While the educational technologies aim to solve a variety of teaching and learning challenges, one notable challenge is orchestration of learning activities. The [Technology Enhanced Learning \(TEL\)](#) field refers to orchestration of learning as the teacher-centric process performed during the real-time management of learning activities in formal learning environments [51, 53]. The typical learning session is generally initiated with the educator defining a learning scenario, comprising of multiple activities to be performed during the learning session. During the duration of the learning session, the educator plays the leading role of performing and/or coordinating the various learning activities. The process of the educator performing, coordinating and managing the learning activities is what is referred to as orchestration of learning. It is the multi-faceted nature of orchestration of learning activities that makes it especially challenging, coupled with the multiple constraints presented by formal learning environments. In addition, the orchestration of learning activities has been noted to have a particular focus on technology integration, further adding to the complexities and challenges associated with the process managing the technologies [155, 169].



## 1.2 Challenges and complexities of orchestration

The increasing adoption of technology use within formal learning environments has resulted in a number of orchestration challenges. The STELLAR Network of Excellence has identified orchestrating learning as one of the key themes to focus on while leveraging the potential of technology in enhancing learning [16].

Recent studies of orchestrating learning have highlighted the complexities associated with orchestration and the unique challenges associated with it [51, 147, 155]. Most notably, the multi-faceted nature of orchestration, and the multiple constraints of learning environments, have been singled out as some of the more challenging aspects. A survey of existing literature, on technology-driven orchestration of learning, also highlights the ad hoc nature of orchestration of learning. There is especially a lack of tools and services for performing general orchestration tasks during pre-session management, such as sequencing of learning activities.

**Orchestration challenges.** Even though there are various challenges, such as interactions and communication among actors in formal learning environments, during orchestration of learning activities, this thesis focuses on challenges associated with management of learning activities.

- *Multiple learning activities.* Orchestration has been noted as encompassing a variety of activities and, unlike instructional design, orchestration involves both intrinsic—activities and events that are explicitly part of the learning scenario—and extrinsic—activities and events that are not part of the learning scenario—activities [51]. The design of core activities needs to be adaptive and is typically pre-defined.
- *Constraints during orchestration.* Orchestration of learning needs to take into account constraints imposed by the content and knowledge to be taught and the learner profiles. In addition, intrinsic activities need to be addressed [51]. For instance, educators need to factor in the limited time they have available to orchestrate the learning activities.

**Ad hoc nature of orchestration.** The main argument presented in this thesis is that technology-driven orchestration of learning activities can be streamlined through explicit organisation of learning activities. Although there are tools and services that help facilitate the orchestration of learning activities, their usage is ad hoc in nature. This thesis proposes to provide structure during the enactment—the actioning of learning activities during in-session management—of learning activities and, additionally, provide a means of streamlining processes and procedures involved when performing orchestration tasks in an organised manner.

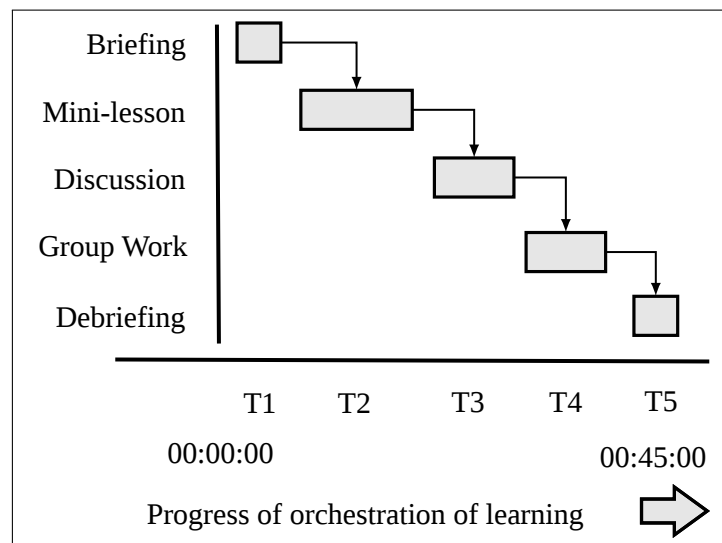
In [Chapter 3](#), the challenges, constraints and ad hoc nature of orchestration are discussed in more detail.

## 1.2.1 Scenario: Orchestrating an undergraduate programming lecture session

In this section, a hypothetical learning scenario is presented in order to highlight the challenges and complexities of technology-driven orchestration of learning.

A lecturer for a first year undergraduate programming course, comprising of 50 enrolled learners, employs the workshop model [174] as the primary teaching method. The lecturer orchestrates a range of activities, depending on the topic being covered in a typical 45-minute long lecture session. Figure 1-1 shows five activities, performed in one of the lecture sessions, described below.

**Figure 1-1.** An example teaching session showing learning activities and corresponding times when they are orchestrated.



- *Briefing.* The lecturer spends two minutes (T1), giving a brief overview of the lecture session and also makes a series of important announcements.
- *Mini-lesson.* The lecturer then proceeds and gives a presentation related to the topic of the lecture, for a total of 20 minutes (T2).
- *Discussion.* Thereafter, an open ended discussion is held in order to reinforce concepts introduced during the presentation. This activity lasts for a total of 10 minutes (T3).
- *Group work.* The lecturer then has students form groups, and subsequently perform group-based tasks. The group tasks last a total of 10 minutes (T4).
- *Debriefing.* Finally, the lecturer spends two minutes (T5) giving closing remarks.

From an orchestration perspective, there is an array of challenges that the lecturer needs to grapple with, prior to each lecture session and during the lecture sessions.

- *Scripting challenges.* Scripting is associated with pre-session management tasks that the lecturer has to perform prior to each lecture session. Among other things, the lecturer needs to (1) carefully plan how the different activities will be orchestrated, the order of orchestration and the tools to be used to orchestrate the activities and (2) organise the teaching resources to be used during the lecture.

- *Context switching.* During the lecture session, the lecturer needs to grapple with the context switching that occurs when transitioning among the five different activities.
- *Timing constraints.* The five activities need to be orchestrated within a limited period of time—45 minutes in this case—and so the lecturer needs to take into account the fact that time is a premium resource.
- *Awareness challenges.* Awareness challenges form part of extrinsic activities that educators have to grapple with when orchestrating learning activities. In the illustration, the lecturer needs to be aware of what is transpiring during the lecture session, especially during the “Discussion” and “Group Work” activities.
- *Tooling challenges.* The five different activities might require different tools and services to facilitate their orchestration and so the lecturer needs to be able to effectively manage these tools.

Collectively, the orchestration challenges could potentially have an adverse impact on the lecturer’s ability to effectively orchestrate the learning activities. As such, supporting educators by enabling them to overcome these orchestration challenges and constraints is desirable. While there are numerous ways educators can be supported with orchestration, a potentially viable solution could take the form of providing support during the scripting of learning activities, in order to facilitate the effective orchestration of learning activities.

### 1.3 Streamlining orchestration of learning

While numerous approaches [5, 52, 93, 105, 128] have been proposed for overcoming the challenges and complexities of orchestration, this thesis proposes an approach aimed at streamlining orchestration by focusing on the learning activities during enactment. We argue that streamlined orchestration is attainable through explicit organisation of learning activities using an orchestration workbench platform. It is premised that the streamlining of learning activities could potentially make educators more effective during the orchestration of learning activities.

The orchestration approach proposed draws inspiration from Dillenbourg’s description of how pedagogical scenarios integrate learning activities [51]. Dillenbourg states that the integration mirrors technical integration of different tools that are distributed over multiple artefacts. Furthermore, inspiration is drawn from the successful use of unified platforms—scientific workbench platforms for performing scientific computing tasks [9, 19, 131, 186], and *Integrated Development Environments (IDEs)* for performing software development tasks [151, 181]—in other domains, to effectively perform heterogeneous related tasks.

Orchestration has been noted to comprise of two core components: (1) pre-session management involves scripting—planning and organisation learning activities for a typical learning scenarios; and (2) session management involves the enactment of the learning activities [155]. Preliminary exploratory studies conducted—outlined in [Chapter 4](#)—identified *activity management*, *resource management* and *sequencing* as the minimal set

of core pre-session management orchestration aspects necessary for the streamlining of orchestration.

- *Activity management.* The multiple learning activities to be performed form units of learning and need to be organised before session management.
- *Resource management.* Resource management will allow educators to associate teaching and learning resources with activities to be orchestrated during session management.
- *Sequencing activities.* Sequencing of learning activities will make it possible for educators to specify the desired order of orchestrating learning activities.

Although the workbench platform is primarily aimed at facilitating the orchestration of learning activities, its design is also aimed at enabling the seamless integration of tools and services for effective learning activities.

### **1.3.1 Motivation**

The motivation for this thesis results from the emphasis on the quality of teaching and learning and, the growing need of ensuring that educators are effective when teaching in formal learning spaces. In addition, while there is a gradual shift towards more student-centric learning strategies, educators continue to play a vital role—empirical studies conducted have yielded evidence [177] citing the roles of educators as a major contributing factor to improving the quality of education.

It is anticipated that aiding educators with the process of orchestration of learning activities will provide them with supporting mechanisms that could potentially turn formal learning spaces into more effective learning environments. While the focus of attention is on educators, it is hoped that this will complement other technology solutions aimed at improving the quality of teaching and learning and, additionally, sharing the orchestration load between educators and learners [159].

### **1.3.2 Research questions**

This thesis is aimed at exploring organised technology-driven orchestration of learning activities in order to understand the extent to which the explicit organisation of learning activities influences the effectiveness of orchestrating learning activities in formal learning spaces. The goal is to contribute towards making formal learning spaces effective learning environments, thus improving the quality of teaching and learning. The thesis statement of this research is as follows:

*Streamlined orchestration—attainable through explicit organisation of enactment activities using an orchestration workbench—could potentially make educators more effective.*

The scientific goal of this thesis is two-fold: (1) investigate the feasibility of organised technology-driven orchestration of learning activities; and (2) investigate the effectiveness

and successful use of organised technology-driven orchestration of learning activities. This thesis aims to address the following overarching research question.

*How can technology-driven orchestration of learning be streamlined in order to facilitate the effective management of learning activities, and to what extent does the streamlining affect the orchestration of learning activities?*

This research question is answered by understanding orchestration in order to identify the aspects of orchestration required to address the challenges of enactment of learning activities; and evaluating the efficacy of focusing on these aspects. In order to adequately answer the main research question, it is broken down into the following sub-questions.

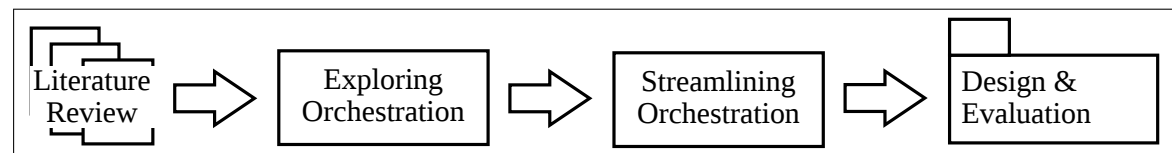
- *Research question 1—Supporting technology-driven orchestration of learning. How can educators be supported with orchestration of learning, in order to enable them to become more effective?* This research helped guide the systematic process of identifying key orchestration aspects that can positively influence the effectiveness of orchestration of learning activities. The question also helped guide design and implementation of effective orchestration toolkits. The research question is addressed in [Chapters 3](#) and [4](#). Additionally, design and implementation details are described in [Part III](#).
- *Research question 2—Effectiveness of organised technology-driven orchestration. How does the explicit organisation of learning activities influence the effectiveness of the orchestration of learning activities?* This research question helped with the process of coming up with appropriate studies that were aimed at evaluating the effectiveness of the explicit organisation of learning activities. [Chapters 5](#) and [6](#) present controlled studies designed to measure the effectiveness of organised orchestration of learning.
- *Research question 3—Impact of organised technology-driven orchestration on the user experience. What is the effect of organised orchestration of learning activities on the user experience of educators?* User experience evaluation deals with evaluating the experiences of software users [79]. This research question was aimed at gathering empirical measurements of perceived user experience of users of orchestration toolkits designed and implemented using the proposed organised orchestration approach.
- *Research question 4—Feasibility of organised technology-driven orchestration. What is the feasibility of deploying authoring tools for streamlining orchestration?* This research question helped explore the extent to which the proposed approach to orchestration of learning activities is feasible. Specifically, the question examined the applicability of the proposed approach in authentic educational settings—a real-world formal educational setting comprising of an educator and learners. [Chapters 7](#) and [8](#) describe and discuss case studies, conducted in order to determine the feasibility of organised orchestration of learning activities.

## 1.4 Research methodology

The research methodology used to address the principle research question employed a mixed methods approach, using a convergent parallel mixed methods design [45]. The mixed

methods approach involved collecting data from different sources and, was in part inspired by numerous TEL studies [92, 118, 145] that have employed the approach in order to capture different study perspectives. The methods were used in the research phases—summarised in Figure 1-2—outlined below:

- A comprehensive literature review was conducted to explore the orchestration landscape.
- preliminary studies were then conducted in order to gain an in-depth understanding of the challenges and complexities associated with orchestration of learning.
- Core aspects of orchestration that can potentially result in more effective orchestration of learning were then identified.
- Prototype orchestration toolkits, based on the streamlined approach to orchestration, were designed and evaluated in order to assess their feasibility, effectiveness and applicable when deployed in authentic learning environments.



**Figure 1-2.** Summary of thesis research process phases.

The mixed methods approach used a combination of rapid prototyping during the implementation of orchestration toolkits; log analysis, surveys and participant observations for collecting data; and meta-analysis, controlled experiments and case studies research designs.

### 1.4.1 Rapid prototyping

Rapid prototyping during software development allows for software functionality to be quickly implemented, in order to demonstrate its feasibility [162]. Fundamentally, it also allows for early user interaction.

In this thesis, rapid prototyping was employed when implementing toolkits in order to demonstrate the feasibility of the proposed approach of streamlining orchestration of learning. Specifically, toolkits were implemented as follows: (1) the orchestration toolkit used for baseline measurements when compared with ad hoc orchestration (see Chapter 5); (2) the toolkit used to orchestrate guided orchestration during peer tutoring (see Chapter 6) (3) the toolkit used for orchestrating a flipped classroom strategy (see Chapter 7) (4) the toolkit used to implement a workflow for sharing reusable orchestration appliances (see Chapter 8).

## 1.4.2 Research design

This thesis used three core research designs: (1) meta-analysis; (2) controlled experiments; and (3) case studies

**Meta-analysis.** A meta-analysis is a systematic review that provides a comprehensive summary of the body of evidence associated with a specific research question [69]. In this thesis, a meta-analysis of technology-driven orchestration of learning was conducted (see [Section 3.1](#)) in order to explore and understand orchestration of learning.

**Controlled experiments.** Controlled experiments are conducted when studies require that control be exerted over the situation [185]. The control involves systematic manipulation of the behaviour of experiment variables in order to determine their effect on the results.

In this thesis, controlled studies were employed in a comparative analysis study (see [Chapter 5](#)) and guided orchestration study (see [Chapter 6](#)), in order to assess the effectiveness and user experience effect of toolkits on orchestration of learning.

**Case studies.** Case studies are conducted in order to understand a phenomenon in a real-world setting and, allow for data to be collected using a variety of methods in a specific context [23, 188].

In this thesis, two case studies were conducted: (1) a flipped classroom study (see [Chapter 7](#)) was conducted in order to demonstrate the feasibility of streamlined orchestration in an authentic educational setting (2) a workflow—and associated reference implementation—for sharing reusable orchestration appliances (see [Chapter 8](#)) was devised in order to illustrate the applicability streamlined orchestration.

## 1.4.3 Data collection

The preliminary studies and empirical studies used a combination of log analysis, participant observations and surveys techniques for collecting data.

**Log analysis.** Log analysis involves the process of analysing log data generated by information management systems and, provides a mechanism for tracing of human behaviour during system use [3]. While log analysis is commonly used for Web log analysis, it is also used to analyse usage behaviour in other types of information systems [34].

In this thesis, video logs and segments generated by Opencast Matterhorn were analysed in order to understand challenges and complexities associated with orchestration of learning (see [Section 3.4](#)). Video logs and segments were also analysed in a flipped classroom study (see [Chapter 7](#)) in order to assess how orchestration of learning was impacted when using an implemented prototype toolkit.

**Participant observations.** Participant observation is a qualitative data collection technique that allows researchers to become familiar with a given group of individuals and their practices, over a period of time [94].

In this thesis, participant observations were conducted as follows:

- (1) During preliminary studies, observations were made by attending lecture sessions for selected courses (see [Section 3.3](#)) in order to understand how orchestration of learning was conducted
- (2) An orchestration toolkit was deployed and used in a course that employed a flipped classroom teaching strategy (see [Chapter 7](#)) and observations were conducted by attending lecture sessions, in order to gain insight into how the toolkit was being utilised.

**Surveys.** Surveys provide a means of collecting data before or after the use of a technique or toolkit. The goal of conducting a survey could either be descriptive, explanatory or explorative, with the primary survey techniques being interviews and questionnaires [185].

In this thesis, semi-structured interviews were used during preliminary studies conducted in order to understand the orchestration landscape (see [Section 3.2](#)). Specifically, expert interview interview were conducted with academic teaching staff. Standard questionnaires were used to gather data for assessing the effectiveness of toolkits (see [Part III](#)).

## 1.5 Thesis outline

This thesis manuscript is logically divided into four main parts.

[Part I](#) covers background information related to the thesis.

- [Chapter 1](#) provides the thesis introduction, outlining the thesis research questions explored and scientific goals.
- [Chapter 2](#) explores the orchestration landscape, with a particular focus on different approaches that have been proposed to solve the challenges associated with orchestration, and scripting of learning activities. Design considerations for designing orchestration tools are also discussed.

[Part II](#) describes challenges associated with orchestration and the proposed approach to orchestration.

- [Chapter 3](#) builds the case for why contemporary orchestration is challenging and complex. A series of exploratory studies are described, aimed at comprehensively studying technology-driven orchestration.
- [Chapter 4](#) describes an approach to orchestration, aimed at addressing the complexities and challenges outlined in [Chapter 3](#).



**Part III** covers experiments and studies conducted to evaluate the proposed approach to orchestration.

- **Chapter 5** describes and discusses a controlled laboratory experiment conducted to compare the proposed approach to orchestration and general contemporary ad hoc orchestration.
- **Chapter 6** presents a controlled laboratory experiment aimed at measuring the orchestration load imposed by the proposed approach.
- **Chapter 7** presents a case study conducted in an authentic educational setting. The chapter described a toolkit implemented and deployed to be used for a second year Computer Architecture course using a flipped classroom model.
- **Chapter 8** presents a practical usage scenario of the proposed approach—an end-to-end ecosystem for sharing reusable orchestration appliances.

**Part IV** covers concluding remarks and potential future work.

- **Chapter 9** presents general conclusions of the thesis and potential future work.

# Chapter 2

## Related work

This thesis builds on the body of work associated with orchestration of learning activities in the TEL field. This chapter presents a detailed literature review of the following areas: (1) the different definitions of orchestration and proposed frameworks; (2) the different approaches of orchestration used in service-oriented computing; (3) the role of scripting during enactment of learning activities; (4) the different approaches that have been proposed to provide solutions to challenges associated with orchestration; (5) the different design considerations for orchestration tools and services; and (6) the different empirical strategies employed during evaluation of orchestration of learning

The chapter is organised as follows: A broad overview of the orchestration landscape is presented in [Section 2.1](#). [Section 2.2](#) describes references to orchestration in computing and how they relate to orchestration of learning. In [Section 2.3](#), scripting of learning activities is presented. [Section 2.4](#) discusses different existing approaches and techniques that have been proposed to solve challenges associated with orchestration. Some key design considerations for orchestration tools are then discussed in [Section 2.5](#) and, [Section 2.6](#) provides a broad overview of empirical strategies employed to evaluate orchestration of learning. Finally, the chapter summary is provided in [Section 2.7](#).

### 2.1 Orchestration of learning

#### 2.1.1 Contextualising orchestration of learning

There is a large body of existing literature, dating as far back as three decades, that was aimed at investigating aspects of orchestration of learning. Although such work does not explicitly refer to the term orchestration, core aspects of orchestration, associated with planning and management have been explored.

Classroom management generally involves activities that educators perform to solve problems associated with maintaining orderly classrooms [31]. Doyle notes that classroom management literature has focused on the analysis of activities for regulating behaviour [60].

Doyle also points out that analysing activities is vital in that it provides mechanisms for describing important aspects of the classroom that are crucial during teacher planning and decision making. More importantly, Doyle highlights that activities have the characteristic of being short blocks of classroom time that reflect organisational focus. Building up on Doyle's work, Brophy states that effective classroom management should, in part, include organisation of instructions and supporting activities for maximum learner engagement [31].

Although prior references to orchestration of learning focused on aspects of management of learning activities, there was a lack of focus on integration of technology during orchestration.

### **2.1.2 Characterising technology-driven orchestration**

TEL involves the adoption, integration and application of technology in teaching and learning in order to improve the quality of education. TEL is increasingly becoming popular due to rapid technological advancements. Orchestration of learning is a TEL approach that has a particular emphasis on activities and tasks that educators perform. The STELLAR Network of Excellence has identified orchestration as one of the grand challenges of TEL [16]. The notion of orchestration of learning in the TEL field has numerous definitions and descriptions, which all broadly focus on educators' use of technology when managing learning activities [155] and, additionally, the coordination required during the management of learning activities [55].

Dillenbourg defines and elaborates orchestration as the processes and procedures educators perform in complex multi-constrained learning environments, characterised by heterogeneous intrinsic and extrinsic activities [51]. He classifies the functionalities performed during orchestration depending on whether they are enabling activities, monitoring activities or adapting activities. Dillenbourg further states that instructional design, though exhibiting similar characteristics with orchestration, is fundamentally different from orchestration due to its focus on intrinsic activities. Coordination has been highlighted as being an integral part of orchestration, with Fischer and Dillenbourg identifying orchestration as a process that partly involves the productive coordination of supportive interventions involving multiple learning activities at different social levels [55]. Fischer and Dillenbourg further add that orchestration covers different forms of co-ordinations that involve the orchestration of activities, scaffolds, self-regulation and individual motivation; with the teacher conducting the orchestration in an adaptable and flexible manner.

Roschelle et al. note, in their synthesis of orchestration studies, that the focus of orchestration is on supporting educators with the challenges associated with technology use within the classroom [155]. Formal learning spaces are also described to be complex and highly variable, resulting in the failure to adopt learning technologies. Tchounikine proposes to distinguish such technologies as being orchestration technology or orchestrable technology, in order to clarify the concept of designing for orchestration [169]. Orchestration technology is aimed at supporting orchestration activities, while orchestrable technology includes tools that can easily be adapted during orchestration. Díaz et al. argue that

orchestration is aimed at integrating learning activities with educational technology, providing robust and innovative forms of teaching and learning [50].

Sharples points to the increasing introduction of heterogeneous computing devices, such as smartphones and tablets, as imposing additional tasks, on teachers, of orchestrating complex interactions with students [159]. Sharples describes three approaches to managing these interactions, while designing for orchestration: (1) complex systems components could be simplified, resulting in technology that is easier to use, simpler lesson plans and simplified tasks; (2) remove the orchestration technology layer and only use orchestration to describe the real-time management designs used during orchestration; or (3) adopt a more disruptive approach that would result in sharing the orchestration load between the teacher and students. The notion of shared orchestration is illustrated with nQuire [120], that enables teachers and students to use similar computer toolkits that guide students through an 'Activity Guide'. The 'Activity Guide' is designed during pre-session management or modified during session management by either the teacher or student.

Some existing work provides alternative views regarding the focus of orchestration. Perotta and Evans argue that although technology is a crucial aspect of orchestration, emphasis should be placed on human elements in order to better understand the challenges associated with orchestration [141]. Kollar and Fischer propose that a focus on creation, adaptation and enactment of TEL scenarios could potentially lead to a more comprehensive definition of orchestration [100]. Glahn presents learning orchestration systems as tools used for supporting learning processes by arranging and monitoring tasks. He also states that they rely on process models that are used to define task sequences using sets of rules in learning environments [68].

While similar to instructional design, orchestration has been identified as being different to it. Tchounikine notes that orchestration is real-time, while instructional design is a pre-session activity [169]. Dillenbourg states that while instructional design is only aimed at addressing limited intrinsic constraints, orchestration has to cope with extrinsic constraints [51].

### 2.1.3 Orchestration frameworks

Some attempts have also been made to provide formal orchestration models, that are aimed at providing a theoretical basis for understanding orchestration. In order to provide a comprehensive view of orchestration, Prieto et al. proposed the '5 + 3 Aspects' orchestration framework, a unified conceptual orchestration framework, after conducting a literature review of the TEL field. The framework characterises orchestration into eight aspects, five of which provide a descriptive view of orchestration and three of which are key factors describing how orchestration should be done [147]. The results of the evaluation of the framework suggests its usefulness, understandability and suitability as a basis for considering vital factors during design and evaluation of learning technologies [146].

Looi and Toh present an orchestration conceptual framework for achieving dynamic adaptations. The framework classifies orchestration as an iterative process involving learning design, lesson enactment and knowledge dissemination. Looi and Toh also describe how the framework was used as an analytical lens for understanding orchestration [114].

The orchestration approach presented in this thesis focuses on the learning design and enactment of learning activities, and is aligned with the five aspects of the ‘5 + 3 Aspects’ orchestration framework that characterise orchestration, as outlined in [Section 4.3](#).

### 2.1.4 Summary

There is a broad spectrum of existing work that has characterised technology-driven orchestration. [Table 2-1](#) summarises the different orchestration characteristics identified in existing literature.

**Table 2-1.** Technology-driven orchestration research classifications with references to relevant literature.

Classification	Description	Literature
Management	Real-time management of orchestration activities	[51, 100]
Technology support	Supporting technology use using orchestration	[50, 141, 155, 159, 169]
Interaction	Facilitating interactions between teachers and students	[5, 105, 116]
Frameworks	Conceptual frameworks and models	[75, 114, 146, 147]

## 2.2 Orchestration techniques in computing

While the orchestration metaphor in [TEL](#) has been loosely compared with writing music for an orchestra [141, 169, 182], the orchestration term is used in a number of service-oriented computing fields to broadly refer to the management of computing services and infrastructure. In particular, there are similarities between orchestration of learning and orchestration techniques employed during Web services orchestration, business process modeling orchestration and cloud services orchestration.

### 2.2.1 Web service orchestration

Web services provide a software driven way of exposing reusable functionalities of information systems using standard Web technologies [8]. Exposing the functionalities in this manner facilitates the support of interoperable machine-to-machine interactions over computer network infrastructure.

As Web services evolve and increase in complexity, it has become necessary for service oriented architectures [135] to seamlessly integrate such services. One of the building blocks of service oriented architectures is their ability to combine several Web services into a single complex Web service [42]. The combination of Web services into such complex executable workflows is what is referred to as Web service orchestration, and is normally distinguished from Web service choreography, which describes the interactions among multiple services [140]. The orchestration of Web services enables centralised control, a major aspect of enterprise applications that allows for inefficiencies to be eliminated [126]. An orchestrator manages and coordinates the Web service composition workflow, with the orchestrations described using an orchestration language, on an orchestration engine [110].

The process of Web service orchestration is typically supported by a [Business Process Execution Language \(BPEL\)](#). BPEL uses standard flow constructs for sequential, conditional and concurrent execution of activities [126].

## 2.2.2 Cloud service orchestration

Cloud computing enables the provision of network services, in order to provide cost-effective on-demand scalable computing infrastructure [13, 180]. However, as cloud computing technologies evolve, they present additional layers of management complexity. Most of these layers of complexity can be overcome through automation techniques that revolve around orchestration workflows. The orchestration of workflows required to manage different cloud services have thus become an important part of cloud management.

Recently, the use of software application virtualisation, known as containers, has become popular in the cloud computing domain and present an example scenario where orchestration of cloud computing services becomes crucial [36, 189]. Containers provide a sandbox software environment that allows for the installation of application components needed to run an application [24, 189]. In order to improve the quality of service, most cloud service providers make available sets of operations for selecting, deploying, monitoring and the dynamic control of resources through the process of orchestration. However, the orchestration of containers in distributed environments is considered challenging. Casalicchio states that research problems such as run time resource management need to be resolved in order to realise autonomic container orchestration [36].

Fundamentally, cloud service process such as resource allocation and storage management present operational complexities that require automation [113]. For these processes to be effectively managed, dynamic orchestration of services and resources is necessary.

## 2.2.3 Summary

The focus of orchestration in the domains outlined varies substantially, as shown in [Table 2-2](#). However, the motivation for employing orchestration is driven by the goal to simplify complexities that exist within workflows and processes in the respective domains.

Furthermore, in all the different domains, orchestration serves the core purpose of enabling the effective management and support of processes and procedures.

- *Cloud services orchestration.* Orchestration of cloud services aims to resolve operational complexities associated with resource allocation and storage management.
- *Web services orchestration.* Web services orchestration involves the centralised control of Web services through management and coordination of Web service composition.

**Table 2-2.** A comparison of the focus of orchestration for various computing-oriented domains.

Domain	Orchestration Focus
Web services	Web services composition
Cloud computing	Service workflows; resource allocation
Technology-enhanced learning	Teaching & learning activities management

## 2.3 Scripting and enactment of learning activities

Scripting is a [Computer-Supported Collaborative Learning \(CSCL\)](#) mechanism that provides the structure necessary for fostering interactions within learning spaces. The significance of scripting within the orchestration ecosystem has been highlighted in numerous existing literature [[17](#), [57](#), [169](#), [171](#)].

Dimitriadis points out that teachers experience a number of problems when orchestrating technology-enhanced classrooms when dealing with complex pedagogy [[59](#)]. Specifically, the integration of technology in classrooms with face-to-face interactions has introduced additional layers of complexities. Dimitriadis adds that extensive knowledge is required when designing lesson plans, and also argues that the orchestration requires carefully designed lesson plans, scripts and scaffolds, all of which need to be effectively enacted and managed. Dimitriadis also suggests formalising scripts using modeling languages such as the IMS Learning Design specification [[88](#)], in order to facilitate scaffolding of learners.

The crucial role of scripts in [CSCL](#) is also highlighted by Dillenbourg and Tchounikine and, they note that integrated scripts especially ensure the teacher remains the ‘orchestra-conductor’, while orchestrating the sequence of activities. They also propose to manipulate multiple representations of the script during the management of [CSCL](#) scripts [[57](#)]. The approach proposed in this thesis focuses on pre-session management, typically conducted during scripting of learning activities and, ensures that teacher effectively performs the ‘orchestra-conductor’ role referred to by Dillenbourg and Tchounikine.

While distinguishing scripting and conducting, Tchounikine defines scripting as a set of means for addressing teaching objectives. An example of scripting in a [CSCL](#) environment is noted to include: (1) analysis of tasks and sub-tasks; (2) making

design decisions; (3) anticipating real-time issues and (4) representing decisions in order to facilitate implementation. Tchounikine also differentiates between initial scripting—primo-scripting—and runtime scripting, which may optionally be performed during orchestration [171].

While existing literature on scripting in relation to orchestration contextualises it within CSCL [54, 57, 171], we argue that its significance can be leveraged to solve more general orchestration challenges. The approach to orchestration advocated for in this thesis focuses on general primo-scripting, during the initial design of learning activities.

## 2.4 Orchestration techniques and approaches

Numerous technology-driven orchestration approaches to solving orchestration challenges have been proposed, and applied in a wide variety of TEL fields, most notably CSCL [55, 58, 59, 104, 145]. While the approaches are specific to unique challenges to be solved, the key focus area and the type of orchestration scenarios they are aimed at addressing, they can largely be categorised, in terms of focus areas, into: (1) feedback mechanism approaches; (2) learning design approaches; and (3) data modeling approaches.

### 2.4.1 Feedback mechanism approaches

Awareness has been cited as an important aspect of orchestration. The ‘5 + 3 Aspect’ [147] framework identifies “Awareness/Assessment” as an important aspect for characterising orchestration. The importance of awareness has also been highlighted in numerous prior works. Alvi et al. [5] note that awareness is an important factor for optimising time management. Martinez-Maldonado et al. [116] suggest awareness tools as forming three crucial factors when integrating orchestration in ubiquitous and pervasive environments.

Rojas et al. [153] present an *Awareness System* for use during problem-based learning scenarios, in laboratory sessions. The system uses websockets to connect assignment Web pages with a tablet Web interface for the teacher. The websockets are also used to implement real-time communication of events among students and teachers. The teacher Web interface enables the teacher to monitor the physical classroom layout and the computers used by the students.

Kreitmayer et al. [105] propose the use of a ubiquitous computing set-up for students and teachers to actively engage amongst each other in small groups and during whole classroom activities. The computing set-up makes use of UniPad, a face-to-face classroom-based simulation, for creating scenarios.

A multi-tabletop classroom system was proposed by Martinez-Maldonado et al. [116], in order to enhance learning and collaboration, by enabling teachers to plan and enact learning activities. A teacher orchestration tool was implemented as a multi-platform application, in order to control the tabletops. The orchestration tool has a synchronous start feature for starting activities, a feature for enabling the tabletops move between activity phases



and, a feature for blocking tablespots to enable the teacher draw the attention of the class. Visualisation can also be displayed through configuration of the dashboard.

Do-Lenh et al. argue for the need for better orchestration support in formal classroom settings and, additionally point to the lack of design guidelines for developing such tools [111]. They propose TinkerLamp 2.0, a toolkit with features for explicitly supporting classroom orchestration. TinkerLamp 2.0 is inspired by TinkerLamp 1.0 [90], with two new and redesigned features—TinkerKey and TinkerBoard—that aid teacher orchestration. TinkerKey enables the teacher to orchestrate the class by enabling them to adapt and improvise learning situations, while TinkerBoard handles challenges with classroom awareness by facilitating class-wide debriefings.

## 2.4.2 Learning design approaches

Learning design involves educational processes used to describe planning, sequencing and management of learning activities [44, 101]. There have been a number of orchestration tools that have been implemented using the learning design approach, using basic principles of learning design tools [73].

Dalziel [47] illustrates the implementation of learning design by describing *LAMS*, a learning design tool implemented with environments for user administration, teacher run-time monitoring and authoring of sequences.

*CADMOS* is a graphical learning design tool that supports the design of units of learning [93]. The tool is aimed at teachers who are non-experts in learning design. It uses a two-step design process involving the creation of conceptual learning activities models, and the creation of a flow model for orchestrating the learning activities.

The *GLUE!-PS* system was proposed as a solution to problems with deploying learning designs in different learning environments and the lack of adoption of learning design tools by teachers. *GLUE!-PS* is a multi-tier architecture and data model that uses a service-oriented architecture with a centralised Group Learning Unified Environment for pedagogical scripting. Furthermore, the data model used represents scripting properties for learning design languages [149]. *GLUE!-PS* proposes to solve four orchestration challenges: (1) deployment ability, (2) time-efficiency, (3) usage in authentic practice and (4) run-time flexibility. A similar learning design system, *GLUE!-PS AR*, was proposed by Muñoz-Cristóbal et al. [123] for orchestrating across spaces learning scenarios.

Niramitranon et al. [128] have proposed *SceDer*, an authoring system that enables teachers to design lessons by describing sequences and resources, through dragging and dropping components on to five columns. The orchestration of learning is achieved using one-on-one technologies, with the teacher specifying a learning scenario and, as the lesson progresses, *SceDer* is used to step through the five columns. The final outcome of the *SceDer* authoring process is a [Classroom Orchestration Modeling Language \(COML\)](#) package, comprising of a [COML](#) documents and all corresponding resources used in the lesson.

### 2.4.3 Data modeling approaches

**Educational Modeling Languages (EMLs)** are information models that are used to describe pedagogical learning designs, learning objectives and learning activities, by facilitating reuse and interoperability [102, 103, 117, 136]. Some prior research have proposed orchestration approaches that use **EMLs** [52, 129].

Dillenbourg proposes *Orchestration Graphs*, an **EML** that models pedagogical scenarios as directed geometrical graphs, in order to scale up rich learning activities for use with many participants. *Orchestration Graphs* provide a structured view of learning scenarios, with learning activities presented as nodes [52, 75]. Håklev et al. [75] describe a prototype framework and ecosystem for sharing and authoring *Orchestration Graphs* in rich pedagogical scenarios in **Massively Open Online Courses (MOOCs)**.

The **COML** use a generic XML description to export learning diagrams such as interactive learning designs, actors and learning artefacts created with a *Scenario Designer* component. The *Scenario Designer* component is used to create a learning scenario, with is subsequently converted into a **COML** package [128, 129].

### 2.4.4 Summary

There have also been proposed solutions that have taken a hybrid approach. For instance, Niramitrannon et al. propose an architecture that integrates a learning design tool, *SceDer*, with a modeling language, **COML** [128, 129]. Other learning tools, such as *GLUE!-PS* and *GLUE!-PS AR* have taken a similar approach by integrating data models within their architectures.

**Table 2-3** shows a classification summary of the different orchestration approaches. This thesis proposes an approach to orchestration that uses a learning design approach, which is outlined in **Chapter 4**. Additionally, fundamental aspects of learning design tools related to the proposed approach are discussed in **Section 2.5**.

**Table 2-3.** Classification of some notable software tools and services implemented based using varying orchestration approaches to address orchestration challenges.

Tools	Orchestration Orchestrable	Classification	Approach	Challenges Addressed
<i>Awareness System</i> [153]	— X	Feedback mechanism	Orchestrating learning using awareness artefacts	Communication difficulties in face-to-face sessions

(Continued on next page)

**Table 2-3.** (continued)

Tools	Orchestration	Orchestrable	Classification	Approach	Challenges Addressed
<i>CADMOS</i> [93]	X	—	Learning design	Layered approach for designing flows of learning activities	Learning design support for non-experts
<i>COML</i> and <i>SceDer</i> [128, 129]	X	—	Learning design; modeling language	Orchestrate learning with one-on-one technologies	support for scaffolding; switching between activities; re-using lesson components
<i>GLUE!-PS</i> [4, 124, 149]	X	—	Learning design; data model	Support deployment of learning designs	Complexity orchestrating TEL scenarios
<i>GLUE!-PS AR</i> [123]	X	—	Learning design; data model	Support deployment of learning designs	Orchestration in augmented spaces
<i>LAMS</i> [47]	X	—	Learning design	Teacher authoring/adaptation of sequences	Re-use of educational processes
<i>Multi-tabletop classroom</i> [116]	—	X	Feedback mechanism	Designing multi-tabletop classroom for planning learning activities	Managing multiple devices
<i>Orchestration Graphs</i> [75]	X	—	Modelling language	Designing rich and complex scenarios	Scripting scenarios in large settings
<i>UniPad</i> [105]	—	X	Feedback mechanism	Supporting group activities	Managing devices and software in real-time
<i>TinkerLamp 2.0</i> [111]	X	X	Feedback mechanism	Supporting class activities & awareness	Orchestration support in classroom settings

## 2.5 Design considerations for orchestration software

There is a wealth of prior work [22, 154, 170] that has focused on general educational software design. While educational software covers a broad spectrum of considerations, such as target users and the problems they aim to address, most teacher-centric management software tools have focused on turning learning spaces into effective interactive environments [21]. For instance, notable teacher-centric tools such as Classroom Presenter<sup>1</sup> focus on awareness by linking instructor and student devices, providing a feedback channel for information to be exchanged between educators and students [11]. This thesis focuses on design considerations for orchestration design principles, outlined in Section 2.5.1, and learning design tools principles, described in Section 2.5.2.

### 2.5.1 Orchestration design considerations

A number of recent studies have highlighted design considerations and factors for orchestration of learning.

Dillenbourg and Jermann extract 14 design factors from metaphors of orchestration and educational ecosystem. They represent an orchestration model using 10 of the design factors, clustered into five themes: (1) Teacher-centrism; (2) Cross-plane integration; (3) Sequentiality; (4) Time management; and (5) Physicality. In addition, a list of main orchestration constraints—(1) curriculum constraints (2) assessment constraints (3) time constraints (4) energy constraints (5) space constraints and (6) safety constraints—are also presented to aid designers of orchestration technologies [56]. Collectively, the design factors illustrate a teacher-centric view of educational technologies used in the classroom. In order to show the applicability of the orchestration model, Dillenbourg and Jermann present and describe three example learning environments—ManyScripts environments, TinkerLamp environments and Lantern environments—that illustrate how the orchestration model works.

Dillenbourg et al. propose to view orchestration as a usability problem and propose a set of simple principles for the ‘design for orchestration’ in CSCL environments [58]. In a follow up study [51], Dillenbourg describes designing for orchestration as the dual flow of information, across digital and physical information containers, that integrates learning activities. Dillenbourg further states that through regular interactions with teachers and from experimental results conducted, design principles were extracted from common themes. A set of five design principles are enumerated: (1) Enabling the *control* of orchestration activities; (2) *visibility* to ensure awareness; (3) *flexibility* to facilitate changes to orchestration activities; (4) *physicality* to take into account physical aspects of orchestration, such as mobility; and (5) *minimalism* to minimise extrinsic orchestration load [51]. While different contexts have unique requirements and challenges, the design principles proposed by Dillenbourg provide general guidelines, forming a basis for suitable designs to consider when designing orchestration tools and services.

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<sup>1</sup><https://github.com/ClassroomPresenter/CP3>

Cuendet et al. argue that educational software adoption and use is scarce, in part, because requirements specific to their use within learning environments is usually ignored in preference to needs of the users of such software [46]. They illustrate how to incorporate requirements specific to learning environments using a paper-based interface used to orchestrate individual, group and classroom activities. Cuendet et al. highlight the importance of taking into account unique orchestration requirements specific to learning environments.

Tchounikine proposes to view orchestration design by distinguishing scripting and conducting of learning activities [169]. Scripting aims to address teaching objectives through analysis and design of tasks, while conducting involves adapting the setting components. Tchounikine's view of orchestration underscores the significance of scripting and enactment of learning activities when designing orchestration tools and services.

The approach to orchestration proposed in this thesis focuses on explicitly organising activities through scripting and enactment of learning activities [51]. Furthermore, we aim to incorporate general design principles proposed by Dillenbourg. More importantly, the core design considerations, presented in [Chapter 4](#), were arrived at after comprehensively exploring contemporary orchestration of learning.

## 2.5.2 Learning design for orchestration

In [Section 2.4.2](#) identified learning design as one approach used to address orchestration challenges. This thesis proposes to streamline orchestration by taking a learning design approach to implement an orchestration workbench platform, for the enactment and orchestration of learning activities.

The learning design process involves the design of learning units, learning activities and learning environments [26, 28]. One of the benefits of learning design is the potential reuse and interoperability exhibited by resulting tools. In order for this to be realised, a number of existing standards and specifications have been proposed to be used during the implementation of learning design tools. For instance, the IMS Learning Design specification [88] has been applied to a number of tools discussed in [Section 2.4.2](#).

Gruber et al. describe how key parameters of the IMS Learning Design specification provide a semantic framework modeling orchestrating learning processes [74]. A relation mapping of the dimensions of orchestration and IMS Learning Design semantic concepts is also provided, showing the applicability of using IMS Learning Design to designing tools for effective orchestration of learning. IMS Learning Design is further noted to include all aspects for prearranging learning scenarios. From an orchestration perspective, this characteristic of IMS Learning Design makes it well suited for implementing scripting actions performed during pre-session management.

While few orchestration tools and services explicitly mention the adoption of notable standards such as the IMS Simple Sequencing specification [86, 87], some their features provide functionalities that could be potentially useful when implementing orchestration tools. Specifically, the adaptive nature of the IMS Simple Sequencing specification [1]

could be used to implement workflows for specifying how enacted learning scenarios could be orchestrated during session management. A description of how this implementation is attainable is provided in [Chapter 4](#), and examples of actual implementation details are outlined in [Chapter 7](#). Furthermore, the availability of other well-established guidelines [15], standards [88] and modeling languages [26], like the coUML design language [49] facilitates the effective design of Learning Design tools.

## 2.6 Empirical evaluation strategies

There have been a number of empirical studies presented in existing literature, each employing different empirical strategies and focused on the evaluation of different orchestration aspects. In addition, case studies presented in existing literature were conducted in varying contexts. The summaries of prior studies—presented in existing literature—outlined below provide insight into different aspects of orchestration that have been evaluated and specific measurable metrics.

1. Kreitmayer et al. used a UniPad implementation to enable easy use of devices in the classroom [105]. UniPad was evaluated by a teacher, in a classroom with 26 students.
  - Result 1: The orchestration load resulting from the use of UniPad in the classroom did not burden the teacher.
  - Result 2: The UniPad handheld interface was used to effectively keep time and initiate transition between groups.
  - Result 3: UniPad was found to be easy to use and set up. In addition, it was noted to be engaging and satisfying.
2. Prieto et al. proposed a system architecture and data model, *GLUE!-PS*, for orchestrating [CSCL](#) scenarios [145]. In order to empirically determine the orchestration support provided by the system, a series of studies were conducted using a mixed-methods approach. The system was deployed and used by three teachers in authentic university course settings.
  - Result 1: *GLUE!-PS* supported the deployment of learning scenarios for use in enactments with students.
  - Result 2: *GLUE!-PS* was perceived to be useful for complex resource and sequence structures.
  - Result 3: *GLUE!-PS* was perceived to be usable in real practice, in authentic settings.
3. Niramitranon et al. evaluated *SceDer* in trials of ‘Year 7’ and ‘Year 9’ students [128]. The effectiveness of *SceDer* was performed by comparing teaching and learning outcomes after using Group Scribbles with Group Scribbles combined with *SceDer*. The data collection was performed using video observations and interviews.
  - Result 1: The learnability of Group Scribbles was within acceptable limits for both teachers and the students.

- Result 2: Similarly, SceDer Authoring was noted to be easily learnable for teachers, when creating learning scenarios.
4. Rojas et al. propose to help teachers and students with orchestrating learning by targeting four orchestration aspects: (1) management of resources; (2) teacher interventions and formative feedback; (3) summative assessment; and (4) re-design of activities [153]. They proposed an awareness system and evaluated it in an authentic setting of a Multimedia Applications course. The study was conducted with four different teachers and, in five sessions, each comprising of 20 to 30 students.
 

Result 1: The awareness information regarding students' progress and help enabled the teacher to plan and execute necessary interventions.

Result 2: The teacher was able to use awareness information to manage session times and to determine the students' progress.
  5. Muñoz-Cristóbal et al. evaluated the level of orchestration support provided by *GLUEPS-AR*, a system for coordinating across-spaces learning situations [122]. *GLUEPS-AR* was evaluated by a pre-service teacher—responsible for the design and enactment process—and an in-service teacher—responsible for assessing the pre-service teacher and offering support with orchestration. The evaluation was aimed at identifying how *GLUEPS-AR* is characterised by the '5 + 3 Aspects' orchestration framework [147].
 

Result 1: *GLUEPS-AR* enabled non-expert teachers to deploy learning designs and, additionally, enabled the management of learning situations, from design to enactment. Furthermore, *GLUEPS-AR* is able to support the adaptation of designs before, during and after enactment sessions.

Result 2: *GLUEPS-AR* allowed teachers to be aware of students' actions and also provided students with the flexibility to self-regulate their learning artefacts; this enabled the teacher to share the orchestration load.

Result 3: *GLUEPS-AR* enabled the creation of a ubiquitous learning environment, helping achieve learning objectives and keeping students engaged. *GLUEPS-AR* also allowed teachers to utilise desired pedagogical approaches.
  6. Prieto et al. used a mix-methods approach to measure the orchestration cognitive load experienced by educators during face-to-face classroom teaching sessions, where a teacher was supported with orchestration using a projector connected to a laptop and, running NetSupport School<sup>2</sup> classroom management software [148]. Subjective ratings and first-person video recordings were used in combination with physiological measures from mobile eye-tracker to measure the orchestration load. The study was conducted as part of a small case study, with two sets of secondary school students in two separate sessions.
 

Result 1: The subjective load ratings from the teacher were found to be significantly lower for the low load episodes than those for the high load episodes.

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<sup>2</sup><http://www.netsupportschool.com>

- Result 2: The high-load episodes mostly occurred when the teacher was giving explanations, lecturing or asking questions.
7. Do-Lenh et al. evaluated TinkerLamp 2.0—a redesigned and improved version of TinkerLamp 1.0 [90], which supports classroom-level activities and teacher orchestration—with two teachers and 93 vocational college apprentices [111]. The TinkerKey and TinkerBoard TinkerLamp 2.0 features supported the teacher with class orchestration and awareness.
- Result 1: The use of TinkerLamp 2.0 resulted in higher understanding and problem-solving scores in comparison to baseline measurements.
- Result 2: TinkerKey was observed to be used throughout classroom activities by teachers in order to ask questions, encourage student reflection and facilitate awareness.
- Result 3: TinkerBoard was observed to be used often by teachers and, more importantly, confirmed to be non-distracting to normal classroom activities.
8. Hernández-Leo et al. investigated the use of the Orchestration Signal system, a system that provides digital orchestration information to devices that can be worn by students [83]. Their study was aimed at investigating a Jigsaw collaboration flow. A mixed-methods evaluation approach was used to determine the effectiveness of the system in facilitating orchestration and, its potential usability. The evaluation was conducted with 27 students of a master seminar, which was facilitated by two teachers.
- Result 1: The orchestration of collaborative learning flow was successful, resulting in reduced teacher orchestration workload. Most students found the approach useful.
- Result 2: In comparison to prior experiences, teachers and students perceived the approach to effectively facilitate organised and dynamic collaboration and, additionally, a more engaging experience.

In [Table 2-4](#), a summary and comparison of the empirical studies is presented to highlight similarities and differences of the different empirical strategies. The studies indicate an emphasis on evaluating orchestration techniques in authentic educational settings. Although most studies place an emphasis on teacher roles, there are some studies, such as those conducted by Díaz et al. [50] and Niramitranon et al. [128], that focus on learners. Furthermore, the studies involve a variety of contexts and scenarios, indicating that proposed orchestration approaches typically aim to solve specific [TEL](#) problems.



**Table 2-4.** Summary of studies showing empirical evaluation strategies.

Study	Purpose	Strategy	Context	Subjects
Kreitmayer et al. [105]	Orchestration of group mechanisms	Case study	—	1 teacher; 26 students
Prieto et al. [145]	Orchestration of CSCL scenarios	Case study	Undergrad	3 teachers
Niramitranon et al. [128]	Orchestration with one-to-one technologies	Case studies; controlled design	7 <sup>th</sup> & 9 <sup>th</sup> Grade	4 teachers; 68 students
Rojas et al. [153]	Orchestrating learning using awareness artefacts	Case study	—	4 teachers
Muñoz-Cristóbal et al. [122]	Orchestrating across-space learning situations	Case study	6 <sup>th</sup> Grade	2 teachers
Prieto et al. [148].	Evaluating orchestration cognitive load	Case study	High school	1 teacher
Do-Lenh et al. [111].	Supporting class-level activities & teacher orchestration	Case study	Vocational college	93 apprentices
Hernández-Leo et al. [83].	Orchestrating face-to-face CSCL settings	Case study	Postgrad	2 teachers; 27 students

## 2.7 Summary

This chapter provided a critical review of key prior related work associated with this thesis. The chapter described the general orchestration landscape, key approaches of technology-driven orchestration and design considerations for orchestration tools and services. In addition, a discussion of learning design guidelines associated with orchestration,

and scripting of learning activities was provided. Some empirical evaluation strategies, described in prior studies, were also described, giving a broad overview of important evaluation aspects employed when assessing orchestration approaches. Finally, the use of orchestration in some computing fields was discussed, illuminating the main similarities that exist when orchestration is applied to different domains.

This thesis proposes an approach to orchestration—outlined in [Chapter 4](#)—that is strongly rooted in Dillenbourg’s view of orchestration involving the management of learning activities [51], and also resonates with his notion of using technology to make formal learning spaces effective learning environments. Furthermore, the approach to orchestration is aligned with the ‘5 + 3 *Aspects*’ conceptual framework [146, 147].

## **Part II**

### **Orchestration in perspective**

## Chapter 3

# Understanding challenges and complexities of contemporary orchestration

This chapter describes and presents an analysis of contemporary technology-driven orchestration of learning activities. A situational analysis was conducted at [University of Cape Town \(UCT\)](#), involving a series of studies that were aimed at comprehensively exploring and understanding orchestration of learning activities. The studies were conducted using a mixed-methods approach involving a meta-analysis of existing literature, expert interview sessions, participant observations and archival records analysis. The results of the situational analysis, highlighting the challenges of technology-driven orchestration, provided a basis for the design decisions of the proposed approach outlined in [Chapter 4](#).

The structure of the chapter is as follows: [Section 3.1](#) presents a meta-analysis of existing literature on orchestration challenges. In [Section 3.2](#), details of expert interview sessions held with faculty teaching staff are discussed. [Section 3.3](#) outlines a participant observation study conducted in authentic educational settings. An analysis of archival records of historical lecture sessions is then outlined in [Section 3.4](#). The results of the studies and their implications are discussed in [Section 3.5](#) and, finally, [Section 3.6](#) presents a summary of the chapter.

### 3.1 Study 1. Meta-analysis of orchestration challenges

A desk based literature review, involving a meta-analysis [69] of orchestration challenges, was conducted in order to identify the main challenges faced by educators during the technology-driven orchestration of learning activities. This was done as part of the main literature review exercise outlined in [Chapter 2](#).

Studies on orchestration of learning, which have focused on understanding orchestration, have, in part, attempted to identify the main challenges of orchestration of learning activities and its complex nature.

Dillenbourg highlights the multi-layered activities and multi-constraints as presenting significant challenges during the orchestration of learning. Dillenbourg further notes that, unlike instructional design whose focus is primarily on intrinsic activities and constraints, orchestration involves extrinsic and intrinsic activities and constraints [51].

In differentiating between orchestration and orchestrable technology, Tchounikine proposes to analyse orchestration of learning by distinguishing between scripting and conducting [169]. The complexities associated with scripting present further challenges to orchestration.

A conceptual orchestration framework devised by Prieto et al. uses five thematic groups—design/planning, regulation/management, adaption/flexibility/intervention, awareness/assessment and role of teacher and other actors—to characterise orchestration, each of which present unique challenges. In addition, the framework attempts to provide solutions for how orchestration should be done [146, 147].

There have been other studies that have focused on challenges specific to unique environments. For instance, several studies [17, 105, 128] have attempted to provide solutions for challenges in CSCL.

The challenges presented in this section highlight the complexities associated with orchestration of learning. In Chapter 4, we discuss how these challenges and the ad hoc nature of orchestration, shown in Sections 3.2, 3.3 and 3.4, necessitate the streamlining of orchestration of learning.

## 3.2 Study 2. Expert interviews

Expert interviewing is a qualitative empirical research method that explores expert knowledge [25, 119]. Interviews with experts not only shorten the data collection process, but also serve as an efficient method during the exploratory phase of a project [25].

### 3.2.1 Methods

Exploratory expert interviews were conducted with eight academic staff at UCT after ethical clearance approval<sup>1</sup> was granted. The participants were recruited from a sample pool of faculty that had previously participated in educational technology “Show and Tell” sessions—regular workshops aimed at helping and encouraging academic staff to integrate technology within teaching and learning processes—at UCT [39]. The participants can be considered early educational technology adopters as they had and/or were experimenting with various technologies within formal learning sessions.

Semi-structured face-to-face interview sessions [132] were held with each of the eight participants. The interview sessions lasted an average of 30 minutes each. Participants were asked about their experience integrating software tools for orchestrating learning activities within formal lecture sessions, and especially challenges they faced while

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<sup>1</sup>UCT ethical clearance approval code FSREC 021–2014

orchestrating learning activities. They were also asked to provide notable examples of novel software-driven approaches they used to improve students’ engagement and learning experiences.

### 3.2.2 Expert interview findings

The participants were from various disciplines, as shown in [Table 3-1](#). In addition, the participants had experience teaching both undergraduate and postgraduate courses.

**Table 3-1.** List of participants and their disciplines.

Participant	Discipline
[Faculty 1]	Architecture and Planning
[Faculty 2]	
[Faculty 3]	Centre for Innovation in Learning and Teaching
[Faculty 4]	Chemical Engineering
[Faculty 5]	
[Faculty 6]	Computer Science
[Faculty 7]	
[Faculty 8]	Mechanical Engineering

Common recurring themes from the interview sessions suggest that the class size, level of study of the learners and the teaching model followed are major contributing factor to challenges with technology-driven orchestration of learning. [Table 3-2](#) shows a summary of interview responses associated with the themes and, additionally, the main challenges experienced by the participants.

**Table 3-2.** Participants’ responses to interview questions.

Participant	Level	Size	Tools	Remarks on orchestration challenges
[Faculty 1]	Undergraduate	50	Laptop; Microsoft Powerpoint	• Challenges orchestrating collaborative activities.
[Faculty 2]	Postgraduate	15	Tablet computer	• Orchestration challenges using mobile device.

(Continued on next page)

**Table 3-2.** (continued)

Participant	Level	Size	Tools	Remarks on challenges
[Faculty 3]	—	—	—	<ul style="list-style-type: none"><li>• Workshop outcomes suggest most teaching staff have challenges appropriating existing generic tools.</li></ul>
[Faculty 4]	Undergraduate	150	Collaborative tools e.g. Google Docs	<ul style="list-style-type: none"><li>• One-to-one orchestration challenges due to size of class.</li><li>• Each student had access to a laptop.</li></ul>
[Faculty 5]	Undergraduate	100	Laptop; Microsoft Powerpoint	<ul style="list-style-type: none"><li>• Participant stated that they had no orchestration challenges.</li></ul>
[Faculty 6]	Undergraduate	300	Desktop computer; Microsoft Powerpoint	<ul style="list-style-type: none"><li>• Awareness challenges due to large class size.</li><li>• One to many orchestration using traditional lecture style.</li></ul>
[Faculty 7]	Undergraduate	50	Laptop; Microsoft Powerpoint	<ul style="list-style-type: none"><li>• Feedback and awareness challenges.</li></ul>
[Faculty 8]	Undergraduate	25	Laptop; Microsoft OneNote; Web browser	<ul style="list-style-type: none"><li>• Use of different tools for orchestrating varying activities.</li><li>• Non-flexibility of Microsoft OneNote when planning activities.</li></ul>

In general, the participants used a range of tools and services to orchestrate learning activities during their respective lecture sessions.

[Faculty 6] used Twitter<sup>2</sup> for classroom discussions with a relatively large first year course comprising of more than 300 students.

[Faculty 2] used a range of applications on a tablet to easily orchestrate activities for a postgraduate course.

The participants used various teaching models, largely depending on the size of the class.

[Faculty 8] lectured a relatively small class of first year students and was experimenting with the flipped classroom model.

<sup>2</sup><https://www.twitter.com>

[Faculty 4] took a student-centred approach when lecturing a course that was part of the UCT “Laptop Project” [32, 33, 40]—students enrolled for the course had access to a laptop. As a result, most orchestration tasks were shared with the students [159], resulting in the lecturer performing few orchestration tasks.

### 3.2.3 Summary

The expert interviews provide valuable insight into the different approaches and tools and services used to orchestrate activities by academic staff.

The responses from the participants suggest a correlation between the size of the class and the types of activities orchestrated. In addition, the responses also indicate a link between the learning models used and the orchestrated activities. More importantly, a range of tools and services are used to orchestrate activities in formal learning sessions.

## 3.3 Study 3. Participant observations

Participant Observation is a research method that involves the researcher becoming part of a group, observing behaviour in a natural setting. In so doing, the researcher is able to not only observe group members’ actions, but also interact with them [91].

Direct participant observations were conducted with two academic staff at UCT in order to gain an in-depth understanding of how educators orchestrate learning activities in authentic educational settings. An important point about the observations is that they were specifically aimed at understanding technology-driven orchestration of flipped classrooms.

### 3.3.1 Methods

Participant observations were conducted by attending lecture sessions and, in some instances, participating in in-classroom activities, for courses lectured by two academic staff at UCT. The observations were conducted after ethical clearance approval<sup>3</sup> was granted. In addition, interactions and conversations between the lecturers and students were monitored by regularly analysing chat messages within the respect course sites in the Learning Management System (LMS). The observations were conducted as outlined in Table 3-3, which shows a summary of the courses where the observations were conducted.

Furthermore, regular interview sessions were held with respective lecturers in order to gain more insight into specific activities taking place in the lecture sessions.

### 3.3.2 Participant observations findings

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<sup>3</sup>UCT ethical clearance approval code FSREC 021–2014



**Table 3-3.** The details of courses that were part of the participants observation study.

Participant	Course
[Lecturer 1]	Introductory Statistics (STA1000P)
[Lecturer 2]	Mathematics for Engineers (END1020F)

**Introductory Statistics (STA1000P).** The observations for STA1000P were conducted during the 2014 academic year summer school. An average of 35 students attended the observed lecture sessions. The course lecturer—[Lecturer 1]—lectured the course using The Workshop Model [174], involving the following three activities.

- An information session for class announcements and a recap of previous lecture sessions.
- A mini-lecture session in the form of a workshop explaining basic workshop concepts.
- An in-classroom exercise session that involved students working through workshop exercises, with [Lecturer 1] walking around to answer student queries.

[Lecturer 1] used a fixed desktop computer installed in the lecture venue [89] due to the nature of the activities orchestrated during the lecture session. The software tools used were limited to *Adobe Acrobat Reader*—for presenting the workshop mini-lecture session—and *Microsoft Excel*—for illustrating practical examples.

[Lecturer 1] expressed a desire for a seamless way of orchestrating the workshop exercise activity in order to effectively keep track of students who required the most help.

**Mathematics for Engineers (END1020F).** The observations for END1020F were conducted during the 2015 academic year. A total of 23 students were enrolled into the course. The course lecturer—[Lecturer 2]—ran the course using the flipped classroom model [107], where the students were required to go through selected course content—videos, Web resources, notes and textbook references—prior to the lecture session. [Lecturer 2] then orchestrated a range of activities aimed at reinforcing students’ knowledge of course concepts.

[Lecturer 2] used a personal laptop and a data projector. In addition, there were instances when a document camera was used when working through examples and during curve sketching. Furthermore, a range of software tools and services were used during the in-classroom activities.

*Google Chrome Web browser* was used to access Web resources such as online animations and illustrations from Websites like Mathdemos<sup>4</sup> and WolframAlpha<sup>5</sup>.

*Microsoft OneNote* was used to take important notes as [Lecturer 2] orchestrated the in-classroom activities.

<sup>4</sup><http://www.mathdemos.org>

<sup>5</sup><http://www.wolframalpha.com>

Interestingly, [Lecturer 2] also used *Microsoft OneNote*<sup>6</sup> to plan the order of orchestration of the different in-classroom activities. This was done during pre-session management.

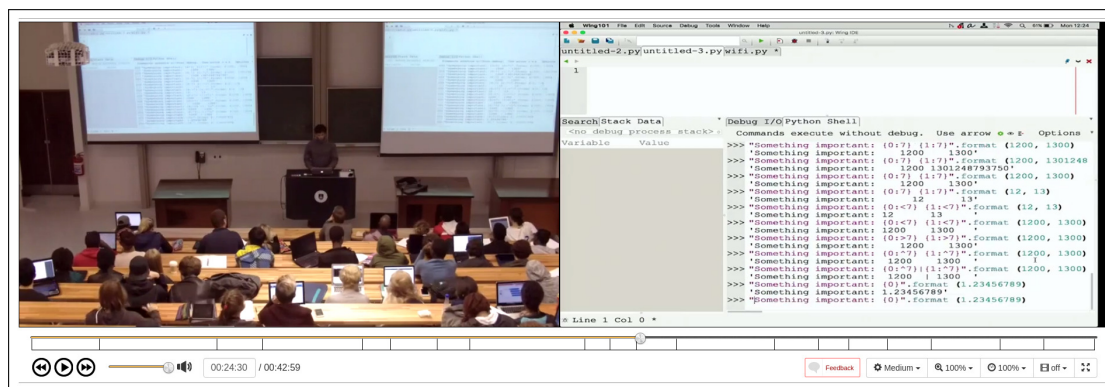
### 3.3.3 Summary

While most of the observations made reinforced the findings from expert interview sessions, outlined in [Section 3.2](#), conducted prior, the observations provided an in-depth understanding of orchestration workflows employed by educators that may otherwise have been left out during the interview sessions. More importantly, the observations revealed the potential effects that orchestration mechanisms have on learners; [Lecturer 2] was particularly conscious of this and regularly modified her approach to orchestrating learning activities.

## 3.4 Study 4. Archival records

Lecture recording is increasingly becoming popular and being implemented in a number of institutions of higher learning due to the low setup cost of required computing infrastructure [41, 125, 158]. The lecture recording process generally involves recording a face-to-face traditional lecture session and making the audio and video recording available for later use [190].

The archival records analysis study outlined in this section was conducted at [UCT](#), using publicly available lecture recordings. [UCT](#) has setup and implemented lecture recording infrastructure in most large lecture venues [37]. The final output of the lecture recordings consists of: (1) a presenter recording—a recording of the front of the lecture venue, (2) a presentation recording—a screencast recording of contents projected onto the data projector, and (3) a composite view consisting of a collage of the presenter view and presentation view. A sample composite recording is shown in [Figure 3-1](#).



**Figure 3-1.** Lecture recording showing a composite video of the presenter video (left) and the presentation screencast (right) for a first year Computer Science course.

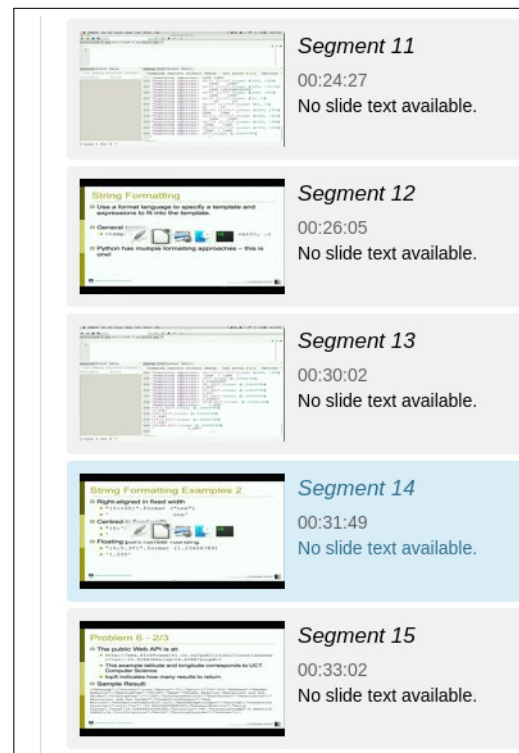
<sup>6</sup><https://www.onenote.com>

### 3.4.1 Methods

Publicly available lecture recordings at UCT [38] were randomly sampled in order to gain a more comprehensive overview of tools and services used to orchestrate learning activities.

UCT makes use of Opencast Matterhorn to process the lecture recordings. Opencast Matterhorn provides a lecture capture platform for video processing and media playback [30]. The video processing workflows produce segmented presenter video recordings as one of the outputs, using Opencast Matterhorn's slide segmentation service [96]. Figure 3-2 shows a screencast of a sample segmented presenter recording. The archival record study primarily involved a segmentation analysis of recorded presenter recordings using the Opencast Matterhorn generated segments as input. The segmentation represents time points of context switches of the presentation timeline. As an example, the five segments in Figure 3-2 show two software tools that were used during the lecture session: *Microsoft PowerPoint* was used during segments 12, 14 and 15; *Wing 101 IDE* was used in segments 11 and 13.

**Figure 3-2.** Opencast Matterhorn video segmentation divides a video presentation screencast into segments of different time frames of the presentation.



The segmentations from processed screencasts were analysed by noting the applications that were in use in each segment snapshot, as shown in Figure 3-2.

### 3.4.2 Opencast Matterhorn segmentation analysis

The results of the segmentation analysis show that a wide variety of software tools and services were used to orchestrate learning activities in the sampled recordings. The vast majority of the tools were used to render content, for instance presentation software such as

**Table 3-4.** The table shows some recorded screencasts that were randomly analysed during the archival records analysis exercise.

Lecturer	Course
[Lecturer 1]	
[Lecturer 2]	CSC1015F
[Lecturer 3]	
[Lecturer 4]	MAM1043H
[Lecturer 5]	ECO4112F

*Microsoft PowerPoint* and Web browsers. However, specialised tools were used to perform tasks specific to individual courses; for instance Computer Science courses, in part, involved the use of Integrated Development Environments.

Expectedly, the results suggest that the range of activities and range of tools used to orchestrate activities is linked to the type of course. This observation is further supported by the outcomes of the expert interviews discussed in [Section 3.3](#).

A key observation made was the lack of use of software for organising the different activities performed during the lecture session.

## 3.5 Discussion

The studies conducted during the situational analysis illustrate the nature and challenges of orchestration of learning activities in formal learning spaces. Another key finding is the ad hoc nature of technology-driven orchestration of learning.

### 3.5.1 Complexities with orchestration

While there is a range of challenges associated with orchestration, the studies conducted confirm that its multi-faceted nature makes it extremely complex to manage the range of activities. This, coupled with the constraints associated with orchestration, further complicates the orchestration process. Furthermore, the coordination of the different activities, during orchestration, proves to be a challenge.

In addition, the use of teaching models that increasingly require the use of additional technologies further adds to the complexities associated with orchestration. This is especially the case for non-traditional teaching models that require frequent interactions between educators and learners.

### 3.5.2 Ad hoc nature of orchestration

Although limited in scope, the studies conducted as part of the situational analysis suggest that orchestration of learning activities is performed in a variety of ways. This was especially evident from the segmentation analysis discussed in [Section 3.4](#), the participant observations outlined in [Section 3.3.2](#), and the expert interview sessions described in [Section 3.2](#).

The expert interview sessions, in particular, provided details of orchestration challenges experienced by individual educators employing varying teaching techniques. The observations revealed nuanced details associated with the impact that orchestration tools and techniques have on learners. The segmentation analysis provides an overview of the ranges of tools used, their usage frequencies and, additionally, how generic tools are adapted by educators to perform orchestration tasks.

## 3.6 Summary

This chapter presented a series of studies conducted as part of a situational analysis that was aimed at exploring contemporary orchestration. The challenges associated with orchestration of learning activities have been highlighted and, additionally, different approaches for orchestrating learning activities using educational technology have been discussed.

There are two main findings from the situational analysis, and they form the basis of the argument for why orchestration should be streamlined. Further details of the approach to streamline orchestration are outlined in [Chapter 4](#).

**Finding 1: Challenges associated with orchestration.** The challenges associated with orchestration of learning activities are well documented in existing literature, and were uncovered through the meta-analysis study. In addition, the participant observation study and the archival analysis study further confirmed these challenges.

**Finding 2: Ad hoc nature of technology-driven orchestration.** Generally, a variety of tools and services are used to orchestrate learning activities. This, for the most part, involves adapting existing general purpose tools to suit specific needs.

# Chapter 4

## Streamlining orchestration of learning activities

This chapter presents an approach to orchestration that aims to address some of the challenges and complexities of orchestration outlined in [Chapter 3](#).

The chapter is organised as follows: [Section 4.1](#) provides an introduction to the chapter. [Section 4.2](#) describes the inspiration and motivation behind the proposed approach and, in [Section 4.3](#), the core aspects of the proposed approach are outlined. [Section 4.4](#) describes an example use case of streamlined orchestration and, finally, [Section 4.5](#) provides the chapter summary.

### 4.1 Introduction

While there are numerous techniques and approaches that could potentially be used to address the challenges discussed in [Chapter 3](#), based on the outcomes of the exploratory studies, we propose a solution aimed at streamlining orchestration by focusing on core aspects associated with scripting during pre-session management outlined in [Section 4.3](#). The significance of scripting on orchestration of learning has been highlighted in existing literature [[98](#), [169](#)].

The proposed approach to orchestration of learning activities, presented in this thesis, is based on Dillenbourg's definition of orchestration [[51](#)], which focuses on the roles performed by educators during the management of learning activities. Furthermore, by focusing on the core aspects of scripting, we aim to address the "Adaptation/Flexibility/Intervention", "Regulation/Management", "Design/Planning" and "Role of the teacher and other actors" aspects of the '5 + 3 Aspects' conceptual framework [[147](#)]. In terms of the revised conceptual framework for achieving the desired learning effect [[146](#)], the proposed approach aims to focus and address challenges of the activities associated with orchestration. In essence, the approach aims to contribute towards the implementation of orchestration tools and services that are designed for adaptation, awareness and, the effective management of activities.

Table 4-1 shows a mapping of the three orchestration aspects of the proposed approach, to the five key aspects of the ‘5 + 3 Aspects’ framework. We argue that the challenges associated with these aspects can, in part, be resolved when scripting learning activities during pre-session management.

**Table 4-1.** Mapping of the three proposed approach aspects to the five key aspects of the ‘5 + 3 Aspects’ conceptual framework [147].

Sequencing	“Design/Planning”	“Adaptation/ Flexibility/ Intervention”
Activity management	“Awareness/ Assessment”	“Regulation/ Management”
Resource management	“Role of the teacher & other actors”	

Specifically, we propose to streamline orchestration—using a software-driven approach—by providing an effective way of organising learning activities during pre-session management. The organisation of the activities is done through a unified software platform with integrated tools and services required to perform scripting functionalities.

## 4.2 Inspiration and motivation

The proposed streamlined orchestration approach is, in part, inspired by the successful use of similar approaches in other domains. A number of domains make use of software platforms with integrated tools and services for performing related tasks. The practical advantages of using such platforms are centred around the notion that such software platforms facilitate effectiveness and efficiency by providing easy access to functionalities. In addition, a unified platform provides a familiar interface for accessing different tools and services.

Scientific workflow workbench platforms such as Kepler [9], Taverna [131] and Trident [19] are specialised systems that are used in scientific domains to perform scientific computations. The workbenches provide scientists with integrated graphical tools and services for conducting analyses, running models, and creating workflows. In their classification of scientific workflow environments, Woollard et al. state that orchestration forms a central part of in silico experimentation and, that it is a complex task involving several processes between processing elements [186].

Software development generally involves performing several different, but related tasks. For instance, a text editor is required to write source code, a compiler or an interpreter is required to compile/run the source code and version control software is used for versioning the source code. Software developers typically use IDEs to perform these different tasks [181]. IDEs integrate the required tools, providing a unified platform for the developer. Eclipse is an example of a popular IDE, and is implemented using a plugin architecture [151] that facilitates the integration of different tools and services.

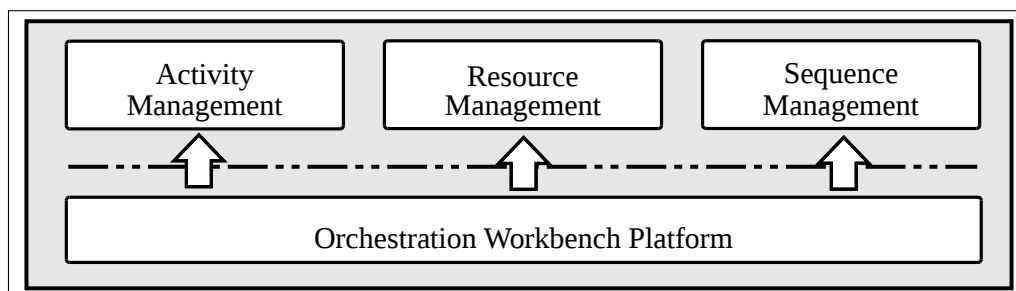
The idea of organisation has also been used elsewhere within the TEL domain. For instance, Hernández-Leo et al. propose an Integrated Environment for Learning Design (ILDE) for supporting the creation of effective computer-supported learning situations [80, 81, 82]. ILDE is tagged as a networked system that integrates collaborative functions, design editors and middleware for the effective deployment of learning situations in Virtual Learning Environments [80]. In contrast to ILDE, this thesis focuses on the organisation of learning activities in order to streamline orchestration of learning.

Similarly, this thesis proposes an approach to orchestration of learning activities which aims to provide a means of centrally performing core orchestration tasks in an organised manner. The underlying argument is that orchestration of learning activities could potentially become more effective by providing educators with a platform integrated with tools and services for performing core orchestration tasks.

### 4.3 Orchestration scripting aspects

As earlier stated, the main focus of the proposed approach to orchestration is to streamline the orchestration process in order to enable the effective orchestration of learning activities. We argue that orchestration can potentially be streamlined by facilitating the enactment of learning activities through scripting, during pre-session management.

Specifically, we propose to focus on three core aspects of orchestration—the management of activities, the management of resources used during orchestration and the sequencing of the activities—that are primarily conducted during pre-session management, as shown in Figure 4-1. The three aspects are described in Sections 4.3.1, 4.3.2 and 4.3.3.



**Figure 4-1.** The three key components of proposed streamlined orchestration approach using an orchestration workbench platform.

#### 4.3.1 Activity management

A crucial part of pre-session management involves planning what activities are to be orchestrated during session management. A notable challenge of orchestration is that it is multi-faceted and generally involves multi-layered activities that are both intrinsic and extrinsic in nature [51]. There are a range of activities that are orchestrated in formal learning environments, each of which depends on the learning model used by educators and



the objectives of the learning session. The varying nature of these activities requires careful management of the individual activities.

The management of the activities could be achieved by providing a means for specifying appropriate actions associated with individual activities.

### 4.3.2 Resource management

The orchestration of most activities generally requires associated teaching and learning media resources. The resources come in different types and are both static—such as PDF documents and videos—and interactive in nature.

There needs to be a flexible way to specify the resources to be used during orchestration and, more importantly, a way to associate the resources with the activities during the activity management process outlined in [Section 4.3.1](#).

### 4.3.3 Sequencing

The orchestration of activities needs proper coordination. An alternative way of achieving proper coordination could involve explicit sequencing of the activities during pre-session management. Orchestration typically takes place in a linear and directed manner, with planned activities sequentially performed in a pre-defined way. While, the sequence of activities is in most cases fixed, the sequencing could possibly be performed dynamically. In such scenarios, the sequencing of activities could be implemented in ways that enable such dynamic changes to be performed during session management.

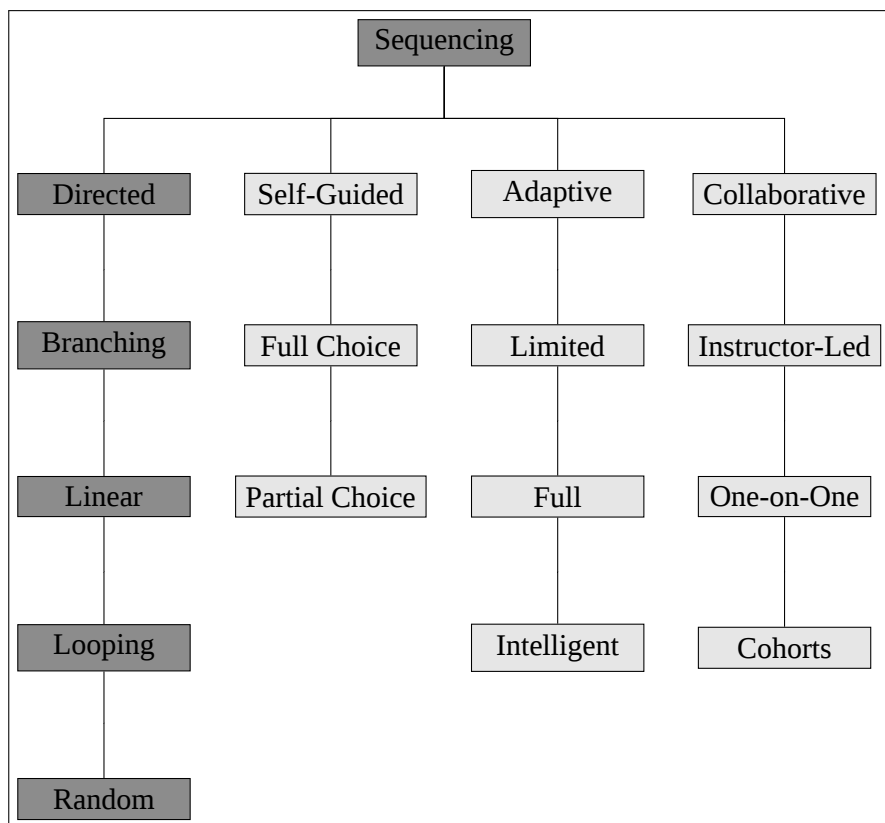
The actual implementation of this sequencing of behaviours could potentially be modelled using existing standards such as the IMS Simple Sequencing standard [86, 87]. The IMS Simple Sequencing activity tree shown in [Figure 4-2](#) outlines the different ways in which the activities could be sequenced.

The *Directed* path can be used to model fixed and directed sequencing; the *Self-guided* path could be used to model activities to be orchestrated by the learners; the *Adaptive* path can be used to model activities that would need sequencing during orchestration; and the *Collaborative* path can be used to model shared orchestration [105, 159].

### 4.3.4 Relationships between orchestration aspects

The relationships that exist between the three orchestration aspects exist as a linear workflow in which successive stages of the process utilise outputs of previous stages of the orchestration process as input, as shown in [Figure 4-3](#).

The orchestration workflow is initiated during pre-session management and progresses as follows.



**Figure 4-2.** IMS Global Simple Sequencing activity tree [86] showing the four possible sequencing paths for modeling different potential orchestration scenarios.

**Step 1: Pre-session management.** The pre-session management stage involves planning and scripting of learning activities to be performed during session management in the formal learning environment.

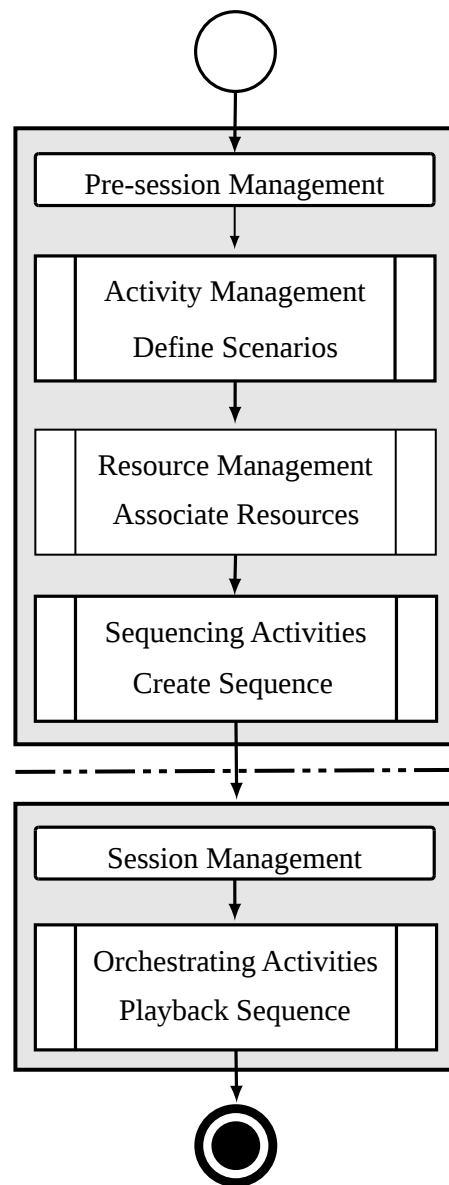
*Step 1.1: Activity management.* The educator defines learning activities to be performed in the formal session and, additionally, defines learning scenarios to be performed. Defining the scenarios, in part, involves providing descriptive details of the session to be orchestrated and providing relationships that exists with other course units.

*Step 1.2: Resource management.* The learning scenarios defined in *Step 1.1* typically have associated teaching resources. The resource management stage involves the association of teaching resources to the defined activities and scenarios. The teaching resources could be associated in their native formats, or alternatively, as links to remote locations.

*Step 1.3: Sequence activities.* Sequencing involves the explicit specification of the activities order of orchestration to be followed during session management . Essentially, the activities and their associated resources are used as input for the sequencing stage.

**Step 2: Session management.** The sequenced activities resulting from *Step 1.3* are played back during session management. While potential toolkits are ideally meant to aid the teacher with orchestration, Depending on the purpose of the orchestration toolkit

**Figure 4-3.** The three key components of the proposed streamlined orchestration approach, showing the workflow of the proposed solution.

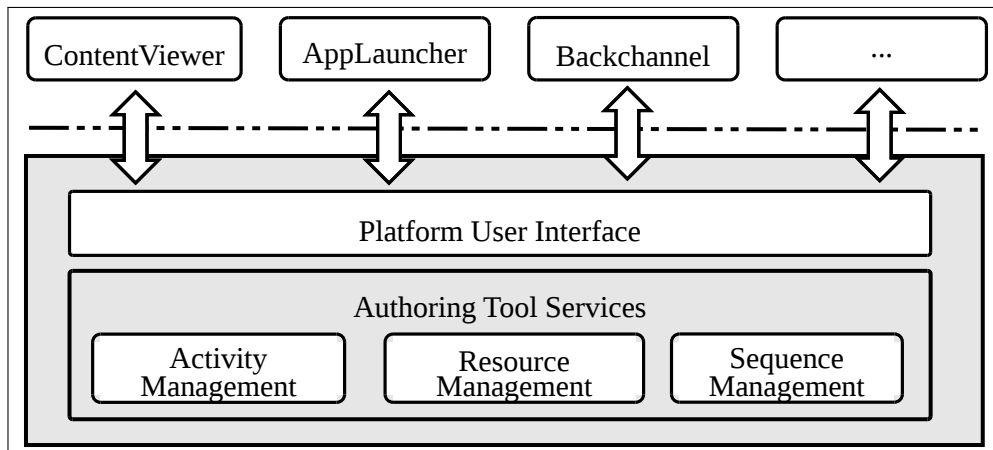


We further argue that focusing on these aspects could ultimately provide the scaffolding necessary for building orchestration workbench platforms that would enable the effective orchestration of learning activities. [Section 4.4](#) provides an illustration of a potential use case of the proposed approach. Furthermore, prototype toolkits implemented using the proposed approach are described in [Part III](#).

## 4.4 Streamlined orchestration: Example use case

By centralising access to platform tools and services, they would ultimately be easily accessible. In addition, additional services, indirectly associated with the aspects outlined in [Section 4.3](#), could be integrated within the platform.

Different orchestration workbench platform configurations are possible depending on the types of activities to be orchestrated and specific user needs and preferences. For instance, the platform could run as a standalone local service on a user's machine, or as a remote Web service. [Figure 4-4](#) shows an example use case of a potential workbench implementation. The use case is integrated with services for performing the core orchestration aspects—activity management, resource management and sequencing—and, additionally, add-on functionalities.



**Figure 4-4.** An example of a possible implementation of the proposed approach.

In [Part III](#), example prototype orchestration workbench toolkits, implemented for use in the experiments, are described.

## 4.5 Summary

This chapter presented key aspects of our proposed approach to streamlining orchestration. In addition, fundamental design decisions for building tools and services of the proposed approach are highlighted.

In [Part III](#), a series of studies are presented, illustrating the feasibility of the approach, its potential effectiveness, and its potential on positively impacting the teaching experience.

## **Part III**

### **Empirical studies**

# Chapter 5

## Comparative analysis: Ad hoc vs. organised orchestration

This chapter presents a comparative analysis conducted to compare two technology-driven orchestration approaches: ad hoc orchestration and organised orchestration. The contents of this chapter have been, in part, adapted from a paper published in the proceedings of the 8<sup>th</sup> IEEE Conference on Technology for Education [142].

An orchestration toolkit was implemented, based on the streamlined orchestration approach described in [Chapter 4](#) and then experimentally compared with an off-the-shelf orchestration platform. A within-subjects experiment, involving 61 participants, was conducted to comparatively measure the effectiveness and teaching experience of the two orchestration techniques.

This chapter is organised as follows: [Section 5.1](#) details the motivation and also highlights the core contributions of the chapter. [Section 5.2](#) and [Section 5.3](#) describe the two orchestration software toolkits that were used to conduct the comparative analysis of organised orchestration and ad hoc orchestration. [Section 5.4](#) outlines the experiment design and, the results gathered are presented in [Section 5.5](#). [Section 5.6](#) then presents a discussion and interpretation of the results. Some limitations with the study are presented in [Section 5.7](#) and, finally, [Section 5.8](#) concludes the chapter.

### 5.1 Motivation and contributions

The premise of this thesis is centred around the organisation of learning activities in order to streamline technology-driven orchestration. It is argued that streamlining orchestration could potentially result in more effective technology-driven orchestration of learning activities. The motivation for the proposal to streamline orchestration stems from the fact that most current approaches—contemporary orchestration—for orchestrating learning activities are ineffective, as outlined in [Chapter 3](#).

In [Chapter 3](#), the challenges associated with orchestration and, more importantly, its ad hoc nature are highlighted as being the two main reasons for why contemporary orchestration is flawed. It has also been shown, from the results gathered from expert reviews, direct observations and analysis of archival records, that while there exists software tools and services that educators use to orchestrate learning activities, these tools and services are often used in an ad hoc manner.

In order to determine the comparative advantages of the proposed organised approach, a prototype Web-based workbench platform, outlined in [Section 5.2](#), was designed and implemented, using the organised orchestration principles detailed in [Chapter 4](#). The prototype workbench was thus used to evaluate organised orchestration. In order to provide a basis for baseline measurements, the PortableApps platform—detailed in [Section 5.3](#)—was used for the evaluation of ad hoc orchestration.

The main contributions presented in this chapter are as follows:

1. The empirical evaluation techniques used to compare technology-driven orchestration approaches.
2. The results from the comparative analysis of the two different technology-driven orchestration approaches.

## **5.2 Implementation: Workbench platform toolkit**

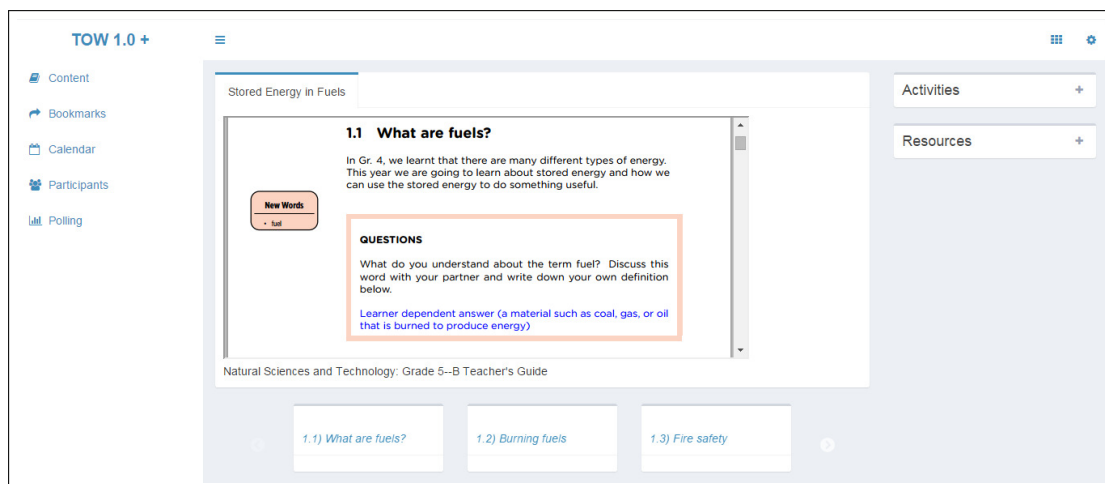
### **5.2.1 Design considerations**

The main objective of the toolkit implementation was to provide a platform that would serve as a basis for the comparison of orchestration activities during in-session management. In essence, the goal was to evaluate the efficacy of organised orchestration of learning activities, when compared with ad hoc orchestration of learning activities. Since the focus was on the evaluation of in-session management of learning activities, pre-session management of learning activities was assumed.

### **5.2.2 Toolkit features**

A prototype Web-based workbench user interface was implemented in order to serve as the basis for measuring the efficacy of organised orchestration. The workbench was implemented using HTML, CSS and JavaScript. Bootstrap [[134](#)] was used to implement the user interface and Plain Old JavaScript Objects [[7](#)] served as the basis for implementing the backend services. [Figure 5-1](#) is a screenshot of the landing page for the prototype interface.

The prototype user interface was loosely implemented based on the IMS Global Simple Sequencing specification [[87](#)]. The scope of the study was restricted to effort required to assess software tools and services in order to perform the different orchestration activities and, as such, the implementation of the prototype was limited to two content viewers: a



**Figure 5-1.** Screenshot of the prototype workbench home page interface. The left, right and bottom navigation panels facilitate easy access to tools and services, while the central content panel renders different content types.

textual content viewer and a video content viewer. Furthermore, the user interface was implemented with navigation panels to enable easy access to orchestration services. Using [Figure 5-1](#) as reference, the interface components function as follows:

- The left navigation panel enables the end user to access core high-level session activities.
- The bottom navigation panel facilitates access to potential topics associated with a particular course.
- The right navigation panel renders teaching resources associated with each of the topics rendered in the bottom navigation.
- The content panel, located at the middle of the home page, displays teaching resources. For the purposes of the study, two content types were considered: textual content and video content.

### 5.3 PortableApps platform

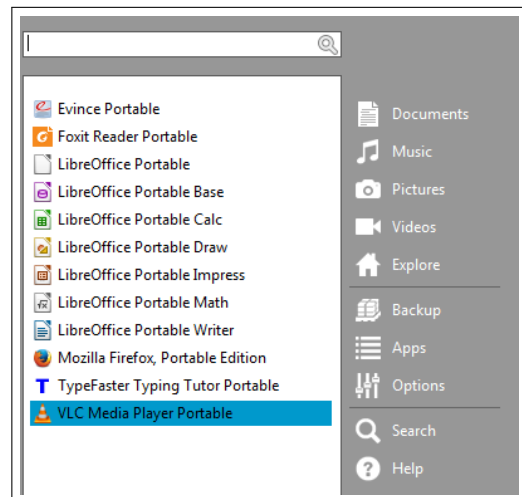
In [Chapter 3](#), it was mentioned that due to the ad hoc nature of contemporary orchestration results, most educators orchestrate learning activities use a variety of software tools and services. A typical scenario in which learning activities are orchestrated in an ad hoc manner would generally involve the use of a computer running a popular operating system such as Microsoft Windows, installed with an assortment of generic software applications. In such a scenario, the educator uses the installed software applications to orchestrate different learning activities that take place in their formal learning sessions.

PortableApps, a fully open source and free platform that optionally works on portable storage devices [150], was used to evaluate ad hoc orchestration, while the prototype workbench toolkit was used to evaluate organised orchestration. PortableApps makes



available a number of commonly used Microsoft Windows applications that are packaged and optimised for portability. Figure 5-2 shows a screenshot of the PortableApps interface menu with applications configured for the experiment. Similar to operating systems such as Microsoft Windows, PortableApps has an application launcher that handles path redirection and changes to environment variables. In addition, the platform has a menu listing the installed application with the platform, an application directory containing all installed applications and a search feature.

**Figure 5-2.** PortableApps platform screenshot showing the menu used to access software tools and documents.



The PortableApps platform was used for three primary reasons:

- It implicitly enables access to applications in a similar manner as with commonly used operating systems.
- It ensured that all participants had access to a consistent ad hoc orchestration interface. The PortableApps configuration and software applications installed was the same on all the machines used during the experiment.
- There was limited control of the computing infrastructure of the experimental setting and PortableApps thus provided the best possible alternative.

## 5.4 Experiment design

A controlled experiment was conducted in order to perform a comparative analysis between ad hoc orchestration and organised orchestration. The study experiment was conducted using a within-subject design using random experimental blocks, with participants initially assigned to orchestrate a learning scenario using either of the orchestration approaches—using PortableApps or the prototype Workbench—, yielding a total of two experimental conditions, as shown in Table 5-1.

The main objective of the study was to empirically compare ad hoc orchestration and organised orchestration. In order to guide the study, the following research question was investigated:

**Table 5-1.** Experiment conditions constructed after applying random experiment blocks.

	Approach	
	PortableApps	Workbench
Group 1	Second	First
Group 2	First	Second

*When compared to ad hoc orchestration, to what extent does organised orchestration affect the effectiveness and teaching experience of educators when orchestrating learning activities?*

In order to answer the study research question, participants orchestrated learning activities using the two orchestration approaches:

- Ad hoc orchestration using the PortableApps platform, described in [Section 5.3](#), and
- Organised orchestration using the prototype Workbench toolkit user interface implementation outlined in [Section 5.2](#).

PortableApps was used to orchestrate learning activities, in a manner similar native desktop application, by using its application launcher. Orchestrating the learning activities using the Workbench involved using only a Web browser as the prototype was implemented to render textual and video content. In both cases, the participants were required to self-report task times at stipulated checkpoints and, additionally, answer questions associated with learning activities to prevent them from skipping important steps.

### 5.4.1 Hypothesis formulation

Two hypotheses related to the efficacy of the two orchestration approaches are stated below. The hypotheses address the impact of technology-driven orchestration on the effectiveness and user experience while orchestrating learning activities.

**Hypothesis 1.** The effectiveness—success and rate of orchestration—of educators’ ability to orchestrate learning activities is better when using the organised orchestration approach than when using ad hoc orchestration.

- Null hypothesis,  $H_0$ : There is no difference in the effectiveness of orchestrating learning activities between organised orchestration and ad hoc orchestration.
  - $H_0$ : Effectiveness(Workbench) = Effectiveness(PortableApps)
- Alternative hypothesis,  $H_a$ : Organised orchestration results in more effective orchestration of learning activities.
  - $H_a$ : Effectiveness(Workbench)  $\neq$  Effectiveness(PortableApps)

**Hypothesis 2.** The user experience of educators while orchestrating learning activities using the organised orchestration approach is better than when using the ad hoc orchestration approach.

- Null hypothesis,  $H_0$ : The effect of organised orchestration on teaching experience is comparable to ad hoc orchestration.
  - $H_0: UX(\text{Workbench}) = UX(\text{PortableApps})$
- Alternative hypothesis,  $H_a$ : Organised orchestration has a more positive effect on teaching experience in comparison to ad hoc orchestration.
  - $H_a: UX(\text{Workbench}) \neq UX(\text{PortableApps})$

## 5.4.2 Metrics and measurements

### AttrakDiff 2 instrument

AttrakDiff 2 [78] was used as the core method of investigation; specifically, the “Comparison A–B” [178] approach was utilised. AttrakDiff 2 assesses the perceived pragmatic quality, the hedonic quality and the attractiveness quality of an interactive product, by measuring how users personally rate the usability and design of the product. The instrument comprises of 28 opposite adjectives—wordpairs—that are grouped into four dimensions, each making up seven wordpairs. The wordpairs are rated on a 7-point Likert scale that specifies their subjective contributions.

AttrakDiff 2 was used as it assesses perceived user feelings about a system in the form of quantitative comparative data. The four AttrakDiff 2 dimensions were interpreted as follows:

**Pragmatic Quality (PQ).** Indicates the extent to which participants were successful at achieving the desired goal of orchestrating the learning scenario.

**Hedonic Quality – Identity (HQ-I).** Indicates to what extent the orchestration techniques allow participants to identify with the orchestration process.

**Hedonic Quality – Stimulation (HQ-S).** Indicates the extent to which each orchestration technique supported participants’ need to develop and move forward in terms of novel, interesting, and stimulating functions, contents, and presentation styles.

**Attractiveness (ATT).** Describes the value of the orchestration techniques on the quality of perception.

The four dimensions were evaluated using the standard evaluation methodology—dimension means and wordpair means were computed for the two orchestration techniques. In addition, the results are presented using standard AttrakDiff 2 graphs—portfolio-presentation and line graphs for dimension means and wordpair means.

### Time on tasks

The time taken to complete the orchestration of learning activities (time taken to perform Task 3—see Section 5.4.4), and the PQ and HQ-I dimensions were used to compare the effectiveness of the two approaches. This was done in order to ascertain the following:

- Whether learning activities were orchestrated more successfully, easier or faster.
- Extent towards which orchestration goals are realised.
- Users' level of comfort while orchestrating learning activities.

In order to assess the user experience during the orchestration of the learning activities, the [HQ-I](#), [HQ-S](#) and [ATT](#) dimensions were used to compare the two approaches. [Table 5-2](#) shows a summary of the experimental factors and associated experimental variables.

**Table 5-2.** The two experiment evaluation aspects, with their associated scales.

Aspect	Factor	Variable	Scale
Effectiveness	Speed	Time	Minutes
	Success	<a href="#">PQ</a>	[-3 - 3]
	Comfort	<a href="#">HQ-I</a>	[-3 - 3]
User experience	UX	<a href="#">HQ-I</a> , <a href="#">HQ-S</a> , <a href="#">ATT</a>	[-3 - 3]

### 5.4.3 Participant recruitment

Participants were recruited using poster advertisements to Bachelor of Education, [Intermediate and Senior Phase \(ISP\)](#) students in the Faculty of Education at [CPUT](#), after ethical clearance approval<sup>1,2</sup> was granted. All students pursuing education-oriented programmes at [CPUT](#) are required to undergo teaching practice beginning in their second year of study. The participants were thus selected for convenience and more importantly, due to their prior experience teaching in authentic educational settings.

Each participant was compensated with ZAR 40.00.

### 5.4.4 Orchestration tasks

Participants used the two techniques to orchestrate five learning activities detailed in a fifth grade science “What are fuels?” learning scenario from a standard teacher guide text book [12] using standard Desktop computers. The learning scenario comprised of the following five learning activities:

**Activity 1: Teaching lesson content.** The teacher guide text book has detailed notes of content expected to be taught to learners. Participants read the teaching material as they would in a real-world setting.

**Activity 2: Viewing a video clip.** The video shows the “Formation of fossil fuels”. The video is provided as a link to a YouTube video in the teacher guide text book.

<sup>1</sup>UCT ethical clearance approval code FSREC 021–2014

<sup>2</sup>Ethics clearance granted by [CPUT](#) Institutional Ethics Committee

**Activity 3: Accessing a Web resource.** describing how “Fossil fuels are made”. As with the video, the Web resource is also provided as a link in the teacher guide text book.

**Activity 4: Conducting a class activity.** The activity involves students working in pairs. The teacher guide text book has details including instructions, materials and questions students are expected to provide solutions for.

**Activity 5: Performing a teacher-led experiment.** The experiment—“How much energy can we get from different fuels”—is in the form of an investigation. The teacher guide text book has details of materials and apparatus required, and questions to ask students.

The scenario effectively involved using three educational resources: (1) the teacher guide PDF document; (2) the “Formation of fossil fuels” video; and (3) the “Fossil fuels” remote Web resource.

Participants performed three tasks while using the two orchestration approaches, by following a sequence of instructions provided to them, as outlined in [Table 5-3](#).

**Table 5-3.** Description of experiment orchestration tasks performed by participants

Task	Description
Task 1	<ul style="list-style-type: none"> <li>• The first task was devised to enable participants to become familiar with the two interfaces.</li> <li>• For both PortableApps and the Workbench, this included instructions on how to access and launch the applications and, additionally, instructions on how to perform actions specific to each approach.</li> </ul>
Task 2	<ul style="list-style-type: none"> <li>• The second task was aimed at illustrating how to locate the three educational resources to be used when orchestrating the lesson.</li> <li>• In the case of PortableApps, this involved knowing the location of the offline resources: the PDF document and the video. The instructions associated with the Workbench involved identifying the interface components to be used to render the PDF document, view the video and access the remote Web resource.</li> </ul>
Task 3	<ul style="list-style-type: none"> <li>• The third task involved the orchestration of the five learning activities. Orchestrating the five learning activities using PortableApps involved using a “Foxit Reader” to view activities 1, 4 and 5; “VLC Media Player Portable” to playback activity 2 and “Mozilla Firefox Portable Edition” to view activity 3.</li> <li>• The prototype workbench toolkit, however, was implemented with features that enabled the viewing of activities 1, 3, 4 and 5 and playback of activity 2.</li> </ul>

### 5.4.5 Procedure

Participants were briefed about the experiment and asked to sign a consent form and fill out demographic information in the background section of the questionnaire. In order to assess the influence of control variables on the results, the following demographic information was collected:

- Level of study: the year of study of participants, including their specialisations.
- Teaching experience: the number of times participants had been on teaching practice.
- Computing experience: how long participants had been using computing devices.

Participants were then randomly assigned to two groups—Group 1 and Group 2—to prevent potential order effects. The random assignment ensured that the two orchestration techniques were counterbalanced by alternating the order of exposure to the two techniques. Participants in Group 1 orchestrated learning activities using the workbench interface, followed by PortableApps; while those in Group 2 started with PortableApps, followed by the workbench interface.

Each participant was then asked to fill out two AttrakDiff 2 questionnaires (see [Appendix A.2.4](#)) corresponding to the two orchestration techniques. The two questionnaires also had an option for participants to specify open ended comments associated with their experiences using the two orchestration approaches. Finally, participants were debriefed upon completion of all the experiment tasks.

## 5.5 Data analysis

### 5.5.1 Result 1. Participants' demographics

61 individuals participated in the study, with 59 of them completing all the experiment tasks. Participants' level of study ranged from second year ([ISP 2](#)) to fourth year ([ISP 4](#)), with varying specialisations. In addition, participants had been on teaching practice at least three times. Furthermore, most of the participants had at least two years experience working with computers.

[Table 5-4](#) is a summary of the participants' demographic details.

In summary, the design was as follows:

61 participants ×  
2 orchestration techniques ×  
random blocks

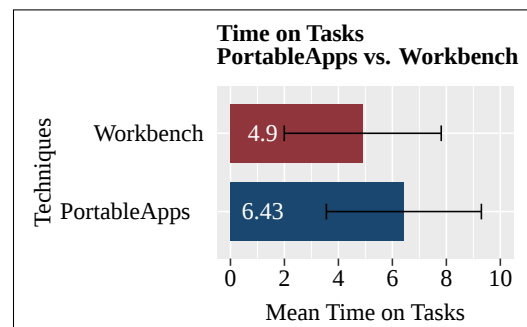
**Table 5-4.** Participants’ demographic information anticipated to be correlated with the study outcomes.

Participants’ Demographics		Group 1	Group 2
ISP levels	ISP 2	11	10
	ISP 3	14	13
	ISP 4	5	4
	N/A	0	2
Teaching experience	2 times	5	7
	3 times	5	4
	4 times	20	18
Computing experience	0–1 yrs	3	2
	2–3 yrs	14	13
	4–5 yrs	2	6
	5+ yrs	11	8

### 5.5.2 Result 2. Time on tasks

Figure 5-3 shows the average time it took for participants to complete the orchestration activities for each of the two approaches.

**Figure 5-3.** Participants’ mean time taken to perform experiment tasks for the two orchestration approaches.

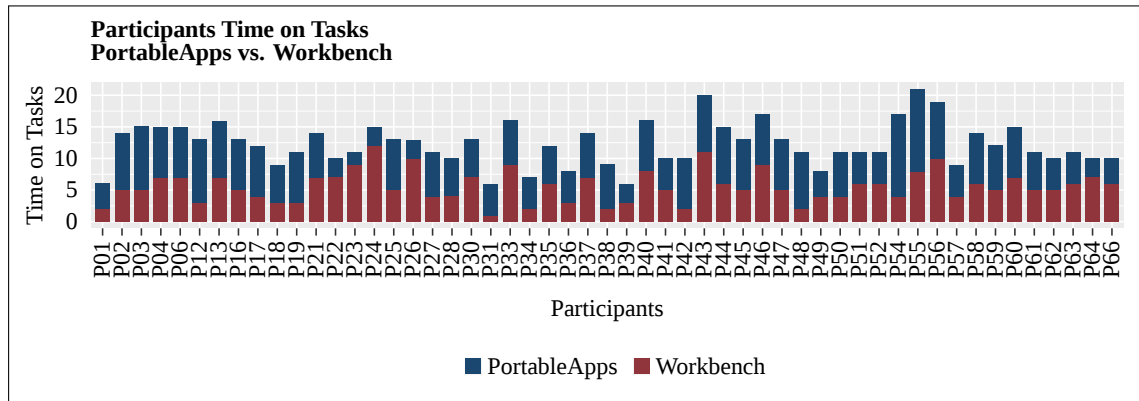
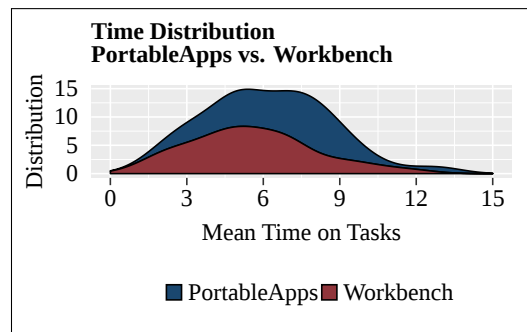


A Wilcoxon Signed-rank test indicates a significant difference in the mean times on tasks ( $Z = -3.70, p < 0.05$ ). The overall mean time on tasks was 6.15 minutes. The time taken to orchestrate learning activity, when using the Workbench, by 66% of participants was less than the overall average orchestration time. In contrast, when using PortableApps, 43% of participants orchestrated the learning activities in less than the average mean time on task.

### Demographic differences and counterbalancing

The distribution of the participants’ mean time of tasks is shown in Figure 5-4. Further more, Figure 5-5 shows the time on tasks by individual participants.

**Figure 5-4.** The time on tasks distribution for the two orchestration approaches.



**Figure 5-5.** Participants’ individual times on tasks for the two orchestration approaches.

A Factorial ANOVA was conducted to compare the main effects of orchestration techniques and *ISP* levels; orchestration techniques and teaching experience; orchestration techniques and computing experience; and, finally, orchestration techniques and counterbalanced groups.

**Counterbalancing effect.** The ANOVA revealed no significant main effect as a result of counterbalancing ( $F_{1,118} = 0.20, p = 0.65$ ). Table 5-5 shows the mean time on tasks for the two counterbalanced groups. On average, participants orchestrated learning activities 21% faster when using the workbench approach in comparison to using PortableApps.

**Table 5-5.** The mean time on tasks for the two orchestration approaches, showing the effects of counterbalancing for the two experiment groups.

	Approach	
	PortableApps	Workbench
Group 1	7.44 (2.24)	5.84 (2.30)
Group 2	6.10 (2.38)	5.32 (2.61)

Participants in Group 1 orchestrated the learning activities 27.4% faster using the workbench approach than with the ad hoc approach, while those in Group 2 orchestrated the learning activities 14.7% faster when using the workbench. Interestingly, workbench orchestration was faster for participants in Group 1 than those in Group 2.



**Demographic differences effect.** The ANOVA revealed no significant main effect as a result of **ISP** levels ( $F_{4,112} = 1.35$ ,  $p = 0.26$ ), teaching experience ( $F_{1,118} = 0.070$ ,  $p = 0.79$ ) or computing experience ( $F_{1,118} = 0.62$ ,  $p = 0.43$ ). In terms of demographic patterns, participants in all study levels orchestrated activities faster using the workbench approach. For all teaching practice frequencies, participants orchestrated activities faster using the workbench approach. Participants with 0–1 years, 2–3 years and 5+ years computing experience orchestrated learning activities faster using the workbench approach, however, those with 4–5 years experience orchestrated them faster using PortableApps.

### 5.5.3 Result 3. AttrakDiff responses

As stated in [Section 5.4.2](#), the results were analysed and presented using the standard AttrakDiff 2 methodology. The four dimension mean scores were computed by aggregating their associated wordpair mean responses. Furthermore, the dimension means were used to present a portfolio presentation graph.

#### Wordpair means

The wordpair means correspond to the participants' aggregate responses to the 28 bipolar scales, outlined in [Appendix A.2.4](#). [Figure 5-6](#) show the results of the analysis conducted on the wordpairs associated to each of the four dimension means.

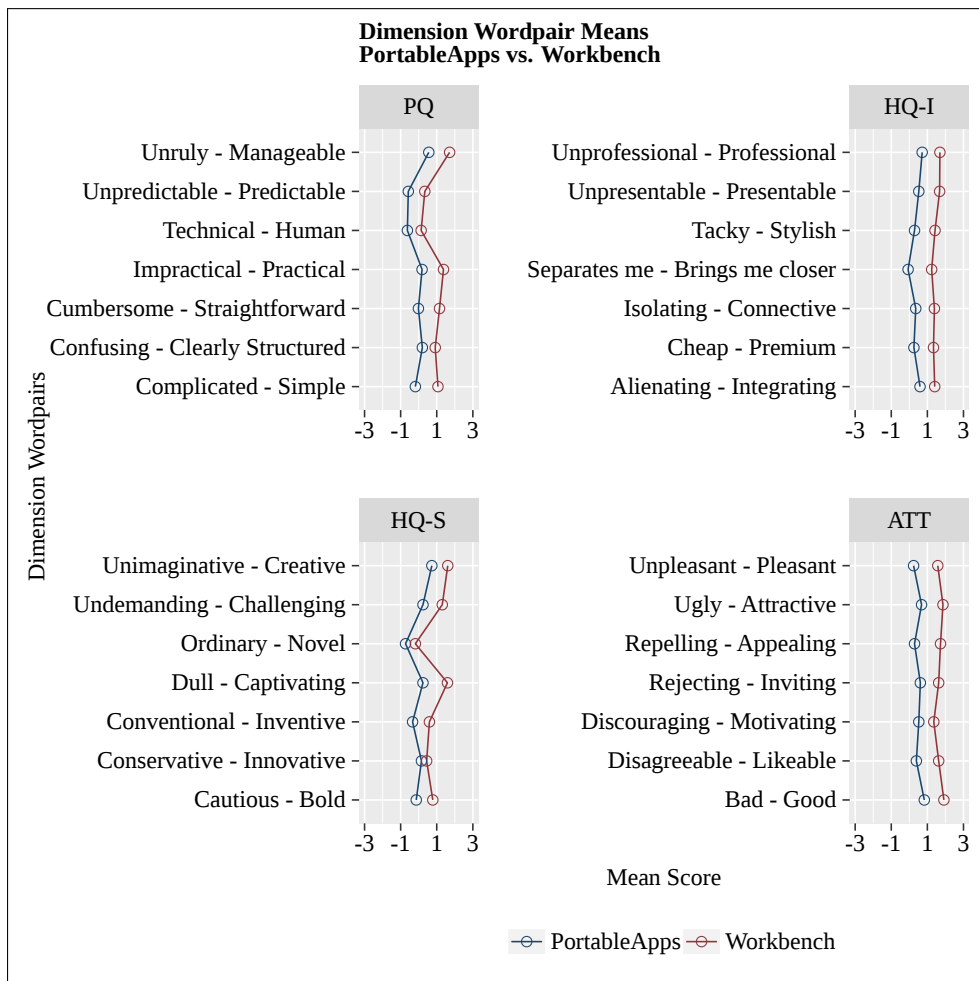
The wordpair ratings for the **PQ** dimension indicate that the workbench approach, in comparison to the PortableApps approach, was highly perceived as being more simple, clearly structured, straightforward, practical, and manageable. However, although scoring higher than the PortableApps approach, it was perceived as being somewhat technical and unpredictable. These lower ratings can, in part, be attributed to the fact that participants were unfamiliar with the prototype interface.

All wordpairs associated with the **HQ-I** dimension were rated with higher scores for the workbench approach. The workbench approach had a marginally lower score for the “Ordinary–Novel” and “Conservative–Innovative” wordpairs of the **HQ-S** dimension.

In the **ATT** dimension, the workbench approach had a higher score in all the wordpairs, suggesting that the workbench approach was perceived to be pleasant, attractive, appealing and, more importantly, motivating.

#### Dimension means

The dimension means were calculated by aggregating means ratings of wordpairs associated to each of the four dimensions, outlined in [Section 5.5.3](#). Paired samples t-tests computed for the four dimension means indicate significantly higher dimension means scores for the Workbench, in comparison to PortableApps for **PQ** ( $t = 5.5295$ ,  $df = 54$ ,  $p < 0.001$ ), **HQ-I** ( $t = 6.9894$ ,  $df = 54$ ,  $p < 0.001$ ), **HQ-S** ( $t = 6.0187$ ,  $df = 54$ ,  $p < 0.001$ ) and **ATT** ( $t = 6.3972$ ,  $df = 54$ ,  $p < 0.001$ ) dimensions.



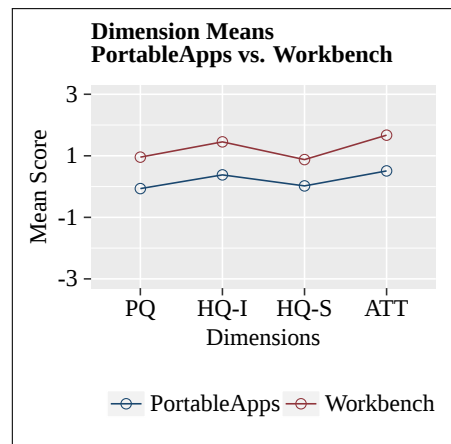
**Figure 5-6.** The participants mean score ratings for each of the seven AttrakDiff wordpairs corresponding to each of the four dimensions highlight participants’ subjective views of the two orchestration approaches.

Figure 5-7 shows the results of the four dimension means. In all the four dimensions—pragmatic quality, hedonic qualities and attractiveness—the workbench approach performs better than the PortableApps approach.

### Portfolio presentations

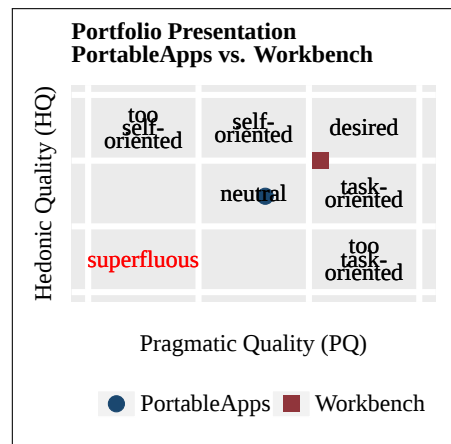
Figure 5-8 shows the portfolio-presentation graph, with the character-regions occupied by the two orchestration approaches. The portfolio-presentation uses the PQ, HQ-I and HQ-S dimension values to provide a classification for a product quality, in order to determine if it is desirable. In the portfolio-presentation graph, the values for hedonic quality are represented in the vertical axis, while those for the pragmatic quality are presented in the horizontal axis. The bottom and left values represent low values, while the top and right values represent high values. The aggregate values of the dimensions determine the position occupied by each approach. The product quality values fall in either of seven character

**Figure 5-7.** The mean values for the four AttrakDiff 2 dimensions for the two orchestration approaches.



regions—*superfluous, too self oriented, self-oriented, tool task oriented, task-oriented* and *desired*—or on the region borders.

**Figure 5-8.** AttrakDiff 2 portfolio-presentation graph showing average values for the PQ and HQ-I/HQ-S dimensions of the PortableApps and Workbench toolkit orchestration techniques.



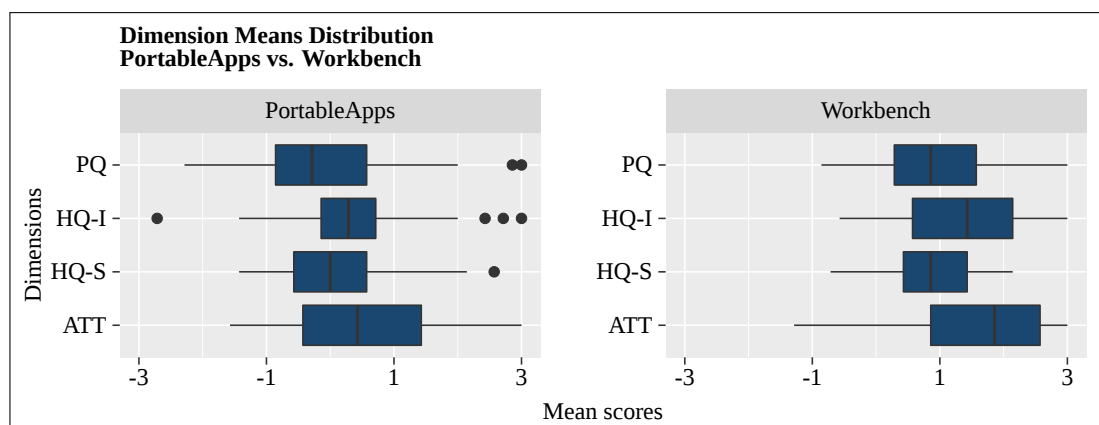
As shown in [Figure 5-8](#), the workbench approach is located in the lower sector of the desired character region. However, the PortableApps approach is located in the neutral character region, implying that it meets ordinary standards.

### Demographic differences and counterbalancing

[Figure 5-9](#) shows the distribution of the participants’ mean scores for the four dimensions. The effects of counterbalancing and demographic differences were analysed in order to determine their influence on the dimension mean scores.

A Factorial ANOVA was conducted to determine the main effects of the [ISP](#) levels, teaching experience, computing experience and the counterbalanced groups, on the mean dimensions.

**Counterbalancing effect.** The ANOVA revealed no statistically significant differences, resulting from counterbalancing, in the mean scores of the two orchestration approaches, for the four dimensions—[PQ](#) ( $F_{1,118} = 0.28, p = 0.60$ ), [HQ-I](#) ( $F_{1,118} = 0.096, p = 0.76$ ), [HQ-S](#) ( $F_{1,118} = 0.029, p = 0.86$ ) and [ATT](#) ( $F_{1,118} = 0.41, p = 0.52$ ).



**Figure 5-9.** Participants’ dimension means distribution.

The dimension mean trends resulting from counterbalancing are similar to the overall results, as shown in [Table 5-6](#). For both Group 1 and Group 2, the workbench approach mean scores are higher in all the four dimensions.

**Table 5-6.** The mean scores for the four dimension means, showing the effects of counterbalancing the two experiment groups.

Group	Approach	PQ	HQ-I	HQ-S	ATT
Group 1	Workbench	0.83 (1.03)	1.27 (1.00)	0.82 (0.69)	1.46 (1.19)
	PortableApps	-0.38 (1.12)	0.18 (0.72)	-0.11 (0.69)	0.32 (1.02)
Group 2	Workbench	1.22 (0.85)	1.79 (0.84)	1.01 (0.79)	2.05 (0.88)
	PortableApps	0.25 (1.32)	0.62 (1.23)	0.19 (1.06)	0.80 (1.40)

**Demographic differences effect.** The ANOVA, on the effects of the [ISP](#) levels, revealed a statistically significant difference for the [HQ-S](#) ( $F_{4,112} = 3.38, p < 0.05$ ) dimension, however, there was no statistical significance for the [PQ](#) ( $F_{4,12} = 0.86, p = 0.49$ ), [HQ-I](#) ( $F_{4,12} = 1.01, p = 0.41$ ) and [ATT](#) ( $F_{4,112} = 0.78, p = 0.54$ ) dimensions. Participants from all [ISP](#) levels, with the exception of those from [ISP 4](#), ascribed higher mean scores to the workbench approach, for all dimensions. However, the PortableApps approach had higher scores by fourth year students in the [HQ-S](#) dimension.

Participants rated the workbench approach higher than PortableApps, in all four dimensions—[PQ](#) ( $F_{2,116} = 1.82, p = 0.17$ ); [HQ-I](#) ( $F_{2,116} = 1.82, p = 0.17$ ); [HQ-S](#) ( $F_{2,116} = 2.28, p = 0.11$ ); and [ATT](#) ( $F_{2,116} = 1.91, p = 0.15$ ), irrespective of the number of times they had been on teaching practice.

Participants’ prior computing experience had no significant effect on the dimension mean score differences—[PQ](#) ( $F_{3,114} = 1.74, p = 0.16$ ); [HQ-I](#) ( $F_{3,114} = 1.19, p = 0.32$ ); [HQ-S](#) ( $F_{3,114} = 1.29, p = 0.28$ ); and [ATT](#) ( $F_{3,114} = 1.07, p = 0.36$ )—for the two orchestration approaches.

## 5.5.4 Result 4. Participants' remarks

As stated in [Section 5.4.5](#), the participants were optionally given the opportunity to provide open ended comments associated with each of the two orchestration approaches. In order to further understand the results from participants' time on tasks and AttrakDiff 2 ratings, their comments were analysed. 37 participants supplied at least one comment after performing the assigned task with either one of the two approaches, or both approaches.

The participants' comments were detailed and quite useful. Most of the comments indicate a preference for the Workbench approach.

*"If I were to do this with my learners I would definitely do approach 1"*  
[Participant 6]

*"Approach number 1 would be easy for learners"* [Participant 39]

However, there were some participants who preferred the PortableApps approach.

*"Simple, straight forward :) I loved this approach, nice application[sic]"*  
[Participant 61]

There were some participants who provided suggestions on how the two orchestration approaches could be integrated within teaching processes.

*"It would be good if it was used as just one component of the lesson & not the whole lesson[sic]"* [Participant 30]

There was no noticeable correlation between the participants' demographics and their comments. In addition, the counterbalancing did not have an effect on the participants' comments.

## 5.6 Interpretation

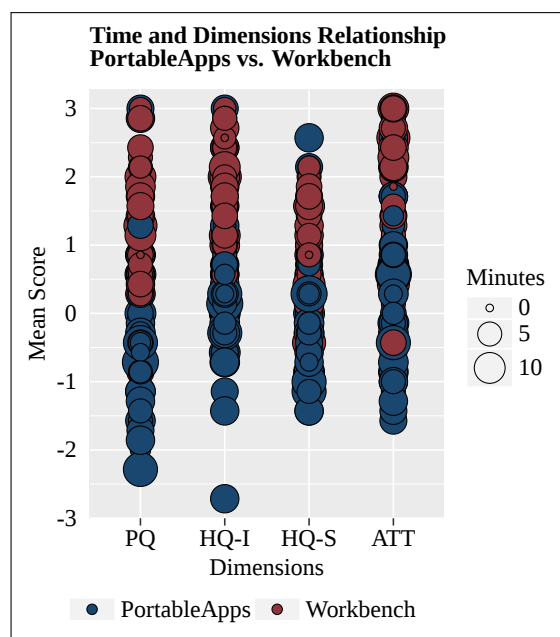
### 5.6.1 Analysis 1. Techniques effectiveness

As outlined in [Section 5.5.2](#), learning activities were on average orchestrated faster using the organised approach. This is because the workbench interface facilitated easy access to tools and services required to perform the tasks.

Participants' perceived success at orchestrating activities is best supported by PQ wordpairs such as "Cumbersome – Straightforward" and "Complicated – Simple", which were rated highly in favour of the workbench approach.

The potential effectiveness of streamlining orchestration is further supported by the relationship between the dimension mean scores and the orchestration times. [Figure 5-10](#) illustrates the relationship between the mean time taken to orchestrate learning activities and the subjective mean score ratings for the dimension means. A large proportion of participants who orchestrated the learning activities faster had corresponding higher ratings for the four dimension means.

**Figure 5-10.** The scatter plot shows the relationship between the time spent orchestrating the experiment tasks, with the AttrakDiff dimension mean score ratings. The size of the bubble represents the time taken to orchestrate learning activities.



## 5.6.2 Analysis 2. User experience

All wordpairs for the **ATT** dimension—a strong indicator of user experience—were highly rated for the workbench approach. The overwhelming positive responses in favour of the workbench approach are further corroborated by the following comments from some participants.

*“If I were to do this with my learners I would definitely do approach 1”*  
[Participant 6, Group 1]

*“Having to use approach 2 with my learners would take longer than doing the first one”* [Participant 6, Group 1]

*“I liked it more than the first approach. This was really good and creative, easy to access your resources and activities”* [Participant 2, Group 1]

*“The second activity was harder for me to do.”* [Participant 3, Group 1]

## 5.6.3 Analysis 3. Counterbalancing effect

As shown in [Table 5-6](#), the counterbalancing had a similar effect on the results for the dimension means. However, as shows in [Table 5-5](#), it is interesting to note the effect it had on the task completion times: while participants orchestrated the learning activities faster in both groups, they were fastest in Group 1. The one possible explanation for the variation is the complexity and effort required during the transition between the two approaches.

As shown in [Figure 5-6](#), the workbench was perceived to be both simple and requiring less effort during the orchestration of learning activities. Transitioning from the simple approach

to the complex approach resulted in increased task times, while transition from a complex approach to a simpler one has little effect.

#### 5.6.4 Analysis 4. Demographic differences

The influence of all the control variables resulted in minor variations from the overall results for both task time and AttrakDiff dimension means. There was some correlation between demographics—year of study, teaching experience and computing experience—and task times: participants' task time patterns were similar for both approaches; for instance fourth year students orchestrated activities quicker using both approaches.

### 5.7 Limitations

The main limitation of the study is that it was designed to be conducted in a controlled setting and, as such, it was inevitably constrained by the fact that it was not conducted in an authentic educational setting. The controlled experimental setting lacked certain core aspects and actors that would typically be present in an authentic educational setting—for instance, learners were not present. In addition, however, the following limitations may also have impacted the results.

- The study participants had no prior experience using either of the two platforms. This may especially have had an impact on the times it took the participants to orchestrate the learning activities.
- The study participants had limited experience teaching and as a result, their user experience subjective views of the two orchestration approaches may not have been comprehensive.

### 5.8 Summary

In this chapter, results from a comparative study of ad hoc and organised orchestration were presented and interpreted. Two interfaces representing ad hoc and organised technology-driven orchestration were compared against each other. A within-subject study was conducted in order to compare the two technology-driven orchestration approaches.

The following two hypotheses were investigated:

**Hypothesis 1.** The effectiveness scores are higher when using the organised orchestration approach than the ad hoc orchestration approach.

**Hypothesis 2.** The subjective user experience scores are higher for the organised approach than for the ad hoc orchestration approach.

The major findings are that an organised approach to orchestration enables participants to orchestrate learning activities faster than the ad hoc approach, and that their perceived success at orchestrating the activities was more pronounced when using the workbench. In addition, participants' experience was generally positive when using the workbench. The results also indicate the following:

- In terms of complexity, the organised approach is noticeably less complex than the ad hoc approach.
- There is little variation between the overall results and results arising from demographic differences.

In [Chapter 6](#), further empirical proof of the efficacy of organised orchestration is present and, additionally, [Chapter 7](#) and [Chapter 8](#) describe and present case studies, outlining the applicability and practical usage scenario of organised orchestration, respectively.



# Chapter 6

## Guided orchestration for peer-led tutoring

This chapter presents an experimental study aimed at assessing the effectiveness and applicability of organised guided orchestration in peer-led tutoring. The contents of this chapter have been, in part, adapted from a paper published in the proceedings of the 9<sup>th</sup> International Conference on Computer Supported Education [143].

Peer tutoring is a well established practice in most large universities and generally involves senior students—tutors—teaching junior students. The range of activities performed by tutors during tutorial sessions are typically performed in a directed manner because of the emphasis on the curriculum content and, additionally, the lack of formal teaching training of tutors.

An orchestration tutoring toolkit was implemented to facilitate face-to-face tutoring sessions. A laboratory study was conducted with 24 tutors in order to evaluate the orchestration load imposed by the toolkit and to assess its potential usefulness to tutors.

This chapter is organised as follows: [Section 6.1](#) highlights the motivation and main contributions presented in the chapter. [Section 6.2](#) is a synthesis of related work, and [Section 6.3](#) presents design and implementation details of Peer Orchestra: a prototype Web-based toolkit built to facilitate organised orchestration. [Section 6.4](#) describes the experiment design of the study conducted to evaluate the toolkit and, [Section 6.5](#), presents the results of the study. In [Section 6.6](#), a discussion of the results is provided, outlining the implication of the study. Finally, [Section 6.7](#) presents summary remarks.

### 6.1 Motivation and contributions

Peer tutoring involves students learning with and from one another [63]. The learning broadly involves individuals from similar social groupings helping one another to learn. The individuals who take on the role of teaching are tutors while those being taught are tutees [172]. In higher education, tutors are typically senior students in higher levels with little or

no teaching qualification. The advantages of peer tutoring in higher education, such as small group learning and cost savings, are well documented [20, 27, 172]. With the widespread availability of general purpose technology and specialised educational technology, peer tutoring is increasingly becoming more effective [62].

A technique commonly employed in large undergraduate courses involves forming smaller manageable tutorial groups, which are administered by tutors. However, in the majority of these cases, the tutorial sessions are typically conducted in an informal manner. This is, in part, due to the fact that tutors usually do not have the formal training required to teach. In this chapter, the potential of technology-driven organised orchestration on peer-led tutoring, with a particular focus on pre-session management of learning activities, is explored.

The primary argument of this thesis is that the ad hoc nature of orchestration is as a direct result of a lack of a standardised way of orchestrating learning activities [142]. In [Chapter 4](#), a more streamlined approach for orchestration of learning activities—organised orchestration [144]—is outlined.

This chapter is a further attempt to explore the potential applicability of the proposed approach in a different educational setting: peer tutoring sessions. We argue that due to its focus on curriculum content and, additionally, the lack of formal teaching training of tutors, peer tutoring could potentially be made more effective by leveraging organised orchestration.

We propose the design and implementation of a peer tutoring teaching platform aimed at facilitating the orchestration of tutor-led learning activities. A proof of concept pre-session management toolkit was developed based on an existing standard: IMS Global Simple Sequencing Specification [87]. We also present experimental results gathered, after evaluating the implementation of this toolkit.

The main contributions presented in this chapter are as follows:

1. A new potentially viable approach to facilitate technology-driven orchestration of peer-led learning activities.
2. A use of the IMS Global Simple Sequencing Standard to facilitate organised orchestration of learning activities.
3. The design and implementation of an orchestration toolkit for facilitating peer-led tutoring.
4. Experimental results to demonstrate the viability of tools for pre-session management of peer-led tutorial sessions.

## 6.2 Related work

[Peer Assisted Learning \(PAL\)](#) has historically been employed in higher education, particularly in difficult courses and those with significantly large enrolments. While

there exists many different models of [PAL](#), Topping emphasises that Peer Tutoring and Cooperative Learning are the most common models [173].

- Peer Tutoring typically focuses on the curriculum content, with clearly outlined procedures. In addition, participants will generally receive some form of training [173].
- Cooperative Learning generally involves collaboration in order to achieve a shared goal [173].

There is a wide range of tools that have been employed to facilitate peer tutoring. However, most of these tools are aimed at facilitating interaction between peers and, additionally, enabling teachers to monitor interactions between peers.

[Classwide Peer Tutoring Learning Management System \(CWPT-LMS\)](#) provides tools and services required by teachers to implement CWPT [71]. The software enables teachers to plan and measure progress. Unlike [CWPT-LMS](#), our work focuses more on facilitating the activities performed by the tutors.

G-Math Peer-Tutoring System is a Web-based application developed as a Massive Multiplayer Online Game, in order to facilitate interactions among connected users [176]. The system is composed of two modules, which are operated by teachers and students. The core focus of the system is to improve mathematics outcomes of learners by facilitating interactions amongst the learners.

Due to the size of most [MOOCs](#), peer feedback has become an integral part of the assessment process. PeerStudio is an assessment platform that was implemented to take advantage of large [MOOC](#) enrolment numbers in order to facilitate rapid assessment feedback [106].

Our work is explicitly aimed at facilitating the orchestration of learning activities by peer tutors during formal face-to-face interaction with learners.

## **6.3 Peer orchestra: Tutoring orchestration toolkit**

### **6.3.1 Design goals**

It is premised that peer-led tutorial sessions can be made more effective by the use of organised orchestration tools. A proof of concept toolkit was developed to serve as the basis for experiments to test this premise, and an evaluation was then conducted to assess the usability of the toolkit by tutors in the context of actual tutorial/course content.

The toolkit has two major functions: pre-session management and in-session orchestration of activities. The pre-session management involved three specific tasks:

- Activity management, which is the specification of metadata associated with the activity;
- Resource management, which is the uploading and organising of resources; and
- Activity sequencing, which is the ordering of resources within the activity.

After an activity has been designed, using the tool, it can be viewed or played back by a tutor in a tutorial session. There are two viewers for this purpose: a built-in viewer that uses HTML; and a PowerPoint export feature.

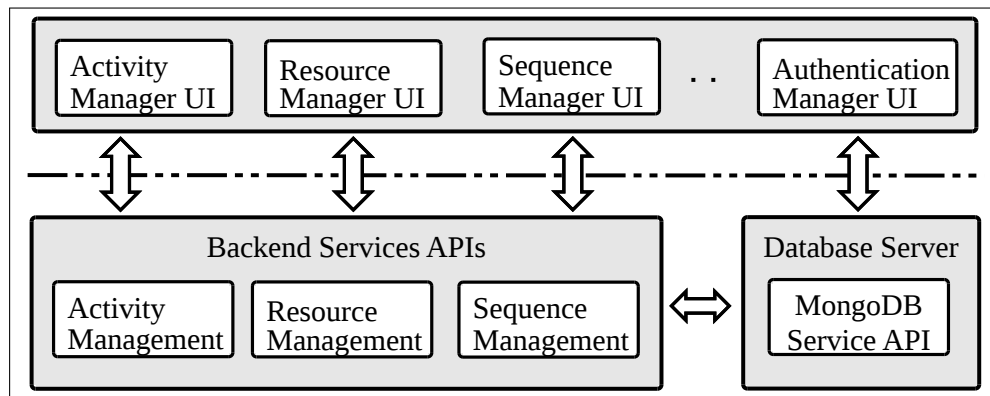
## 6.3.2 Implementation

### Data storage standard

The IMS Global Simple Sequencing Specification [87] was used as the underlying standard representation for data storage. The standard can be used to represent many different types of sequenced activities, as shown in Figure 4-2. In this proof of concept implementation, only the Directed path was used, as tutorial sessions are typically linear-structured directed activities.

### Scripting platform

The scripting platform toolkit was implemented as a Web-based system<sup>1</sup>. The front-end was implemented using HTML, CSS and JavaScript, together with Bootstrap [134]. Node.js [130] was used to implement core backend module services, as described below. Figure 6-1 illustrates the high-level system architecture, showing the interaction between the key components of the toolkit.



**Figure 6-1.** System architecture showing interaction between key components.

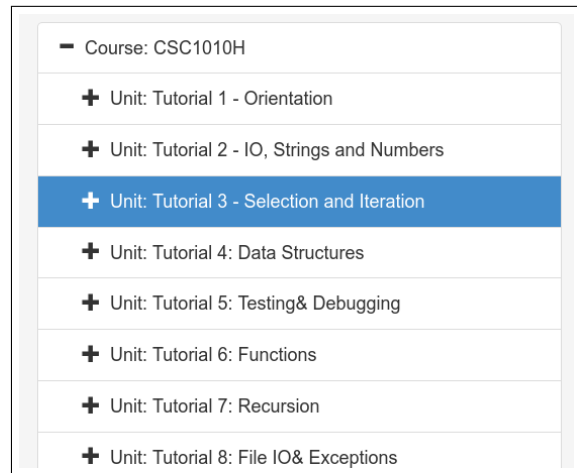
### Key components

As described in Section 6.3.1, there are three key components that implement the major function of pre-session and in-session management of the tool. These are described further in the following sections.

<sup>1</sup><http://simba.cs.uct.ac.za/indefero/index.php/p/simplescripting>

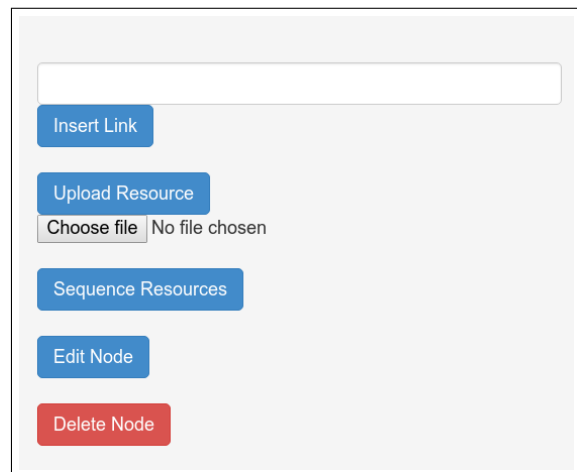
**Activity manager.** The Activity Manager module makes it possible for session activities to be appropriately structured and organised. A two-level hierarchical node structuring technique allows for courses or modules to act as top-level container structures and for session activities to be presented as level two node structures. Teaching resources are then associated to the level two nodes. [Figure 6-2](#) shows a screenshot of the structuring.

**Figure 6-2.** Activity management is performed using a hierarchical two-level node structure for associating course and activity metadata.



**Resource manager.** The Resource Manager module allows for resources such as PDF documents, video and audio files to be uploaded and associated with level two nodes. As shown in [Figure 6-3](#), this is accomplished by selecting a specific level two node and subsequently uploading the desired resources. In addition associated resources can later be downloaded.

**Figure 6-3.** Resource management enables end users to upload teaching resources and associate them with respective courses.



**Activity sequencer.** The Activity Sequencer module enables the user to construct a sequence chain that explicitly specifies the order in which the associated resources should be orchestrated.

**Activity viewers.** A basic HTML viewer can then be used to play back the sequence chain. In addition, another proof of concept viewer allows for the sequence chain to be downloaded as a PowerPoint document with the specified order. Furthermore, the sequence chain is accessible through the RESTful API, described in [Section 6.3.2](#).

## Scripting API

A RESTful Web service API [64] enables access to specific activities and resources. This would effectively make it possible for tailored viewing user interfaces to be implemented. The API is currently implemented to facilitate access to sequenced activities and resources and, as such, only GET requests are allowed. [Table 6-1](#) shows a summary of the scripting REST API methods.

**Table 6-1.** Summary of the scripting REST API methods.

Method	Endpoint	Description
GET	/courses?user_email='useremail'	<ul style="list-style-type: none"> <li>• Get courses owned by a specified user</li> <li>• Example request: <code>http://localhost:8080/api/courses?user_email=lphiri@cs.uct.ac.za</code></li> </ul>
GET	/courses/course_id	<ul style="list-style-type: none"> <li>• Get information for a given course (including associated units)</li> <li>• Example request: <code>http://localhost:8080/api/courses/5742e3eea3ef27ac2288769b</code></li> </ul>
GET	/units	<ul style="list-style-type: none"> <li>• Get all units</li> <li>• Example request: <code>http://localhost:8080/api/units</code></li> </ul>
GET	/units/unit_id	<ul style="list-style-type: none"> <li>• Get information for a particular unit (including associated resources)</li> <li>• Example request: <code>http://localhost:8080/api/units/5742e3fda3ef27ac2288769c</code></li> </ul>
GET	/resource/user_email/unit_id/resource_name	<ul style="list-style-type: none"> <li>• Download a specified resource</li> <li>• Example request: <code>http://localhost:8080/api/resource/lphiri@cs.uct.ac.za/5742e3fda3ef27ac2288769c/PM4.4+Course+Assessment+--+some+more+detail.pptx</code></li> </ul>

## 6.4 Experiment design

A user study was performed to better understand the orchestration load imposed by the described tool, during scripting of learning activities and, additionally, to assess its potential usefulness to tutors. The emphasis of this study was on the reaction of tutors to the tool in a controlled environment, rather than an assessment of the tool in tutorial sessions.

### 6.4.1 Context and participant recruitment

The experiment was conducted in the Department of Computer Science at The University of Cape Town. The context provides for an ideal environment in which peer-led learning is essential. In order to complement the formal traditional lectures, the department hires senior undergraduate students to act as peer tutors.

Students enrolled for a typical course are split into smaller, more manageable tutorial groups that are administered by tutors. Table 6-2 shows the 2016 tutorial groups for all the first year Computer Science courses offered in the department.

**Table 6-2.** Study environment context showing first year courses, student enrolments and corresponding tutorial groups.

Course	Students	Tutors	Tutorial Groups
CSC1015F	754	38	12
CSC1017F	165	9	3
CSC1010H	80	6	5
CSC1011H	26	2	2

In some of the courses, the tutors' role involves facilitating tutorial sessions aimed at revising lecture material and responding to ad hoc student queries. Tutorial sessions are held once a week and topics addressed are those from the previous week.

The study participants were chosen based on convenience, from a sample pool of 96 tutors who had tutored either of the first year courses outlined in Table 6-2. A total of 24 participants were recruited, via email, after ethical clearance approval<sup>2</sup> was granted.

Each participant received ZAR 50.00 as compensation for their time.

### 6.4.2 Metrics and measurements

The orchestration load was measured to determine the amount of effort needed to use the tool, or the degree of complexity of the tool. If the load is low, this indicates that the tutors are able to use the tool effectively to achieve the necessary orchestration of activities.

<sup>2</sup>UCT ethical clearance approval code FSREC 021–2014

**Orchestration load** Measuring the orchestration load was accomplished through the use of the [NASA Task Load Index \(NASA-TLX\)](#) [77], using the [NASA-TLX](#) pencil and paper version [127]. The [NASA-TLX](#) measurement instrument measures the subjective workload score using a weighted average rating of six subscales, defined in [Table 6-3](#). Measuring the subjective workload requires two core processes involving head-to-head pairwise comparisons [157] among the six subscales and, computation of individual ratings on each of the subscales. The results of the pairwise comparisons determine the weight contribution of each of the subscales. Finally, the weights and ratings are combined to determine the overall workload score.

**Table 6-3.** The NASA-TLX measurement instrument uses six subscales to compute the overall workload score. This table outlines the six subscale definitions.

Subscale	Description
Mental Demand	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

**Usability and usefulness** In order to measure the usability and usefulness of the tool, the [Technology Acceptance Model \(TAM\)](#) was used to evaluate the [Perceived Usefulness \(PU\)](#) and [Perceived Ease of Use \(PEU\)](#) [48]. [TAM](#) facilitates the prediction of user attitudes and actual usage by using participants' subjective perceptions of usefulness and ease of use of a system, using a 7-point Likert scale (1=Extremely Unlikely, 2=Quite Unlikely, 3=Slightly Unlikely 4=Neither, 5=Slightly Likely, 6=Quite Likely 7=Extremely Likely). The [TAM](#) questionnaire was used in its entirety. [Table 6-9](#) outlines the [PU](#) and [PEU](#) questions used in the questionnaire.



### 6.4.3 Tasks

The experiment used official teaching materials for CSC1010H—outlined in [Table 6-2](#)—normally used and/or referenced by tutors during tutorial sessions. [Table 6-4](#) provides a description of teaching resources that were used during the experiment sessions.

**Table 6-4.** Description of teaching resources used as input during the experiment session tasks.

Resource	Description
Lecture slides	Archived lecture slide notes used by lecturers in formal lecture sessions.
Laboratory exercises	Practical laboratory exercise questions used in practical programming sessions.
Pre-practical tutorials	Assessment questions, similar to assignment questions, meant to orient students to the assignment questions.
Assignment tutorials	Assignment questions which are required to be handed in by students.

[Table 6-5](#) shows the list of the three experiment tasks performed by the participants. For each of the three tasks, participants repeated the procedures for two tutorial session scenarios: “Tutorial 6: Python Functions” and “Tutorial 7: Recursion”.

**Table 6-5.** Description of experiment session tasks performed by the study participants.

Task	Description
Task 1	Task involved activity management by creating two-level hierarchically structured orchestration activity nodes.
Task 2	Task involved resource management of all teaching materials required to orchestrate a typical learning session. This involved uploading teaching materials and subsequently associating them to their respective nodes.
Task 3	Task involved the creation of a learning session sequence chain using specified teaching resources.

### 6.4.4 Procedure

One-on-one hour-long sessions were held with each of the 24 participants. Participants were briefed about the study; they were then requested to read and sign an informed consent form, explaining the purpose and procedures of the experiment.

Thereafter, participants performed experiment tasks outlined in [Table 6-5](#), using the tool described in [Section 6.3](#). After completing each of the three tasks described in [Table 6-5](#),

participants were asked to fill out a [NASA-TLX](#) questionnaire in order to assess their subjective workload for each of the individual tasks. Specifically, this process was conducted as follows for each of the three tasks:

- Participants executed the experiment task.
- Participants then filled out a [NASA-TLX](#) questionnaire.
  - Participants performed 15 pairwise comparisons for the six [NASA-TLX](#) subscales, as shown in [Table 6-6](#).
  - Participants provided raw ratings for the six [NASA-TLX](#) subscales.

**Table 6-6.** The 15 [NASA-TLX](#) subscales—Physical Demand (PD), Mental Demand (MD), Temporal Demand (TD), Performance (OP), Effort (EF), Frustration (FR)—pairs used during the head-to-head pairwise comparison process.

	FR	EF	OP	TD	MD	PD
PD	X	X	X	X	X	
MD	X	X	X	X		
TD	X	X	X			
OP	X	X				
EF	X					
FR						

Finally, after performing the activities specific to each of the three tasks, participants filled out a [PU](#) and [PEU](#) questionnaire.

## 6.5 Results

### 6.5.1 Result 1. Participants’ demographics

The vast majority of participants were in their second year of study and were thus tutoring for the first time, although there were some with more than one year of experience. In addition, the tutors’ degree majors were either Computer Science, Computer Games Design or Information Systems. Furthermore, most of the participants had tutored at least two of the courses outlined in [Table 6-2](#).

[Table 6-7](#) shows a summary of the participants’ demographic details.

### 6.5.2 Result 2. [NASA-TLX](#) workload

The overall weighted [NASA-TLX](#) workload is computed by taking into account the sources of load—resulting from head-to-head pairwise comparisons tally scores of the six subscales—and adjusted ratings—resulting from the raw ratings for the individual six subscales [127]. The overall orchestration load for each of the three tasks was computed as follows, using individual responses from study participants:

**Table 6-7.** Study participants’ demographic information anticipated to be correlated with the experiment results.

Gender	Female	6
	Male	18
Level	CS2	14
	CS3	8
	CS4	1
	—	1
Major	CS	8
	ENG	8
	Games	2
	IS	4
	—	2
Experience	1 year	16
	2 years	6
	3 years	1
	—	1
Courses	CSC1010H	4
	CSC1011H	2
	CSC1015F	18
	CSC1016S	13
	CSC1017F	2

**Step 1.** Sources of workload were computed.

- The total tally score for each of the six subscales, using Equation (6.1), was calculated to determine its weight contribution. Since each subscale can be compared with five other subscales, the minimum tally score is 0—in the case where the subscale loses the head-to-head pairwise comparison—while the maximum is 5—in instances where the subscale wins the head-to-head pairwise comparison.

$$Weight = \sum Tally\ Score \quad (6.1)$$

**Step 2.** Adjusted ratings were computed.

- The participants’ raw rating responses, on the 0–100 scale, were collected.

- Adjusted ratings were calculated, using Equation (6.2), by computing the product of the raw rating and the weight. The ratings need to be adjusted in order to account for the weighting contributions of the six subscales.

$$Adjusted\ Rating = Weight \times Raw\ Rating \quad (6.2)$$

**Step 3.** The overall workload was computed.

- The overall weighted workload was calculated, using Equation (6.3), by dividing the sum of adjusted ratings by 15.

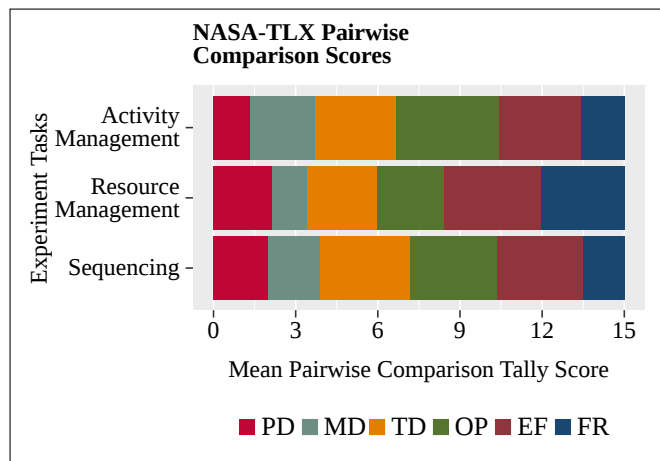
$$Weighted\ Rating = \frac{\sum Adjusted\ Rating}{15} \quad (6.3)$$

### NASA-TLX sources of load

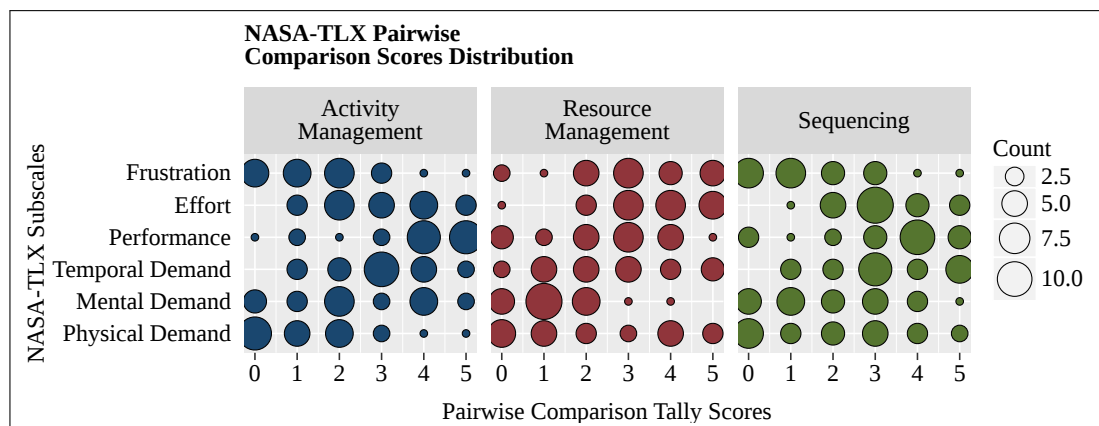
The NASA-TLX sources of load are determined by results of the cumulative tally scores of the head-to-head pairwise comparisons of the six subscales. As stated in Section 6.4.4, 15 pairwise comparisons were conducted for each of the three tasks. For each of the task pairwise comparisons, tally scores were computed for winning subscale candidates.

Figure 6-4 shows the mean tally scores for each of the activity management, resource management and sequencing tasks. The participants' distribution of the tally scores for each of the three experimental tasks are shown in Figure 6-5, providing a detailed view of the nuances in the individual pairwise comparison score results. The results suggest that the workload associated with the different activities was perceived to be influenced by different subscales.

**Figure 6-4.** The NASA-TLX mean subscale—Physical Demand (PD), Mental Demand (MD), Temporal Demand (TD), Performance (OP), Effort (EF), Frustration (FR)—pairwise comparison tally scores for the activity management, resource management and sequencing.



The workload associated with the Activity Management task is mostly influenced by the Performance subscale. There are also noticeably higher contributions from the Temporal Demand and Effort subscales. However, the workload is least influenced by the Physical Demand and Frustration subscales.



**Figure 6-5.** The NASA-TLX pairwise comparison scores were computed by obtaining the tally scores for each of the 15 pairwise comparisons of the six subscales.

The Resource Management task is mostly influenced by the Effort subscale, followed by the Frustration subscale. There is also considerable weighting exhibited by Temporal Demand, Physical Demand and Performance subscales. The smallest weighting is attributed to the Mental Demand subscale.

The Temporal Demand subscale has the highest workload weighting contribution to the Sequencing task, followed by the Performance and Effort subscales. The lowest contributions are from the Physical Demand and Frustration subscales, with the latter having the least contribution.

### NASA-TLX raw ratings

The NASA-TLX numerical ratings were compiled from participants’ responses and, as earlier stated, used in combination with the weights from the pairwise comparisons, in order to compute the adjusted ratings.

Table 6-8 shows summaries of the mean weights and raw ratings—used to compute the adjusted ratings—for each of the three experiment tasks.

**Table 6-8.** The NASA-TLX mean weights and raw ratings of the six subscales, for each of the three experiment tasks.

Subscale		Task 1	Task 2	Task 3
Mean Weights	Physical Demand	1.33 (1.40)	2.17 (1.83)	2.00 (1.69)
	Mental Demand	2.38 (1.61)	1.25 (0.99)	1.92 (1.50)
	Temporal Demand	2.96 (1.12)	2.58 (1.59)	3.25 (1.33)
	Performance	3.79 (1.44)	2.42 (1.47)	3.21 (1.59)

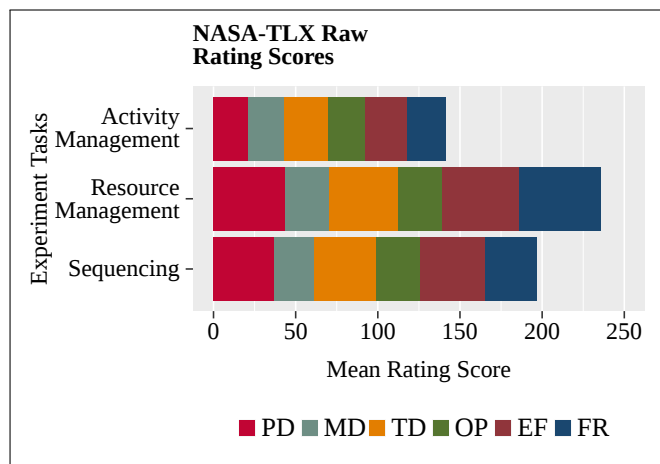
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**Table 6-8.** (continued)

Subscale		Task 1	Task 2	Task 3
Effort		2.96 (1.27)	3.54 (1.25)	3.13 (1.03)
Frustration		1.58 (1.35)	3.04 (1.49)	1.50 (1.41)
Mean Ratings	Physical Demand	21.25 (23.23)	43.54 (33.89)	37.08 (28.01)
	Mental Demand	22.08 (17.69)	26.67 (16.20)	23.96 (18.59)
	Temporal Demand	26.25 (20.71)	42.29 (22.84)	37.71 (24.05)
	Performance	22.92 (32.77)	26.46 (28.61)	27.29 (30.96)
	Effort	25.21 (19.14)	47.08 (26.45)	39.58 (24.58)
	Frustration	23.33 (25.09)	49.58 (27.66)	31.46 (25.34)

Figure 6-6 shows a graphical representation of the subscale raw ratings for the three tasks.

**Figure 6-6.** The NASA-TLX mean subscale—Physical Demand (PD), Mental Demand (MD), Temporal Demand (TD), Performance (OP), Effort (EF), Frustration (FR)—ratings for the activity management, resource management and sequencing.



While the raw ratings do not provide a comprehensive indication of the workload, when used in isolation, they provide a good indicator for the final workload. Grier’s analysis of NASA-TLX global workload scores [72] indicates that scores below the 50 mark fall well within acceptable workload scores.

The Activity Management task has the least subscale raw ratings, with each of the six subscales registering ratings below the 50 mark—Physical Demand (M = 21.25, SD = 23.23), Mental Demand (M = 22.08, SD = 17.69), Temporal Demand (M = 26.25, SD = 20.71), Performance (M = 22.92, SD = 32.77), Effort (M = 25.21, SD = 19.14) and Frustration (M = 23.33, SD = 25.09).

The lowest workload ratings for the Resource Management task are from the Mental Demand (M = 26.67, SD = 16.20) and Performance (M = 22.92, SD = 26.61) subscales. The Physical Demand (M = 43.54, SD = 33.89), Temporal Demand (M = 42.29, SD = 22.84),

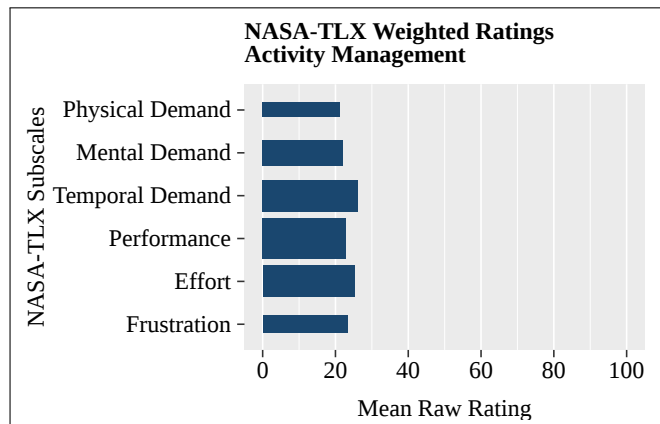
Effort (M = 47.08, SD =26.45) and Frustration (M = 49.58, SD =27.66) subscales have noticeably higher ratings, with the Frustration subscale registering the highest rating.

The Mental Demand (M = 23.96, SD = 18.59) subscale had the lowest rating for the Sequencing task, followed by the Performance (M = 27.29, SD = 30.96) subscale. The Physical Demand (M = 37.08, SD = 28.01), Temporal Demand (M = 37.71, SD = 24.05), Effort (M = 39.58, SD = 24.58) and Frustration (M = 31.46, SD = 25.34) subscales had higher ratings, however, all the scores were below the 50 mark.

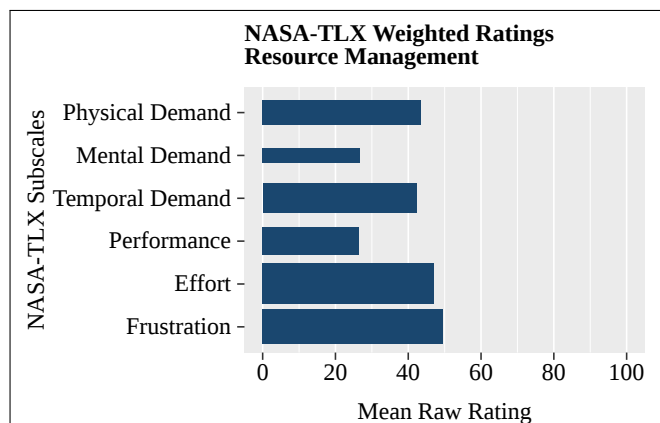
### NASA-TLX subscale weighted ratings

The weighted ratings present a holistic weighted view of the workload contributions of each of the six subscales. The weighted ratings for Activity Management, Resource Management and Sequencing are shown in Figure 6-7, Figure 6-8 and Figure 6-9, respectively. The width of the subscale bars indicate the importance of each factor, while the length represents the raw rating scores for the subscales. In addition, Figure 6-10 provides further insight into the individual contributions of the six subscales, for Activity Management, Resource Management and Sequencing.

**Figure 6-7.** The NASA-TLX weighted ratings for the activity management experiment task. The width of the bars reflect the importance of each factor while the height represents the magnitude of the factor.

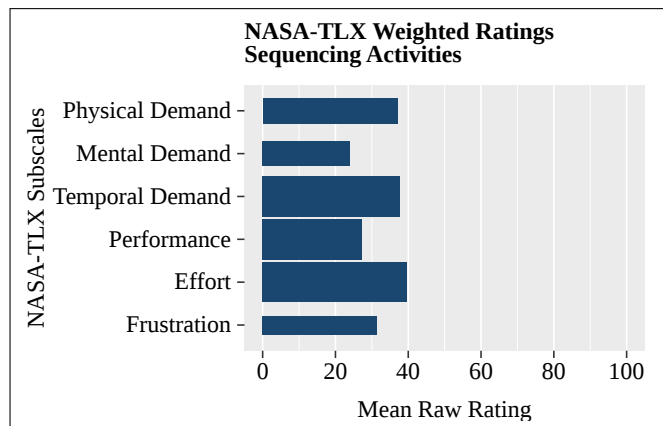


**Figure 6-8.** The NASA-TLX weighted ratings for the resource management experiment task. The width of the bars reflect the importance of each factor while the height represents the magnitude of the factor.

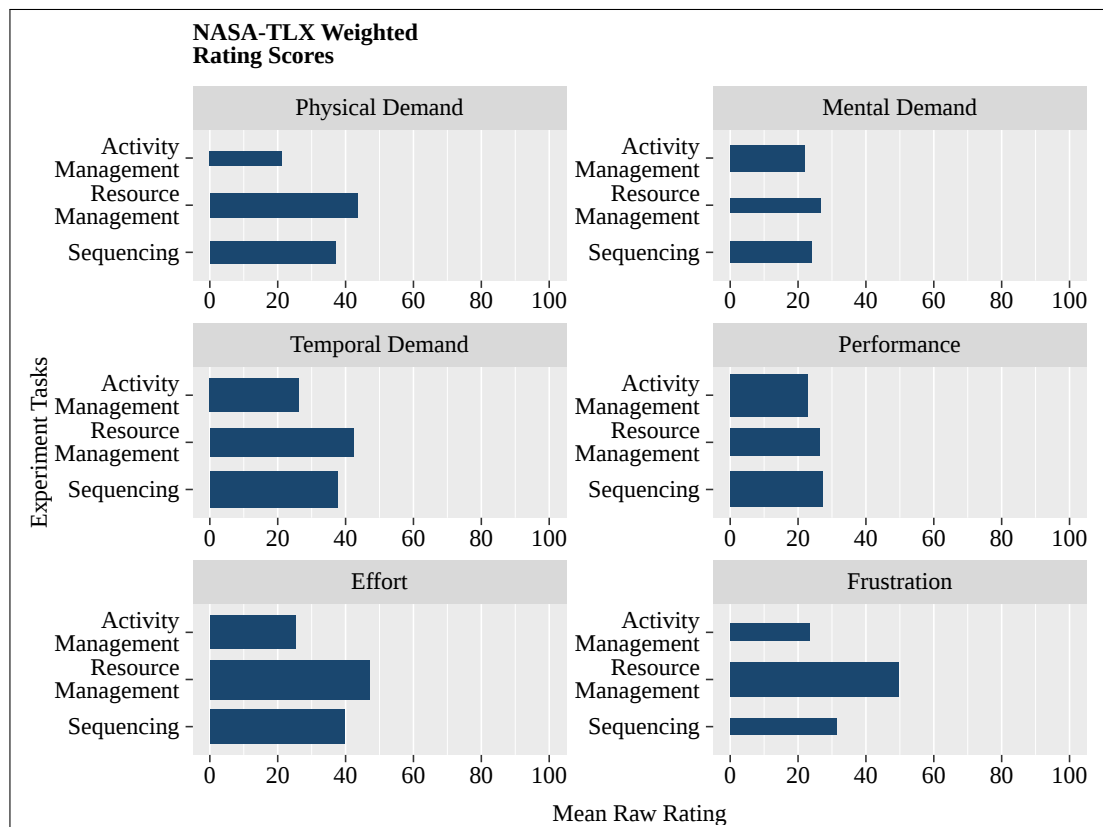


In the Activity Management task, the Performance subscale contributed the most towards the overall workload, while the Physical Demand subscale was the least contributor. For the

**Figure 6-9.** The NASA-TLX weighted ratings for the sequencing experiment task. The width of the bars reflect the importance of each factor while the height represents the magnitude of the factor.



Resource Management task, the Effort subscale was the highest contributor to the overall workload, while the Mental Demand subscale contributed the least. Then, for the Sequencing task, the Performance subscale contributed the most to the workload and the Frustration subscale was the least contributor.



**Figure 6-10.** The NASA-TLX adjusted ratings for the three experiment tasks, faceted by each of the individual six subscales. The width of the bars reflect the importance of each factor while the height represents the magnitude of the factor.

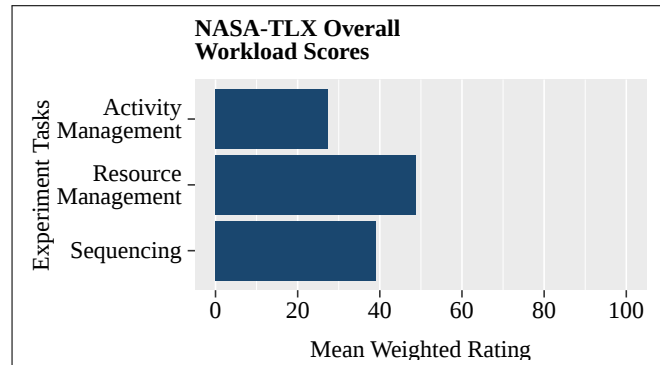
In terms of the raw ratings, all subscale ratings were rated below the 50 mark, however, the Frustration subscale for Resource Management and Effort subscale for Sequencing were closer to the 50 mark.



## NASA-TLX overall workload

The final NASA-TLX overall workload is the mean of the weighted ratings, calculated using Equation (6.3), which is in turn calculated using Equation (6.2). Figure 6-11 shows the weighted workload scores for all the three tasks.

**Figure 6-11.** The mean NASA-TLX weighted workload scores for the three experiment tasks.

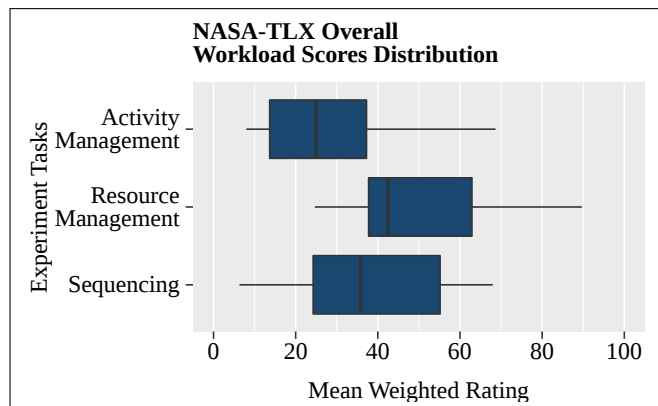


The overall weighted scores for all the three tasks are below the 50 mark, with Activity Management requiring the least workload and Resource Management requiring the most workload. The Shapiro-Wilk test was used to test the normality of the participants' workload scores for the three tasks. The Activity Management means are not normally distributed, while scores for Resource Management and Sequencing were normally distributed. A Wilcoxon signed rank test on the Activity Management task ( $M = 27.29$ ,  $SD = 17.33$ ,  $p < 0.001$ ) results indicate that the scores are significantly less than the 50 mark workload range. Similarly, a One Sample t-test on workload scores for the Sequencing task ( $M = 39.18$ ,  $t = -2.7848$ ,  $df = 23$ ,  $p < 0.01$ ) also indicate that the means are significantly less than the 50 mark workload range. However, a One Sample t-test on Resource Management workload means ( $M = 48.79$ ,  $t = -0.32925$ ,  $df = 23$ ,  $p > 0.05$ ) indicate that results are not significant.

**Task workload differences.** The workload mean distribution, shown in Figure 6-12, was further analysed, in order to compare the workloads for the different tasks. One-way ANOVA reveals that there are significant differences ( $F_{2,69} = 8.47$ ,  $p < 0.001$ ) between the overall workload for the Activity Management, Resource Management and Sequencing tasks. Post hoc comparisons using pairwise t-tests, with Bonferroni correction, showed a significant difference between Activity Management and Resource Management workloads ( $p < 0.001$ ). However, there were no significant differences between Activity Management and Sequencing, and Resource Management and Sequencing.

**Effect of demographic differences.** The factors—participants' demographics—that could potentially affect the results were highlighted in Table 6-7. A repeated measures ANOVA revealed that there is no significant difference among participants' tutoring experience ( $F_{6,58} = 0.675$ ,  $p = 0.67$ ), their levels of study ( $F_{6,58} = 0.716$ ,  $p = 0.64$ ), their majors ( $F_{8,55} = 0.356$ ,  $p = 0.94$ ), and their gender ( $F_{2,64} = 0.062$ ,  $p = 0.94$ ).

**Figure 6-12.** The mean NASA-TLX weighted workload scores distribution for the three experiment tasks.



### 6.5.3 Result 3. Perceived Usefulness and Ease of Use responses

Table 6-9 shows the PU and PEU mean scores and their associated standard deviations. The Shapiro-Wilk test was used to test the normality of the individual question scores and aggregate PU and PEU scores. One-sample t-test and Wilcoxon signed rank test were conducted as shown in Table 6-9, with p-value results represented with the asterisk.

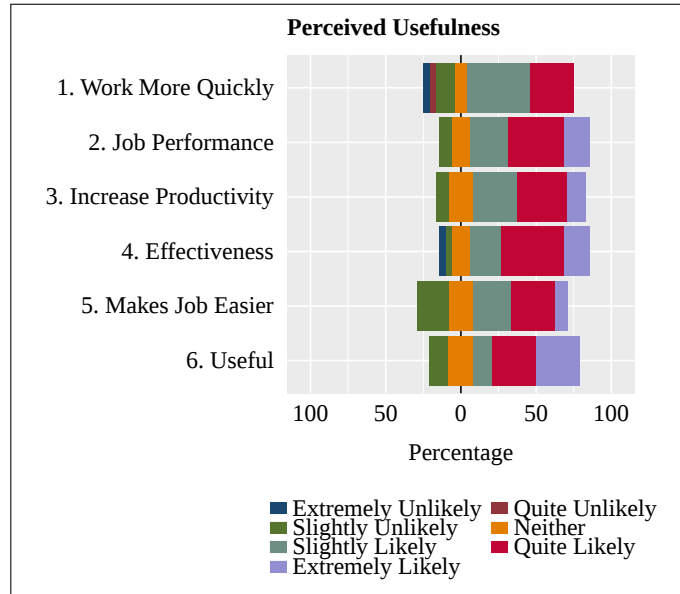
**Table 6-9.** The PU and PEU results, showing aggregate scores and scores for individual questions. \* p < 0.05, \*\* p < 0.01, \*\*\* p < 0.001

Perceived Usefulness and Ease of Use (n=24)	Mean (sd)
A. Perceived Usefulness	5.12 (1.14) ***
1. Using the system in my job would enable me to accomplish tasks more quickly	4.50 (1.67) *
2. Using the system would improve my job performance	5.42 (1.18) ***
3. Using the system in my job would increase my productivity	5.25 (1.15) ***
4. Using the system would enhance my effectiveness on the job	5.38 (1.41) ***
5. Using the system would make it easier to do my job	4.71 (1.63) *
6. I would find the system useful	5.46 (1.41) ***
B. Perceived Ease of Use	5.80 (0.85) ***
7. Learning to operate the system would be easy for me	6.25 (1.15) ***
8. I would find it easy to get the system to do what I want it to do	5.46 (1.69) ***
9. My interaction with the system would be clear and understandable	5.79 (1.10) ***
10. I would find the system to be flexible to interact with	4.83 (1.40) ***
11. It would be easy for me to become skillful at using the system	6.33 (0.82) ***
12. I would find the system easy to use	6.13 (1.12) ***

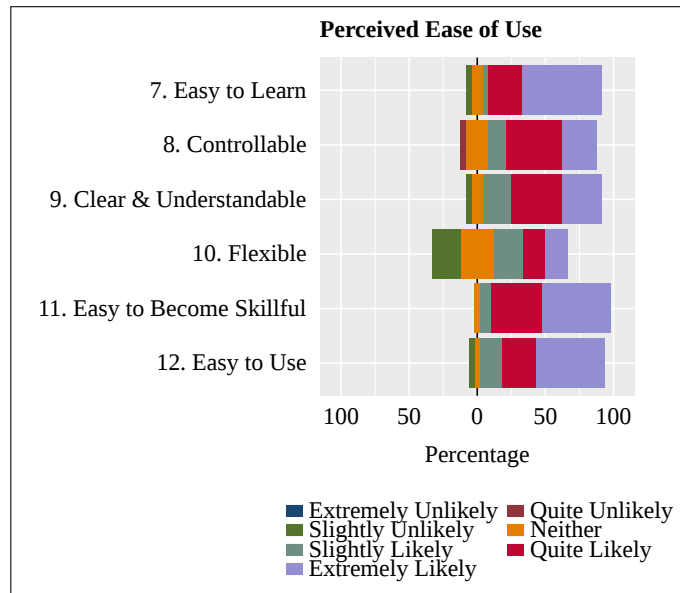
The aggregate **PU** ( $M = 5.12$ ,  $SD = 1.14$ ,  $p < 0.001$ ) and **PEU** ( $M = 5.80$ ,  $SD = 0.85$ ,  $p < 0.001$ ) scores were all significantly greater than 4, where 4 is the mid-point of the scale of responses. In addition, responses to all the individual 12 questions were also significantly greater than 4. The implication of this is that all results were statistically better than average. The results indicate the potential usefulness and ease of use of the tool.

The **PU/PEU** questions were also analysed in order to understand the distribution of the participants' responses. **Figure 6-13** and **Figure 6-14** show the **PU** and **PEU** responses, respectively.

**Figure 6-13.** The mean responses to individual six questions of the Perceived Usefulness component.



**Figure 6-14.** The mean responses to individual six questions of the Perceived Ease of Use component.



The **PU** responses were generally positive; 70.8% of the participants felt the toolkit was likely to enable them work more quickly ( $M = 4.50$ ,  $SD = 1.14$ ,  $p < 0.05$ ) and 79.2% felt that the toolkit could potentially improve their job performance ( $M = 5.42$ ,  $SD = 1.18$ ,  $p <$

0.001). Participants also felt the toolkit could significantly increase their productivity ( $M = 5.25$ ,  $SD = 1.15$ ,  $p < 0.001$ ) and enable them to become more effective at performing tutorial tasks ( $M = 5.38$ ,  $SD = 1.41$ ,  $p < 0.001$ ). Furthermore, most participants felt that the toolkit was useful ( $M = 5.46$ ,  $SD = 1.41$ ,  $p < 0.001$ ) and would make their jobs easier ( $M = 4.71$ ,  $SD = 1.63$ ,  $p < 0.05$ ).

Similarly, the responses to the **PEU** questions were mostly positive. 70.8% of the participants indicated that the toolkit was easy to use ( $M = 6.25$ ,  $SD = 1.15$ ,  $p < 0.001$ ), 91.7% indicated that it was easy to learn to use ( $M = 6.13$ ,  $SD = 1.12$ ,  $p < 0.001$ ) and 95.8% indicated that they would find it easy to become skillful at using the toolkit ( $M = 6.33$ ,  $SD = 0.82$ ,  $p < 0.001$ ). In addition, 87.5% felt that the toolkit was clear and understandable ( $M = 5.79$ ,  $SD = 1.10$ ,  $p < 0.001$ ).

### **Perceived Usefulness and Ease of Use responses demographic differences**

A repeated measures ANOVA revealed that there is no significant difference resulting from participants' tutoring experience ( $F_{3,38} = 0.028$ ,  $p = 0.99$ ), their levels of study ( $F_{3,38} = 0.110$ ,  $p = 0.95$ ), their majors ( $F_{4,36} = 0.716$ ,  $p = 0.59$ ), and their gender ( $F_{1,42} = 0.682$ ,  $p = 0.41$ ). Similarly, there is no significant difference resulting from the participants' demographics on the individual **PU** and **PEU** questions.

## **6.5.4 Result 4. Perceived Usefulness and Ease of Use participants' comments**

The **PU/PEU** questionnaire—see [Appendix B.2.5](#)—had a section for participants to state open-ended comments about what they perceived to be three most positive aspects and three most negative aspects of the toolkit. In addition, there was a provision for participants to provide general comments about their experience using the toolkit. The comments were analysed and classified into themes that best describe the message the participants were attempting to convey.

### **Toolkit positive aspects**

**Planning and organisation.** Some participants' comments suggest that the approach would be effective at facilitating organisation of orchestration activities.

*“(1) It makes the organisation easier”* [Participant 3]

*“(1) It allows one to look forward and plan in advance which will make the process of teaching more effective. (2) And instead of having a ‘mind-plan’ one gets to put it in a system which is effective.”* [Participant 4]

*“(1) User friendly interface and enhance the organisation of the course material is easy.”* [Participant 6]

*“(1) The ordering of resources was very nice to use”* [Participant 12]

*“(1) Gives great structure to the tutorials”* [Participant 15]

*“(1) Easy to manage resources for multiple courses”* [Participant 16]

*“(1) Push me to plan a structured lesson (2) Centralised zone for all resources to be stored & accessed”* [Participant 18]

*“(1) It organise my work and it will help improve my performance and effectiveness”* [Participant 19]

*“(1) Intuitive tree structure (2) resources well organised”* [Participant 21]

*“(1) It makes it easier to prepare for a tutorial (2) It allows for a quick refresh in what you need to teach”* [Participant 23]

**Additional toolkit usecase scenarios.** There were also some remarks suggesting that specific features of the toolkit could be used for more specialised tasks not directly related to orchestration.

*“(1) creating slides easy”* [Participant 10]

*“(1) Will increase efficiency by allowing an interface for the tutors and students”* [Participant 15]

**User interface design.** There were numerous positive participants’ comments that made reference to the simplicity of the toolkit and its relative ease of use of interface.

*“(1) Simple UI. (2) Easy to learn and use”* [Participant 1]

*“(1) It is very intuitive”* [Participant 2]

*“(1) Not a hard system to learn (2) Quite user friendly.”* [Participant 5]

*“(1) It is easy to use”* [Participant 6]

*“(1) Simple interface (2) like node ideas”* [Participant 10]

*“(1) Sign up was nice and simple (2) Very nice and clean interface”* [Participant 12]

*“(1) Interface is intuitive and simple to use”* [Participant 14]

*“(1) User interface is simple and intuitive”* [Participant 16]

*“(1) Simple to use”* [Participant 17]

### **Toolkit negative aspects**

**Toolkit functionalities.** Most of the negative aspects reported by the participants were specific to features of the toolkit used for conducting the experiment.

*“(1) The nodes close up everytime/upload a new resource. (2) No space to put comments/note on node’s resources”* [Participant 1]

*“(1) Having to restart the process when adding resources” [Participant 2]*

*“(1) I have to click and type a lot. (2) The nodes are reset to closed so I start at the top everytime” [Participant 3]*

*“(1) Uploading the resources one by one is frustrating. (2) Refreshing the page is required every now and then. (3) Having to go back to the node after one upload is also frustrating.” [Participant 4]*

*“(1) User should be able to upload multiple files at once (2) Having to go back to the node after one upload is also frustrating. (3) The sequencing layout can be simplified.” [Participant 5]*

*“(1) Having to reload the page after uploading resources (2) No back button when done sequencing. (3) The add unit must be of different colour for each section.” [Participant 6]*

**Toolkit feature enhancements.** While most of the negative comments could be resolved by making minor changes to the toolkit, some of them would require extensive changes.

*“(1) Multiple uploading and drag and drop should be used (2) Name of uploads should accompany files as you sequence them (3) Refreshing of the dashboard every-time” [Participant 24]*

**Tutoring workflow integration.** Some of the negative aspects that were highlighted were related to potential issues that might arise if the toolkit was integrated within the tutoring workflow.

*“(1) The process of sequencing had a lot of work to do. It should be simpler without the need for sequencing from the clean state but rather rearranging.” [Participant 3]*

*“(1) May be time-consuming if there are many resources to upload (2) Would add a fair amount of admin to the student (tutor)” [Participant 15]*

*“(1) Effort to get my laptop and open it up and log in. (2) I wouldn't be sure if I was choosing the right resources for my student” [Participant 18]*

### **Toolkit general comments**

Some participants provided insight into how to ensure the effective use of the toolkit if integrated into their workflow.

*“If resources were provided for tutors easily it would motivate them to use it more rather than have to gather all of the manually.” [Participant 8]*

*“This will be a very useful tool for tutors and the students” [Participant 12]*

*“Time should be given to tutor as part of the tutoring slot since they usually rush in to tutor from lecturers” [Participant 17]*

There were some participants who proposed how toolkit features could be improved.

*“The sequencing page: things are too far apart, the dragging can be tedious. Also, multiple files uploading.” [Participant 5]*

*“Using the system is easy. My lazyness to actually sit down and open my laptop and log-in would be the biggest downfall. I am also not 100% sure I would be skilled enough as a teacher/tutor to create an effective workflow. I better at just dealing with individual question from students. ” [Participant 18]*

## **6.6 Discussion**

The purpose of this chapter was to present results of the effect of technology-driven organised orchestration when applied to a specific educational setting: peer tutoring sessions. The [NASA-TLX](#) workload and, [PU](#) and [PEU](#) scores provided an avenue for measuring the orchestration load and usability of the tool, respectively.

### **6.6.1 Analysis 1. Orchestration load**

The orchestration load required during pre-session and in-session management has implications on the relative effectiveness of orchestration of learning activities. The results of the overall [NASA-TLX](#) workload suggest that the proposed approach’s focus on Activity Management, Resource Management and Sequencing results in acceptable workloads [72].

The results indicate that Resource Management requires the most workload. The high workload is as a result of four subscales—Physical Demand, Temporal Demand, Effort and Frustration—with raw rating scores above 40 and also because all the four scales contributed significantly to the weighted score. This can be attributed to the fact that this is the most complex of the three tasks as all teaching resources have to be individually associated to specific activity nodes. Incidentally, some participants expressed a desire for there to be a bulk upload feature in order to cut down on the amount of time required to associate resources to activity nodes. Another potential workaround would be to create templates that would only require a user to edit important fields.

Activity Management required the least workload due to the simplistic nature of the task. All the subscales scored below 25, with the subscales contributing the most to the workload having the lowest raw ratings. The task only requires a user to specify metadata necessary to uniquely identify nodes. Furthermore, the experimental task only required participants to create one level-one node and two level-two nodes.

As with Activity Management, the sequencing of learning activities did not require much workload. In fact, the reason why the score is significantly higher than Activity Management could be attributed to it having been the last task to be performed.

Further analysis of the subscale contributions—as shown in [Figure 6-10](#)—provide useful and valuable insight for designing effective orchestration tools. Interestingly enough, participants’ comments on their experience using the toolkit provide some explanation for the workload results. For instance, the high Resource Management workload rating for the Frustration subscale coincides with some of the following participants’ perceived negative aspects of the toolkit, also outlined in [Section 6.5.4](#).

*“(1) The nodes close up everytime/upload a new resource. (2) No space to put comments/note on node’s resources”* [Participant 1]

*“(1) Uploading the resources one by one is frustrating. (2) Having to go back to the node after one upload is also frustrating.”* [Participant 4]

While the context for the study was specific to peer-led tutoring setting, the participants’ remarks can be generalised to other educational settings and, more importantly, the comments also suggest that the workload results could potentially result in more effective orchestration tools and services.

## **6.6.2 Analysis 2. Toolkit usability**

The results for the usability were very revealing. Most notably, the aggregate scores for both the [PU](#) and [PEU](#) were significantly greater than 4, therefore better than average. Furthermore, the individual mean scores for the [PU](#) and [PEU](#) questions were also greater than 4, therefore better than average.

While the positive responses for the toolkit usability can largely be attributed to participants’ overwhelming positive comments on the ease of use of the toolkit, as outlined in [Section 6.5.4](#), some participants’ positive comments were as a result of the explicit structure facilitated by the toolkit. Participants’ positive comments, such as the ones presented below, explicitly note the toolkit’s ability to easily facilitate structured activities, thus enabling the effective orchestration of learning activities.

*“(1) It allows one to look forward and plan in advance which will make the process of teaching more effective. (2) And instead of having a ‘mind-plan’ one gets to put it in a system which is effective.”* [Participant 4]

*“(1) Gives great structure to the tutorials”* [Participant 15]

*“(1) Push me to plan a structured lesson”* [Participant 18]

These participants’ positive comments, pointing to the toolkit’s ability to enable organised orchestration activities are in line with the main premise presented in this thesis—to streamline orchestration, and thus enable the effective orchestration of learning activities, by explicitly organising the learning activities.



## 6.7 Summary

This chapter explored the potential of applying the proposed approach to streamline orchestration in facilitating the orchestration of learning activities during face-to-face peer-led tutoring.

The chapter described the implementation of a toolkit, designed and developed for the effective organisation of pre-session and in-session activities, with an emphasis placed on Activity Management, Resource Management and Sequencing.

The various functions of the toolkit were then assessed by tutors, in order to measure the orchestration load exhibited by the toolkit and its potential usability. The results indicate that the tool, and therefore the approach, are viable as a means of organising tutor-led activities in tutorial sessions. The toolkit has also been demonstrated to be usable and potentially useful from the tutor's perspective. The orchestration load results for the three aspects of organised orchestration—Activity Management, Resource Management and Sequencing—provide insight into key focus areas during the design of effective toolkits with acceptable workloads, based on the proposed approach. In addition, the comments from the study participants provide complementary information indicating the effectiveness of tools designed based on the proposed approach.

# Chapter 7

## Orchestrating a flipped classroom

In [Chapter 4](#), a streamlined approach to orchestration of learning proposed and described. This chapter presents a case study of a deployment of a prototype orchestration toolkit platform, aimed at facilitating the orchestration of learning activities for a flipped classroom, in order to demonstrate the feasibility of the proposed approach in authentic educational settings. The contents of this chapter have been, in part, adapted from a paper published in the *Computers & Education* journal [[144](#)].

The orchestration toolkit was deployed and used in 12 in-class lecture sessions of a Computer Architecture course. A log analysis of the toolkit usage was performed for all the lecture sessions. In addition, a learner survey was conducted in order to assess the potential effect of using the toolkit on the learners' learning experience. The results suggest that the approach has potential to positively impact the learners' learning experience.

This chapter is organised as follows: [Section 7.1](#) presents an overview of the chapter, including the motivation and main contributions of the chapter. The toolkit deployment context setting and its implementation details are presented in [Section 7.2](#). The details of the deployment evaluation are presented in [Section 7.3](#). [Section 7.4](#) presents a discussion of the case study and its implications. Finally, [Section 7.5](#) presents a summary of the chapter.

### 7.1 Introduction and contributions

The increasing use of technology to enhance teaching and learning has resulted in the use of blended learning teaching and learning models. Blended learning generally involves combining traditional face-to-face teaching models with student self-learning through access to online digital media [[66](#)]. The student self-learning process has the advantage of enabling learners to control the pace, time and learning environment based on individual needs. A flipped classroom model, also known as an inverted classroom, is a form of blended learning that involves inverting events that are traditionally conducted outside the classroom with those conducted inside the classroom [[107](#), [156](#)].

There are a number of flipped classroom studies [65, 115], in existing literature, that have focused on computing courses. However most of these studies have either focused on evaluating the comparative advantages of traditional models with flipped classroom models [84], or, in some cases, evaluating the effectiveness of flipped classroom models. Campbell et al. describe their implementation and assessment of an inverted introductory programming course [35]. Their results from student pre-course and post-course surveys indicated increased enthusiasm and enjoyment. An inverted lecture model for a computer architecture case study conducted by Gehringer and Peddycord revealed that students exhibited high levels of engagement [67].

The focus of the case study described in this chapter was on the orchestration of in-classroom activities of the flipped classroom detailed in [Section 7.2.1](#) and [Section 7.2.2](#). The chapter details the deployment of an orchestration toolkit, implemented using the approach to orchestration outlined in [Chapter 4](#). The toolkit was specifically designed to enable a lecturer to orchestrate in-classroom activities of a flipped classroom.

The main contributions presented in this chapter are as follows:

1. The design and implementation of an orchestration toolkit for orchestrating a flipped classroom educational setting.
2. The case study results of the toolkit deployment, illustrating the feasibility and implications of organised orchestration in an authentic educational setting.

## **7.2 Orchestrating a flipped Computer Science course**

### **7.2.1 Context**

The case study was conducted on a Computer Architecture module of a second year Computer Science course—CSC2002S—offered by the Department of Computer Science at [UCT](#). CSC2002S is a semester-long course that is designed for students majoring in Computer Science and Computer Engineering.

The course is split into three modules—Concurrent Programming, Mobile Computing and Computer Architecture—that are taught independently in semester blocks. 175 students were enrolled into the course, comprising of a mixture of Computer Science and Computer Engineering majors, as the course is a requirement of both degrees.

### **7.2.2 Course setting**

The Computer Architecture module was previously taught using the traditional lecture style, where the predominant activity involved the lecturer giving a formal lecture to the students. The teaching model was switched to a flipped classroom approach in order to benefit from the many advantages of the flipped classroom approach [84].

The course was conducted using a flipped classroom learning model and, comprised of activities broadly classified into pre-preparation, preparation, pre-session and in-session activities. The lecturer initiated the process by identifying and arranging teaching materials associated with the topic and, subsequently making them available to the students. The students then performed activities—watching video clips and reading accompanying materials—before each lecture session. Finally, the classroom sessions were then facilitated by the lecturer, and comprised of demonstrations, discussions and quizzes [165, 166].

### **Pre-preparation**

The lecture processes and procedures were initiated by the lecture by first identifying teaching resources to be used by students prior to the lecture session.

**Activity 1: Identify teaching resources.** The primary teaching resources to be used by students, prior to the lecture session, were identified and organised by the lecturer and subsequently made available to the students.

### **Preparation**

The description and details tasks to be performed by students were made available through the university [LMS<sup>1</sup>](#), before each lecture and, involved two main activities.

**Activity 1: Video content.** Video clips for each session were made available through a curated YouTube playlist [164].

**Activity 2: Readings.** Course readings comprised of extracts from the recommended textbook, and verified Wikipedia articles [166].

### **Pre-session activities**

The activities to be orchestrated by the lecturer during in-session management were set up and configured prior to be lecture session.

**Activity 1: Orchestration set up.** The set up involved configuration of the core in-session activities to be performed.

### **In-session activities**

The in-session activities were conducted in order to complement the pre-session readings. Three core activities were performed during the lecture session.

**Activity 1: Demonstrations.** Due to the practical nature of the course module, most of the topics covered required demonstrating concepts introduced.

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<sup>1</sup><https://vula.uct.ac.za>

**Activity 2: Open ended discussions.** The in-session discussions were facilitated by the lecturer and, additionally, open ended so as to encourage discussions among the students.

**Activity 3: Timed quiz sessions.** Each lecture session had an associated quiz based on the assigned readings and videos. The quiz was graded and contributed to the overall course assessment. This was done in order to encourage students to thoroughly go through the assigned readings and videos.

Table 7-1 shows a summary of the pre-session and in-session activities, in addition to the respective actor responsible for initiating and/or performing the activities.

**Table 7-1.** The course module activities were classified into pre-session and in-session activities. The table shows the activities and the actors—lecturer or students—responsible for them.

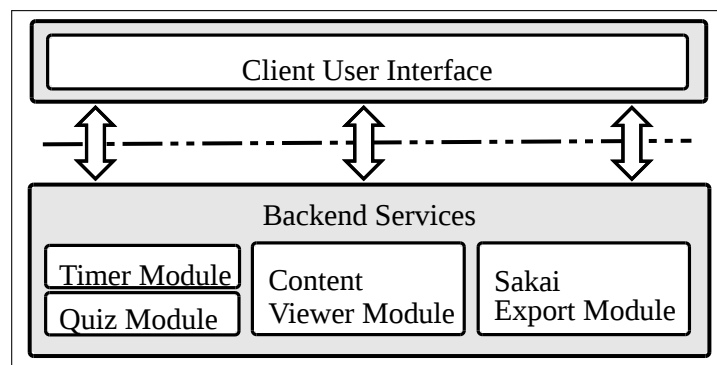
Course Module Activities		Lecturer	Students
Pre-preparation	Identify resources	X	–
Preparation	Topic readings	–	X
	Watch videos	–	X
Pre-session activities	Set up orchestration	X	–
In-session activities	Demos	X	–
	Discussions	X	X
	Quizzes	X	X

### 7.2.3 Implementation: Orchestration toolkit platform

A Web-based orchestration toolkit was implemented in order to enable the lecturer to facilitate the management of the in-session activities described in Section 7.2.2. The toolkit was implemented using HTML, CSS, Bootstrap [134] and JavaScript. The choice of the technology stack was made to take advantage of the browser as a host environment. Figure 7-1 shows the key toolkit components and modules and modules.

The application was then launched and accessible through a Web browser running on a machine that connected to a data projector. Figure 7-2 shows a collage of an Opencast Matterhorn recorded lecture session with the lecturer orchestrating a discussion activity by displaying the individual discussion question on to a data projector.

**Figure 7-1.** System architecture showing interaction between key components.



### Toolkit features

The toolkit was implemented with features aimed at enabling the lecturer to orchestrate the in-classroom activities described in [Section 7.2.2](#).

**Content Viewers.** The demonstration and discussion activities required, in part, the lecturer to present information to the students. The toolkit was implemented with Content Viewers, for rendering discussion questions and details of the demonstration to be performed during the classroom session.

**Timed Quiz.** The management of the classroom quiz sessions was performed using the quiz feature. The toolkit rendered each of the five quiz questions for a predefined fixed period of time.

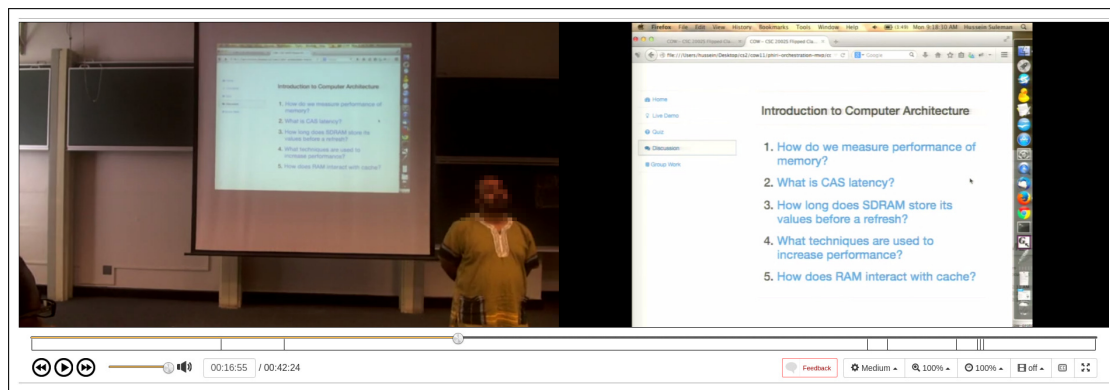
**Countdown Timer.** Due to the size of the class—175 students—the toolkit was implemented with a countdown timer in order to draw students’ attention to the lecture start time. The timer counted down to the start time of the lecture session.

**Sakai Export.** Teaching and learning materials are primarily made available through the university LMS, running an instance of Sakai<sup>2</sup>. The toolkit was implemented with a backend export service for exporting quiz questions, discussion questions and demonstration details to the LMS.

### Toolkit scripting and sequencing

Scripting of in-classroom activities was performed by the lecturer before the lecture session to reflect details for each lecture session. The scripting involved updating JSON configuration files for the different application features—demonstration, discussion and quiz. The sequencing of the different in-classroom activities was achieved using a dashboard and menu items associated with the individual activities.

<sup>2</sup><https://www.sakaiproject.org>



**Figure 7-2.** A composite Opencast Matterhorn [38, 96] lecture recording showing the presenter video (left) and the presentation screencast (right) of the lecturer performing an in-session activity.

## 7.3 Deployment evaluation

### 7.3.1 Evaluation aspects

The deployment of the toolkit was aimed at assessing the feasibility of organised orchestration, as outlined in [Chapter 4](#), and additionally, its potential effect on the learning experience of the learners. The evaluation was conducted as follows:

- Log analysis of recorded lecture sessions was conducted.
- Participants were observed at lecture sessions.
- A learning experience survey was conducted with the learners in order to elicit their perceived learning experience while the lecturer used the toolkit.

### 7.3.2 Study 1. Toolkit usage analysis

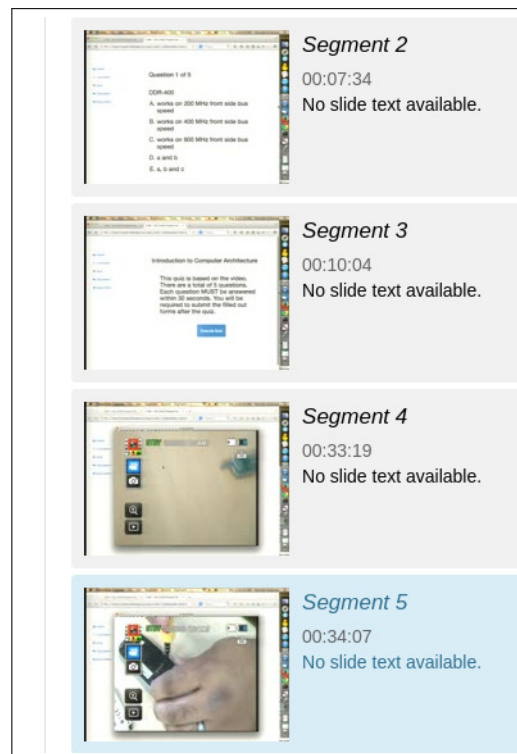
In order to better understand the lecturer's interaction with the toolkit during the orchestration of learning activities, the usage of the orchestration tool was evaluated through direct observations of in-classroom activities and video analysis of segmented lecture recordings.

#### Video segmentation analysis

As outlined in [Section 3.4](#), UCT has put in place lecture recording infrastructure in most lecture venues, enabling the scheduled recording of lecture sessions<sup>3</sup>. Opencast Matterhorn [30] is used to automatically process the recordings. The processing, in part, results in the

<sup>3</sup><https://media.uct.ac.za/engage/ui>

**Figure 7-3.** An example of an Opencast Matterhorn segmented video. The four segments show screenshots of the applications used in each segment, and the time when the applications were initiated.



automatic segmentation of recorded screencasts. Figure 7-3 shows a screenshot of one of the segmented lecture recordings.

Opencast Matterhorn provides a slide segmentation service that divides captured screencasts into segments for fast preview and navigation [96]. The generated segments were analysed and used to easily identify the different applications that the lecturer used during the lecture sessions.

### Direct observations and interviews

Direct participant observations were conducted by observing the toolkit usage in all the 12 lecture sessions. Furthermore, regular informal meetings were held with the lecturer during the study period in order to gain more insight from the lecturer, and to determine potential improvements to the toolkit.

### Results

The toolkit usage frequencies, during the orchestration of learning activities in all the lecture sessions, were noted. In addition, usage frequencies and times for other software applications used during the lecture sessions were noted. This was done to determine the context switching occurring when switching between software applications.

Table 7-2 shows all the software tools and services used to orchestrate in-session activities during all the 12 lecture sessions, the number of times they were used, and the average



duration they were used for. Nine different software tools, including the toolkit, were collectively used when orchestrating in-classroom learning activities, as follows:

- VideoGlide Capture<sup>4</sup> was used to showcase live hardware demonstrations to the learners using the projector.
- The Firefox<sup>5</sup> Web browser was used to access online resources in one of the sessions.
- LibreOffice Impress<sup>6</sup> is a presentation viewer; it was used in some sessions for presenting generic information not directly related the topics of discussion.
- Evince<sup>7</sup> is a PDF viewer and was used to access PDF documents.
- QtSpim<sup>8</sup> is an IDE, and was used to view and write Assembler code.
- Robotic Arm<sup>9</sup> was used to control a basic robot during one of the hardware sessions.
- TextEditor<sup>10</sup> was mostly used to view assembler code.
- VirtualBox<sup>11</sup>, a free and open-source hypervisor, was used to illustrate how virtualisation works.

Table 7-3 shows the toolkit usage pattern across the 12 lecture sessions, compared with the other tools and services.

**Table 7-2.** Usage frequency of software applications across the 12 in-classroom lecture sessions.

Application	Classification	Count	Mean Duration
Toolkit	Organisation	10	00:30:31
VideoGlide	Content Viewer	8	00:07:56
Firefox	Content Viewer	1	00:21:29
LibreOffice Impress	Content Viewer	1	00:38:26
Evince	Content Viewer	1	00:00:50
QtSpim	Programming IDE	1	00:12:47
Robotic Arm	Content Viewer	1	00:01:24
TextEditor	Text Editor	1	00:02:07
VirtualBox	Simulator	1	00:00:58

<sup>4</sup><https://www.echofx.com/videoglide.html>

<sup>5</sup><https://www.mozilla.org/en-US/firefox>

<sup>6</sup><https://www.libreoffice.org/discover/impress>

<sup>7</sup><https://wiki.gnome.org/Apps/Evince>

<sup>8</sup><http://spimsimulator.sourceforge.net>

<sup>9</sup><https://armctrl.codeplex.com>

<sup>10</sup><https://developer.apple.com/library/mac/samplecode/TextEdit>

<sup>11</sup><https://www.virtualbox.org>

**Table 7-3.** The usage statistics and patterns for software tools and services used to orchestrate learning sessions. The prototype Workbench was used in all but LT12 session and, on average, was used during more than 50% of lecture time.

**Prototype Workbench Usage Pattern Relative to Lecture Sessions**

**Usage Pattern for Other Tools Relative to Lecture Sessions**

	Lecture Duration	Prototype Duration			Lecture Duration	Tools	Tools Duration	
LT01	00:46:57	00:25:39	54.63%	LT01	00:46:57	2	00:21:18	45.37%
LT02	00:42:48	00:26:13	61.25%	LT02	00:42:48	3	00:16:35	38.75%
LT03	00:38:34	00:30:00	77.79%	LT03	00:38:34	1	00:08:34	22.21%
LT04	00:39:14	00:31:04	79.18%	LT04	00:39:14	1	00:08:10	20.82%
LT05	00:44:16	00:32:57	74.44%	LT05	00:44:16	1	00:11:19	25.56%
LT06	00:42:07	00:38:53	92.32%	LT06	00:42:07	3	00:03:14	7.68%
LT07	00:43:35	00:38:51	89.14%	LT07	00:43:35	1	00:04:44	10.86%
LT08	00:36:32	00:14:43	40.28%	LT08	00:36:32	2	00:21:49	59.72%
LT09	00:42:24	00:33:19	78.58%	LT09	00:42:24	2	00:09:05	21.42%
LT10	00:38:25	00:33:31	87.25%	LT10	00:38:25	1	00:04:54	12.75%
LT11	–	–	–	LT11	–	–	–	–
LT12	00:38:26	00:00:00	0.00%	LT12	00:38:26	1	00:38:26	100.00%

In general, the toolkit was used in all but the last lecture session—an information session centred on non-core module content. On average, it was used 66.72 % of the time. The toolkit was least used during lecture sessions requiring the use of specialised applications; for instance during session 08, 58.80 % of the lecture was dedicated to referencing content from an external Web application service. In addition, the number of software applications used in some sessions was higher because the activities involved the use of specialised application features not supported by the toolkit. For instance, session 02 was a practical Assembler programming session that required the use of a QtSpim terminal application, a text editor and a simulator.

Also, context switching between software applications occurred an average of two times, with a noticeable period observed during the switchover process. It would thus seem appropriate to devise an easier and more flexible way of launching external applications to reduce the switchover times.

As shown in Table 7-2, most of the applications performed the role of rendering content of different types, such as video content. A mechanism for viewing content of different types would thus be desirable.

### 7.3.3 Study 2. Learning experience survey

The main objective of the learning experience survey was to investigate the potential effect of the toolkit on the learners. Specifically, a survey was conducted in order to understand the extent to which the toolkit helped organise the lecture sessions and its usefulness to the learners.

#### Study design

Ethical clearance approval<sup>12</sup> was obtained prior to undertaking the study. The 175 students registered for the course were targeted as potential participants, of which 71 were recruited. 70 of the study participants successfully completed the questionnaire.

A paper-based questionnaire (see [Appendix C.1.1](#)) was used in order to leverage a captive audience within the lecture theatre. Participants' demographic information perceived to confound the results was captured using two close-ended questions: the total lecture sessions attended and previous semester marks for each participant. [Table 7-4](#) shows the results of the demographic distribution of the participants, faceted based on lecture attendance and previous final semester marks.

**Table 7-4.** Learners' demographic information. Participants were required to self-report the number of lecture sessions they attended and marks they scored in the previous semester.

Lecture Sessions		Exam Scores	
	Count		Count
1–3 sessions	0	0–49%	0
4–6 sessions	8	50–59%	8
7–9 sessions	8	60–74%	29
10–13 sessions	54	75–100%	33

In order to elicit student's subjective feedback on the potential effect of using the tool, four questions were asked. The questions were aimed at assessing the role of the tool in helping organise the lecture session and the usefulness of specific features. Participants' responses were to the following questions (see [Appendix C.1.1](#)):

**Item 1: Organisation.** The use of the tool helped in organising the lecture sessions.

**Item 2: Timer feature.** The countdown timer before the lecture session was useful in preparing for the session.

**Item 3: Activity listing.** The listing of classroom activities was useful.

Furthermore, an open-ended questionnaire was used to capture general comments by participants.

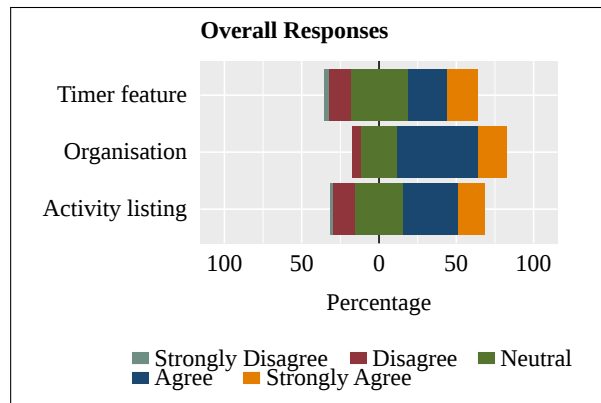
<sup>12</sup>UCT ethical clearance approval code FSREC 021–2014

## Results

**Toolkit feature effect responses.** Participants' responses to questions, on a 5-point Likert scale, were noted and analysed. In addition, One sample median tests were conducted on participants' responses in order to confirm if they were significantly higher/different than the neutral score of 3.

The graph in [Figure 7-4](#) shows overall means scores for the learner survey results of participants' responses.

**Figure 7-4.** Learner survey results for showing overall mean scores for the participants' responses.

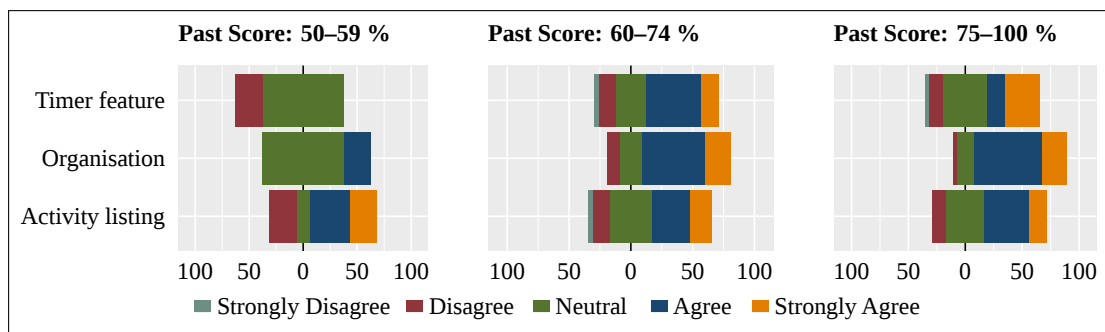


The results in [Figure 7-4](#) indicate that, overall, the participants felt that the toolkit was useful and that it helped facilitate the organisation of the in-classroom activities. 52.86% agreed and 18.57% strongly agreed that the tool helped organise the lecture sessions ( $p < 0.001$ ). More importantly, most of them agreed that the listing of activities—static sequencing—was useful, with 35.71% agreeing and 17.14% strongly agreeing that the tool was useful ( $p < 0.001$ ). However, some participants had reservations with regards to specific features, such as the countdown timer—37.14% had neutral responses and 14.29% disagreed ( $p < 0.001$ ). It should be pointed out here that the timing feature was only used before the lecture, possibly rendering it irrelevant to some students.

**Demographic differences.** Krushal-Wallis tests were conducted in order to determine the effects of the participants' demographic differences: (1) the number of lecture sessions they attended; and (2) their examination scores in the previous semester.

**Past examination scores effect.** A Krushal-Wallis test revealed a significant effect on participants' responses as a result of their past examination scores ( $\chi^2(2) = 7.51, p < 0.05$ ), with regards to whether the toolkit helped structure and organise lecture sessions. However, participants' past examination scores had no significant effect on the usefulness of the Timer feature ( $\chi^2(2) = 4.98, p = 0.083$ ) and Activity Listing feature ( $\chi^2(2) = 0.31, p = 0.86$ ).

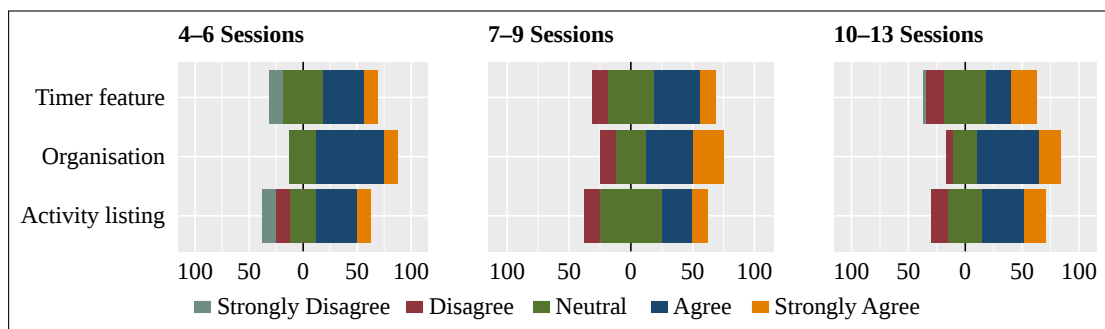
[Figure 7-5](#) shows the participants' responses to the survey questions, in relation to their previous examination scores. While both the high and average performing students indicated that the tool helped to organise the in-classroom activities, more of the average performing students found the timer feature useful.



**Figure 7-5.** Learner survey results for showing overall mean scores for the participants' responses based on past examination scores demographic differences.

**Lecture attendance effect.** A Krushal-Wallis test revealed that the number of lecture sessions attended by participants had no significant effect on their responses to survey questions related to lecture organisation effectiveness ( $\chi^2(2) = 0.055$ ,  $p = 0.97$ ), the usefulness of the Activity Listing feature ( $\chi^2(2) = 0.77$ ,  $p = 0.68$ ), and the usefulness of the Timer feature ( $\chi^2(2) = 0.014$ ,  $p = 0.99$ ).

Figure 7-6 shows the results of the participants' responses, in relation to the number of lecture sessions they attended. Unsurprisingly, most of the participants attended most of the lecture sessions—10–13 Lecture Sessions—and their responses, as shown in Figure 7-6, do not vary much with the overall results.



**Figure 7-6.** Learner survey results for showing overall mean scores for the participants' responses based on lecture attendance demographic differences

**Participants' open-ended comments.** The comments from the learners reflecting their experience relative to the lecturer using the toolkit were generally positive. While most of the comments were related to specific toolkit features and suggestions on how they could be improved, there were some comments that broadly referred to the flipped classroom teaching model.

The comments specifically making reference to the toolkit usage suggest a perceived positive experience by the learners. Perhaps more important are some comments that suggest that using the toolkit did not adversely interfere with the learning experience, a trait consistent with observations made during the classroom sessions.

*“I did not really notice the tool”* [Participant 19]

*“No features were really used except for the quiz and timer”* [Participant 28]

*“It would be a good tool for distributing those discussion points. If the discussion points were made available, it would be very helpful in jogging my memory”*  
[Participant 30]

*“The fading effect was pretty cool (for the quiz)”* [Participant 59]

There were a number of comments that offered suggestions on how specific features of the toolkit could be improved upon. Incidentally, the majority of such comments referred to the quiz feature whose fading effect was viewed as problematic.

*“Each individual quiz question should be timed so we can see how long till next one”*  
[Participant 68]

*“It would be nice to keep the fading effect, but rather fade the questions out instead of fading in”* [Participant 3]

*“The fade in for quiz was annoying—glad you fixed it”* [Participant 8]

*“I would remove the ‘fade in’ effect of the questions, it can be difficult to try and read. Also, a visual progress bar of time left for the question might be useful”*  
[Participant 10]

Some of the comments were more aligned with the learners’ perception of the flipped classroom model, rather than the tool. The comments included comments on the different activities and the overall structure of the course.

*“I found the classroom experience fun”* [Participant 53]

*“Enjoyed the lecture layout thoroughly!”* [Participant 13]

*“The pre-lecture readings were a bit of a challenge, as you had trouble figuring out what sections are relevant for the course.”* [Participant 16]

*“It definitely made me arrive on time!”* [Participant 17]

*“The quiz at the end might be better because if the student has a carpool, being on time isn’t always in their hands[sic]”* [Participant 18]

## **7.4 Discussion**

The toolkit usage frequencies, its usage times for each lecture session, and the results from the learner survey, all provide good indicators for assessing the feasibility of organised orchestration when deployed in an authentic educational setting.

### 7.4.1 Toolkit interaction analysis

The toolkit was observed to have been used to orchestrate the three core learning activities described in [Section 7.2.2](#), except for scenarios when specialised tools and services were required. This is further supported by the toolkit usage frequency results in [Table 7-2](#), and the mean usage time for each session, shown in [Table 7-3](#).

The results further suggest that usage of the toolkit did not disturb the normal flow of classroom activities. This outcome was also observed as the lecturer used the prototype during the lecture sessions.

### 7.4.2 Learning experience analysis

The results from the learner survey responses suggest two things: first, that usage of the toolkit did not adversely interfere with the learning experience, and more important, that there was a perceived positive impact on the students' learning experience. This is further supported by some participants' comments in survey responses outlined below.

*"I did not really notice the tool"* [Participant 19]

*"I found the classroom experience fun"* [Participant 53]

*"Enjoyed the lecture layout thoroughly!"* [Participant 13]

The comment from Participant 19 is especially of interest because it suggests that, when compared to the conventional mode of teaching, the toolkit was perceived to be impact neutral when used to orchestrate learning activities.

## 7.5 Summary

This chapter presented a case study conducted in an authentic educational setting in order to assess the feasibility of organised technology-driven orchestration of learning activities.

An orchestration toolkit was implemented, deployed, and used to orchestrate in-classroom activities for a flipped Computer Architecture course. The toolkit usage was evaluated through a segmentation analysis of recorded lecture sessions and through participant observations. In addition, a learning experience survey was conducted in order to assess the potential impact of organised orchestration on the learners.

The toolkit usage analysis suggests that it facilitated a neutral flow of classroom activities, reinforcing the feasibility of such an approach in facilitating orchestration. The results of the learner survey suggest that organised orchestration has the potential to positively impact the learning experience of learners.

## Chapter 8

# Complex Reusable Orchestration Packages as Open Education Resources

In [Chapter 3](#), contemporary orchestration was highlighted as being fundamentally flawed and, its associated challenges and ad hoc nature are attributed as the main factors for why this is the case. A potential solution to this problem is further presented in [Chapter 4](#). The proposed approach is, in part, aimed at standardising the orchestration of learning activities. This chapter presents a case study of a practical usage scenario that leverages the streamlining and standardising of orchestration proposed in [Chapter 4](#). The contents of this chapter have been, in part, adapted from Technical Report CS18-02-00 [138].

With the amount of digital educational material online, educational resources are increasingly being shared online as [Open Education Resource \(OER\)](#). In an attempt to broaden the scope of types of educational material shared as [OER](#), an end-to-end platform was implemented in order to facilitate the sharing of complex orchestration packages. The platform consists of an offline authoring component, for creating and viewing the packages, and an online repository for long-term storage of the packages.

This chapter is organised as follows: [Section 8.1](#) presents the motivation and main contributions of this chapter and [Section 8.2](#) outlines closely related work. [Section 8.3](#) details the platform workflow and [Section 8.4](#) describes design and implementation details for a reference implementation, composed of two architectural components: an offline authoring tool and an online repository. In [Section 8.5](#), evaluation aspects used to evaluate the offline authoring tool and the online repository are described. A usability study of the authoring tool is described in [Section 8.5.1](#), while the repository usability and performance evaluations are described in [Section 8.5.2](#) and [Section 8.5.3](#), respectively. [Section 8.6](#) presents the discussion and, finally, [Section 8.7](#) presents concluding remarks.

### 8.1 Motivation and contributions

Rapid advancements of information and communication technologies are increasingly making it possible for more individuals to become producers of digital content, as opposed



to merely being consumers of content. For instance, the educational sector has had a noticeable increase in the open distribution of digital educational content as **OERs** [184].

**OERs** are teaching and learning digital materials that are available for free to educators and learners. The educational materials are licensed using flexible licensing options in order to enable anyone to reuse, modify or share the content [133]. The types of **OER** content includes all digital content that can be used as educational content, such as learning content, media, software, and even implementations of interoperability standards [184].

While access to **OERs** is targeted towards both educators and learners, the focus of this work is facilitating such resources to educators. The immediate benefits for using **OERs** is that they are able to cut down on the amount of time educators spend to preparing for a typical lesson, since the resources they would require would already have been created and curated by other educators. The openness of **OERs** especially makes it possible for existing resources to be quickly adapted to suit a particular need.

In this chapter, a workflow is outlined that describes how educators can effectively share complex orchestration packages, which detail lesson activities, their associated resources and how they are sequenced to facilitate the smooth orchestration of learning activities during a formal learning session. The workflow primarily uses the sequence chain—the main output of the proposed approach to streamline orchestration, described in **Chapter 4**—as input, and then allows for a content package to be prepared for eventual ingestion into an online repository.

The main contributions presented in this chapter are as follows:

1. A workflow for creating, sharing and reusing complex orchestration packages.
2. A reference implementation, comprising of an offline authoring tool and an online repository, demonstrating the feasibility of implementing the workflow.

## 8.2 Related work

### 8.2.1 **OER** repositories and authoring tools

A number of **OER** repositories have been set up to provide free and open educational content to educators and learners. Most of the platforms do not offer additional services beyond facilitating searching and browsing of content.

MIT **OpenCourseWare (OCW)**<sup>1</sup> is an **OER** platform that publishes organised curated high-quality educational course materials, for consumption by tertiary institutions [2]. While the principle audience of **OCW** are independent learners, educators were the initial target audience. A variety of services have thus been implemented that are specifically tailored for educators. **OCW** Educator helps educators easily search through the **OCW** library through a search and browse interface. **OCW** Educator also provides an Instructor Insights services where instructors share their teaching experiences and approaches to teaching [97].

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<sup>1</sup><https://ocw.mit.edu>

OER Commons is an OER repository comprising of content for different education levels [43]. OER Commons is designed to be a global network of OERs and is thus integrated with the Open Author service that allows for the creation of different authoring formats. Resource Builder is used for creating bundled resources consisting of different content types. Authors can also create content views using Lesson Builder and Module Builder. Lesson Builder is used to build interactive lessons, while Module Builder is used to build interactive modules.

While some OER platforms have integrated authoring tools and services for interacting with OERs, most of these services are only aimed at creating and manipulating OERs. More importantly, the resources shared are typically basic documents and media files. Table 8-1 shows a summary of some popular OER platforms with corresponding content types available and authoring services available to educators. This chapter presents a workflow for sharing sequenced interactive bundled resources for use during orchestration of learning activities.

**Table 8-1.** Some notable examples of OER repositories, with associated authoring tools and details of types of complex content available.

OER Platform	Authoring Tools	Complex Objects
OER Commons	Resource Builder; Lesson Builder; Module Builder	Bundles; Content Views
OCW	OCW Educator; Instructor Insights	—

## 8.2.2 Repository software tools

Repository software tools are specialised forms of information management systems that are used to manage Digital Libraries (DLs)—organised collections of digital content that can easily be accessed by end users. Repository software tools are thus Digital Library Systems (DLSES), whose primary goals are to ensure the long-term preservation of digital objects, facilitate the management of the digital objects and enable effective and easy access to the digital object [14].

**Fundamental aspects.** There are a number of elements that guarantee the effectiveness of repository software tools. Unique identifiers are used to identify digital objects when making reference to them. Metadata provides representational information necessary to understand digital objects, once stored in the repository. The metadata is either used to administer the digital objects (administrative metadata), to enable digital objects to be easily discovered (descriptive metadata) or to store preservation information (preservation metadata). Finally, interoperability standards enable repository software tools to easily interact with external services. For instance, Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) enables external services to automatically harvest repository metadata [109], while the Sword protocol facilitates remote deposit of digital objects into repositories [6, 112].

**Core repository features.** Fundamentally, repository software tools perform three core functions: facilitate access to repository objects, enable the management of the digital objects and, finally, facilitate the long-term storage of the digital objects. The access to repository objects involves information discovery services such as searching and browsing. The management of objects is necessary in order to make changes to metadata entries, update digital objects and to delete digital objects. Finally, the storage of digital objects typically involves associating metadata with digital objects and properly organising the objects for future reference.

**Open source repository tools.** There currently exists a number of open source digital repository software tools that can be used to build and set up repositories, and they all share common characteristics of providing features and functionalities necessary to store, manage and enable access to digital objects. Some of the popular open source tools that are used for OER platforms include DSpace<sup>2</sup>, EPrints<sup>3</sup> and Fedora Commons<sup>4</sup>. DSpace is a digital asset management system designed for long-term storage of scholarly research output [161, 167]. EPrints is an online archival tool specifically tailored for document-style content [168]. Fedora Commons is an architectural framework that provides standards-based services for the development of repository software tools [139].

Most repository tools provide services for interacting with repository objects. In addition, a number of them implement popular international standards that ensure interoperability with external services [99]. However, of the existing open source tools, Fedora Commons is explicitly designed to handle complex digital objects. In addition, it is known to be scalable. Furthermore, it has a flexible architecture that allows for implementation of specialised front-end applications.

## 8.3 Reusable orchestration packages workflow

A three-step workflow for facilitating the sharing of orchestration packages was designed as [Reusable Virtual Orchestration Appliances \(rVOA\)](#). In the workflow, an offline authoring tool is used to prepare a content package containing a sequence chain and teaching resources. Once prepared, the content package is ingested into the online repository where it becomes available to be downloaded by other users. [Figure 8-1](#) shows a high-level overview of the [rVOA](#) workflow used to create, share and reuse the orchestration packages.

The three steps of the workflow are described in greater detail in [Sections 8.3.1, 8.3.2 and 8.3.3](#).

### 8.3.1 Step 1. Scripting

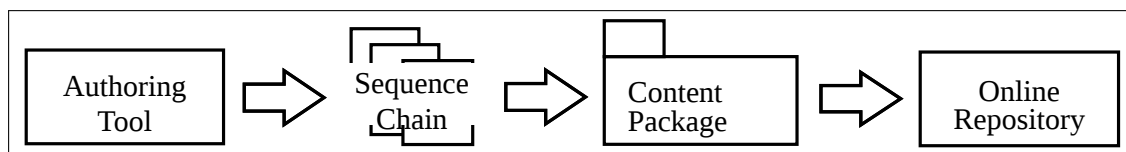
Scripting, outlined in [Chapter 4](#), is performed during pre-session management of the proposed approach to streamlining orchestration. This step consists of three sub-steps that

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<sup>2</sup><http://www.dspace.org>

<sup>3</sup><http://www.eprints.org>

<sup>4</sup><http://fedora-commons.org>



**Figure 8-1.** The **rVOA** workflow facilitates reusability and sharing of complex orchestration packages by integrating an offline authoring tool with an online repository.

enable the user to specify the range of activities to be performed in the formal session and, the associated teaching resources to be used. The user goes through a directed process as follows:

**Step 1.1: Activity management.** Define activities to be performed in the formal session.

**Step 1.2: Resource management.** Associate teaching resources to the defined activities.

**Step 1.3: Sequence activities.** Specify the order in which to perform the activities.

As stated in [Chapter 4](#), a key aspect of the technical implementation details of the scripting step is that it incorporates the IMS Global Sequencing standard [87]. The final output of the scripting phase is a sequence chain comprising of the sequenced resources.

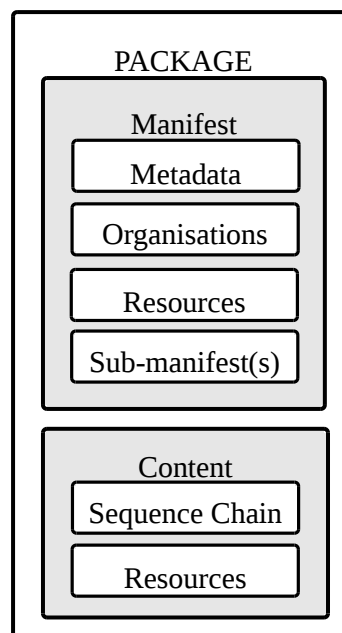
### 8.3.2 Step 2. Content packaging

The content packaging step is essential as it allows for digital objects and the associated sequence chain to be uniformly bundled together thus making them easily accessible for later use. In addition, the packaging makes the eventual repository ingestion process easier. The output from the scripting step, outlined in [Section 8.3.1](#), is the primary input for this step.

**Step 2.1: Create content package.** Compressing and packaging content allows for it to be easily transported and exchanged between different systems. The content packaging step implements the IMS Content Packaging Specification [85] in order to properly package the sequence chain and the corresponding resources. The specification describes how learning resources are wrapped and packaged into a single package interchange format for transport. Along with the learning resources, the package also comprises an XML-encoded manifest file that contains three core sections: (1) a metadata section describing the entire package; (2) an organisations section that describes the structure of resources wrapped within the package; and (3) a resources section with a list of all resources wrapped within the package, including externally referenced URLs. In addition, there is an optional sub-manifest section that allows for nested packages to be defined in a similar manner as the main package.

The specification is used in its entirety, with the sequence chain and resources stored in the package as content, as shown in [Figure 8-2](#). The content included in the package includes the sequence chain, resulting from the scripting phase, outlined in [Section 8.3.1](#) and, the actual learning resources. Using the IMS Content Packaging specification also makes it possible for the resources to be used by any authoring tool that implements the standard.

**Figure 8-2.** The content packaging of the rVOA payload to be ingested into the online repository is implemented using the IMS Global Content Packaging standard[85].



**Step 2.2: Generate descriptive metadata.** This process generates descriptive information required to identify the content package. The descriptive metadata associated with the content package includes author details of the content package creator and descriptive information about the content package. While there are a number of metadata standards available, the Dublin Core metadata element set [61, 183] is recommended due to its flexibility and widespread support in existing repository software tools.

**Step 2.3: Prepare repository object.** Digital objects are ingested into the repository alongside descriptive metadata. In order to simplify the ingestion process, the content package in Step 1.1 is bundled together with the metadata generated in Step 1.2 into a single ZIP file. It is the ZIP file that is finally ingested into the repository.

The output of this step is a compressed ZIP file containing the content package and an XML file with the descriptive metadata.

### 8.3.3 Step 3. Package ingestion

The ingestion process involves depositing the repository object generated in Step 2, as outlined in Section 8.3.2, into the repository. The ZIP file is ingested into the repository and then internally uncompressed before the content package is permanently stored and tagged with the descriptive metadata. The repository object can either be ingested using the authoring tool using the Sword protocol for remote deposit, or directly using the online repository.

Once ingested into the repository, the content package can then be accessed through the standard repository search and browse features. Section 8.4 describes a reference implementation of the workflow.

## 8.4 Reusable Virtual Orchestration Appliances reference implementation

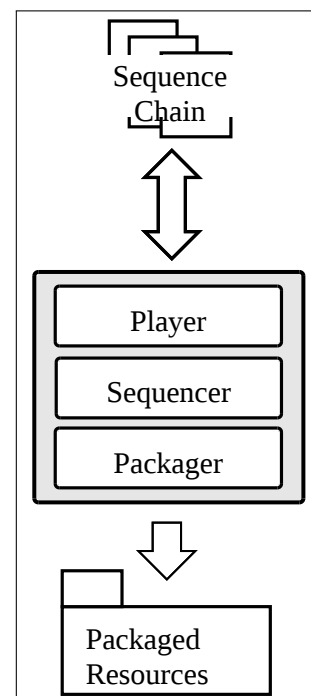
A reference implementation, based on the workflow outlined in [Section 8.3.1](#), was designed and developed as part of the [rVOA](#) project<sup>5</sup>. A browser-based [rVOA](#) player was developed as an offline authoring tool, while a [rVOA](#) repository was developed and set up as an online repository.

### 8.4.1 Offline authoring tool

The [rVOA](#) player toolkit is implemented as a Web-based application, with PHP used for server scripting of the backend and a combination of HTML, CSS, JavaScript and Bootstrap [134] for the user interface. The toolkit is Web-based so it can run and be used on multiple devices.

[Figure 8-3](#) shows a high-level overview of [rVOA](#) player, with its three core modules: the player module, the sequencer module and the packager module.

**Figure 8-3.** The [rVOA](#) offline authoring tool is used to playback created sequence chains, create/modify sequence chains and package the sequence chain for ingestion into the online repository.



**Player module.** The player module allows for existing sequence chains to be played back. The input sequence chain would either have been originally created by the user, using the sequencer module, or alternatively downloaded as a package from the online repository described in [Section 8.4.2](#). The playing back process enables the viewing of activities and resources defined during pre-session management. This process would be performed during a formal learning session.

<sup>5</sup>[http://projects.cs.uct.ac.za/honsproj/cgi-bin/view/2016/parker\\_valentyn.zip/](http://projects.cs.uct.ac.za/honsproj/cgi-bin/view/2016/parker_valentyn.zip/)

**Sequencer module.** The sequencer module implements the three core scripting aspects of orchestration outlined in [Section 8.3.1](#) and also in [Chapter 4](#). Resources and activities for a typical lesson are used as the primary input. The user then associates the resources to the defined activities and explicitly specifies the desired order of orchestration during the playback of the activities and resources. The final output of this process is a named sequence chain that is saved and used as input by the packager module.

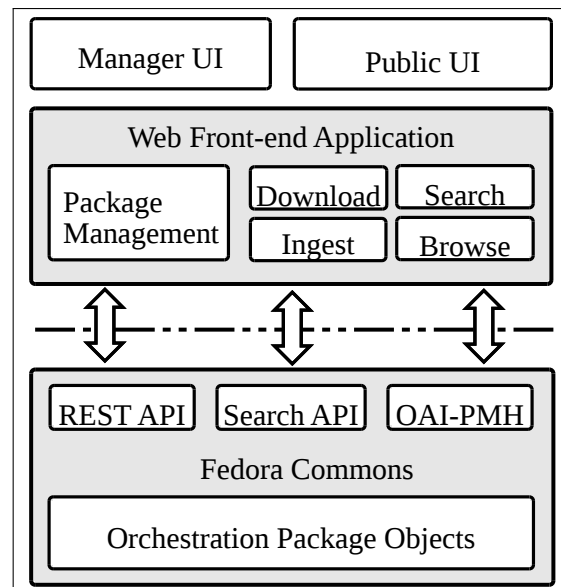
**Packager module.** The packager module is responsible for creating a self-contained package that is ingested into the repository. The packaging process is implemented to (1) create a content package of the sequence chain generated by the sequencer module, together with the associated resources; (2) enable the creation of descriptive metadata to be used to identify the package when ingested into the repository; (3) prepare a final ZIP package, for ingestion into the repository, consisting of the content package and corresponding metadata.

## 8.4.2 Online repository

The [rVOA](#) repository was implemented using the open source Fedora Commons digital asset management system as the base architecture. Fedora Commons was used due to its modular architecture, its scalability and its ability to handle complex digital objects [[108](#)].

A Web-based front-end application was developed with HTML, CSS and JavaScript used to build the user interface. PHP used to implement backend services used to interact with the Fedora Commons services. [Figure 8-4](#) shows a high-level interaction diagram between the front-end application and Fedora Commons.

**Figure 8-4.** The [rVOA](#) repository stores curated orchestration packages and, additionally provides services for searching and browsing packages via a Web front-end application.



The core repository features that facilitate access and management of the orchestration packages are described below.

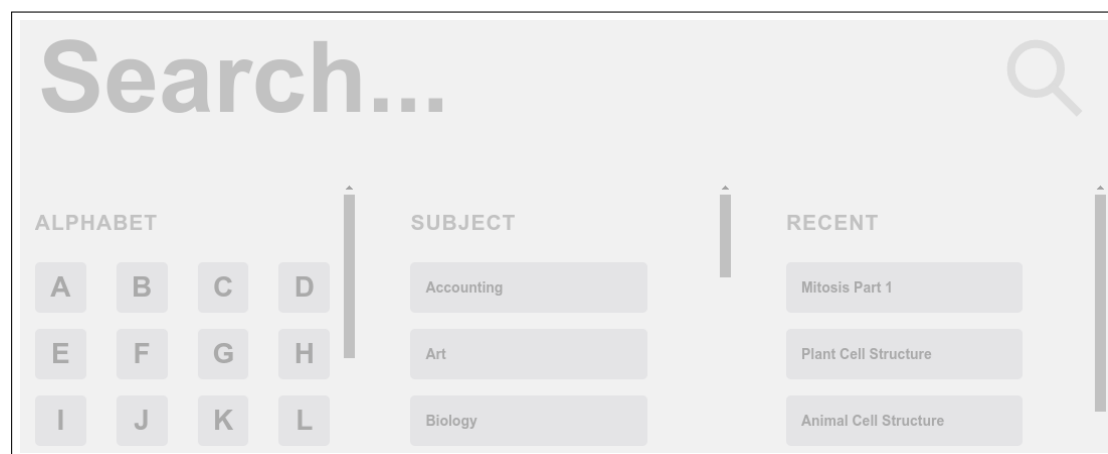
**Package ingestion.** Ingestion of packages is currently supported by an upload feature, however, creators of packages need to be authenticated by the system before uploading content. This is done in order to prevent upload of malicious content.

**Searching and browsing.** Information discovery of repository packages is facilitated through search and browse features. Searching is done on descriptive metadata associated with the packages during ingestion, with the option to search through author, title, subject or description metadata elements. Browsing of content can be performed by subject, the first letter of package titles and, finally, by package creation date. [Figure 8-5](#) shows a screenshot of the search and browse interface.

**Package download.** A download feature enables end users to download packages from the repository.

**Package management.** Package management by package owners is possible, once users have been authenticated, and makes it possible for packages to be re-uploaded and metadata to be modified.

**Auxiliary features.** In addition to the front-end features, there are additional repository services that are provided by the Fedora Commons framework. An OAI data provider allows for orchestration packages to be harvested by external services, while an [OAI-PMH](#) harvester enables the repository to harvest content from external services. Both these make it possible for the orchestration packages to be easily shared. Fedora Commons also implements the Sword protocol, making it possible for orchestration package to be ingested using remote services.



**Figure 8-5.** The [rVOA](#) front-end Web application provides information discovery services for searching and browsing curated orchestration packages in the repository.

## 8.5 Evaluation

The main aim of developing the workflow and its corresponding reference implementation was to assess the feasibility of integrating orchestration packages with typical [OER](#)



workflows. The authoring tool and online repository, outlined in [Section 8.4](#), were evaluated independently.

A key aspect of authoring tools is the potential effect they might have on the overall user experience. A user experience study was thus conducted in order to measure the usability of the [rVOA](#) player authoring tool, as outlined in [Section 8.5.1](#).

From an evaluation perspective, the online repository serves to facilitate user interaction with orchestration packages and to ensure the optimal retrieval and storage of the packages. The usability of repository features and potential scalability of the Web front-end application was assessed.

### 8.5.1 Study 1. Offline authoring tool usability

The authoring tool was evaluated in order to assess its potential effectiveness and ease of use of features associated with sequencing of resources, playback of sequenced resources and packaging of sequence chains in preparation for ingestion into the repository.

#### Study design

A user study was conducted with 20 educators from various schools in Cape Town after obtaining ethical clearance approval. The ease of use was measured using the [System Usability Scale \(SUS\)](#) questionnaire. The [SUS](#) questionnaire uses a 5-point Likert scale to measure 10 items with positively worded odd-numbered questions and negatively worded even-numbered questions [29].

Participants were briefed about the study and subsequently required to sign a consent form. The participants then performed a series of seven pre-defined tasks, shown in [Table 8-2](#). Finally, after performing all the pre-defined tasks, participants were required to complete a [SUS](#) questionnaire.

**Table 8-2.** The three core features of the authoring tool—sequencing of resources, playback of sequenced resources and packaging—were independently assessed to assess their perceived usability.

Task	Description
Task 1	Upload of resources
Task 2	Sequence and download resources
Task 3	Sequence and save resources
Task 4	Preview sequenced resources
Task 5	Delete resources
Task 6	Package resources
Task 7	Share resources

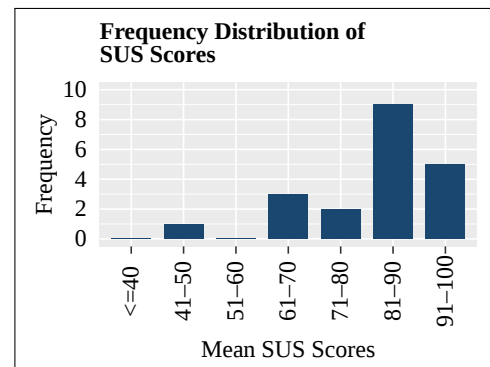
## Results

The individual participants' **SUS** scores were calculated using the prescribed method [29] as follows:

- The sum of all the scores for the 10 questionnaire items was computed:
  - Odd numbered questionnaire items (1, 3, 5, 7 and 9) were scored by subtracting 1 from the scale position
  - Even numbered questionnaire items (2, 4, 6, 8 and 10) were scored by subtracting the scale position from 5
- The sum of the **SUS** scores was then multiplied by 2.5 to obtain the overall value of system usability

The overall mean **SUS** score was 82.38, a score which falls above the average of the 0–100 **SUS** score range. The frequency distribution of the mean **SUS** scores are shown in [Figure 8-6](#). Using the acceptability range and adjective scale proposed by Bangor et al. [18], the overall **SUS** score of 82.38 indicates that the authoring tool is acceptable and Excellent.

**Figure 8-6.** The frequency distribution of the mean **SUS** scores for the 20 participants, showing higher scores for the majority of the participants.



### 8.5.2 Study 2. Repository usability

In order to test the usability of the repository services, a usability study of the front-end application was conducted. The usability was measured using the **SUS** questionnaire.

#### Study design

The user study involved 20 participants, recruited using snowball sampling [70], after obtaining ethical clearance approval. The participants had varying education backgrounds and computer literacy skills.

Participants were given a brief introduction to the study and the front-end Web application and then required to sign a consent form to confirm their willingness to participate in the study. The participants subsequently performed four experiment tasks, shown in [Table 8-3](#), which involved interacting with the front-end application.

**Table 8-3.** The usability of the repository front-end involved assessing package ingestion, discovery and downloading features. System login was assessed alongside ingestion of packages since this is only possible for registered users.

Task	Description
Task 1	Register for a new account
Task 2	Search and download a package
Task 3	Browse and download a package
Task 4	Login and ingest a package

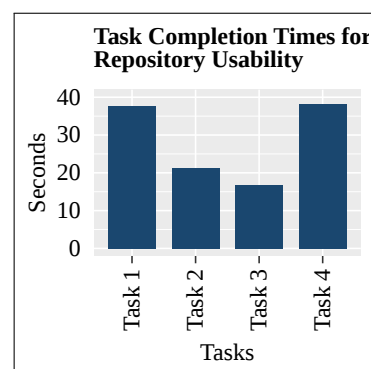
The time taken by each participant to complete each of the experiment tasks was noted, and, once they had completed all the tasks, participants were required to complete a [SUS](#) questionnaire.

## Results

The results suggest that performing basic repository front-end application functionalities was generally intuitive, as shown from the mean task completion times shown in [Figure 8-7](#).

The [SUS](#) score was calculated as outlined in [Section 8.5.2](#). The mean [SUS](#) score was 96, suggesting that the acceptability and adjective rating of the repository front-end application to be acceptable and Excellent, respectively.

**Figure 8-7.** The mean tasks times during the [rVOA](#) repository usability study.



### 8.5.3 Study 3. Repository performance

The scalability tests of the Web front-end application were conducted in order to assess the performance of the application during access of packages, with increasing package workload. The tests did not focus on the performance of Fedora Commons because its scalability has already been established [187].

## Experimental setup

The performance experiments were conducted on an i5-4210U 2.7GHz machine with 4 GB of RAM, running Microsoft Windows 10. Fedora Commons 4.0<sup>6</sup> was used for the repository storage layer.

The tests were conducted using three run averages on the linearly increasing workload sizes shown in Table 8-4. The packages were ingested into the repositories and request, processing and response times for displaying package results were recorded for each of the different workload sizes.

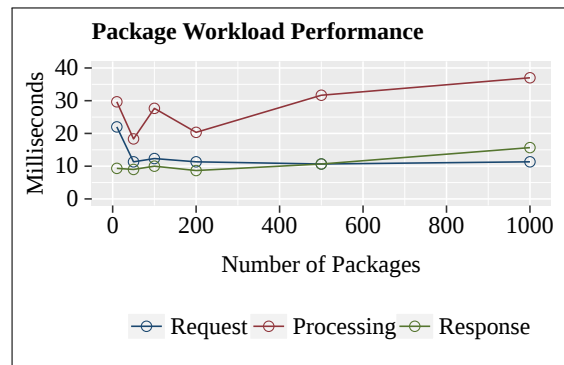
**Table 8-4.** Experiment package workload sizes used to conduct the performance tests.

Workload	W1	W2	W3	W4	W5	W6
Packages	10	50	100	200	500	1000

## Results

Figure 8-8 shows a comparison of request times, processing times and response times for the six package workloads. The response time—time taken to display the results—remains consistent at around 10ms. A comparison of the response times between W1 and W6 indicates a slight linear difference in the times. A similar pattern is observed for the request times and processing times.

**Figure 8-8.** The rVOA repository performance results indicates linearly increasing times with increasing workloads



## 8.6 Discussion

### 8.6.1 Workflow for reusing and sharing orchestration packages

In Chapter 4, a streamlined approach to orchestration of learning, that focuses on activity management, resource management and sequencing of activities, was proposed and outlined. This chapter has demonstrated a practical usage scenario of the proposed approach to

<sup>6</sup><https://github.com/fcrepo4/fcrepo4>

orchestration by illustrating how orchestration packages could be shared and reused by leveraging organised orchestration.

While educators are able to easily share teaching resources using [OER](#) platforms and, free and readily available cloud-based platforms, sharing process and procedures of learning activities is a non-trivial exercise. The proposed workflow provides a mechanism for facilitating this by reusing and sharing of orchestration packages. The mechanism aims to enable a more efficient and effective means for orchestrating activities. Educators are able not only reuse teaching resources, but, additionally, gain access to processes and procedures used by other individuals.

The reference implementation described in [Section 8.3](#) illustrates the feasibility of implementing the workflow. The implementation consists of two core components: an offline authoring tool and creating, managing and playing back orchestration packages; and an online repository platform that facilitates the storage and easy access to the packages. The offline authoring tool takes advantage the storage model used by most educators, that involves storage of teaching resources on local computing devices. Furthermore, it guarantees the manipulation and playback of teaching resources without the need for a dedicated Internet connection. The online repository provides features and functionalities for facilitating easy access to packages through searching and browsing.

Furthermore, the results of the usability studies for both the authoring tool and the repository platform suggests the potential usability of the two components. In addition, the performance tests indicate the linear scalability of the repository component.

## **8.6.2 Limitations**

Although the reference implementation described in [Section 8.3](#) demonstrates the feasibility of the workflow, there are limitations associated the results and implementation of the workflow.

The results from the user studies conducted to evaluate the offline authoring tool and the online repository are based on data collected from two controlled experiments aimed at assessing the two components. As such, the presented study falls short of uncovering the broader implications of a long-term deployment of the workflow implementation. Specially, due to timing constraints, it was not possible for the study to assess the efficacy of the proposed workflow on orchestration of learning.

In addition, the workflow reference implementation only incorporates the basic features necessary to demonstrate the feasibility of the workflow. There is a broad spectrum of features and functionalities that could be built into the two components in order to ensure a more positive user experience.

Finally, the implementation used in the study is only one of many alternative implementations that could be explored to demonstrate the feasibility of the workflow. For instance, alternative implementations could explore the possibility of implementing an online authoring tool, capable of being integrated together with the repository.

## 8.7 Summary

In this chapter, a practical usage scenario of streamlining orchestration, as outlined in [Chapter 4](#), is presented. A workflow for enabling the sharing and reusability of orchestration packages is presented, and a reference implementation of the workflow is described.

The [rVOA](#) workflow heavily relies on the three core aspects of streamlined orchestration—activity management, resource management and sequencing—but, additionally, also involves packaging in order to easily transport and eventually ingest the orchestration packages into the repository.

Finally, the [rVOA OER](#) platform—a reference implementation for sharing complex reusable orchestration packages—was presented. The [rVOA](#) platform implements the proposed workflow through an offline authoring tool and an online repository.

[rVOA player](#) is a standalone authoring tool that is used to create orchestration packages and, additionally, playback the orchestration packages.

[rVOA repository](#) is an online repository platform that primarily facilitates the long-term preservation of curated orchestration packages. More importantly, the repository allows orchestration packages to be easily accessed through searching and browsing.

The main contribution presented in this chapter is the workflow for sharing complex orchestration packages as [OERs](#).

# **Part IV**

## **Conclusions**

# Chapter 9

## Conclusions and future work

This thesis presented and explored a novel streamlined approach to orchestrating learning activities, which places an emphasis on the organisation of learning activities. In this chapter, a summary of the thesis and the general concluding remarks are presented. The chapter is organised as follows: [Section 9.1](#) presents a summary of the thesis and [Section 9.2](#) is a discussion of the broad guiding research questions. [Section 9.3](#) outlines the major contributions of the thesis. In [Section 9.4](#), the key thesis limitations are presented, while potential avenues for future work, beyond the scope of this thesis, are discussed in [Section 9.5](#). Finally, [Section 9.6](#) provides concluding remarks.

### 9.1 Thesis summary

The orchestration of learning activities is known to be challenging and also, arguably, performed in an ad hoc manner. The thesis focused on exploring and understanding how the orchestration of learning activities could potentially be streamlined. The details presented in the thesis are summarised below.

1. [Chapter 1](#) presents motivating factors, scientific goals and research questions associated with the thesis.
2. [Chapter 2](#) provides a detailed literature review of prior work associated with this thesis.
3. [Chapter 3](#) describes a series of studies that were conducted, using a mixed-methods approach, in order to comprehensively understand orchestration of learning activities.  
Result 1: The challenges and ad hoc nature of orchestration were identified.  
Result 2: Three core aspects of orchestration—Activity Management, Resource Management and Sequencing—were identified as being crucial in order for orchestration to be streamlined.
4. [Chapter 4](#) outlines the approach to orchestration of learning proposed in this thesis. The focus of the proposed approach is on three orchestration aspects: Activity Management, Resource Management and Sequencing. In order to evaluate the effectiveness of the



approach, emphasis is placed on assessing its feasibility, its potential effectiveness and, its impact on the user experience.

5. [Chapter 5](#) presents a comparative analysis study that was aimed at comparing two orchestration techniques—organised orchestration with a Workbench toolkit and ad hoc orchestration with PortableApps—in a controlled setting [142]. The experiment was conducted with 61 participants and employed a within-subjects study design. The effectiveness of the two orchestration techniques and, additionally, their effect on the user experience, were measured.

Result 1: Orchestrating learning activities using the Workbench was 23.8% faster than using PortableApps.

Result 2: The AttrakDiff dimension means had significantly higher ratings for the Workbench than for PortableApps.

Result 3: The Workbench approach was perceived to have had a significantly higher positive effect on the user experience.

Result 4: Participants' teaching experience and their experience using computers had no significant effect on the experiment results.

6. [Chapter 6](#) discusses a controlled study that investigated guided orchestration in a peer-led tutoring setting, using an orchestration toolkit for facilitating peer-led tutoring sessions [143]. The study was conducted with 21 computer science tutors of first year programming courses. The orchestration load and usability of organised orchestration were measured.

Result 1: The overall workload required for Activity Management, Resource Management and Sequencing are within acceptable limits, all falling below the 50 mark of the 0–100 workload range.

Result 2: The [NASA-TLX](#) results indicate that Activity Management significantly requires the least workload, while Resource Management requires the most workload.

Result 3: The usability results for [PU](#) and [PEU](#) suggest that the organised approach to orchestrating learning activities has a potential to result in usable and easy to use orchestration tools.

Result 4: The study participants' gender, level of study and their tutoring experience had no significant effect on the workload scores and usability ratings.

7. [Chapter 7](#) presents a case study conducted in a flipped classroom setting [144]. An orchestration toolkit was deployed and used during in-classroom lecture sessions of a second year computer architecture course. The toolkit usage patterns were collected and, additionally, a learner survey was conducted in order to assess the impact of organised orchestration on the learners' learning experience.

Result 1: The toolkit was used in 12 lecture sessions and was used, on average, 66.72% of the time.

- Result 2: The learner survey suggests that the organised orchestration approach has a potential to positively influence learners' learning experiences.
- Result 3: The deployment and use of the toolkit during the 12 lecture sessions demonstrate the applicability of organised orchestration in authentic educational settings.
8. [Chapter 8](#) presents a practical usage scenario of organised orchestration within [OER](#) workflows [138]. The chapter describes a workflow that leverages organised orchestration in order to facilitate the sharing and reuse of orchestration packages.
- Result 1: The implementation of the offline [rVOA](#) play authoring tool and the online [rVOA](#) repository suggest that it is feasible to implement a workflow for sharing reusable orchestration packages.
9. [Chapter 9](#) provides concluding remarks and potential future directions associated with this thesis.

[Table 9-1](#) shows a summary of empirical studies conducted in order to empirically evaluate organised technology-driven orchestration of learning.

**Table 9-1.** Summary of results from empirical studies conducted to evaluate organised orchestration of learning.

	Comparative analysis study	Guided tutoring study	Flipped classroom study	<a href="#">OER</a> packages study
Study objectives	Compare the effectiveness of organised orchestration & ad hoc orchestration.	Demonstrate the effectiveness and usability of organised orchestration.	Demonstrate the feasibility of organised orchestration in authentic setting.	Demonstrate potential practical usage scenario of organised orchestration.
Study context	General technology-driven orchestration by pre-service teachers	Peer-led tutoring environments for first year programming	Second year computer architecture flipped classroom environment	<a href="#">OER</a> orchestration packages workflow reuse
Subject selection	K-12 pre-service teachers	First year undergraduate programming tutors	University lecturer; Second year computer architecture students	K-12 in-service teachers

(Continued on next page)

**Table 9-1.** (continued)

	Comparative study	Guided study	Flipped study	OER study
Design & implementation	<ul style="list-style-type: none"> <li>• Toolkit based on organised orchestration guidelines</li> </ul>	<ul style="list-style-type: none"> <li>• Toolkit for peer-led tutoring</li> </ul>	<ul style="list-style-type: none"> <li>• Toolkit for orchestrating classroom activities</li> </ul>	<ul style="list-style-type: none"> <li>• Offline authoring toolkit</li> <li>• Online repository</li> </ul>
Evaluation aspects	<ul style="list-style-type: none"> <li>• Effectiveness</li> <li>• User experience</li> </ul>	<ul style="list-style-type: none"> <li>• Orchestration load</li> <li>• Ease of use</li> <li>• Usefulness</li> </ul>	<ul style="list-style-type: none"> <li>• Feasibility</li> <li>• Effectiveness</li> <li>• Learning experience</li> </ul>	<ul style="list-style-type: none"> <li>• Feasibility</li> <li>• Usability</li> <li>• Ease of use</li> </ul>
Results & findings	Organised orchestration more effective than ad hoc orchestration and results in more positive user experience	Organised orchestration has minimal effect on orchestration load and results in potentially usable tools	Organised orchestration has potential for a positive effect on learning experience	OER workflow for sharing and reusing orchestration packages feasible

## 9.2 Response to research questions

The main objective of this thesis was to investigate and explore organised technology-driven orchestration of learning activities and, additionally, assess its effectiveness and successful use. It has been argued that streamlining orchestration can be attained by explicitly organising learning activities and, furthermore, that streamlining orchestration can enable educators to become more effective when orchestrating learning activities. The following overarching research question was used as a basis for guiding the exploration of the thesis statement.

*How can technology-driven orchestration of learning be streamlined in order to facilitate the effective management of learning activities, and to what extent does the streamlining affect the orchestration of learning activities?*

The guiding research question was further broken down into the research questions presented in [Table 9-2](#), in order to adequately address the key elements of the thesis statement.

Table 9-2 also provides a mapping to the thesis manuscript chapters where each of the research questions is addressed.

**Table 9-2.** Mapping of research questions and thesis chapters

No.	Research questions	Chapters
RQ 1.	How can educators be supported with orchestration of learning, in order to enable them to become more effective?	Chapters 3 and 4
RQ 2.	How does the explicit organisation of learning activities influence the <i>effectiveness</i> of the orchestration of learning activities?	Chapters 5, 6 and 7
RQ 3.	What is the effect of organised orchestration of learning activities on the <i>user experience</i> of educators?	
RQ 4.	What is the <i>feasibility</i> of deploying authoring tools for streamlining orchestration?	Chapters 6, 7 and 8

Specifically, the research questions were addressed as follows:

- RQ 1: Chapter 3 described a series of preliminary studies that helped uncover the challenges associated with contemporary orchestration of learning activities. In addition, orchestration was identified to be predominantly managed in an ad hoc manner. Activity Management, Resource Management and Sequencing were subsequently identified as core orchestration aspects necessary for the effective orchestration of learning activities. Chapter 4 discussed how the three orchestration aspects could be leveraged in order to streamline orchestration.
- RQ 2: The empirical evidence presented in Chapters 5 and 6 was gathered in order to assess the effectiveness of the organised approach to orchestration of learning activities. The comparative analysis study, presented in Chapter 5, in part, revealed that organised orchestration is significantly more effective when compared with ad hoc orchestration—orchestration of learning activities was noted to be faster when using the organised approach and, additionally, it had significantly higher ratings, with all average user response scores rated above the mid-point of the 7-point TAM scale used. The orchestration load measurements, presented in Chapter 6, further illustrate the effectiveness of the approach seeing as the workload required to perform the core orchestration aspects all fall within acceptable limits.
- RQ 3: Similarly to RQ 2, the empirical evidence presented in Chapters 5 and 6 helped address RQ 3. The rating results from the AttrakDiff dimensions mapped to perceived user experience were, on average, higher for the organised approach in comparison to the ad hoc approach. In addition, the PEU ratings for the toolkit described in Chapter 6 were significantly more positive. Furthermore, the open ended comments from study participants in the studies outlined in Chapters 5

and 6 suggest that the organised approach to orchestration has a potential to improve the user experience of tools and services implemented using the approach.

RQ 4: The PU results in Chapter 6 indicate the feasibility of designing usable orchestration tools and services based on the proposed approach of streamlining orchestration. The feasibility of the proposed approach was demonstrated through the deployment of an orchestration toolkit in a computer architecture flipped classroom environment. The toolkit was successfully used during the duration of the course and was shown to potentially have a positive impact on the learners' learning experience. Additionally, the practical usage scenario that is described in Chapter 8, outlining how orchestration packages can be shared and reused, further demonstrates the feasibility of the approach.

In response to the main research question, this thesis has outlined, in Chapters 3 and 4, how educators can be supported with the orchestration of learning activities by organising learning activities prior to in-session management. It has been shown that the organisation potentially leads to more streamlined orchestration by focusing on Activity Management, Resource Management and Sequencing. The feasibility of organised orchestration has further been demonstrated through the studies conducted in authentic educational settings to assess the feasibility and applicability of organised orchestration. Finally, the results from studies conducted to assess the approach's effectiveness and its impact on the teaching experience suggests that the approach results in more effective orchestration of learning activities and has a potential to positively affect the teaching experience of educators.

### 9.3 Summary of contributions

The major contributions of this work are made by identifying and applying aspects of orchestration of learning to workflows aimed at streamlining the orchestration process. In addition, prototype toolkits were implemented and evaluated in order to assess their effectiveness. Furthermore, the applicability of the proposed approach is evaluated by assessing its feasibility in authentic educational settings. In summary, the major contributions are as follows.

- *Contribution 1—Core aspects for streamlining orchestration.* Identification of Activity Management, Resource Management and Sequencing as the core aspects required for streamlining orchestration of learning activities. In addition, the workflow necessary to link the three orchestration aspects in order to facilitate effective orchestration of learning activities.
- *Contribution 2—Mapping of proposed approach to 5+3 orchestration framework.* A mapping of the three orchestration aspects—Activity Management, Resource Management and Sequencing—to the 5+3 orchestration framework's design-time activities.
- *Contribution 3—Proof of concept toolkits and services.* Design and implementation of authoring toolkits based on the proposed approach to streamline orchestration of learning.

- *Contribution 4—Empirical evidence from experiment results.* Empirical results demonstrating the effectiveness of streamlined orchestration, its potential to positively affect the user experience and its feasibility.
- *Contribution 5—Deployment of orchestration toolkit in authentic setting.* The results from a case study, conducted in a computer architecture flipped classroom setting, illustrating the feasibility of streamlining orchestration of learning in authentic educational settings.
- *Contribution 6—OER workflow for sharing orchestration packages.* A practical usage scenario of the proposed approach, describing workflows and authoring tools for sharing, reusing and integrating orchestration of learning activities as [OER](#).

## 9.4 Limitations

This thesis proposed an organised approach to orchestration of learning activities by focusing on three core aspects: Activity Management, Resource Management and Sequencing. Prototype orchestration toolkits were implemented and the feasibility of deploying them in authentic educational settings assessed. In addition, the toolkits' effectiveness and potential impact on teaching experience was assessed. While the research was designed to evaluate important aspects of the proposed approach, it was constrained by time and the availability of participants. The limitations can be categorised as follows:

### 9.4.1 Toolkit implementation

The focus of the toolkit implementations, outlined in [Chapters 5, 6, 7 and 8](#), was on features associated with the three core aspects—Activity Management, Resource Management and Sequencing—associated with the proposed approach. While the usability and user experience of the toolkits was assessed in some of the studies, little focus was directed towards the design of the user interfaces during rapid prototyping. Additionally, the implementation of front-end interfaces was rudimentary as the aim was to assess the implications of the three orchestration aspects. Furthermore, there are numerous potential use cases that might be implemented based on the approach. However, the toolkit implementations presented in this research only form a few potential use case scenarios and may not be representative of the different potential implementations.

### 9.4.2 Evaluation in authentic educational settings

The evaluation of the approach in authentic educational settings forms a crucial part of the feasibility assessment. Studies conducted in authentic educational settings are typically associated with timing constraints and as a result, the evaluation of the approach in authentic educational settings was restricted to the flipped classroom study presented in [Chapter 7](#). While the results from this study provide data to draw conclusions on the implications of

using the approach in real-world settings and, especially the implications on the learners' learning experience, it has limitations on its potential generalisation.

### **9.4.3 Analysis of confounding variables**

The studies that were conducted to explore contemporary technology-driven orchestration of learning revealed that factors such as class size, teaching models and learner levels of study are major contributing factors during orchestration of learning. Due to the complex nature of educational settings, there are other wide-ranging factors that could potentially influence the evaluation of the proposed approach. The studies conducted during this research were limited in scope, due to timing constraints, and present limitations in generalising the proposed approach.

## **9.5 Future direction**

The proposal, presented in this thesis, to focus on the three core aspects—Activity Management, Resource Management and Sequencing—of orchestrating learning opens up a number of potential opportunities and new challenges to be addressed as future work.

### **9.5.1 Investigating additional orchestration aspects**

Chapter 3 explored challenges associated with contemporary orchestration. Based on the results from the preliminary studies, three core orchestration aspects—*activity management*, *resource management* and *sequencing of activities*—required to streamline orchestration were identified.

Although the aspects give rise to promising results when applied to the design of orchestration tools and services, the limited scope of the preliminary studies could potentially have resulted in a limited set of aspects. A promising future direction would be to conduct additional exploratory studies aimed at identifying additional aspects. Another possible direction would be to identify subsets of aspects specific to unique educational settings.

### **9.5.2 Implementation of additional tools and services**

The prototype toolkits designed and implemented were, for the most part, aimed at conducting the experimental studies. In order to comprehensively understand the effects of the proposed approach on a large scale, future work might look into designing and implementing production quality tools for large scale deployment studies.

In addition, specialised tools and services for unique scenarios and environments could be implemented to assess the effectiveness of the approach in such environments. This would especially be useful in extremely challenging TEL environments such as CSCL [145].

### 9.5.3 Feasibility of addressing unique orchestration concerns

In Chapter 4, a mapping of the proposed approach with the more established ‘5 + 3 Aspects’ conceptual framework [146, 147] was described and illustrated in Table 4-1. There are characteristics of the ‘5 + 3 Aspects’ orchestration framework that need to be rigorously evaluated to assess how the proposed approach conforms to the framework.

Efforts could thus be directed towards establishing how the other characteristics of the 5 + 3 Aspects framework, such as “Awareness/Assessment”, could be handled within tools and services implemented using the proposed approach.

### 9.5.4 Exploration of alternative sequencing paths

Chapter 4 discussed the use of the IMS Simple Sequencing standard [86, 87] as the basis for implementing sequencing behaviour. The toolkit implementations described in this thesis were all based on the standard’s “Directed” path. This limitation resulted from that fact the focus of the thesis was to broadly assess the core aspects of streamlined orchestration and, additionally, to explore the effect of streamlining orchestration in different educational settings. To comprehensively understand the implication of organised orchestration, future work might be directed towards implementation and experimentation of the “Self-Guided”, “Adaptive” and “Collaborative” paths. For instance, adaptive toolkits could be implemented in order to facilitate dynamic sequencing of activities.

### 9.5.5 Applicability of streamlined orchestration to MOOCs

There have been some efforts directed towards research in MOOCs, such as work by Haklev et al. [75]. Future work in this area could, in part, be aimed at effectively managing activities performed by learners of MOOC courses.

### 9.5.6 Feasibility of the approach in different educational settings

There is a broad spectrum of attributes of educational settings that could potentially affect the effectiveness of the proposed approach. The studies presented in this thesis only took into account a subset of the potential range of factors. Factors that could be explored include: different learning models employed by educators; the effect of learning environment characteristics such as the group size of learners; and the learners’ level of study.



## 9.6 Final remarks

With the rapid technological advances, understanding the unique challenges in educational settings and how technology can improve teaching processes has value. This thesis focused on supporting educators with the process of orchestration, using a technology-driven approach that leads to the design and implementation of effective and usable orchestration software tools and services. While limited in scope, the results from the studies are promising and demonstrate the feasibility of the approach.

On one hand, the increasing adoption of teacher-centric software tools and services are anticipated to improve teaching and learning processes. On the other hand, these technologies need to be managed to ensure their effective use. The efforts presented in this thesis are aimed at ensuring effective use of orchestration tools.

While the major outcomes of this thesis are the experimental results and demonstrable results showing the feasibility of the approach, perhaps an important point to note is that the adoption and practical use of educational technologies still remains a challenge [95, 121, 152, 163]. Research efforts should thus also be directed towards understanding how novel educational technologies can be seamlessly integrated into existing workflows.

# **Appendices**

# Appendix A

## Comparative analysis: Ad hoc vs. organised orchestration

This appendix presents study materials, experiment tasks, questionnaires and raw data dumps for the comparative analysis controlled study described in [Chapter 5](#).

[Appendix A.1](#) is the recruitment flyer that was placed around the [CPUT](#) campus, to advertise the study. [Appendix A.2](#) presents the experiment protocol, tasks and associated questionnaires used in the study. The raw data dump is presented in [Appendix A.3](#).

## A.1 Participants recruitment flyer

### We Need Your Help with a Teaching Research Study

Do you fit the following profile?

- You are a student in the General Education and Training department.
- You are an [ISP 1](#), [ISP 2](#), [ISP 3](#) or [ISP 4](#) student.

What is in it for you?

- You will be helping make teaching more effective.
- You will be paid ZAR 40.00 for your time.

If you fit the profile and are eager to help, we would love it if you could spare 30 minutes of your time— please come through anytime between 12H30 and 16H30; on Thursday June 2, 2016; in Room 0.36—to use our apps and answer a few questions.

Sign up here: <https://goo.gl/IjXCY4>



For further information and/or clarification

Call/SMS/WhatsApp: +27725378670 | Email: [lphiri@cs.uct.ac.za](mailto:lphiri@cs.uct.ac.za) | WWW: <https://goo.gl/IjXCY4>

This research is approved by the [CPUT](#) Institutional Ethics Committee.

## A.2 Materials

### A.2.1 Experiment protocol

#### 1. Briefing

Hello! Thank you for taking the time to participant in the study. This study is part of my doctoral studies; I am exploring organised technology-driven orchestration of learning activities, with the broader goal of making educators more effective an managing learning activities. The focus of this session will be on comparison of two orchestration techniques—the traditional ad hoc approach and an orchestration workbench approach.

You will be required to perform some tasks using the two orchestration approaches.

After completion of all the tasks, you will be required to fill out two questionnaires to share your experiences using the two techniques.

The questionnaire consists of descriptive word-pairs. You are expected to rate your experiences using a 1–7 Likert scale.

If you have any questions regarding these words, either their meaning or how they relate to the orchestration techniques, please do not hesitate to ask.

I would like to urge you all to feel free during the session.

Before we begin, do you have any questions?

## 2. Consent form

I will now distribute consent forms that I shall require you sign before we begin. This is so you can confirm that you have been made aware of what we shall be doing.

## 3. Experimental groups

### 3.1. Group 1

You will be expected to perform the three tasks outlined below.

#### 3.1.1. Activity 1: Workbench Orchestration Using Prototype

- 1) Task 1: Learning to use Workbench
- 2) Task 2: Locating teaching tools and resources
- 3) Task 3: Student tasks

#### 3.1.2. Activity 2: Ad Hoc Orchestration Using PortableApps

- 1) Task 1: Learning to use PortableApps
- 2) Task 2: Locating teaching tools and resources
- 3) Task 3: Student tasks

#### 3.1.3. AttrakDiff Questionnaire

We will now hand out questionnaires for you to fill out. While your responses are anonymous—notice that we are not capturing any identifying information—please be honest with your responses. The questionnaire is split up into two core sections.

- Background Section
- Technique Rating Section

### 3.2. Group 2

You will be expected to perform the three tasks outlined below.

#### 3.2.1. Activity 1: Ad Hoc Orchestration Using PortableApps

- 1) Task 1: Learning to use PortableApps
- 2) Task 2: Locating teaching tools and resources
- 3) Task 3: Student tasks

#### 3.2.2. Activity 2: Workbench Orchestration Using Prototype

- 1) Task 1: Learning to use Workbench
- 2) Task 2: Locating teaching tools and resources
- 3) Task 3: Student tasks

#### 3.2.3. AttrakDiff Questionnaire

We will now hand out questionnaires for you to fill out. While your responses are anonymous—notice that we are not capturing any identifying information—please be honest with your responses. The questionnaire is split up into two core sections.

- Background Section
- Technique Rating Section

#### 4. Documentation

- Please make sure that:
  - You have signed the consent form
  - You have completely filled out the questionnaire
- We shall check to confirm that the consent form has been signed and that you filled out the questionnaire before giving you the ZAR 40.00.
- We will then request that you sign the payment schedule before collecting the ZAR 40.00 compensation.

#### 5. Debriefing

Thank you very much for your participation in this study. If you wish to acquire further information about this study, please contact me.

## A.2.2 Experiment tasks

Comparative Analysis Experiment

Participant#: ... Group #: ...

## Teaching a Grade 5-B Natural Sciences and Technology Class

You will be asked to access a range of teaching resources using two different approaches—Approach #1 and Approach #2. You will also be required to write down some text that appears in the resources.

### Scenario

You are teaching a Grade 5-B Natural Sciences and Technology Class. The concept being taught is “What are fuels”, under the topic “Stored energy in fuels”. You would ideally

- Teach the concept to the students
- Have them work in pair to perform an activity in class
- Have them perform an investigation in class

## [Approach #1|Approach #2]—Using Orchestration Prototype

### Task 1—Learning to use Orchestration Prototype.

- 1) Open USB drive
- 2) Double click “COW” icon

An application is launched within the browser;

- The right panel has “Activities” and “Resources” sections
- If sections are not yet expanded, please click the “+” sign of each section
- The main panel is where content is displayed

### Task 2—Locating teaching resources.

- 1) Use the computer to take note of the time .....
- 2) Click the “Teacher Guide (*PDF*)” link to access the ‘*Gr5\_B\_Teacher\_Eng.pdf*’ document
  - Go to page 5 of the document and quickly skim through that page
- 3) Click the “Fossil Fuels (video)” link to open video on “Formation of fossil fuels”
  - Watch video—you can mute the volume on computer

### Task 3—Orchestrating student activities.

- 1) Click the “Teacher Guide (*PDF*)” link to access the ‘*Gr5\_B\_Teacher\_Eng.pdf*’ document
  - Go to page 9 to see details about the class activity—“Energy from food”
  - Page 9 has activity details, materials and instructions
  - How many instructions are listed on the page? .....
- 2) Use your computer to take note of the time .....

**[Approach #1|Approach #2]—Using PortableApps**

**Task 1—Learning to use PortableApps platform.**

- 1) Open USB drive
  - 2) Double click “Start” icon
- A start menu appears;
- The left side of the menu has software applications
- Click ‘*Foxit Reader*’—used to open *PDF* documents
  - Click ‘*VLC*’—used to play videos
- The right side of the menu has
- Click ‘Documents’ and then open the ‘CPUT’ folder to access teaching resources
    - You should see the ‘*Gr5\_B\_Teacher\_Eng.pdf*’ document
    - You should see the ‘*Fossils.mp4*’ video file

**Task 2—Locating teaching resources.**

- 1) Use the computer to take note of the time .....
- 2) Use the ‘*Foxit Reader*’ application to open the ‘*Gr5\_B\_Teacher\_Eng.pdf*’ document
  - Go to page 5 of the document and quickly skim through that page
- 3) Use the ‘*VLC*’ application to open video on ”Formation of fossil fuels”
  - Watch video—you can mute the volume on computer

**Task 3—Orchestrating student activities.**

- 1) Use the ‘*Foxit Reader*’ application to open the ‘*Gr5\_b\_Teacher\_Eng.pdf*’ document
  - Go to page 9 to see details about the class activity—“Energy from food”



- Page 9 has activity details, materials and instructions
  - How many instructions are listed on the page? .....
- 2) Use your computer to take note of the time .....

**A.2.3 Background questionnaire**

Comparative Analysis Experiment	Participant#: ... Group #: ...
---------------------------------	--------------------------------

**Section A: Background information**

What is your present year of study?

ISP 1    ISP 2    ISP 3    ISP 4    Other .....

Specialisation (e.g. Physical Sciences) .....

How often have you been on teaching practice?

1 time    2 times    3 times    4+ times

What is your experience working with computers?

0–1 years    2–3 years    4–5 years    5+ years

**A.2.4 AttrakDiff 2 questionnaire**

Comparative Analysis Experiment	Participant#: ... Group #: ...
---------------------------------	--------------------------------

**[Approach #1|Approach #2]—Technique Ratings**

With the help of the word-pairs, please enter what you consider the most appropriate description for Approach #1. Please circle on your choice in every line.

Human	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	Technical
Isolating	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	Connective
Pleasant	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	Unpleasant
Inventive	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	Conventional
Simple	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	Complicated

Professional	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Unprofessional
Ugly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Attractive
Practical	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Impractical
Likeable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Disagreeable
Cumbersome	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Straightforward

With the help of the word-pairs, please enter what you consider the most appropriate description for Approach #1. Please circle on your choice in every line.

Stylish	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Tacky
Predictable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Unpredictable
Cheap	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Premium
Alienating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Integrating
Brings me closer to people	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Separates me from people
Unpresentable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Presentable
Rejecting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Inviting
Unimaginative	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Creative
Good	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Bad

With the help of the word-pairs, please enter what you consider the most appropriate description for Approach #1. Please circle on your choice in every line.

Confusing	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Clearly structured
Repelling	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Appealing
Bold	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Cautious
Innovative	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Conservative
Dull	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Captivating
Undemanding	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Challenging
Motivating	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Discouraging
Novel	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ordinary
Unruly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Manageable

Do you have any general comments or concerns? .....

## A.3 Raw data dump

### A.3.1 AttrakDiff 2 responses and times on tasks

**Table A-1.** Comparative analysis study results showing AttrakDiff 2 scores and times on tasks.

Participant	Group	Level	Teaching	Computing	Task_time	Workbench				Task_time	PortableApps			
						PQ	HQ-I	HQ-S	ATT		PQ	HQ-I	HQ-S	ATT
P01	1	4	4	4	2	0.71	-0.43	-0.29	0	4	0.14	0.43	-0.43	0
P02	1	4	4	4	5	2.43	2	0.57	2.86	9	-1.14	-0.71	0	-0.86
P03	1	3	4	3	5	-0.57	-0.14	0	-1.29	10	0.57	-0.57	-0.86	-0.14
P04	1	3	3	3	7	1.43	1.71	0.86	2	8	1.71	1.86	0.43	1.71
P06	1	4	4	4	7	-0.86	-0.57	-0.71	-0.57	8	2	1.57	0.86	2.29
P08	1	4	4	4	–	1.29	1.43	0	1.29	–	0.71	0.86	0.57	1.43
P09	1	4	4	4	–	0.71	1.43	1.29	1.71	–	0.43	0.57	1.14	1.14
P12	1	3	3	4	3	–	–	–	–	10	–	–	–	–
P13	1	3	4	4	7	1.14	1	1.14	1.43	9	0.86	0.14	-0.29	0.71
P14	1	3	4	1	–	0	0	0	0.29	–	0.29	-0.14	-0.29	0.43
P15	1	2	4	1	–	1	1.29	0.43	1.86	–	0.57	1	0.57	1.71
P16	1	2	4	2	5	0	0.43	0.43	0.14	8	-0.14	0.71	0.29	0.57
P17	1	2	4	4	4	0.29	0.29	0.14	0.43	8	0.29	0.57	0.14	0.71
P18	1	2	4	2	3	-0.71	0.29	0.57	-0.14	6	-0.57	-0.57	0.57	-1
P19	1	2	4	2	3	0.14	0.57	0	0.86	8	-0.43	0.57	0.43	1
P21	2	4	4	4	7	0.57	1.57	0.71	1.29	7	-1.57	-0.57	0	-1.57
P22	2	4	4	3	7	0.57	2.14	1	2.29	3	0	1.29	1.57	2.43
P23	2	3	4	2	9	0.29	1	1.57	2.14	2	1.57	1.14	0.86	2.14
P24	2	3	4	4	12	1.29	2	-0.43	2.57	3	1.71	1.14	1.29	2.29
P25	2	4	4	4	5	2.29	2.71	1.71	2.29	8	2.86	2.43	2.57	2.57
P26	2	NA	2	3	10	2	1.14	0.29	3	3	1.57	1.43	0.71	2.14
P27	2	4	4	4	4	3	3	2.14	3	7	3	3	2.14	3

(Continued on next page)

**Table A-1.** (continued)

Participant	Group	Level	Teaching	Computing	Task_time	Workbench				Task_time	PortableApps			
						PQ	HQ-I	HQ-S	ATT		PQ	HQ-I	HQ-S	ATT
P28	2	3	3	2	4	-	-	-	-	6	-	-	-	-
P30	2	3	4	4	7	0.43	0.57	1	1	6	-0.57	0.43	0.71	0.86
P31	2	NA	2	3	1	1.14	2.57	1.29	2.43	5	1.86	2	0.86	2.14
P33	2	2	4	3	9	-	-	-	-	7	-	-	-	-
P34	2	2	4	2	2	0.71	0.71	0.43	1.14	5	0.29	0.86	0.86	0.29
P35	2	2	4	4	6	-	-	-	-	6	-	-	-	-
P36	2	2	4	2	3	2	2.71	-0.29	2.57	5	1.86	2.71	0.86	2.86
P37	1	2	2	1	7	-0.29	1.14	0.57	0.86	7	-0.43	0	-0.29	-0.14
P38	2	3	3	2	2	-0.43	1.57	0.86	1.43	7	0.29	0.29	-0.57	-0.29
P39	1	2	2	2	3	2.86	2.29	1.43	2.86	3	-2	-1.29	0.29	-1.29
P40	1	2	3	2	8	1.43	2.43	1.14	2.14	8	-1.14	0.43	-1.43	-0.86
P41	1	2	2	2	5	2.14	2.86	1.71	2.71	5	1.29	0.57	-0.43	1.43
P42	2	2	3	2	2	1.71	0.71	0.57	2.29	8	0.86	1.29	-1.14	1.71
P43	1	2	2	2	11	-0.71	0.14	0.43	0.43	9	-1.57	0	-1	-0.43
P44	2	2	2	1	6	2.43	2.43	1.29	3	9	-0.29	0	-0.14	-0.29
P45	2	2	2	1	5	1.29	1	0.57	1.14	8	-0.43	-2.71	-1	-1
P46	1	3	4	2	9	1.86	2	1.57	2.43	8	-0.57	0.29	-0.57	0.86
P47	2	3	4	4	5	1	2.43	2	2.14	8	-1.14	-0.14	-0.86	-0.14
P48	2	2	2	2	2	1.57	0.43	0.43	1.14	9	-0.71	-0.14	-0.86	-0.71
P49	2	3	3	3	4	1.71	2.71	2	3	4	-0.29	1.29	0.71	1.29
P50	1	3	3	2	4	0.29	0.14	0.86	0.86	7	-1.14	-1.14	-1.14	-1.43
P51	1	3	4	2	6	0.86	1.57	1.57	3	5	-0.86	0.57	1.29	1.71
P52	1	2	2	2	6	1.43	2.14	1.43	1.43	5	-1.57	0.29	0.29	-0.14
P53	2	3	4	2	-	1.57	2.71	1.86	2.57	-	-0.71	0.14	0.29	0.57

(Continued on next page)

**Table A-1.** (continued)

Participant	Group	Level	Teaching	Computing	Task_time	Workbench				Task_time	PortableApps			
						PQ	HQ-I	HQ-S	ATT		PQ	HQ-I	HQ-S	ATT
P54	2	3	4	2	4	1.57	2	-0.14	2.57	13	-0.43	0.29	-1.14	0.57
P55	1	3	4	4	8	0.43	2.71	1.29	2.71	13	-2.29	-0.29	-1	-0.43
P56	1	3	4	4	10	1.14	2.14	1.57	2.29	9	-1.14	-0.29	-0.29	0.29
P57	2	2	2	2	4	2.14	2.57	2.14	3	5	-0.86	0.14	0.29	-1.14
P58	2	3	4	2	6	-0.43	0.57	-0.29	-0.43	8	-1.29	-1.43	-1.43	-1
P59	1	3	4	2	5	0.29	2	1.43	2.71	7	-1.71	0.29	-0.43	1
P60	1	3	3	2	7	1.71	1.86	1.71	2.14	8	-1.86	-0.71	-0.71	-1.29
P61	2	2	2	4	5	0.57	2.86	1.14	1.57	6	1.29	0.71	-0.57	0.86
P62	2	3	4	2	5	0.71	1.43	0.86	0.86	5	-1.43	-0.29	-1.14	-1
P63	2	3	4	3	6	0.43	1.14	1.86	2.43	5	-0.43	0.29	-0.29	0.86
P64	2	3	4	2	7	1.57	1.71	1.57	3	3	-0.43	0.57	0.29	1.43
P65	1	3	4	2	-	0.86	2.57	0.86	1.86	-	-0.57	0.29	-0.71	0.29
P66	1	3	4	4	6	2.86	1.43	1.71	3	4	-0.86	-0.14	-0.14	0

# Appendix B

## Guided orchestration for peer-led tutoring

This appendix presents study materials, experiment tasks, questionnaires and raw data dumps for the guided orchestration for peer-led tutoring study described in [Chapter 6](#).

[Appendix B.1](#) shows recruitment email templates used to automatically send out emails recruitment messages to the 96 sample pool of potential study participants. The emails were sent in batches, using the Mail Merge<sup>1</sup> Mozilla Thunderbird<sup>2</sup> add-on. [Appendix B.2](#) presents the experiment protocol, tasks and associated questionnaires used in the study. The raw data dump is presented in [Appendix B.3](#).

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<sup>1</sup><https://addons.thunderbird.net/en-us/thunderbird/addon/mail-merge>

<sup>2</sup><https://www.thunderbird.net>

## B.1 Participant recruitment

### B.1.1 Participant initial recruitment email template

Subject: [{{ParticipantCourseTutored}} Tutors] Request to Take Part in Paid Research Opportunity

Hello {{ParticipantName}},

I hope you are well as you brace yourself for the upcoming examinations. Best of luck with this.

You are receiving this email at {{ParticipantEmail}} because you have tutored the {{ParticipantCourseTutored}} course in the recent past.

We will be conducting a peer-led guided orchestration study, as part of my doctoral studies. The study is about technology-driven orchestration of learning activities by individuals such as yourself: Tutors. You will be asked to perform a series of tasks using a Web application and then answer a few questions. The entire session will take approximately 30 minutes. Participation is confidential and voluntary. In addition, you can withdraw any time should you wish to. Furthermore, there are no known risks involved. This study has been cleared by the Faculty of Science Research Ethics Committee (approval code: FSREC 021–2014) and approval has been granted by Department of Student Affairs to work with students (Ref. No.: PHRLIG001/ Mr. Lighton Phiri).

**\*\*You will be compensated with ZAR 50.00 cash for 30 minutes of your time. We shall also have snacks available during the session. In addition, you will be helping work towards making the support given to first year Computer Science students much better. Also, though not part of the study, we would LOVE to informally chat to you about your experience working with first years.\*\***

If you would like to be part of the study, we will be holding sessions between October 27 2016 and November 6 2016, from 07H00 till 19H00 GMT+2.

If you would like to help, by participating in the study, [please specify your availability via this Doodle Poll \[1\]](#) OR reply with a date and time when you can come through. Please remember that the session will take only about 30 minutes. I will send a follow-up message with information about the location.

If you do not want to participate, please send me a reply e-mail saying “No thanks.”

If you have questions and/or need clarification, please do let me know: email or ping me via WhatsApp on +27725378670.

Thank you for your time.

[1] <http://doodle.com/poll/hpk3a9bazudai29u>

Best wishes.

–  
Lighton Phiri

<http://people.cs.uct.ac.za/lphiri>

## B.1.2 Participant followup recruitment email template

Subject: [{{ParticipantCourseTutored}} Tutors] Hello {{ParticipantName}}, We Are Still Waiting for Your Response

Hello {{ParticipantName}},

This is a follow up on the email sent to you at {{ParticipantEmail}}, with subject: “[{{ParticipantCourseTutored}} Tutors] Request to Take Part in Paid Research Opportunity”. With how flooded inboxes are these days, we know that follow up is important!

As a reminder, we are conducting a study in an attempt to make tutoring of first year Computer Science students more streamlined. Seeing as you were/are a {{ParticipantCourseTutored}} Tutor, we would really appreciate it if you could help by participating in the study.

- We will be holding one-on-one sessions between October 27 2016 and November 6 2016, from 07H00 till 19H00 GMT+2.
- The sessions will be roughly 30 minutes long; you will be expected to choose a slot that best suits your schedule.
- We will be conducting sessions from the Centre in ICT for Development, Level 3A, Computer Science Building on [UCT's Upper Campus](#).
- You will be compensated with ZAR 50.00 cash for 30 minutes of your time.
- We shall also have snacks available during the session.

If you are keen to help, [please specify your availability via this Doodle Poll \[1\]](#) OR reply with a date and time when you can come through. Please remember that the session will take only about 30 minutes.

If you do not want to participate, please send me a reply e-mail saying “No thanks.”

If you have questions and/or need clarification, please do let me know: email or ping me via WhatsApp on +27725378670.

We look forward to hearing from you.

[1] <http://doodle.com/poll/hpk3a9bazudai29u>

Best wishes.

–



Lighton Phiri

<http://people.cs.uct.ac.za/lphiri>

### B.1.3 Participant Doodle poll schedule

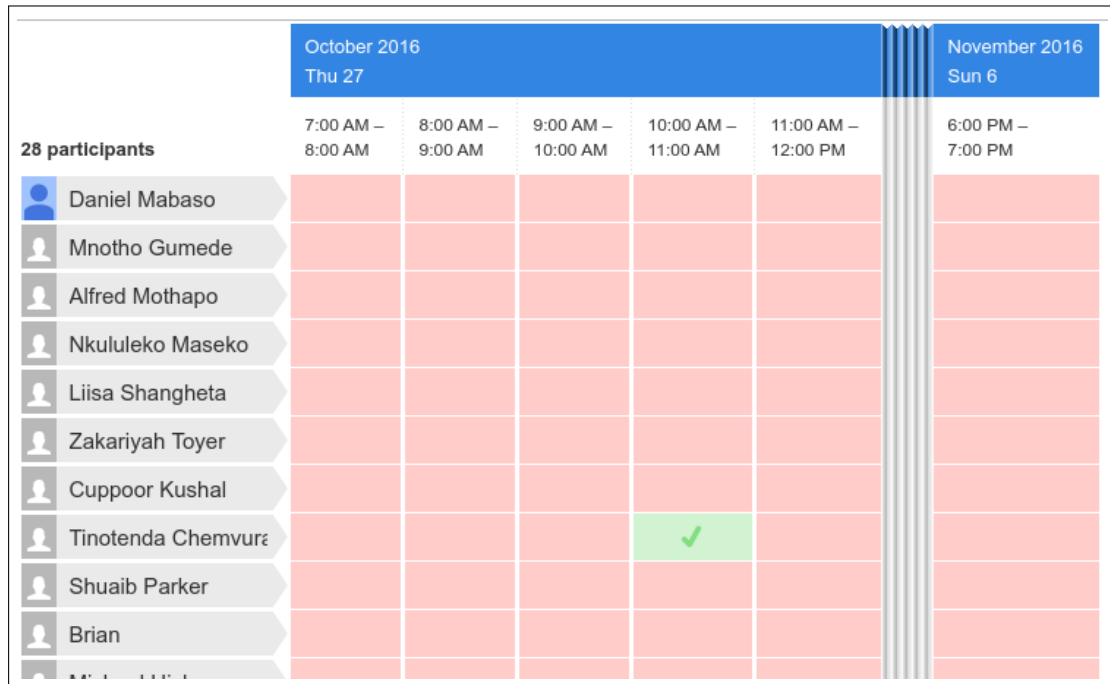


Figure B-1. Doodle poll showing participants' specified scheduled timeslots.

### B.1.4 Participant appointment schedule email template

Subject: [Tutors Study] Hello {{ParticipantName}}; REMINDER About Our Appointment on {{WeekDay}}, {{AppointmentDate}}, at {{AppointmentTime}} GMT+2

Hello {{ParticipantName}},

Thank you for signing up to be part of the study.

A reminder that you signed up to meet with us on {{WeekDay}}, {{AppointmentDate}} at {{AppointmentTime}}. We look forward to interacting with you.

The study will be taking place in the Centre in ICT for Development, Level 3A, Computer Science Building on UCT's Upper Campus.

Please feel free to email or WhatsApp/SMS/Call me on +27725378670.

See you then.

Best wishes.

–

Lighton Phiri

<http://people.cs.uct.ac.za/lphiri>

## B.2 Materials

### B.2.1 Experiment protocol

#### 1. Briefing

Hello! Thank you for taking the time to participate in the study. This study is part of my doctoral studies; I am exploring organised technology-driven orchestration of learning activities, with the broader goal of making educators more effective at managing learning activities. The focus of this session will be on assessing the effectiveness of the approach in peer-led tutoring sessions.

You will be required to perform three tasks using a Web application.

After completion of each of the individual three tasks, you will be required to fill out [NASA-TLX](#) questionnaires to share your experiences using the Web application to perform the tasks.

The instructions for using the [NASA-TLX](#) and [PU/PEU](#) questionnaires are included in the accompanying documentation. I will also walk you through the instructions as you perform the tasks.

If you have any questions regarding anything, please do not hesitate to ask. I would like to urge you all to feel free during the session.

Before we begin, do you have any questions?

#### 2. Consent form

I will now distribute consent form that I shall require you sign before we begin. This is so you can confirm that you have been made aware of what we shall be doing.

#### 3. Debriefing

Thank you very much for your participation in this study. If you wish to acquire further information about this study, please contact me.

### B.2.2 Experiment tasks

**Experimental session task #1: Activity management****Table B-1.** Guided orchestration study experiment tasks for activity management.

Goal:	<ul style="list-style-type: none"> <li>• Create new orchestration activity nodes for CSC1010H tutorial session on Recursive Function</li> <li>• (Node 1: CSC1010H; Node 2: Tutorial; Note: Node 2 is child of Node 1)</li> </ul>
Inputs:	Your login details: username/password
Assumptions:	—
Steps:	<ol style="list-style-type: none"> <li>1) Login into Simple Orchestra application using your credentials</li> <li>2) Create a CSC1010H node <ol style="list-style-type: none"> <li>a) Provide descriptive details about the course in form</li> </ol> </li> <li>3) Create a Tutorial sub-node (level 2) of the CSC1010H node <ol style="list-style-type: none"> <li>a) Provide descriptive details about the course in form Provide descriptive details about the tutorial</li> </ol> </li> <li>4) Create a Tutorial sub-node (level 2) of the CSC1010H node <ol style="list-style-type: none"> <li>a) Provide descriptive details about the tutorial</li> </ol> </li> <li>5) Verify that appropriate nodes have been created</li> <li>6) Logout of the Simple Orchestra application</li> </ol>
Time for expert:	5 minutes
Instructions for user:	<ul style="list-style-type: none"> <li>• Please follow all outlined steps above.</li> <li>• Please remember the names ascribed to the individual nodes as these will be used as input in subsequent tasks.</li> </ul>
Notes:	Your workload experience during this task will be assessed.

**Experimental session task #2: Resource management**

**Table B-2.** Guided orchestration study experiment tasks for resource management.

Goal:	Upload all teaching materials required for CSC1010H tutorial session
Inputs:	<ul style="list-style-type: none"><li>• Your login details: username/password</li><li>• Nodes 1 and 2 create in ‘Task 1’</li><li>• Offline Teaching resources downloaded from Vula</li></ul>
Assumptions:	—
Steps:	<ol style="list-style-type: none"><li>1) Login into Simple Orchestra application using your credentials</li><li>2) Upload all teaching resources associated with tutorial 6<ol style="list-style-type: none"><li>a) Browse for lecture slides</li><li>b) Browse for Lab exercise</li><li>c) Browser for Pre-practical tutorial</li><li>d) Browser for Assignment tutorial</li></ol></li><li>3) Upload all teaching resources associated with tutorial 7<ol style="list-style-type: none"><li>a) Browse for lecture slides</li><li>b) Browse for Lab exercise</li><li>c) Browser for Pre-practical tutorial</li><li>d) Browser for Assignment tutorial</li></ol></li><li>4) Verify that all resources have been uploaded</li><li>5) Logout of the Simple Orchestra application</li></ol>
Time for expert:	5 minutes (assuming required resources are available)
Instructions for user:	—
Notes:	Your workload experience during this task will be assessed.

**Experimental session task #3: Sequencing**

**Table B-3.** Guided orchestration study experiment tasks for sequencing.

Goal:	<ul style="list-style-type: none"><li>• Create sequence chain using uploaded resource</li><li>• Please ensure that appear in the following order: (1) Lecture slides (2) Laboratory exercise (3) Pre-practical tutorial (4) Assignment tutorial</li></ul>
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(Continued on next page)

**Table B-3.** (continued)

Inputs:	<ul style="list-style-type: none"><li>• Your login details: username/password</li><li>• All resources uploaded during ‘Task 2’</li></ul>
Assumptions:	—
Steps:	<ol style="list-style-type: none"><li>1) Login into Simple Orchestra application using your credentials</li><li>2) Sequence tutorial 6<ol style="list-style-type: none"><li>a) Highlight the node corresponding to tutorial 6</li><li>b) Ensure that resources displayed in Resource Panel are correct</li><li>c) Click ‘Sequence’ button</li><li>d) On resulting page, drag resources onto Sequence panel</li><li>e) Order resources in desired sequence</li></ol></li><li>3) Sequence tutorial 7<ol style="list-style-type: none"><li>a) Highlight the node corresponding to tutorial 7</li><li>b) Ensure that resources displayed in Resource Panel are correct</li><li>c) Click ‘Sequence’ button</li><li>d) On resulting page, drag resources onto Sequence panel</li><li>e) Order resources in desired sequence</li></ol></li><li>4) Verify that the final sequence file has output in correct order</li><li>5) Logout of the Simple Orchestra application</li></ol>
Time for expert:	2 minutes
Instructions for user:	—
Notes:	Your workload experience during this task will be assessed.

### B.2.3 Background questionnaire

Guided Orchestration Experiment	Participant#: ...
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#### Section A: Personal details

<ul style="list-style-type: none"><li>• Email address (For us to ping you if necessary) .....</li><li>• Gender<ul style="list-style-type: none"><li><input type="checkbox"/> Male <input type="checkbox"/> Female</li></ul></li><li>• Level of study</li></ul>
--

CS1    CS2    CS3    Honours  
 • Specialisation (e.g. CS, IS) .....  
 • Experience tutoring  
 1 year    2 years    3 years    4+ years  
 • Specify courses you tutor  
 CSC010H    CSC011H    CSC1015F    CSC1016S    CSC1017F

**Section B: Teaching resources**

1) Which of the following CSC1010H educational resources do you use during tutorials?  
 Lecture notes    Assignment tutorials    Video lectures    Assignment pre-practicals    Lab exercises    Other .....  
 2) How do you access educational resources in (1)? .....  
 3) Do you use other teaching resources? **Yes / No**  
 a) If yes, please list example resources .....

**Section C: Teaching with technology**

1) Do you use a computer when conducting tutorials? **Yes / No**  
 a) If yes, is it: ...  
 Laptop    Desktop in tutorial    Desktop in laboratory venue    All of the above    Other (e.g. Tablet) .....  
 2) Which tutorial tasks/activities do you use technology the most? .....  
 3) Do you use Vula (Sakai Learning Management System) during tutorials? **Yes / No**  
 a) If yes, please explain what and how you use it .....  
 4) What software tools and services (e.g. Wing 101 IDE, Word Processor) do you use during tutorial sessions?

**B.2.4 NASA-TLX questionnaire**

Guided Orchestration Experiment	Participant#: ...
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## **NASA-TLX rating scales**

We are not only interested in assessing your performance but also the experiences you had during the different task conditions. Right now, we are going to describe the technique that will be used to examine your experiences. In the most general sense, we are examining the “workload” you experienced. Workload is a difficult concept to define precisely, but a simple one to understand generally. The factors that influence your experience of workload may come from the task itself, your feelings about your own performance, how much effort you put in or the stress and frustration you felt. The workload contributed by different task elements may change as you get more familiar with a task, perform easier or harder version of it, or move from one task to another. Physical components of workload are relatively easy to conceptualise and evaluate. However, the mental components of workload may be more difficult to measure.

Since workload is something that is experienced individually by each person, there are no effective “rulers” that can be used to estimate the workload of different activities. One way to find out about workload is to ask people to describe the feelings they experienced. Because workload may be caused by many different factors, we would like you to evaluate several of them individually rather than lumping them into a single global evaluation of overall workload. This set of six rating scales was developed for you to use in evaluating your experiences during different tasks. Please read the descriptions of the scales carefully. If you have a question about any of the scales in the table, please ask me about it. It is extremely important that they be clear to you. You may keep the descriptions with you for reference during the experiment.

After performing each of the tasks, you will be given a sheet of rating scales. You will evaluate the task by putting an “X” on each of the six scales at the point which matches your experience. Each line has two endpoint descriptors that describe the scale. Note that “own performance” goes from “good” on the left to “bad” on the right. This order has been confusing for some people. Please consider your responses carefully in distinguishing among the different task conditions. Consider each scale individually. Your ratings will play an important role in the evaluation being conducted, thus, your active participation is essential to the success of this experiment and is greatly appreciated by all of us.

## **NASA-TLX sources of workload evaluation**

Throughout this experiment, the rating scales are used to assess your experiences in the different task conditions. Scales of this sort are extremely useful, but their utility suffers from the tendency people have to interpret them in individual ways. For example, some people feel that mental or temporal demands are the essential aspects of workload regardless of the effort they expended on a given task or the level of performance they achieved. Others feel that if they performed well, the workload must have been low and if they performed badly, it must have been high. Yet others feel that effort or feelings

of frustration are the most important factors in workload; and so on. The results of previous studies have already found every conceivable pattern of values. In addition, the factors that create levels of workload differ depending on the task. For example, some tasks might be difficult because they must be completed very quickly. Others may seem easy or hard because of the intensity of mental or physical effort required. Yet, others feel difficult because they cannot be performed well, no matter how much effort is expended.

The evaluation you are about to perform is a technique that has been developed by NASA to assess the relative importance of six factors in determining how much workload you experienced. The procedure is simple. You will be presented with a series of pairs of rating scale titles (for example, Effort vs Mental Demands) and asked to choose which of the items was more important to your experience of workload in the task(s) that you just performed. Each pair of scale titles will appear on a separate card.

*Circle the scale Title that represents the more important contributor to workload for the specific task(s) you performed in this experiment.*

After you have finished the entire series, we will be able to use the pattern of your choices to create a weighted combination of the ratings from that task into a summary workload score. Please consider your choices carefully and make them consistent with how you used the rating scales during the particular task you were asked to evaluate. Do not think that there is any correct pattern. We are only interested in your opinions.

If you have any questions, please ask them now. Otherwise, start whenever you are ready. Thank you for your participation.

### **NASA-TLX rating subscale definitions**

**Table B-4.** Guided orchestration study materials showing NASA-TLX subscale definitions.

Subscale	Endpoints	Description
Mental Demand	Low/High	How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low/High	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?

(Continued on next page)



**Table B-4.** (continued)

Subscale	Endpoints	Description
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Low/High	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration	Low/High	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

**NASA-TLX subscale rankings**

For each of the pairs listed below, circle the scale title that represents the more important contributor to workload in the display.

**Table B-5.** Guided orchestration study results showing NASA-TLX rankings.

Effort	or	Performance	Temporal Demand	or	Frustration
Temporal Demand	or	Effort	Physical Demand	or	Frustration
Performance	or	Frustration	Physical Demand	or	Temporal Demand
Physical Demand	or	Performance	Temporal Demand	or	Mental Demand
Frustration	or	Effort	Performance	or	Mental Demand
Performance	or	Temporal Demand	Mental Demand	or	Effort
Mental Demand	or	Physical Demand	Effort	or	Physical Demand
Frustration	or	Mental Demand	–	–	–

### **NASA-TLX mental workload rating scales**

Please mark “X” along each scale at the point that best indicates your experience with the “[Activity Management|Resource Management|Sequencing]” task.

Mental Demand How mentally demanding was the task?

Very Low           Very High

Physical Demand How physically demanding was the task?

Very Low           Very High

Temporal Demand How hurried or rushed was the pace of the task?

Very Low           Very High

Performance How successful were you in accomplishing the task?

Perfect           Failure

Effort How did you have to work to accomplish your level of performance?

Very Low           Very High

Frustration How insecure, discouraged, irritated, stressed and annoyed were you?

Very Low           Very High

## B.2.5 Perceived Usefulness and Ease of Use questionnaire

Guided Orchestration Experiment

Participant#: ...

### Perceived Usefulness and Ease of Use

Please rate the usefulness and ease of use of the tool.

- Please try to respond to all the items
- For items that are not applicable, use: NA

#### Perceived Usefulness

	Unlikely	1	2	3	4	5	6	7	Likely	N/A
1) Using the system in my job would enable me to accomplish tasks more quickly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2) Using the system would improve my job performance	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3) Using the system in my job would increase my productivity	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4) Using the system would enhance my effectiveness on the job	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5) Using the system would make it easier to do my job	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6) I would find the system useful	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

#### Perceived Ease of Use

	Unlikely	1	2	3	4	5	6	7	Likely	N/A
7) Learning to operate the system would be easy for me	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8) I would find it easy to get the system to do what I want it to do	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9) My interaction with the system would be clear and understandable	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

10) I would find the system to be flexible to interact with

11) It would be easy for me to become skilful at using the system

12) I would find the system easy to use

List the most most **negative** aspect(s)

1) .....

2) .....

3) .....

List the most most **positive** aspect(s)

1) .....

2) .....

3) .....

### B.3 Raw data dump

#### B.3.1 Perceived Usefulness and Ease of Use

**Table B-6.** Guided orchestration study results showing Perceived Usefulness and Ease of Use raw scores.

Participant	Gender	Level	Major	Experience	Courses Tutored					Perceived Usefulness						Perceived Ease of Use					
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	Q01	Q02	Q03	Q04	Q05	Q06	Q07	Q08	Q09	Q10	Q11	Q12
P01	M	CS3	ENG	2	-	-	X	X	-	5	3	4	5	4	4	6	0	5	3	6	7

(Continued on next page)

**Table B-6.** (continued)

Participant	Gender	Level	Major	Experience	Courses Tutored					Perceived Usefulness						Perceived Ease of Use						
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	Q01	Q02	Q03	Q04	Q05	Q06	Q07	Q08	Q09	Q10	Q11	Q12	
P02	M	CS2	CS2	-	1	-	-	X	X	-	5	6	6	6	6	7	7	6	6	5	7	7
P03	M	CS2	IS	1	-	-	X	X	-	6	6	5	5	3	5	5	2	6	4	7	3	
P04	F	CS2	-	1	X	-	-	-	-	6	7	7	7	7	7	6	6	6	7	7	7	
P05	M	CS2	ENG	1	-	X	-	-	-	5	5	4	4	3	4	4	5	3	3	4	4	
P06	M	CS2	CS	1	X	-	-	-	-	5	7	7	7	6	7	6	6	7	7	6	7	
P07	F	CS2	IS	1	-	-	X	X	-	5	6	6	6	6	6	4	4	5	4	6	6	
P08	M	CS2	Games	1	-	-	X	X	-	4	4	5	6	5	5	7	6	6	5	7	5	
P09	M	CS2	CS	1	-	-	X	X	-	3	3	3	3	3	4	7	6	7	6	6	7	
P10	F	CS2	Games	2	-	-	X	X	-	6	5	5	6	6	6	6	6	6	3	7	7	
P11	M	CS3	CS	1	X	X	-	X	-	0	5	5	6	0	3	7	7	4	4	6	6	
P12	M	CS3	IS	2	X	-	X	X	-	6	6	6	6	5	7	7	6	5	3	7	7	
P13	F	CS2	CS	-	-	-	X	-	-	6	6	5	7	5	7	7	7	5	4	7	6	
P14	M	CS3	ENG	1	-	-	X	-	-	3	4	3	1	3	3	7	5	5	4	7	5	
P15	M	-	ENG	2	-	-	X	X	X	2	6	4	5	5	6	7	6	7	5	6	6	
P16	M	CS2	ENG	1	-	-	X	X	-	5	5	6	6	5	7	7	6	6	6	7	7	
P17	M	CS3	ENG	2	-	-	-	-	X	3	5	5	5	3	4	7	7	7	3	7	7	
P18	M	CS3	CS	1	-	-	X	-	-	6	6	6	6	5	6	7	7	7	7	7	7	
P19	M	CS2	CS	1	-	-	X	X	-	6	7	7	7	7	7	7	5	6	6	5	6	

(Continued on next page)

**Table B-6.** (continued)

Participant	Gender	Level	Major	Experience	Courses Tutored					Perceived Usefulness						Perceived Ease of Use					
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	Q01	Q02	Q03	Q04	Q05	Q06	Q07	Q08	Q09	Q10	Q11	Q12
P20	M	CS2	CS	1	-	-	X	X	-	5	6	5	4	4	6	6	7	7	5	6	7
P21	M	CS3	ENG	2	-	-	X	-	-	5	6	6	6	6	5	7	4	7	6	6	5
P22	M	CS3	ENG	1	-	-	X	-	-	5	4	6	6	6	6	7	7	6	7	7	7
P23	F	CS2	CS	1	-	-	X	-	-	5	5	6	5	6	6	6	6	6	5	6	6
P24	F	CS4	IS	3	-	-	-	-	-	1	7	4	4	4	3	3	4	4	4	5	5

### B.3.2 NASA-TLX responses weights and raw ratings

**Table B-7.** Guided orchestration study results showing NASA-TLX pairwise comparison weights.

Participant	Gender	Level	Major	Experience	Courses					Task 1					Task 2					Task 3							
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR
P01	M	CS3	ENG	2	-	-	X	X	-	0	5	3	1	3	3	0	1	2	4	3	5	0	3	5	3	2	2
P02	M	CS2	-	1	-	-	X	X	-	0	4	3	5	2	1	0	1	2	4	4	4	0	2	4	5	3	1
P03	M	CS2	IS	1	-	-	X	X	-	2	3	1	5	4	0	5	0	1	2	3	4	5	0	3	2	2	3
P04	F	CS2	-	1	X	-	-	-	-	1	2	4	5	2	1	2	1	5	4	0	3	0	4	3	4	3	1
P05	M	CS2	ENG	1	-	X	-	-	-	1	4	3	5	2	0	1	4	0	4	4	2	3	2	1	4	4	1
P06	M	CS2	CS	1	X	-	-	-	-	5	1	3	1	3	2	5	1	2	1	4	2	4	3	2	1	5	0
P07	F	CS2	IS	1	-	-	X	X	-	0	2	1	4	4	4	4	0	5	1	3	2	3	0	3	3	3	3

(Continued on next page)

**Table B-7.** (continued)

Participant	Gender	Level	Major	Experience	Courses					Task 1					Task 2					Task 3							
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR
P08	M	CS2	Games	1	-	-	X	X	-	2	2	2	4	4	1	3	2	2	4	4	0	3	1	3	4	4	0
P09	M	CS2	CS	1	-	-	X	X	-	0	2	3	4	5	1	0	1	4	3	5	2	0	1	4	3	5	2
P10	F	CS2	Games	2	-	-	X	X	-	0	5	3	4	2	1	3	1	3	0	4	4	2	3	3	5	2	0
P11	M	CS3	CS	1	X	X	-	X	-	4	0	2	4	3	2	4	1	0	2	5	3	4	0	3	5	2	1
P12	M	CS3	IS	2	X	-	X	X	-	3	1	5	4	2	0	5	0	1	2	4	3	3	2	5	4	1	0
P13	F	CS2	CS	-	-	-	X	-	-	1	4	2	4	4	0	1	0	3	3	5	3	1	4	3	4	3	0
P14	M	CS3	ENG	1	-	-	X	-	-	2	2	2	4	5	0	0	3	2	3	2	5	0	1	2	4	5	3
P15	M	-	ENG	2	-	-	X	X	X	0	3	4	5	1	2	2	1	5	2	2	3	0	1	5	2	4	3
P16	M	CS2	ENG	1	-	-	X	X	-	0	2	3	5	2	3	0	1	3	2	4	5	2	0	5	4	3	1
P17	M	CS3	ENG	2	-	-	-	-	X	0	4	3	2	1	5	1	2	4	0	3	5	1	4	3	0	2	5
P18	M	CS3	CS	1	-	-	X	-	-	3	4	1	0	5	2	4	1	4	0	2	4	5	2	4	0	3	1
P19	M	CS2	CS	1	-	-	X	X	-	2	0	4	4	4	1	2	0	5	3	3	2	2	0	5	4	3	1
P20	M	CS2	CS	1	-	-	X	X	-	1	2	4	5	3	0	4	2	1	5	3	0	4	3	1	4	3	0
P21	M	CS3	ENG	2	-	-	X	-	-	1	0	3	5	4	2	1	2	1	3	5	3	1	1	1	5	3	4
P22	M	CS3	ENG	1	-	-	X	-	-	2	4	3	3	1	2	1	2	3	3	5	1	2	3	3	3	4	0
P23	F	CS2	CS	1	-	-	X	-	-	0	1	4	5	2	3	0	1	3	3	5	3	0	1	5	4	3	2
P24	F	CS4	IS	3	-	-	-	-	-	2	0	5	3	3	2	4	2	1	0	3	5	3	5	2	0	3	2

**Table B-8.** Guided orchestration study results showing NASA-TLX raw ratings.

Participant	Gender	Level	Major	Experience	Courses					Task 1					Task 2					Task 3							
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR
					P01	M	CS3	ENG	2	-	-	X	X	-	1	6	11	5	5	6	2	6	11	6	7	18	2
P02	M	CS2	-	1	-	-	X	X	-	1	2	3	1	1	1	1	4	4	5	5	7	1	1	2	1	1	1
P03	M	CS2	IS	1	-	-	X	X	-	12	13	6	1	15	13	16	8	8	1	17	15	17	5	11	1	17	14
P04	F	CS2	-	1	X	-	-	-	-	4	2	9	14	7	8	7	7	13	13	6	13	9	6	14	15	10	3
P05	M	CS2	ENG	1	-	X	-	-	-	5	7	9	3	3	2	4	10	6	6	9	7	11	6	5	3	11	11
P06	M	CS2	CS	1	X	-	-	-	-	10	4	1	1	5	1	16	4	5	1	5	3	8	6	4	1	5	3
P07	F	CS2	IS	1	-	-	X	X	-	6	2	12	1	6	10	16	1	16	4	16	16	14	1	10	4	12	14
P08	M	CS2	Games	1	-	-	X	X	-	3	6	4	1	10	5	13	11	16	1	8	4	14	7	7	1	8	5
P09	M	CS2	CS	1	-	-	X	X	-	2	2	2	1	3	1	2	4	11	1	12	9	2	4	15	1	15	10
P10	F	CS2	Games	2	-	-	X	X	-	1	9	9	4	12	2	14	12	12	5	14	10	12	4	11	5	7	7
P11	M	CS3	CS	1	X	X	-	X	-	17	1	0	20	12	11	20	4	0	15	19	20	19	9	2	15	15	11
P12	M	CS3	IS	2	X	-	X	X	-	5	3	3	1	2	1	18	7	15	2	20	10	4	1	11	1	1	1
P13	F	CS2	CS	-	-	-	X	-	-	3	2	4	4	3	5	4	5	9	2	11	11	8	9	10	3	6	5
P14	M	CS3	ENG	1	-	-	X	-	-	1	2	2	1	2	3	3	6	4	4	8	9	1	3	3	4	4	3
P15	M	-	ENG	2	-	-	X	X	X	1	2	5	2	1	2	5	5	7	2	4	4	5	3	6	3	4	4
P16	M	CS2	ENG	1	-	-	X	X	-	1	3	2	1	3	1	1	1	3	1	9	10	6	2	3	1	4	1
P17	M	CS3	ENG	2	-	-	-	-	X	1	14	14	1	6	20	4	11	14	1	5	20	3	11	15	1	6	20
P18	M	CS3	CS	1	-	-	X	-	-	1	5	1	1	2	1	11	2	9	3	6	8	3	1	2	1	2	1

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**Table B-8.** (continued)

Participant	Gender	Level	Major	Experience	Courses					Task 1					Task 2					Task 3							
					CSC1010H	CSC1011H	CSC1015F	CSC1016S	CSC1017F	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR	PD	MD	TD	OP	EF	FR
P19	M	CS2	CS	1	-	-	X	X	-	5	7	1	1	7	2	9	3	11	4	9	5	8	1	4	9	10	5
P20	M	CS2	CS	1	-	-	X	X	-	2	5	10	3	6	2	17	5	10	3	5	3	15	5	5	4	14	3
P21	M	CS3	ENG	2	-	-	X	-	-	3	1	3	20	2	1	5	6	6	20	6	12	3	1	4	20	8	11
P22	M	CS3	ENG	1	-	-	X	-	-	1	1	1	20	2	1	1	2	5	20	1	1	1	2	1	20	1	1
P23	F	CS2	CS	1	-	-	X	-	-	1	4	4	2	4	2	1	3	7	3	6	6	1	3	7	2	5	4
P24	F	CS4	IS	3	-	-	-	-	-	15	3	10	1	2	11	19	1	1	4	18	17	11	15	13	3	15	5

# Appendix C

## Orchestrating a flipped classroom

This appendix presents study materials, experiment tasks, questionnaires and raw data dumps for the flipped classroom study described in [Chapter 7](#).

[Appendix C.1](#) presents the experiment tasks and associated questionnaires used in the study. The raw data dump is presented in [Appendix C.2](#).

## C.1 Materials

### C.1.1 Learning experience questionnaire

Flipped Classroom Experiment

Participant#: ...

An orchestration toolkit was used by the lecturer to manage some Computer Architecture classroom activities (pre-session countdown timer, timed quiz, rendering demonstration and discussion information) and we would like to find out your thoughts as pertains to his use of the tool.

A number of changes were made to the tool—for instance, the quiz fading effect was removed. Your responses to the survey should be based on the version used in the last couple of sessions.

Please circle the appropriate options

1) How many Computer Architecture lecture sessions did you attend?

1–3  4–6  7–9  10–13

2) Which range represents the final mark you obtained last semester

75+  60–74  50–59  0–49

3) To what extent do you agree with the following statements?

a) The use of the tool helped in organising the lecture sessions

Strongly Disagree 1 2 3 4 5 Strongly Agree

b) The countdown timer before the lecture session was useful in preparing me for the session

Strongly Disagree 1 2 3 4 5 Strongly Agree

c) The listing of classroom activities (Live Demo, Discussion, Quiz) was useful

Strongly Disagree 1 2 3 4 5 Strongly Agree

4) Do you have any general comments or concerns? .....



**Table C-2.** Flipped classroom study results showing learning experience ratings responses for toolkit usage.

Participant	Lecture Sessions	Exam Scores	Responses			Participant	Lecture Sessions	Exam Scores	Responses		
			Organiser	Timer	Listing				Organiser	Timer	Listing
P01	10–13	60–74	3	2	3	P06	10–13	75–100	2	5	2
P02	10–13	75–100	4	3	3	P07	10–13	75–100	5	4	4
P03	10–13	75–100	4	2	3	P08	10–13	75–100	4	3	4
P04	10–13	60–74	4	4	4	P09	10–13	60–74	5	5	3
P05	10–13	50–59	3	3	2	P010	10–13	75–100	5	4	5
P011	10–13	75–100	4	5	2	P016	10–13	50–59	3	2	5
P012	10–13	75–100	4	2	4	P017	10–13	60–74	4	4	3
P013	10–13	60–74	5	5	5	P018	10–13	75–100	4	4	4
P014	10–13	60–74	2	3	2	P019	10–13	75–100	3	3	3
P015	10–13	60–74	4	4	4	P020	4–6	50–59	3	3	3
P021	4–6	60–74	5	1	1	P026	10–13	60–74	2	2	3
P022	4–6	60–74	4	5	2	P027	10–13	60–74	4	4	5
P023	10–13	50–59	3	2	2	P028	10–13	60–74	3	4	2
P024	10–13	60–74	3	4	4	P029	10–13	75–100	4	2	3
P025	10–13	75–100	3	3	4	P030	10–13	75–100	4	5	4
P031	10–13	75–100	4	5	3	P036	7–9	60–74	2	2	2
P032	7–9	75–100	3	4	4	P037	10–13	50–59	3	3	4
P033	7–9	60–74	4	4	4	P038	10–13	75–100	4	3	3
P034	10–13	75–100	4	3	4	P039	7–9	75–100	2	–	–
P035	7–9	60–74	4	3	5	P040	10–13	60–74	4	4	3
P041	10–13	75–100	4	1	3	P046	10–13	50–59	4	3	4
P042	10–13	75–100	3	5	5	P047	10–13	75–100	5	4	5
P043	10–13	60–74	4	3	3	P048	10–13	50–59	4	3	5
P044	10–13	75–100	4	3	2	P049	10–13	75–100	5	5	5

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**Table C-2. (continued)**

Participant	Lecture Sessions	Exam Scores	Responses		
			Organiser	Timer	Listing
P045	10–13	75–100	3	5	4
P051	7–9	60–74	5	3	3
P052	4–6	60–74	4	3	4
P053	10–13	60–74	5	5	5
P054	10–13	75–100	4	3	3
P055	10–13	75–100	5	5	4
P061	10–13	75–100	4	3	4
P062	4–6	60–74	4	3	4
P063	10–13	60–74	4	4	4
P064	10–13	75–100	4	2	2
P065	10–13	75–100	4	3	3
P071	4–6	60–74	4	4	4
P050	10–13	75–100	4	3	3
P056	10–13	60–74	5	2	4
P057	10–13	50–59	3	3	4
P058	7–9	60–74	3	3	3
P059	7–9	75–100	5	5	3
P060	10–13	75–100	4	3	4
P066	7–9	60–74	4	4	3
P067	4–6	60–74	3	4	3
P068	4–6	60–74	4	4	5
P069	10–13	75–100	5	5	5
P070	10–13	75–100	4	3	4
–	–	–	–	–	–

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## Colophon

This manuscript was typeset with [L<sup>A</sup>T<sub>E</sub>X 2<sub>ε</sub>](#), using the [LuaT<sub>E</sub>X](#) UTF-8 engine, available in the [T<sub>E</sub>X Live](#) distribution. The bibliography was typeset with [BibT<sub>E</sub>X](#), using the [BibL<sup>A</sup>T<sub>E</sub>X](#) package. The main contents were typeset at 12pt with one and a half spacing, using *Liberation Serif*, *Liberation Sans* and *Liberation Mono* type faces (CID TrueType fonts), available in the [fontspec](#) package.

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