Open Learner Model Visualisations in Task-Oriented Portfolio Teaching: Student and Teacher Perspectives

By

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Abstract

The current job market in a knowledge-based society requires continuous development and management of knowledge, skills and competences at all levels. Many higher education institutions have reformed their academic programs to be more outcome-based and student-centred so as to produce graduates who are competitive and sustainable.

Open Learner Model (OLM) visualisations have been used to help learners visualise various learning aspects such as knowledge levels and misconceptions. When students are exposed to their own learner models, there is the potential for them to take greater responsibility for their own learning and to decide for themselves the next course of action to advance in their learning, i.e., to become a more self-regulated learner.

Task-Oriented Portfolio is a teaching and assessment approach based on the principles of Constructive Alignment. Assessment is divided into small tasks aligned to the intended learning outcomes. Students can interact with these tasks and work progressively throughout the semester to attain required learning outcomes, rather than having more traditional 2-3 large high stakes assessment items. Teaching staff facilitate student learning by providing formative feedback to help each student construct their knowledge in small and easy to manage pieces.

This research project designed and evaluated a new independent OLM tool called Doubtfire++. Doubtfire++ supports a Task-Oriented Portfolio approach and provides new features to support student reflection on their achievement in terms of learning outcomes. Doubtfire++ includes novel OLM visualisations that are designed to raise student awareness of their progress and learning outcome achievements as well as to encourage self-regulated learning. A scenario-based design approach was used to solicit user requirements for the design of a new set of OLM visualisations. An explanatory sequential mixed methods research methodology was then applied to collect data regarding prospective user perceived usefulness and preferred representation formats of the proposed OLM visualisations. The results obtained led to the design and development of a new set of OLM visualisations that were implemented in Doubtfire++.

The results of this study indicated that Doubtfire++ is perceived as simple, appealing and easy to navigate besides having depth of information available in different graphs. The visualisations were perceived to be very important in supporting various user roles including the convenors, tutors and students. The teaching staff found that it helped them in creating a supportive learning environment that facilitated student self-regulated learning and students felt supported and rewarded for learning in a self-regulated manner. Both user groups have had a very positive experience using Doubtfire++.

Acknowledgement

Declaration

I declare that,

- This thesis contains no material which has been accepted for the award to the candidate of any other degree or diploma, except where due reference is made in the text of the examinable outcome;

- To the best of my knowledge contains no material previously published or written by another person except where due reference is made in the text of the examinable outcome; and

- Where the work is based on joint research or publications, discloses the relative contributions of the respective workers or authors.

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Chapter 1

Introduction

Facilitation of student self-regulated learning in outcome-based student-centred learning environments has become a hot topic in higher education. The research work in this thesis aims to support student Self-Regulated Learning (SRL) through the application of Open Learner Model (OLM) visualisations in the Task-Oriented Portfolio teaching approach. The application of various open learner model visualisations based on user preferred and perceived useful representational formats have demonstrated the creation of a supportive learning environment that encourages student self-regulated learning in a Task-Oriented Portfolio teaching.

This research effort is built around two key studies, namely Study 1 and Study 2. Study 1 solicits initial user requirements for the design of OLM visualisation representational formats to support the Task-Oriented Portfolio teaching approach. Study 2 investigates user perceptions regarding the use of various OLM visualisations in supporting different user roles in this teaching approach to encourage student self-regulated learning. Results and analysis of these two studies are presented and discussed in this thesis.

Many higher education institutions employ portfolio-based teaching and learning approaches hence supporting a student-centred learning environment besides creating a new learning environment for students. Some researchers have reported on the various benefits of deploying the portfolio-based teaching approach that include increased peer interaction and self-reflection as well as students exposure to a more authentic form of assessment (Kong, Shroff, & Hung, 2009; Orland-Barak, 2005; Pelliccione & Raison, 2009; Shroff, Deneen, & Ng, 2011). Typically, a portfolio-based teaching approach requires students to think about their future in terms of goals so that they can relate their learning goals with their career objectives when demonstrating their achievement in a portfolio or e-portfolio.

Portfolio-based approaches require students to accept more responsibility for their learning, requiring them to work progressively in collecting and showcasing their learning artefacts. These additional responsibilities can be challenging for some students, who struggle to prepare a portfolio for final assessment (Bolliger & Shepherd, 2010). Lack of awareness on

the pedagogical value that the portfolio-based approach can bring to one's personal and professional development has resulted in students who have low motivation towards its usage (Abrami & Barrett, 2005; von Konsky & Oliver, 2012). To this end, Wetzel and Strudler (2005) suggested linking the purpose of deploying portfolio-based teaching to the curriculum and the intended learning outcomes (LOs). This suggestion corresponds to the application of Biggs' idea about Constructive Alignment (CA) (Biggs, 1996).

In facilitating an outcome-based student-centred learning environment, Biggs proposes the Constructive Alignment model (Biggs, 1996). He articulates that the teaching and learning activities underpin active student engagement and thus strongly recommends portfolio assessment. He suggests that the use of portfolio in teaching and learning demonstrates how students could meet the intended learning outcomes, that is, by providing a justification and evidencing their learning with learning artefacts that are related to the intended learning outcomes of a unit. Given the central role of learning outcomes in this model, staff can communicate high expectation by outlining what are expected to be achieved by the students. As for students, they are kept informed about the pedagogical value through the links between learning activities and the intended learning outcomes hence taking greater ownership of their learning.

CA has been applied in various areas of teaching to support a student-centred learning environment (Cain & Woodward, 2012; Gaspar & Langevin, 2012; Hoddinott, 2000; Nightingale, Carew, & Fung, 2007; Thota & Whitfield, 2010). CA approach has also been improved, refined and stabilised through practical action research (Cain, 2013). In order to effectively support student learning in a CA approach, assessment tasks are distributed in small tasks so that each task is firmly linked to the intended learning outcomes. Portfolio is used to enable students to document their learning artefacts as well as to demonstrate their learning outcome achievement. In practising this teaching approach, teaching staff align assessment tasks with the intended learning outcomes of each task. However, the alignment is still vague from student perspectives.

1.1   Motivation for This Study

Open learner model captures and displays a learner's learning state such as concepts known, knowledge levels, difficulties, misconceptions and other learning-related aspects. Additionally, it also offers students a perspective about their learning progress and level of learning outcome achievement. Numerous benefits have been reported when students are exposed to their OLMs. This includes more opportunities for students to collaborate (Bull & Kay, 2005; Bull, Mabbott, & Abu Issa, 2007; Sek, Deng, McKay, & Qian, 2015), enhancing student learning outcomes (Brusilovsky, Somyürek, Guerra, Hosseini, & Zadorozhny, 2015; Long & Aleven, 2013), and prompting student self-regulated learning (Bull & Kay, 2013; Long & Aleven, 2013; Mitrovic & Martin, 2007).

In embracing outcome-based student-centred learning, students have to be supported with a learning environment that provides them with the opportunities to become self-regulated learners. To this end, there is a need for a tool to support staff to communicate expectations by linking the assessment tasks to the intended learning outcomes and to facilitate students' self-reflections as well as their awareness on their achievement of the learning outcomes. Such a tool would also allow staff and students to explore the links between tasks and learning outcomes, besides enabling staff to monitor students' progress towards achieving the learning outcomes, and supporting students to better manage and reflect their learning progress and achievements in terms of learning outcomes.

Open learner modelling applies information visualisation techniques to support learners with information related to their learning progress and achievements. Various information visualisation techniques have been adopted to externalise the learning data that characterize student learning state. Information Visualisation (InfoVis) supports students with various graphic representations to inspect their learning tasks and achievements. Interactive visual representations are used to transform abstract data, information, and knowledge. It is an important research field in aiding users to explore, understand, and analyse data through continuous visual exploration (Shiravi, Shiravi, & Ghorbani, 2012). Such data is useful to both the teaching staff and students for making pedagogical and learning decisions respectively.

Multiple representations have been proposed to support diverse user preferences and information needs as well as to enable users to select a method of their choice for inspecting a

student's learner model (Bull, Gakhal, et al., 2010). However, very few adoption and adaptation of representations are based on experimental data. Most of them solely rely on OLM designer's intuitions. While these intuitions have led to the growth and development of OLM, empirical study is needed to better reach the target end users.

1.2   Research Goals

The main focus of this research work is to encourage student self-regulated learning in Task-Oriented Portfolio teaching based on the CA model through the application of an open learner model visualisation tool called Doubtfire++. The key goal is to create a supportive, outcome-based and student-centred learning environment that facilitates student learning with various OLM visualisations so as to enable them to engage and take greater ownership of their learning.

Creating an effective interface to present a learner model is an important part in open learner modeling. Usefulness of the learner model relies on the use of a clear and effective representational format to facilitate user understanding of the information presented. Existing OLM visualisations can be a good reference but they might not be sufficient to support the depth of user information needs and exploration in a Task-Oriented Portfolio teaching approach. Hence, in this teaching approach, it is necessary to identify the potential users' perceived usefulness and their preferred open learner model representational formats so as to better reach the end users as well as to inspect student learning task status and achievement in terms of learning outcomes. The results can enrich existing OLM visualisations. Besides, it also supports student learning in this teaching approach.

The outcome of the obtained results is the design and development of a visualisation prototype tool to support different user roles including the convenors, tutors and students in a Task-Oriented Portfolio teaching. The results obtained by examining the influence and impact of visual information related to student learning progress and achievement on the teaching staff and students, can be used as a guide to a better understanding of user information needs and exploration.

Also, user experience interacting with the visualisation tool is an important measure to investigate its support to the whole process of the Task-Oriented Portfolio teaching approach. Therefore, this research work also aims to solicit ways to improve the visualisation tool and its use in current practice so as to help the teaching staff to create a supportive learning

environment. Indubitably, this teaching approach facilitates student learning, hence encouraging student self-regulated learning.

1.3 Research Questions

To attain these goals, the research question (*RQ*) for Study 1 has been formulated as follows:

What are user perceived suitable OLM representational formats to present student learning data in terms of task status and learning outcome achievements?

To answer the primary research question, six secondary research questions were developed including:

RQ1: *What representational formats do users perceive as useful for the purpose of presenting learning data in terms of*

  (i)   learning task status?

  (ii)   learning task status statistics?

  (iii)   individual learning outcome achievements?

  (iv)   group learning outcome achievements, and

  (v)   comparison of learning outcome achievements?

RQ2: *What are user perceived preferred representational formats for the purpose of presenting learning data in terms of*

  (i)   learning task status?

  (ii)   learning task status statistics?

  (iii)   individual learning outcome achievements?

  (iv)   group learning outcome achievements, and

  (v)   comparison of learning outcome achievements?

RQ3: *Why is a certain representation perceived to be more useful and preferred?*

RQ4: *How can we enhance the visual representational formats?*

RQ5: *Is there a relationship between user perceived useful visualisations and their preferred visualisations?*

RQ6: *Is there a difference in perceived usefulness of visualisations between staff and students for user perceived most useful and preferred visualisations?*

The primary research question for Study 2 is

How do users perceive the use of Doubtfire++ OLM visualisations in supporting Task-Oriented Portfolio teaching to encourage student self-regulated learning?

Six secondary research questions that follow are:

RQ1: How do users with different roles perceive the usefulness of the OLM visualisation for Task-Oriented Portfolio teaching to support student self-regulated learning?

RQ1 (a): How do users with different roles perceive the use of Shared Student-Centred Visualisations as useful for the purpose of supporting student Self-regulated Phases?

RQ1 (b): How do the teaching staff perceive the use of Teaching Support Visualisations as useful for supporting them in the Task-Oriented Portfolio teaching to encourage student self-regulated learning?

RQ2: How do users perceive the use of Doubtfire++ OLM visualisations in supporting the following user roles in the Task-Oriented Portfolio teaching:

RQ2 (a): Facilitating student self-regulated learning in terms of

(i) Goal setting?
(ii) Performance monitoring?
(iii) Self-reflection?

RQ2 (b): Supporting the teaching staff to facilitate student learning?

RQ2 (c): Supporting convenor in managing the unit?

RQ3: Do different user demographics impact user perceptions of using Doubtfire++ to support student Self-regulated Phases?

RQ4: Do any prior experiences in using Doubtfire++, frequency of use, and different teaching units impact users' perceptions of using Doubtfire++ to support student Self-regulated Phases?

RQ5: Does the use of Doubtfire++ have any impact on student final grades?

RQ6: What is user overall experience in interacting with Doubtfire++?

1.4　　Research Approach

Based on the goal of encouraging student self-regulated learning in a Task-Oriented Portfolio teaching through the application of open learner model visualisations, this research project examines the phenomenon related to target real-world application. It describes, explains and explores the application of open learner model visualisations so as to understand the application as well as to explore possible improvements to better support student self-regulated learning via this teaching approach.

Study 1 adopts a scenario-based design to illustrate the proposed visualisation options to the prospective users through video mock-ups. Explanatory sequential mixed-methods research methodology was then used in both Study 1 and Study 2 to address the research questions that are descriptive, explanatory and exploratory in nature.

This research methodology consists of two distinct phases, including the quantitative strand and the qualitative strand to collect and analyse data as well as to interpret and report the results (Creswell & Plano Clark, 2011). As the research problem stands out to be more quantitative, the quantitative strand has been prioritised for the purpose of addressing the research questions. The quantitative strand was conducted first followed by the qualitative strand. The qualitative strand commenced after the data collection and analysis of the quantitative strand. Although they were two distinct phases, they were connected. Two points of mixing occurred during qualitative data collection and final interpretation. The mixing during qualitative data collection allowed a better exploitation of the qualitative strand as well as added insight into the quantitative results. The mixing during the final interpretation enabled derivation of more comprehensive and in-depth conclusions in response to the research purpose. With the distinct and yet connected phases, results obtained from both strands were interpreted independently, connected in some ways and merged when necessary.

The findings as discussed in this thesis are the results and final interpretations from Study 1 and Study 2 that were derived from this research approach. They provide a complete picture of the application of OLM visualisations and ways to improve the visualisation tool and current practice to better support different user roles as well as encourage student self-regulated learning in a Task-Oriented Portfolio teaching approach.

1.5   Thesis Structure

Chapter One presents an introduction to the research background, motivation of study, research goals, research questions, research methodology and the thesis structure.

Chapter Two provides a comprehensive literature review of portfolio-based teaching, learning outcome and its role in constructive alignment model that forms the foundation of the Task-Oriented Portfolio teaching approach. It also presents the technological tool, Doubtfire that is used to support this teaching approach. The discussion continues with the need to adopt an open learner model to further enhance Doubtfire with additional information visualisation techniques to encourage student self-regulated learning.

Chapter Three discusses the research methodology. From an overview of various research approaches, the rationale of selecting an appropriate research methodology to address the research questions is justified. The mixed-methods approach is presented with a discussion that focuses on the explanatory sequential mixed-methods methodology that is adopted for this research. The application of this research methodology in Study 1 and Study 2 are then discussed to explain the implementation of quantitative and qualitative strands to adequately address the research questions.

Chapter Four describes the adoption and adaptation of various types of existing OLM visualisations and some popular statistical graphic representations for Study 1. The visualisations are proposed for the presentation of five key learning aspects that include visualisations for presenting (i) learning task status; (ii) learning task status statistics; (iii) individual learning outcome achievements; (iv) group learning outcome achievements, and (v) comparison of learning outcome achievements. Scenario-based design that is used to prototype the visualisation tool is also presented.

Chapter Five presents the results of Study 1. This includes descriptive statistics analysis to describe the sample characteristics, the quantitative and qualitative results. A detailed discussion of the findings is presented in the form of a brief summary.

Chapter Six illustrates various OLM representational formats that were designed and developed to support Task-Oriented Portfolio teaching approach. The presentation focuses on two main groups of visualisations known as Shared Student-Centred Visualisations and Teaching Support Visualisations.

Chapter Seven reports the data analysis results of Study 2. The analyses of descriptive statistics for both the quantitative and qualitative sample characteristics are discussed. Results

obtained from quantitative and qualitative strands are presented according to the sequence of the research questions.

Chapter Eight discusses the results obtained from Study 2. The Shared Student-Centred Visualisations is discussed first followed by the Teaching Support Visualisations. The discussion includes user perceived useful visualisations and their use in supporting different user roles in a Task-Oriented Portfolio teaching approach. Factors that could have impacted user perceptions are also discussed. This is followed by user overall experience interacting with Doubtfire++ before it is concluded with a summary.

Chapter Nine concludes the research work. Research questions are revisited to verify research outcomes and accomplishments. This chapter presents the summary of research findings along with its contribution to the fields of open learner modelling, computer education and software development. Research limitations and future research are also discussed.

Chapter 2
Literature Review

2.1   Introduction

Many higher education institutions have reformed their academic programs to be more outcome-based by incorporating intended learning outcomes in their courses. Hence, this reflects students' fundamental content knowledge, skills as well as graduate attributes. Teaching, learning and assessment approaches have been transformed to support such an outcome-based paradigm. Educators are challenged to create a supportive learning environment that facilitates students in taking greater ownership of their learning. Thus, this also teaches them to be self-regulated. In fact, undergraduates of today are increasingly required to retain their learning artefacts which demonstrate their learning outcomes whist preparing themselves for the competitive workplace. To this end, portfolio-based teaching has been used to help students document their learning artefacts and showcase their achievements.

This chapter presents a review of the related literature of the teaching strategies and technological tools that have been used to support outcome-based student-centred teaching and learning environment. The next section discusses the definition of learning outcomes. This is followed by the discussion of constructive alignment model. Portfolio-based teaching and its challenges are then discussed. This leads to the review of self-regulated learning and the application of Open Learner Models (OLM). Lastly, the Task-Oriented Portfolio teaching and an existing technological tool known as Doubtfire that is used to support this approach is reviewed. Additionally, the literature review of these domains provides a solid foundation and justification for a new OLM tool which could better support the Task-Oriented Portfolio teaching besides encouraging student self-regulated learning. The chapter is then concluded with a summary.

2.2   Learning Outcomes (LOs)

In general, learning outcomes are what a learner knows, or can do as a result of learning (Burke, 1995). A learning outcome is a statement of what a learner knows, understands and is able to do on completion of a learning process which covers knowledge, skills as well as personal, social and/or methodological abilities (Najjar & Klobučar, 2009). From the higher education perspective, learning outcomes encompass subject-based outcomes, personal transferable outcomes and generic academic outcomes (Allan, 1996). Allan explains that subject-based outcomes subsume learning objectives and are complex discipline-based outcomes which are capable of being assessed. Personal transferable outcomes include how an individual can act independently, work with others, use information technology, gather information, communicate effectively, and possess organisational skills. On the other hand, generic academic outcomes, refer to the act of utilising information, thinking critically, analysing, synthesising ideas and information.

Yang, Li, and Lau (2014) state that learning outcomes consist of subject-specific knowledge or skills and generic skills which are generally being specified in the syllabus. They define that subject-specific knowledge refers to facts and concepts within a subject domain whereas subject-specific skills refer to the ability to formulate, evaluate, and synthesize matters within a subject. Such skills may be shared among subjects of similar nature. They defined generic skills as the ability that can be applied to various subject domains and student future development.

Learning outcomes as specified in the European Qualification Framework (EQF) capture a broader scope which include theoretical knowledge, practical and technical skills, and social competences where the ability to work with others will be crucial. The European Qualification Framework (EQF) defines learning outcomes as statements of what a learner knows, understands and is able to do on completion of a learning process, which are specified in terms of knowledge, skills and competence (Europen Commission, 2008). In transforming to an outcome-based paradigm, many higher education institutions have embedded graduate attributes as the course learning outcomes.

Graduate attributes that describe the characteristics of graduates demand university graduates to possess skills, knowledge and abilities that exceed disciplinary fundamental content knowledge and generic attributes and to be applicable to a variety of contexts and environments (Barrie, 2004). As a result of globally increasing competition in this knowledge-driven job market, various qualification frameworks have been established to

define skills required and level of responsibility that include graduate attributes in related workplaces and professions. For example, Australian Qualification Framework (Australian Qualifications Framework Council, 2013), Skills Framework for the Information Age, SFIA (SFIA Foundation, 2011) and European Qualification Framework (Europen Commission, 2008) have been drawn up especially to assist graduates for smooth transition from education and training sectors to the labour market. State and federal policy makers too have requested that the institutions of higher education improve the process of measuring student learning outcomes (Tello & Motiwalla, 2010).

In preparing undergraduates for the competitive job market, more and more higher education institutions have embedded graduate attributes and associated learning outcomes with the courses to assess student learning (Klobucar & Najjar, 2010). To this end, associating learning tasks to learning outcomes has become a new trend in course administration as it guides students in their learning besides enabling them to evidence their knowledge and skill levels. The development of learning outcomes not only covers course requirement or teaching and learning strategy but in fact it takes serious consideration of accreditation requirements, job market and industry needs as well as professional standards. As learning outcomes play a central role in the teaching and learning process, this process has undergone a paradigm shift that is from a teacher-centred to a student-centred learning environment. Constructive Alignment (CA) model is a teaching approach used to support such a learning environment that is outcome-based and student-centred.

2.3   Constructive Alignment (CA) Model

Tyler (1949) and Shuell (1986) assert that it is what the student does that accounts for what is learned rather than what the teacher does. Inspired by this proposition, Biggs coined the term "Constructive Alignment" (CA) (Biggs, 1996). Constructive refers to a situation where learners learn by doing or interacting with activities to construct their own knowledge whereas alignment refers to both teaching and assessment that need to be aligned to the intended learning outcomes (Biggs, 2014). CA is an outcome-based driven design for teaching in which the teaching activities are designed around learning outcomes. The assessment methods are designed to engage students to best achieve those outcomes and for assessment tasks to clearly judge student attainment (Biggs, 2014). In this way, students

engage in the learning to achieve the required standard. This means that CA focuses on student-centred learning.

Constructive alignment has been well recognised as a practical framework for improving both the quality of teaching and the quality of learning in tertiary education (McMahon & Thakore, 2006). CA has been widely adopted in various fields of study such as in biology (Hoddinott, 2000), engineering education (Nightingale et al., 2007), programming (Cain & Woodward, 2012; Gaspar & Langevin, 2012; Thota & Whitfield, 2010) and many more. McMahon and Thakore (2006) conducted a comprehensive review of constructively aligned courses and found that the application of CA has brought very positive outcomes to various educational aspects and stakeholders. According to them, CA enables better standardisation for fairer and more reliable assessment, gives greater transparency, provides more effective evaluation, supports programmes of learning with greater coherence and increases the criticality and depth of a student's work.

Constructive alignment aims to create a "web of consistency" in which all aspects of the teaching system are aligned with the unit's intended learning outcomes. This approach requires change in almost every aspect of teaching. For example, change in the preparation of teaching materials and activities in class, availability of learning resources, support for formative feedback and development of intended learning outcomes in engaging student learning in a student-centred environment. Thus, putting CA into practice involves a dramatic shift of a teacher's role from "sage on the stage to a guide by the side" that provide students with the flexibility to construct their own knowledge. This results in a massive change in the teaching approach that is meant to guide and to support students towards this end. Teachers who embrace the CA model in their teaching approach are challenged to create a supportive learning environment.

Besides changes in the teaching aspect, it also involves change in the assessment approach that includes the assessment criteria and instrument. Suggesting active student engagement in teaching and learning activities, Biggs (1996) strongly recommends the use of open-ended assessment format such as portfolio assessment for students to flexibly demonstrate and justify their learning against the Intended Learning Outcomes (ILOs). He opposes the use of examinations or tests as assessment instruments. He comments that these assessment approaches are unlikely to lead students to adopt high cognitive levels as needed for them to achieve high level performances. He embraces portfolio-based teaching in the implementation of the CA model.

2.4   Portfolio-based Teaching

Portfolio-based teaching emerged in the nineties as a key pedagogical strategy to support the teaching and learning process (Lorenzo & Ittelson, 2005). Paulson, Paulson, and Meyer (1991) describe portfolios as a meaningful compilation of student work that demonstrates progress and/or mastery of skills with evidence of student self-reflection. Portfolios are generally classified into three broad categories on the basis of their purpose: (i) assessment or accountability portfolios which serve summative assessment and accreditation purposes; (ii) showcase or marketing portfolios for the presentation of one's achievements and competencies to prospective employers, and (iii) developmental or learning portfolios which facilitate student teachers' reflective learning practices through formative assessment by their tutors and/or peers (Barrett & Carney, 2005; Butler, 2007; Chye, Liau, & Liu, 2013; Granberg, 2010). In reality, the purpose of using portfolios is often a blend of two or more purposes depending on institutional needs and pedagogical designs.

With recent advances in computer applications, electronic portfolios or e-portfolios are being introduced and used in education. An e-portfolio is a software product that supports the collection of one's learning artefacts by documenting one's projects and reflections on learning produced in a course or over one's academic life (Wankel & Blessinger, 2012). Portfolio-based teaching in this thesis refers to both the use of a portfolio or an e-portfolio to facilitate the reflective practice and formative assessment.

Portfolio-based teaching takes advantage of the expected benefits of supporting a variety of student learning activities and showcasing of student achievements. A portfolio provides a safe personal space for students to demonstrate their learning and achievement (Ahn, 2004; Shroff, Trent, & Ng, 2013). It allows sharing of thoughts and ideas among the students to reflect on their progress in order to enhance their skills (Doig, Illsley, McLuckie, & Parsons, 2006). It supports continuous and various forms of feedback throughout the student learning journey in a program (Donnelly & OKeeffe, 2013). As a result, students gain a more meaningful learning experience (Greenberg, 2004) thus enabling them to produce a higher quality of documents and learning artefacts (Bolliger & Shepherd, 2010).

Besides that, it serves a more authentic form of assessment (Bhattacharya & Hartnett, 2007; Cadd, 2016) as compared to more traditional assessment pieces. In this case, portfolio-based assessment supports students in evidencing their learning and achievements with artefacts collected from a single course or a program of study that characterise their personal growth throughout their studies (Abrami & Barrett, 2005). In addition, it involves students in

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ongoing long term self-evaluation and self-reflection practices that documents their continuous development (Shroff et al., 2013). It provides longitudinal views about student learning (Zainal-Abidin, Uisimbekova, & Alias, 2011). In this way, it draws student attention on personal growth and professional development by aligning their learning with future career development (Hallam & Creagh, 2010; von Konsky & Oliver, 2012). It has the potentials to effectively enhance students' personal growth and development planning (Eynon & Gambino, 2017; Gray, 2008).

Portfolio-based teaching has become a popular teaching strategy and extensive research has been carried out in the past few years (Balaban, Mu, & Divjak, 2013; Eynon & Gambino, 2017; Lopez-Fernandez & Rodriguez-Illera, 2009; Mu, Wormer, Foizey, Barkon, & Vehec, 2010; Oliver & Whelan, 2011; von Konsky & Oliver, 2012). A comprehensive portfolio related literature review shows that this teaching approach has widely been used in higher education (Bennett, Rowley, Dunbar-Hall, Hitchcock, & Blom, 2016; Challis, 2005; Hallam & Creagh, 2010; Mccowan, Harper, & Hauville, 2005). Despite the fact that portfolio-based teaching has created a new learning environment and has benefited learners in various aspects, the adoption and deployment of the e-portfolio is not without its challenges.

Among the problems reported include low buy-in by students due to lack of promotion of the e-portfolio system and as to how students could benefit from it (Tosh, Light, Fleming, & Haywood, 2005). A similar finding is evident in another research, e.g. Zainal-Abidin et al. (2011) reports that one of the reasons for the low usage of e-portfolio system among students is the lack of awareness on the importance of the system as well as how it can help them in learning. Students claim that they do not have clear instructions or guidelines on its use and as such they are not sure how the system works. As a result, they are not convinced on its use or on its importance to them. A more specific reason pointed out is that students have difficulty aligning their personal and program goals (Bolliger & Shepherd, 2010). They have a difficult time putting their goals and career objectives in portfolio-based teaching as they do not think about the future in terms of goals. As a consequence, some students struggle to create one, especially when they are needed to submit it for assessment (Bolliger & Shepherd, 2010). Some view the preparation of a portfolio as just another assignment that keeps them busy and they doubt as to why they should even have one (Bolliger & Shepherd, 2010; Tosh et al., 2005). There are students who use it just for the sake of fulfilling the course requirements or as requested by their professor (Ntuli, Keengwe, & Kyei-Blankson, 2009). It

is also reported that students have low motivation in using e-portfolio despite being assessed (Thanaraj, 2012).

Numerous literatures bring to light that students do not see the benefits of using a portfolio or an e-portfolio (Bolliger & Shepherd, 2010; Thanaraj, 2012; Tosh et al., 2005; Zainal-Abidin et al., 2011). Portfolio-based teaching is not well appreciated (von Konsky & Oliver, 2012). In addition, there are students who do not have a distinct goal in their studies. They are not aware of how they could achieve the course learning outcomes and build their competencies through portfolio-based teaching for each course that they undertook (Bolliger & Shepherd, 2010). This could be the main reason for the students' low motivation in using a portfolio or an e-portfolio in their studies.

Motivating and engaging students in portfolio-based teaching is challenging. Abrami and Barrett (2005) suggest that students could be encouraged by allowing them to take ownership and control on the construction of the portfolio. This could be done by allowing them to relate on its effectiveness and pedagogical value. Zainal-Abidin et al. (2011) suggests that efforts need to be taken to create and increase students' awareness on the purpose of having a portfolio. The reasons and benefits for constructing portfolios should be clearly articulated (Klenowski, Askew, & Carnell, 2006). Wetzel and Strudler (2005) posit on the importance of linking the purpose of using the portfolio to the curriculum and to the intended learning outcomes.

These are some of the suggestions to retain the value of using and engaging with portfolio-based teaching and to increase students' awareness on the e-portfolio system. Students should not be left ignorant of how the e-portfolio system works. They should not be confused about the course learning outcomes and anxious about the overall workload and time consumed in preparing an e-portfolio. Students should be fully supported. The value of using an e-portfolio can be retained by making the scope clear to students. This includes the nature and purpose of engaging in portfolio-based teaching. This reveals that while the nature of portfolio-based teaching provides students with more flexibility and control over their learning, students have to be kept aware of the pedagogical value of preparing a portfolio. Their learning has to be supported so as to enable them to work progressively in a self-regulated manner and to achieve the intended learning outcomes.

2.5   Self-regulated Learning (SRL)

Each individual student is different from other students in terms of backgrounds and modes of learning. Social cognitive researchers ascribe these differences to the way students self-regulate their learning process (Schunk, 1989; Zimmerman, 2002). An extensive research work carried out by Zimmerman and Schunk (2001) reveals some exciting findings on the origins, characteristics and development of the self-regulated learning processes. Self-regulation is neither an innate mental ability nor academic performance skills (Zimmerman, 2002). It is a self-directive process in which a grasp of it enables the learners to transform their mental abilities into academic or task-related skills (Zimmerman, 2002). It involves the thoughts, feelings, and behaviors that are elicited from oneself in attaining goals (Zimmerman, 2000).

Self-regulation is teachable and can be enhanced by using high-quality self-regulatory processes (Schunk & Zimmerman, 1998; Zimmerman, 2002). For example, close self-monitoring allows students to discover any subtle progress in their learning that gives them self-satisfaction. This increases their self-efficacy in performing a higher level of skills (Schunk, 1983). Self-regulated learners view learning as an activity they do for themselves and as such they learn in a proactive way. Their motivation to learn emanates from the use of self-regulatory processes, such as self-monitoring.

Zimmerman (2002) delineates on the difference in learner profile in relation to different levels of self-regulatory, low versus high self-regulatory. Learners with low self-regulatory fail to set distinct personal goals. They do not have a systematic way to self-monitor their performance. As their personal goals are vague, they are inclined to comparative self-evaluations in which they judge their performance against other learners. They attribute their learning difficulties to the lack of their inherent ability. They are defensive in changing their learning strategy. As a result, they have low personal satisfaction and there is no initiative to improve their performance.

In contrast, learners with high self-regulatory set hierarchical goals, starting from process goals to outcome goals which they could achieve in succession. They apply powerful and varied strategies to plan and self-monitor their performance. They judge their performance against their personal goals. They attribute any failure to the learning strategies used. They are receptive in changing any unsuitable strategies. As a consequence, they have a greater personal satisfaction and strive to improve their performance in achieving the goals set. These

self-reactions enhance their various self-motivational beliefs such as self-efficacy and intrinsic interest so that they could pursue their learning goals and succeed in the learning.

Self-regulation is believed to have positive effect on learner behaviour and their acquisition of academic skills. Self-regulated learners are found to be high achievers and are more confident than their peers (Pintrich, 1995; Zimmerman & Campillo, 2003). Several researchers have shown positive academic outcomes in using SRL strategies in traditional settings of learning (Beishuizen & Steffens, 2011; Richardson, Abraham, & Bond, 2012), online learning environment (Cho & Shen, 2013; Dignath & Büttner, 2008; Klingsieck, Fries, Horz, & Hofer, 2012) and blended learning (Tongchai, 2016).

It is important to understand the self-regulation phases and processes. Self-regulation consists of three distinct phases: forethought, performance monitoring and self-reflection (Zimmerman, 2002; Zimmerman & Campillo, 2003) as shown in Figure 2.1. The phases explain the combination of the application of specific learning processes, self-awareness, and motivational beliefs in becoming self-regulated learners.
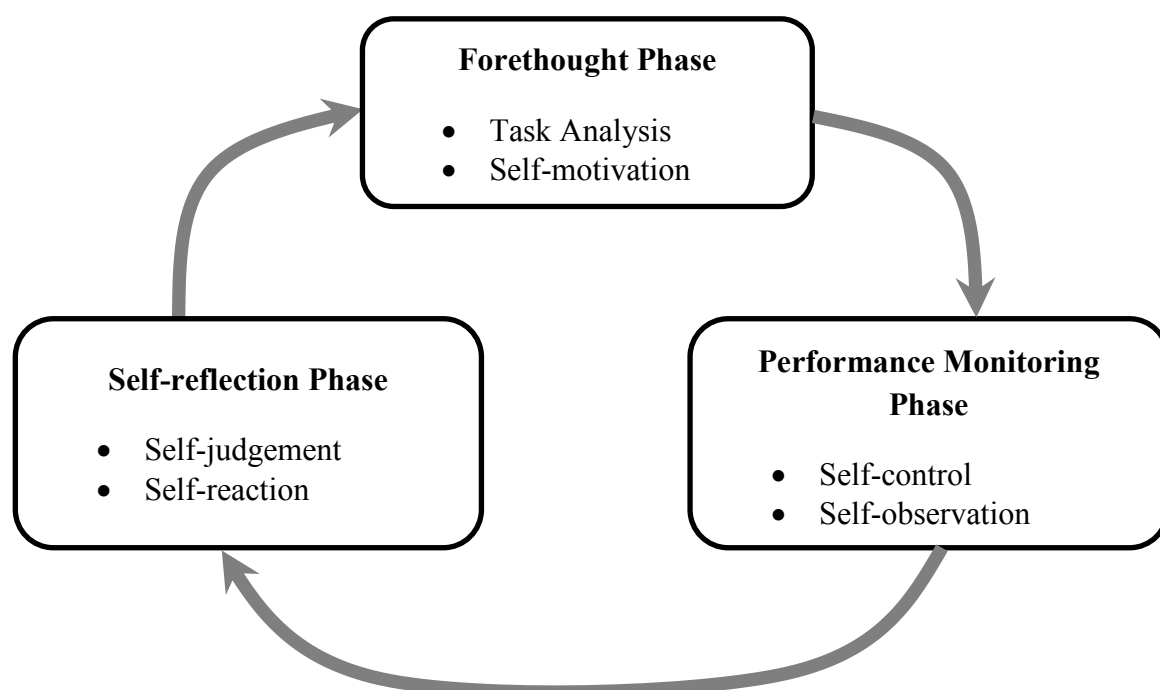
Figure 2.1 Phases and processes of self-regulation

2.5.1 Forethought Phase

The forethought phase involves the processes and learners' beliefs prior to their learning efforts. Two main classes of the processes in this phase include task analysis and self-motivation. Task analysis includes goal setting and task planning needed for learning. Self-

motivation emanates from student beliefs about their learning. This includes their beliefs about their personal capability to learn and the personal consequences of learning such as expected gain or outcome in learning that they will benefit from. The plans made, goals set, and their firm beliefs in this phase have an impact on their strategies planned to be used in the next phase that is the performance monitoring phase.

2.5.2   Performance Monitoring Phase

Performance monitoring phase is a task implementation phase. Two main classes of performance phase processes are known as self-control and self-observation. This involves learner control of strategies and monitoring techniques to engage in learning. Self-control involves the deployment of specific strategies that have been chosen in the forethought phase such as attention focusing and task strategies. Attention focusing means the learner locates a distraction-free place or time to study. Task strategies involve the implementation of the tasks including the sequence, scope, and direction that have been planned with appropriate use of available resources to achieve the task goal. Self-observation involves self-recording and self-monitoring of personal events to gauge the cause of these events. For instance, students are encouraged to record the time to keep them conscious about the total time they take to complete a piece of work. Self-monitoring includes learners' involvement in tracking their own functioning such as identifying the learning activities that need to be completed or redone and the number of activities that remain. The outcomes of the implementation phase are experienced and are evaluated in the following phase through self-reflection.

2.5.3   Self-reflection Phase

The self-reflection phase comprises of processes that are carried out after each learning effort. The processes consist of two main classes known as self-judgment and self-reaction. An example of self-judgement relates to the learners ability to self-evaluate and to benchmark their performances against some standards such as their prior performance, others' performance or a set standard. Another example of self-judgement relates to learner beliefs about the cause of errors made or success attained. Such a belief has a great impact on a student's motivation. Attributing failure to limitation of ability will refrain a student from making improvement to succeed. Ascribing it to controllable processes such as adoption of inappropriate strategies and changing to different strategies will sustain a learner's motivation thus leading to future success. Another aspect of self-reaction concerns learner feelings of self-satisfaction and their responses to the feeling. Self-satisfaction has great impact on the learners' motivation and their efforts invested in learning. Higher self-satisfaction drives

motivation whereas lower self-satisfaction restrains learners from putting further efforts in learning. As a result, learners will respond in an adaptive or defensive way. Adaptive reaction means learners modify their learning strategies to increase the effectiveness of the learning method. When learners take a defensive reaction, effort is used to protect their self-image such as by being absent from class or withdraw from a course.

Self-regulation is a cyclical process in which the result of self-reflection will impact learners' future task analysis and implementation as well as to re-engage with the subsequent forethought phase. It is a self-directive process that enables learners to actively involve in their own learning, plan for their learning strategies, monitor the effectiveness of the strategies and suitably adapt to any changes of strategies towards achieving their desired goals. It is important that learners are aware of their own thought process in order for them to be self-regulated. Understanding the self-regulation processes enable learners to manage their thoughts, feelings and behaviours and transform them into skills for learning. To this end, information visualisation techniques that have been widely recognised in aiding user data exploration and analysis is posited to provoke learner thought process and to encourage their self-regulated behaviour.

2.6   Information Visualisation Techniques

The field of Information Visualisation (InfoVis) has undergone unprecedented growth and development. This is due to easy access of robust technologies and advancement of technological capabilities that lead to greater accessibility and visibility of data. Many information visualisation techniques have been developed for information exploration and communication tasks. Its growth and development can be traced from the two fundamental components that form the core of InfoVis: (i) The representation component and (ii) The interaction component. The representation component is underpinned by the field of computer graphics, for data to be mapped with representation in order to display it in an understandable format to the users (Yi, Kang, Stasko, & Jacko, 2007). The interaction component is underpinned by the study of human-computer interaction (HCI). It opens up the communication loop between the user and the system for the user to explore and gain better insights of the data set (Yi et al., 2007).

Information visualisation is an important research field as it aids users to explore, understand, and analyse data through continuous visual exploration (Spence, 2014). It has become an

important research field and has influenced a variety of domains such as business (Asahi, Turo, & Shneiderman, 1995), healthcare (Saary, 2008), network security (Shiravi et al., 2012) and many more. Extensive studies and research work have been carried out to create new representation and interaction techniques, to improve existing techniques as well as to integrate old and novel techniques to better support diverse user needs in various applications.

While researchers in this field endeavour to find out generic representations and interactions for the application in different domains, some studies have shown that specific representation and interaction techniques are needed for more effective visual exploration in a specific application (Liu, Cui, Wu, & Liu, 2014) such as its application in open learner model research (Law, Grundy, Vasa, Cain, & Cummaudo, 2017). This is because the usefulness of a specific form of representation and interaction technique is affected by many factors especially the stakeholders who will use it for information exploration. Potential end user perceived usefulness of information visualisation formats is an important research field of study in information visualisation as it enables end users to better accommodate their information needs while performing their tasks. Many representation techniques have been adopted and adapted from information visualisation and are used as OLM representations to externalise various learning data that are of interest to teaching staff and students.

2.7   Open Learner Models (OLM)

An OLM is a computer-based representation of a learner's learning aspect that is accessible by the learner it represents. The OLM concept originated from Intelligent Tutoring Systems (ITS). In ITS system, there are three main components, that is, a domain model, a pedagogical model and a learner model. The domain model consists of subject of study such as the topics, concepts and interrelationships of concepts. The learner model keeps the system's inference about an individual learner's understanding of the domain knowledge based on his/her interaction with the system by means of tests or problem solving. The pedagogical model contains the knowledge infrastructure required to customise the presentation of the teaching material based on the student model. It enables the teaching staff to support personalisation of their teaching for the learner (Jeremić, Devedžić, & Gašević, 2004). The learner model plays an important role for initiating personalisation in an ITS (Bull & Kay, 2013). The learner models are stored in a machine-usable format in order for the system to adapt the interaction and to provide individualised instruction to students.

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Traditionally, this format is illegible and the learner models are invisible to the students. Self (1990) has proposed to expose students to the learner model in view of its great potential in terms of educational value and the supporting benefits gain when students are exposed to their own learning models.

In ITS, a leaner model may contain a learner's concepts known, knowledge level, difficulties and misconceptions (Bull & Kay, 2013). The learner model enables ITS to intelligently track student knowledge or skill mastery level. The ability to access the learner model is advantageous to students as they could self-evaluate their progress in various aspects of the domain (Bull & Kay, 2013). This helps them to decide how to proceed with their learning as well as to identify problem that needs to be tackled in order to improve their learning. In this way, the learners gain a sense of autonomy whereby they could make decisions as to the learning activities that they could undertake so as to advance in their learning. They are also able to facilitate the application of metacognitive skills. This helps them to manage their learning in a better way while they interact with the system during the learning.

Bull (2004) found that many students were receptive to the use of OLMs. The direct involvement of learners in engaging with the development of their learner models not only significantly contribute to the maintenance of their model but is also essential in building comprehensive and accurate learner models (Bull & Kay, 2010). At the same time, learners are able to get immediate feedback and response about their current status of learning. The adoption of OLM increases their awareness of their knowledge level and understanding in a specific domain hence prompting them for metacognitive activities such as planning and self-monitoring (Bull, Brusilovsky, Guerra, & Araujo, 2016; Mitrovic & Martin, 2007). The use of OLM can also encourage learner autonomy with increased responsibilities towards their learning processes (Bull et al., 2015; Bull & Kay, 2016).

In addition, it increases learner engagement in the learning process and provides them with better motivation (Brusilovsky et al., 2015; Bull & McKay, 2004; Mitrovic & Martin, 2007). Furthermore, the adoption of OLM promotes learner reflection, which is critical for improving the effectiveness and efficiency of learning in the teaching and learning process (Bull & Pain, 1995; Dimitrova, Self, & Brna, 2000; Long & Aleven, 2013). OLM also provides opportunities for peers, instructors, teachers, and parents to inspect the learner model to facilitate collaboration in teaching and learning (Bull & Kay, 2005; Sek et al., 2015). OLMs are found to be beneficial to both instructors and students in the teaching and learning process as it supports them with information and data in the form of multiple analyses and

visualisations (Kickmeier-Rust & Albert, 2013; Reimann, Bull, Kickmeier-Rust, Vatrapu, & Wasson, 2015).

One of the key challenges in OLM research is the creation of an effective interface to present the learner model and to support user interaction (Bull & Kay, 2010). A wide range of representations have been used to present OLMs. Many representation techniques have been adopted and adapted from information visualisation to be used as OLM representations to externalise various learning data that are of interest to teaching staff and students.

2.7.1 *Various Visualisations Used in Related OLM Research*

There are many visual representational formats that have been developed for open learner models. Their format can be in a simple form, such as a skill meter, or in a more complex form, such as a hierarchical tree structure (Bull & Kay, 2007). The following lists are some examples of OLM visualisations and their applications.

- Skill meters have been used to present a student's progress on domain concepts (Mitrovic & Martin, 2007) and to show student knowledge level and misconception on a topic (Ahmad & Bull, 2009; Bull, Jackson, & Lancaster, 2010).

- Smiley faces have been used to present student knowledge level (Bull & McKay, 2004), to display the development of learning for a specific concept which is known as pedagogical target (Girard & Johnson, 2008) and to show student competencies (Johnson, Bull, & Kickmeier-Rust, 2013).

- Concept maps have been used to show the domain concepts learnt and their relationships (Mabbott & Bull, 2006; Maries & Kumar, 2008; Pérez-Marín & Pascual-Nieto, 2010) and to display student conceptual models (Pérez-Marín, Alfonseca, Rodríguez, & Pascual-Nieto, 2007).

- Mabbott and Bull (2006) and Conejo, Trella, Cruces, and Garcia (2012) have used tree structures to describe a learner's understanding of a subject learnt based on a color scale.

- Albert, Nussbaumer, and Steiner (2010) have used bar graphs and matrix to present student knowledge level for the concepts learnt from a lesson and to show activities performed for a class respectively.

- Pie charts have been used to show relative weight in the total knowledge achieved in the course (Mazzola & Mazza, 2010) whereas tables have been used to display competences achieved (Mor, Guerrero-Roldán, Hettiarachchi, & Antonia Huertas, 2014).

- Targets and arrows have been deployed to guide students in deciding what to learn next (Brusilovsky & Sosnovsky, 2005).

- Grid has been used to show student progress, class progress and comparison between student and class progress by topics (Brusilovsky et al., 2015). A combination of graphical and textual representations have been administered in some research to reveal the open learner models (Bull, Johnson, Alotaibi, Byrne, & Cierniak, 2013; Mazzola & Mazza, 2010).

Some researchers have found that users prefer certain representations to view their learner models. For example, Duan, Mitrovic, and Churcher (2010) report that users prefer simple representations such as skill meters to more complex visualisations. While simple representations are more popular, some complex representations can offer more in-depth information exploration and needs (Brusilovsky et al., 2015; Bull & Kay, 2007). Simple representations use less complicated externalisations and normally present data of a single variable. Complex visualisations are used to show hierarchical data and relationships among data (Bull, Gardner, Ahmad, Ting, & Clarke, 2009). Simple representations enable a viewer to comprehend the data at a glance whereas complex visualisations require the viewers to have sufficiently advanced analytical mind and skills to interpret the information contained in the representations.

The types of visual representations are also affected by the types and number of data they represent. Concept maps have been found to be significantly more effective than a set of skill meters to synthesize an overview of the topic in an open learner model (Maries & Kumar, 2008). Table is believed to outperform graphics for presenting small data sets, e.g. not more than 20 (Tufte, 2001). Tabular formats have also been found to be incomprehensible with a poor logical organisation and difficult to support instructors to track student data (Mazza & Dimitrova, 2004). From the comparative perspective, the shape of the data provides meaningful interpretation and therefore graphics are preferable to tabular formats in textual form (Tufte, 2001). Word cloud is perceived to be useful as it provides an easy way to quickly identify the strongest or weakest competencies but it is not able to provide a hierarchically structured view (Bull et al., 2015). The use of hierarchical tree is perceived to provide ease of understanding in comparison to concept map or network links especially in presenting relationships such as knowledge level by topics or subtopics (Bull et al., 2016). In addition, multiple representations have been found to be useful to accommodate user different visualisation preferences and information needs as well as to provide flexibility for

users to select a method for inspecting the data in their learner models (Bull, Gakhal, et al., 2010).

Bull et al. (2013) recommend the provision of text feedback in addition to multiple graphical forms of OLM views as it provides a narrative description to help students have a better understanding of the learner model representations. Moreover, the stakeholder who will view the intended data is a factor to consider in determining the representation formats used. For example, the Next-TELL (Next Generation Teaching, Education and Learning for Life) open learner model tool has been used to support a variety of stakeholders including students, teachers, parents, peers, school administrators, policy-makers and researchers. It has eight visualisation formats for users to inspect the learner model information related to competencies. These visualisations include skill meters, tables, smiley faces, histograms, word clouds, radar plots, tree maps and network diagrams (Bull et al., 2013).

The effective use of OLM representational formats is closely related to the learning aspect it represents, the depth of information, the stakeholders who inspect it and the purpose of inspection. There are many purposes for exposing a learner to the learner model such as to promote a learner's metacognitive skills, improve learner model accuracy and learner trust on the system, facilitate learner competition and navigation as well as to respect the right of obtaining information about oneself and for assessment purposes (Bull & Kay, 2016). The use of OLM also supports the metacognitive skills of the teacher as the OLM reveals the learning progress of a class and other relevant cohorts that help the teacher to assess the effectiveness of their own teaching strategy (Bull & Kay, 2013; Reimann et al., 2015).

2.7.2 *Independent Open Learner Model*

Tremendous growth of the web technology has provided support for the learner model. This leads to the reuse of some parts of the learner model by other learning applications or allow the creation of learner model from multiple learning applications (Kay, Kummerfeld, & Lauder, 2002; Zapata-Rivera & Greer, 2004). As a result, the growth has transformed the role of leaner model from being contained within the teaching system of ITS to the outside of ITS (Bull & Kay, 2016). These OLMs are known as independent open learner models (Bull et al., 2012; Conejo et al., 2012). Such transformation makes the OLM play an important role as a provider of learning information thus promoting metacognitive processes among the learners besides encouraging student independent learning outside the system (Bull & Kay, 2013, 2016). The metacognitive processes include:

(i)   creating learner awareness of their progress;

(ii)   performing self-evaluation;

(iii)   encouraging reflection on their understanding;

(iv)   prompting student planning for their learning;

(v)   facilitating student independent learning;

(vi)   promoting collaborative interaction and problem-solving; and

(vii)   assisting learners to take greater ownership of their learning (Bull et al., 2013; Bull & Kay, 2016).

There have been increasing use of independent OLMs due to their strong support for self-regulated learning (Bull et al., 2015). The use of independent OLMs helps the learners to perform self-evaluation on their learning including knowledge gained, problems encountered, and to plan further by allocating time and effort to advance in their learning. Thus, it is inherent that while learner progress is unveiled through these OLMs, learners themselves are responsible for determining how they want to advance in their learning. Independent OLM is not used to teach the domain content, instead it serves the purpose of facilitating independent learning and support learners in making decisions for their learning. Thus an independent OLM may or may not have a domain model.

Two examples of independent OLMs that have been used to support student learning alongside classroom lecture are UK-SpecIAL and Next-TELL independent OLM. UK-SpecIAL is used to raise learner awareness of learning outcomes progress across various course components of a degree (Bull & Gardner, 2009). Next-TELL constructed the learner model from multiple sources of data, such as student self-assessments, Facebook discussion, multiple choice questions, and others (Bull et al., 2013). Besides, it is used to support student understanding of their learning and to potentially support peer interaction (Bull et al., 2013).

2.8   Task-Oriented Portfolio Teaching

Programming is a basic and yet a critical skill in pursuing Computer Science and Software Engineering related degrees. Therefore, in most universities, students are taught programming at the beginning of their degree courses. However, learning to program is generally recognised by students as being problematic and challenging (Cain & Woodward, 2012; Thota & Whitfield, 2010). McGettrick et al. (2005) argue that providing simpler models of computing as a discipline is one of the seven grand challenges in computing

education. In view of the problems and challenges in this area, many strategies and practices have been proposed or tried out to improve the way programming is taught and learnt. To this end, Constructive Alignment (CA) (Biggs, 1996) has been applied in computing education research as a means of improving student learning outcomes in the teaching of programming (Cain & Woodward, 2012; Gaspar & Langevin, 2012; Thota & Whitfield, 2010). Extensive research work in CA had been carried out by Cain (2013) through action research to confirm a teaching strategy to improve student learning outcomes. Task-Oriented Portfolio teaching approach is a teaching strategy that has resulted from this research work. This teaching approach is based upon the principles of constructive alignment, with an additional focus on frequent formative feedback (Cain, 2013). Figure 2.2 illustrates this teaching approach.
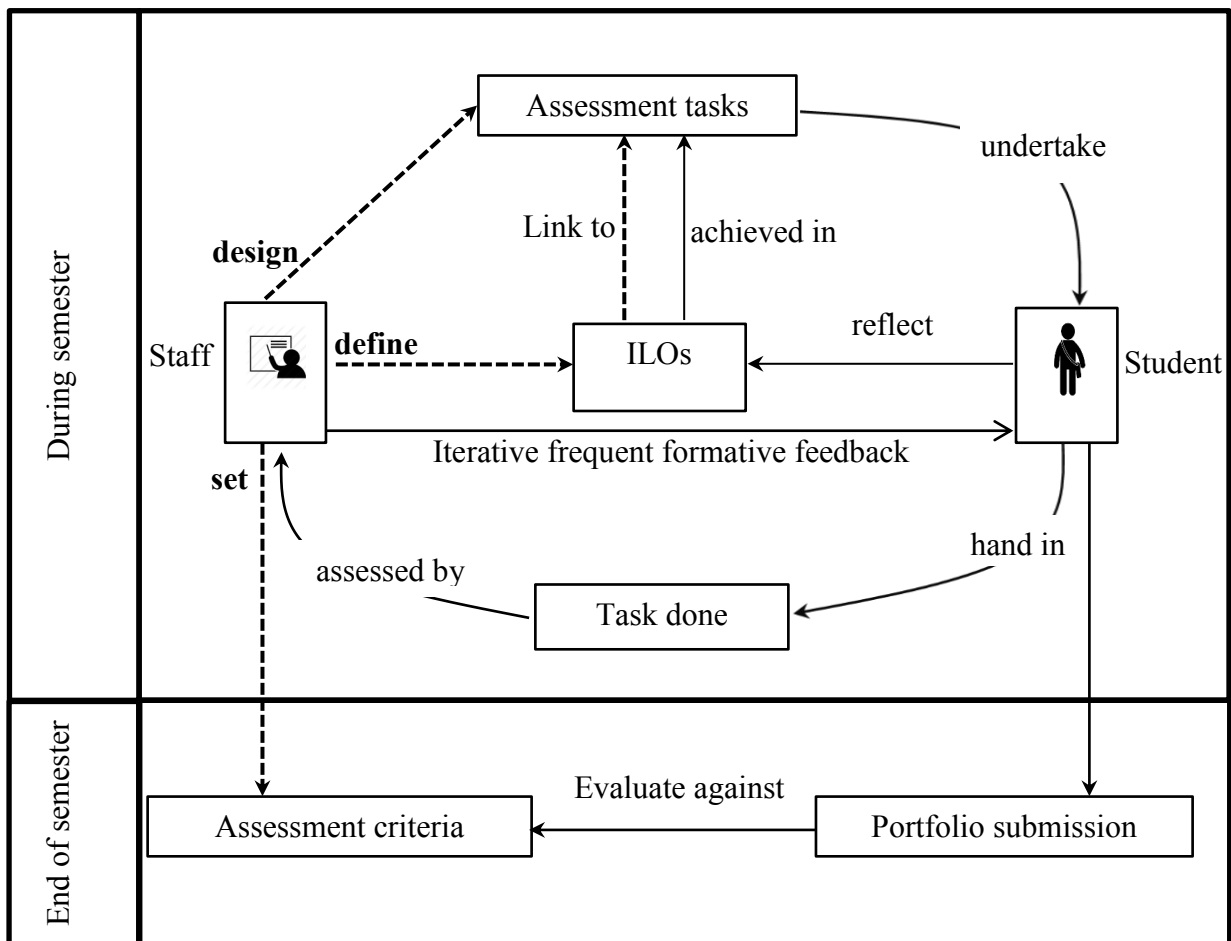
Figure 2.2 Task-Oriented Portfolio teaching approach

This approach begins with the setting up of the teaching context by the teaching staff namely by: (i) defining learning outcomes, (ii) setting assessment criteria, and (iii) designing teaching and learning tasks. As with other approaches to constructive alignment, the learning outcomes guide all the other activities, and are therefore defined at the start of the unit design.

The aim of this process is to define what all students need to demonstrate in order to pass the unit. Once outcomes are set, assessment criteria need to be defined to indicate how students can demonstrate these outcomes to different grade standards. Student activity is then directed by defining a range of tasks designed to help students achieve the unit learning outcomes to each of the grade standards. These tasks can be allocated to different grades, meaning that a Pass can be achieved if all Pass related tasks can be achieved to an adequate standard. Similarly, a Credit can be achieved by satisfactorily completing all Pass and Credit related tasks.

Within this teaching system, the method of unit delivery changes is student-centred, whereby students aim to achieve a given grade by working through the related tasks. During unit delivery, students work on tasks and submit this work for formative feedback. Staff assess student work and provide feedback with the aim of helping the students improve their work besides addressing any misconceptions. Where the task is of a good standard, it is signed off by the staff as being Complete, otherwise students are asked to fix and resubmit the work. This helps to ensure that students take notice of formative feedback, and that this feedback is then acted upon to help inform student learning.

At the end of the teaching period, students use the work that they have completed through the unit's tasks to create a portfolio. Student portfolios are then assessed in order to determine final student grades. The assessment process uses the unit's assessment criteria and unit learning outcomes to determine the results. This process can then be informed by the status of each student's tasks, with the assessor knowing that those that have been marked are complete and have been assessed by staff thus demonstrating the required knowledge.

This approach to unit delivery addresses the scalability issues suggested by Biggs, and has been implemented in units involving hundreds of students. It also helps to change the student-teacher dynamics, with students being more receptive to constructive criticism as this feedback could be used to help them achieve the grades that they aim to achieve. The success of this teaching approach is supported by a number of resources and technological tools. A web application called Doubtfire is specially developed (Woodward, Cain, Pace, Jones, & Kupper, 2013) to support this form of teaching and will be discussed in the following section.

2.9   Doubtfire

With learning outcomes playing a central role in the Task-Oriented Portfolio teaching approach, assessment tasks are firmly linked to the intended learning outcomes. Large assessment items are broken down into small tasks enabling teaching staff to provide fast and frequent feedback. This helps students to develop appropriate understanding and address any misconceptions as early as possible. Doubtfire is a web application designed to support the frequent formative feedback cycles of the Task-Oriented Portfolio teaching approach in teaching introductory programming units (Woodward et al., 2013). It has been used by teaching staff to outline assessment tasks and to provide feedback to students.

Doubtfire has two key visualisations known as Task List and Burndown Chart as shown in Figure 2.3 (Woodward et al., 2013). Different colours are used to enable students to track the status of each task in Task List. The Burndown chart adopts the Agile Scrum technique to present student learning tasks remaining by week. Through these visualisations, students can visualise all the task statuses and are aware of the remaining time to complete the assessment tasks. This enables them to track their progress and manage their time in completing the tasks. In this way, they are responsible to self-evaluate their own learning progress. Doubtfire is an example of an OLM tool.
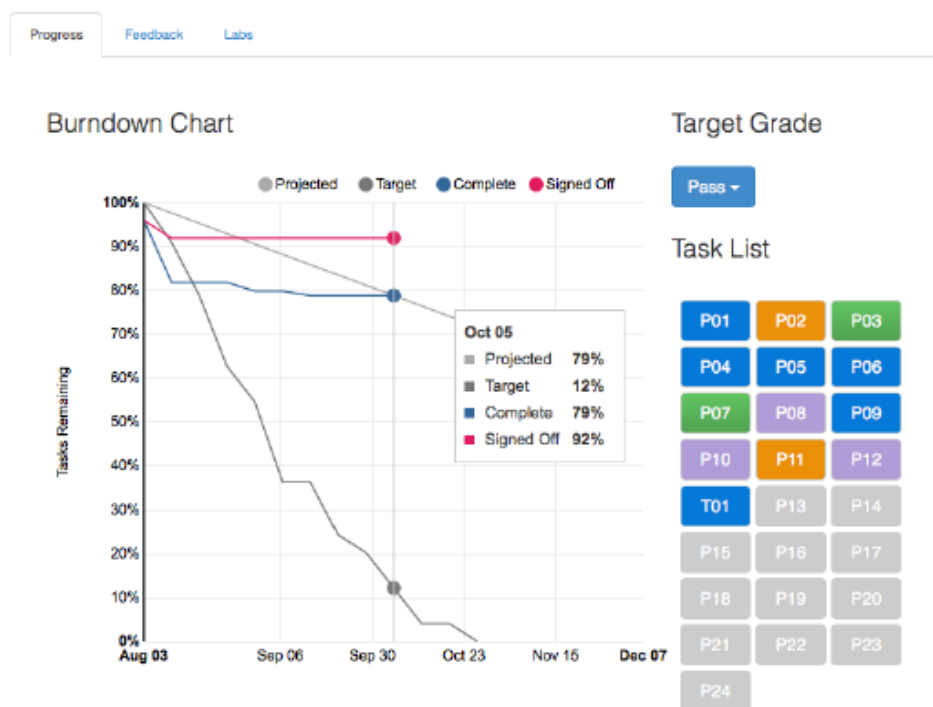
Figure 2.3 The Task List and Burndown Chart in Doubtfire

Figure 2.4 illustrates the use of Doubtfire in supporting the frequent formative feedback in the Task-Oriented Portfolio teaching. Within Doubtfire, students can view the unit's assessment tasks and hand in work for feedback. Staff are then able to provide formative feedback and sign tasks off as complete, or require students to resubmit their work. The thick curved arrows in Figure 2.4 denote frequent formative feedback provided by the teaching staff to support learning in the Task-Oriented Portfolio teaching environment. Doubtfire keeps both the teaching staff and students aware of student progress in managing the assessment tasks. Doubtfire has been used in the teaching of programming units and to address issues regarding time management in a Task-Oriented Portfolio teaching (Woodward et al., 2013).
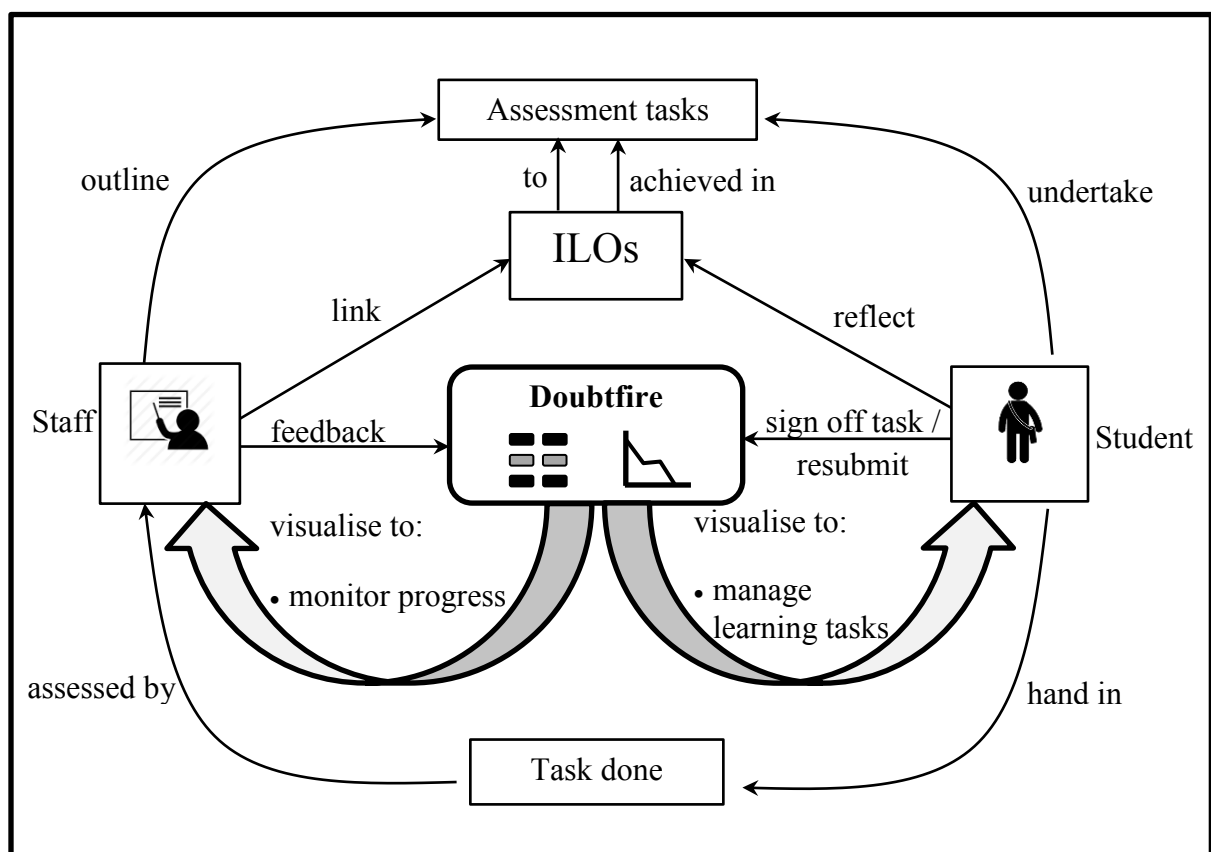
Figure 2.4 Doubtfire in supporting the Task-Oriented Portfolio teaching

Although Doubtfire has many features to support Task-Oriented Portfolio teaching, it lacks good features that can be used to support student reflection of their achievement in terms of learning outcomes. There is no direct support for indicating which tasks are related to which learning outcomes, from either a staff or student perspective. In addition, previous research

on the use of Doubtfire indicates that there may be a potential misalignment issue between staff expectations and student experiences of the assessment tasks (Cain, 2013). This may be because although staff created and aligned assessment tasks with the intended learning outcomes, students might attempt the assessment tasks with different approaches and interpretations. There is no way to see the links between the assessment tasks and the learning outcomes. There is also no evidence to track student progress or achievement in terms of learning outcomes. Despite the success of the Doubtfire tool and Task-Oriented Portfolio teaching (Cain, 2013), there is a real need to find a way to develop the learner's ability to link assessment tasks and intended learning outcomes as this is an important step in achieving self-regulated learning.

2.10   Summary

This chapter reviews the related literature on portfolio-based teaching and the definition of learning outcomes that form the two essential components in a constructive alignment model. The implementation of the Task-Oriented Portfolio teaching approach underpinned by this model is then reviewed with the intention of further supporting student self-regulated learning in this teaching approach. The literature review reveals the need to establish the links between tasks and learning outcomes in Doubtfire, a technological tool that is used to support the Task-Oriented Portfolio teaching. The review on existing OLM research provides a foundation to study and identify suitable representational formats to encourage student self-regulated learning. Visual representation and presentation of learning related data provides evidence of learning that can assist learners to continuously plan during task analysis, perform self-observation over a period of time, and make self-judgement to benchmark their performance against their goals. OLM visualisations are posited to support the teaching staff in creating a supportive learning environment that enables students to take greater ownership of their learning as well as to teach them to be self-regulated. Based on the literature review, the research methodology approach in the next chapter is justified to conduct two key studies, Study 1 and Study 2. Study 1 leads to the design of Doubtfire++ independent open learner model prototype tool to raise student awareness of learning outcome achievements in supporting the Task-Oriented Portfolio teaching approach. Study 2 investigates its support to the stakeholders in encouraging student self-regulated learning.

Chapter 3
Research Methodology

3.1   Introduction

A research methodology refers to an overall procedure used in a research study to collect, analyse, interpret, and report data (Creswell & Plano Clark, 2011). There are a variety of methods and each has a different approach and procedure with which to guide a researcher in adequately answering the research questions that arise from a research problem in a research study. A research problem can be descriptive, explanatory or exploratory (Baran, 2016) thereby leading a researcher to conduct either a descriptive research, explanatory research, exploratory research or a mix of them. Based on different philosophical beliefs among the researchers about the social world, different research designs are exploited to collect quantitative and/or qualitative data to describe, explain and explore a research problem (Crotty, 1998; Moon & Blackman, 2014).

The primary aim of a descriptive research is to investigate the aspects of events in order to describe and document them as they naturally unfold (Polit & Hungler, 1999). Descriptive research yields rich data that prompts important recommendations. It is a popular way to gain a general overview of the research subjects by focusing on "What is happening?". Starting from depicting the research topic under study, a researcher then makes predictions based on the research outcomes obtained. Although it has been criticised to be "simply description", it forms the foundation to the aspects of events under study besides revealing the nature of society and expanding the related knowledge. Explanatory research which concisely and precisely describes "what" the current real situation is also leads to answering the "why" questions in a situation (Baran, 2016).

Explanatory research is a logical process of inquiry to seek causal explanations to the aspects of events under study that have been recognised or described. The main focus is on "why" questions that aims to unfold the aspects of events through the understanding of the nature of relationships as well as by establishing the causal explanations to the situation. A researcher first sets out some specific implications from a general theory in relation to the research topic by stating a research hypothesis. This is followed by a series of steps to test the hypothesis

through the collection and analysis of the scientific data and to verify the hypothesis in order to gain the causal explanations for deductive reasoning (Baran, 2016).

Exploratory research is used to investigate the way on "how" things or events happen. It begins with specific observations and measures, followed by the identification of patterns and regularities so as to formulate some hypotheses which could explore on the development of new theories through deductive reasoning (Trochim, 2006a). This means data are collected and analysed to develop theories. Most exploratory studies are used to develop a causal theory that could be tested later.

This research investigates the adoption of Open Learner Model (OLM) visualisations in supporting student learning in a Task-Oriented Portfolio teaching and learning. Various information visualisation techniques have been exploited in the existing OLM field to externalise a student's learning data. This research starts with quantitative data collection and analysis to describe user perceived usefulness of existing OLM visualisations and their preferred visualisations. This means that the quantitative data is used for addressing the research questions. This data provides a general overview of the key visualisation techniques that are perceived to be useful and preferred by the target research subjects. The researcher also seeks to find causal explanations from the perspective of the user as to why a specific visualisation is perceived to be more useful and preferred, hence soliciting alternative representational formats.

The qualitative data that is collected allows the researcher to find out why a certain representation is perceived to be more useful or preferred and able to find ways to better present the learning data. Hence, this research aims to determine the nature of relationships between users and the visualisation formats. In this way, the researcher is able to identify suitable OLM representational formats to externalise student learning data. An OLM prototype tool is then designed and developed.

Finally, this research investigates on the use of OLM visualisations by different user groups, the teaching staff and students in different teaching units. Apart from gaining causal explanation on user perceived useful visualisations, this research also explores on how to improve the visualisations to better support the Task-Oriented Portfolio teaching and learning.

The selection of a suitable research methodology for a research study greatly depends on the nature of the study (Srivastava & Thomson, 2009). This research is descriptive, explanatory and exploratory in nature. For example, the descriptive aspect relates to the research objective

aimed to identify suitable OLM representational formats so as to externalise student learning data from user perspectives. The explanatory nature of the research is associated to the objective that is meant to elucidate users' perceived usefulness and preferred OLM visualisations. The exploratory aspect is reflected in the pursuit of investigating user experience using OLM visualisations tool in a Task-Oriented Portfolio teaching and how it can be enhanced to better facilitate student learning.

This chapter explains the rationale for the selection and implementation of a suitable methodology to realise the research purpose. Initiating from different philosophical beliefs that affect the choice of selection from various research approaches to address the research questions, it then justifies the selection of the mixed-methods design. Next, it describes the Explanatory Sequential Mixed-Methods Design that includes the characteristics of the design, the challenges and the four key decisions leading to the selection of an appropriate mixed-methods design. This is followed by an explanation on the five major procedural steps in the implementation of the Explanatory Sequential Mixed-Methods Design employed in this research. Next follows details on the implementation of both the quantitative and qualitative strands in the mixed-methods design including the pilot-testing of the research instruments, the data collection procedures, and the data analysis techniques. Then, the sampling method used in the research and the determination of the sample size is discussed. Lastly, this chapter highlights the potential validity threats in a mixed-methods design and the strategies that can be undertaken to minimise the threats effectively. The chapter then concludes with a brief summary.

3.2   Research Approaches

The research approaches used in the social sciences are different from the natural sciences. This is due to the nature of each of these disciplines and heralded by the fact that social processes are more changeable and uncontrollable in comparison to the natural sciences. As a result, certain research in the social sciences are more complex and the processes involved are often hard to measure (Boutellier, Gassmann, & Raeder, 2011). Both disciplines are distinct in terms of the methods used for investigation. Each method produces different types of data that require different ways of data analysis and interpretation. In essence, natural sciences by nature is more uniform and countable. Therefore, the methods used are more mathematically based and include systematic observation, measurement, and experiment.

Further on, as social science environments are more changeable and uncontrollable, popular methods that are used to construct theories and knowledge in such research include observation, interviews, surveys and case studies. Research approaches employed by a researcher are closely related to his/her philosophical belief on how to address the research problems that leads to his/her selection of the research method (Moon & Blackman, 2014). The following subsections discuss the philosophical approaches and the resultant research methods used in each approach.

3.2.1 Philosophical Approaches

This research which is information technology-based and aligned to human-computer interaction and educational aspects, aims to investigate the use of visualisation techniques in an educational setting. Therefore, it is inclined to the social sciences. There are three major philosophical approaches to social science research that are closely related to a researcher's philosophical beliefs about the social world (Creswell, 2013). It is the philosophical beliefs that lead a researcher to carry out research through the collection of different types of data. Data in numerical form is known as quantitative measure whereas data in the form of textual description of things or people's view, experience and feeling is called qualitative measure. Some researchers use both quantitative and qualitative measures to address a research problem. The three philosophical beliefs that drive a researcher to collect different types of data are known as post-positivism, social-constructionism and pragmatism (Creswell, 2013; Robson & McCartan, 2016).

3.2.1.1 Post-Positivism

In post-positivism, people view research as a process of making claims in which they refine, accept or abandon the claims based on the best evidence they have at the time in order to explain the situations or describe the causal relationships (Creswell, 2013). Post-positivism is empirical research that assumes an objective reality. Most post-positivists are constructivists. They believe that each individual has different experience and cultures that shape one's world view. Due to this, perception and observation could be fallible and constructions could be imperfect (Trochim, 2006b). Thus, they recognise any possible biases that arise from all human groups as such relationships of power and influence that arise from human groups can influence the knowledge being shaped as well as the beliefs that are acceptable (Robson & McCartan, 2016). They endeavour to examine the methods and conclusions as well as to minimise any possible bias in order to gain high reliability and validity. Post-positive researchers conduct research by putting forward their claims with detailed hypotheses or

research questions that are then tested by using quantitative measures (Robson & McCartan, 2016). Triangulation across multiple perspectives is used to achieve objectivity (Trochim, 2006b). Knowledge is developed from careful observation and measurement of the objective reality of the world. This is done through the collection of data and evidence, and rational considerations as well as examination of methods and conclusions for bias (Creswell, 2013).

3.2.1.2 Social-Constructionism

Social-constructivists advocate social-constructionism in which they believe individuals develop the world of experience as they lived, felt and engaged in social situations. They are interested in the way individuals interpret and make sense of the world they live in (Robson & McCartan, 2016). Research is conducted to understand various forms of views, meanings, interpretations and knowledge that are being constructed from different individuals' world of experience. In social science research, this is done through interview, observation and discussion to acquire multiple perspectives for examining the underlying nature of reality (Creswell, 2013). These qualitative measures enable a researcher to gain different views from each unique individual as well as to examine and understand the research problem in detail (Creswell, 2013). This means social-constructivists develop ideas rather than restrict their findings to the pre-defined claims, as in the case of post-positivists.

3.2.1.3 Pragmatism

Pragmatism is supported by pragmatists who judge knowledge as both being constructed as well as grounded in the real world that individuals experience, feel and live in (Robson & McCartan, 2016). Beliefs of both post-positivist and social-constructivists are embraced and sought for practical and moderate middle ground solutions and to solve problems (Johnson, Onwuegbuzie, & Turner, 2007). Research has been carried out to examine what really works in solving a problem rather than restraining to traditional dualisms, i.e. post-positivism versus social-constructionism. Pragmatists are value-oriented and as such a range of research methods or multiple strategies are employed to gain a more complete picture to describe, explain and explore a research problem (Robson & McCartan, 2016).

3.2.2 Research Method

Based on a researcher's philosophical belief on how knowledge is gained and theories are constructed, a researcher designs the method to collect and analyse the data as well as to interpret and report the results to address a research problem. In general, there are three research methods known as quantitative, qualitative and mixed-methods or multi-strategy

approach (Creswell, 2013; Robson & McCartan, 2016). A central issue in the differences between them is the type of data obtained to address a research problem.

3.2.2.1 Quantitative Approach

The quantitative approach that is advocated by the post-positivists is theory-driven. Quantitative research is carried out to test a researcher's claims or hypotheses that is derived from theory (Teddlie & Tashakkori, 2006). Survey questionnaires are commonly used in social science research to collect the data. Data is collected in the form of counts, measures of things or people's viewpoints and behaviour to verify the claims (Creswell, 2013). Deductive data analysis is done through the use of statistical analysis techniques to generate descriptive, bivariate, multivariate, and inferential statistics and to verify the pre-defined claims (Baran, 2016).

For example, one of the research questions asked is as follows: "Is there a relationship between user perceived useful visualisations and their preferred visualisations?". To answer this research question, data was collected from a survey questionnaire and participants were asked to rate their view with a five-point Likert scale from 1=not useful to 5=very useful. They were also required to "Select one of your most preferred visualisation to view your achievement." The data of these two questions was collected in the form of interval scale measures and counts respectively. The visualisation that has a higher numerical value indicates that the user perceived more useful visualisation. Visualisation that has the most counts denotes the most preferred visualisation. Bivariate (Pearson) Correlation analysis was then conducted to confirm and deduce the claim.

3.2.2.2 Qualitative Approach

The qualitative approach embraced by social constructivists aims to study the nature of reality. This is done through individuals' world of experience such as the characteristics, meanings, definitions, concepts, symbols, metaphors, and descriptions of things. This enables a researcher to understand the complexities of real life that can give meaningful description to a research phenomenon (Tran, 2016). Data is collected in the form of textual descriptions and image illustrations to explore how individuals' world of experience is formed and the way nature of reality is interpreted. Interviews, observation, documents or audio-visual materials collected from private or public sources and focus groups are among the methods used to collect the data (Tran, 2016) in social science research. Inductive data analysis is used to build patterns, categories and themes. This is done through the organisation of data to

interpret the pattern structure and shape the content of the abstractions that emerge from multiple interpretations and diverse experience from different individuals (Creswell, 2013; Neuman, 2011).

For example, in this research project interviewees were asked "Did you find this visualisation useful to you? Why or why not?", "Did you like the visualisation? Why or why not?", "How did you use it?" and "How did it impact your learning?". User perception and feelings interacting with the visualisation were collected through their responses to these interview questions. The data was then organised and categorised to interpret the content and to form the categories for obtaining meaningful description to the research problem.

Both quantitative and qualitative approaches have their own strengths and weaknesses. While a quantitative approach is commended for validity that is closely related to its replicability and generalisability, it has been a point of criticism in qualitative approach due to its critically small sample size (Creswell, 2013). On the other hand, qualitative approach is credited for its strength of providing meaning and context and for revealing trends in thoughts and opinions. It elicits the development of ideas or hypotheses to a research study that is inherently the drawback of quantitative method due to its structured way of data collection (Manzoor, 2016). Thus when both approaches are mixed and used together, as in the case of pragmatism, they can complement each other.

3.2.2.3 Mixed-Methods Approach

The mixed-methods approach influenced by pragmatists has become popular in recent years and is the third major research approach (Cameron & Miller, 2007; Johnson & Onwuegbuzie, 2004). Being value-oriented, mixed-methods approach accepts ideas from both quantitative and qualitative approaches and builds on the strength of these approaches to make inferences that can lead to an in-depth understanding of the research study (Hayes, Bonner, & Douglas, 2013; Howe, 1988; Mukherjee & Kamarulzaman, 2016). Mixed-methods researchers work in engaging with objective or subjective views. Hypotheses are tested to gain understanding on a range of factors in the theory. Besides that, correlations and relationships are among the factors that are examined. Pragmatists also explore the underlying nature of reality for each of the factors and their relationships (Woolley, 2009).

In this research project, survey questionnaires are used to collect numerical data and to present the counts and measures for the description of data distribution and to test the hypotheses. Open-ended interview questions, field observations or focus group discussions

are used to obtain textual descriptions that characterise people's world of experience in terms of their interpretation, feeling and impressions. Mixed-methods approaches thus apply both quantitative and qualitative data analysis techniques to gain a complete picture for addressing a research problem.

Mixed-methods approach is suitable for researching problems that are related to target real-world applications. It describes, explains and explores the aspects of events under study such as the adoption of visualisation tool in the educational setting. As textual descriptions can complement the numerical data and vice versa, the use of mixed-methods approach can balance the traditional dualisms that seem opposing. Besides that, the effect of numbers and generalisable findings can be further enhanced with different viewpoints, multiple perspectives and true experiences and reflection of subjects (Sosulski & Lawrence, 2008). This means that the merging between quantitative and qualitative approaches can generate coherent ideas and create new insights (Cosgrove & Jonas, 2016). It is an approach to knowledge that seeks multiple viewpoints, perspectives, interpretations, and standpoints. This enables a researcher to gain and construct knowledge for a subject matter under study from qualitative and quantitative data analysis and findings (Tran, 2016). The researcher can have a better understanding of the research problems, gain more comprehensive and convincing evidence to the research questions and is exposed to potential new insights related to the research study. In view of its capabilities in providing a more comprehensive view and complete picture of a research problem, this research is designed to use mixed-methods approach to answer the research questions.

3.3   Mixed-Methods Design

Research design is a framework that provides a logical structure of how a research project should be carried out with the aim of addressing a research problem (Mertens, 2014). The strand of a research design refers to a component in a study that constitutes the fundamental process of a quantitative or qualitative research. This includes posing a question, collecting and analysing data as well as interpreting the data analysis results (Creswell & Plano Clark, 2011; Teddlie & Tashakkori, 2009). Mixed-methods design includes at least one quantitative strand and one qualitative strand to collect and analyse data, as well as to interpret and report the results (Creswell & Plano Clark, 2011). It provides researchers with a step-by-step guide to undertake the study. It outlines the explicit scope and direction for the entire research plan

to run smoothly (Tran, 2016). Thus, it is important that a researcher decides on the research design before a study is carried out to minimise the errors made (Baran, 2016).

The quantitative and qualitative strands are integrated to address the research problem via the research questions. There are six major designs in mixed-methods approach (Creswell & Plano Clark, 2011). The mixed-methods designs are:

(i)   convergent parallel design,

(ii)   explanatory sequential design,

(iii)   exploratory sequential design,

(iv)   embedded design,

(v)   transformative design, and

(vi)   multiphase design

Four key decisions that can be used as a guide in the selection of an appropriate mixed methods design in a research study are:

(i)   the level of interaction between both strands,

(ii)   the relative priority or domination of both strands,

(iii)   the timing in carrying out both strands in either one or more phases, and

(iv)   the procedures or stage of integrating both strands (Creswell & Plano Clark, 2011).

Table 3.1 shows the basic characteristics of the six major mixed-methods design associated with the four key decisions.

Table 3.1 Basic characteristics of the six major mixed-methods design

Major Design	Four key decisions			
	Level of Interaction	Priority	Timing	Stage of Integration
Convergent parallel	Independent	Equal	Concurrent, one phase	During or after data analysis
Explanatory sequential	Interactive	Quantitative dominant	Sequential, two phases, quantitative first followed by qualitative	During data collection
Exploratory sequential	Interactive	Qualitative dominant	Sequential, two phases, qualitative first followed by quantitative	During data collection
Embedded	Interactive	Either quantitative or qualitative	Either concurrent or sequential	During design stage
Transformative	Interactive	Equal, quantitative or qualitative dominant	Either concurrent or sequential	During design stage
Multiphase	Interactive	Equal	Multiphase combination	During design stage

The nature of this research study emphasizes on the quantitative strand. It seeks causal explanation to the initial quantitative results in more depth from the qualitative data. Due to this, some of the qualitative research procedures are fixed and some are developed and

refined based on the quantitative results. This means that the design is planned to be carried out in two distinct phases. The stage of integration happens during data collection in the qualitative phase and the results are connected during final interpretation. Thus, this study applies the Explanatory Sequential Mixed-Methods research design to gain a complete picture of the study in answering the research questions.

3.4   The Explanatory Sequential Mixed-Methods Design

The Explanatory Sequential Mixed-Methods design occurs in two distinct interactive phases as illustrated in Figure 3.1 (Creswell & Plano Clark, 2011).
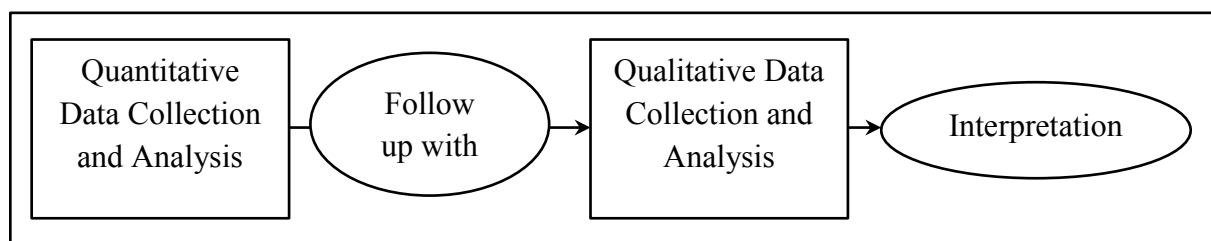
Figure 3.1 The Explanatory Sequential Mixed-Methods Design

The first phase of this research design starts with the quantitative strand. Data is collected through an online survey questionnaire. This strand has the priority for addressing the research questions. This is followed by the second phase, the qualitative strand. The second phase commences only after the completion of the data collection and analysis of the first phase.

Qualitative data in textual description forms are collected through a face-to-face interview. Although the two phases are distinct, they are connected during the study. The qualitative strand can be fixed or built on the first quantitative phase. Researchers can develop or refine the qualitative strand including the research questions, purposeful sampling procedures, and data collection protocols in this phase. Thus, the qualitative results can help to explain the initial quantitative results in more depth (Creswell & Plano Clark, 2011) during the final interpretation. It can be seen that the philosophical assumptions of the explanatory design departs from the post-positivism through the development of instruments, measurement of variables, analysis and interpretation of statistical results. Then it shifts to constructivism via the valuing of multiple perspectives, views and standpoints.

3.4.1 The Purpose of Adopting Explanatory Sequential Mixed-Methods Design

There are a number of reasons for the use of Explanatory Sequential Mixed-Methods Design. This design is suitable for research problems that are more quantitatively oriented. Besides that, it can be carried out with limited resources as researchers deal with only one type of data at a time. In addition, as the quantitative data can be collected and analysed in the first phase before the second phase commences, the researcher is provided with a creative way of qualitative data collection as new questions for qualitative strand can be developed based on the resultant quantitative data. This could be beneficial in the shaping and developing of the research questions as well as its implementation (Greene, Caracelli, & Graham, 1989; Jick, 1979; Manzoor, 2016).

Furthermore, while the quantitative strand provides an initial interpretation of the phenomenon, the qualitative strand further explains the statistical results in more depth from participants' point of view (Creswell & Plano Clark, 2011; Creswell, Plano Clark, Gutmann, & Hanson, 2003; Tashakkori & Teddlie, 1998). This leads the researchers to what is learnt on the overall with respect to the purpose of study. It is well suited to the needs of the researchers as it enables them to examine the cause-and-effect-relationships. Besides, it also seeks to explain the quantitative results in more depth. This may be significant or nonsignificant, unusual or surprising in pattern or trend (Creswell, 2013; Morse & Niehaus, 2016) from the qualitative strand. It is due to its power to explain results that it is called explanatory mixed methods design (Creswell & Plano Clark, 2011).

Most of all, with the distinct and yet connected phases, this means that the results obtained can be interpreted independently, connected in some ways and merged when necessary. The numerical data from the quantitative strand can be converged or triangulated with the narrative details of the qualitative strand (Creswell, 2013) thus providing the researchers with thicker and richer data (Manzoor, 2016). To this end, the inherent drawbacks of one strand can be overcome by the other (Creswell & Plano Clark, 2011; Greene et al., 1989; Neuman, 2011). This helps the researchers to describe, compare, confirm or validate, juxtapose or confound the results from both strands. In this way, the researcher can gain a better understanding and retrieve a more complete picture of a research problem (Rossman & Wilson, 1985; Tashakkori & Teddlie, 2008; Tran, 2016) supported by more comprehensive and concrete evidence (Creswell & Plano Clark, 2011). Thus, they can be more confident of the results obtained (Jick, 1979; Tran, 2016). They can better clarify, enhance and elaborate the overall results (Greene et al., 1989) hence leading to an increase of overall strength,

validity of findings, and the significance of the research study (Collins, Onwuegbuzie, & Sutton, 2006).

3.4.2   Challenges in Explanatory Sequential Mixed-Methods Design

Although the Explanatory Sequential Mixed-Methods Design has numerous advantages and is quite straightforward, generally there are a few challenges (Creswell & Plano Clark, 2011) that a researcher should be aware of. Understanding the challenges in this design enables the researcher to better plan and conduct the research. The challenges are as follows:

- Consuming lengthy time: Although the qualitative strand involves just a few participants, it is anticipated that more time is needed for the qualitative strand. This is because the implementation of the qualitative strand involves redevelopment and refining of the pre-determined research questions, obtaining approval from the institutional Ethics Review board as well as the arrangement and time scheduling with participants. Thus, adequate time has to be budgeted for this phase.

- Securing institutional review board approval: As the purposeful sampling and instrument redevelopment of the qualitative phase is dependent on the initial findings of the quantitative data, this means approval has to be obtained before its implementation. Securing institutional board approval can be a challenge to this design.

- Deciding on the quantitative result that needs further explanation: This can only be done after the quantitative data has been precisely analysed and interpreted. Deciding on which quantitative results to seek further explanation requires the researchers to carefully plan and prepare for the qualitative phase.

- Purposeful sampling: In order to seek the best explanation for the quantitative results, researchers must carefully select the participants in the qualitative strand. Participants can be selected based on some specific criteria or selection predictors or the individuals from the sample can be used in the quantitative phase to gain the best explanation. In the case where the participation is voluntary, as in this study, the researchers must obtain the participants' demographic characteristics before seeking their views in relation to some specific quantitative results.

3.5   The Implementation of Explanatory Sequential Mixed-Methods Design

This research effort is built around two key research studies, named Study 1 and Study 2. Study 1 investigates user perceptions of open learner model visualisation representational formats. Study 2 examines user perceptions of OLM visualisations for supporting the Task-Oriented Portfolio teaching. The results from Study 1 provide a general overview of the visualisations that are perceived useful and preferred by the prospective target end users. Some of the results from Study 1 are used to inform the development of visualisation prototypes in Study 2. Both studies apply the Explanatory Sequential Mixed-Methods Design to realise the research purposes. Figure 3.2 provides an overview of the implementation of this research methodology, followed by a detailed description of the procedural steps conducted in Study 1 and Study 2.

First Phase	Quantitative (QUAN) Strand	• formulate research questions • develop theoretical framework • determine methodology • develop survey instrument • obtain permission • pilot test survey instrument	• obtain permission from faculty chair • identify sample through self-selection sampling strategy • collect survey data • analyse data • generate descriptive statistics • test hypotheses with multivariate, and inferential statistic method • Ensure validity & reliability	• report results • interpret results • determine which results need further explanation	Connect both results
Second Phase	Qualitative (QUAL) Strand	• formulate research questions • form theoretical foundation • determine methodology • prepare interview instruments • obtain permission		• refine and develop qualitative research questions so that they are fixed and/or followed from the quantitative results • purposeful sampling • modify data collection protocols • obtain modification approval • Pre-test interview plan	• identify sample through self-selection sampling strategy • collect data to answer the qualitative and mixed methods research questions • transcribe interview data • conduct Inductive Content Analysis to analyse qualitative data using Nvivo • quantify qualitative descriptions and create content related categories • ensure validity & reliability • report results • interpret results	**Final Interpretation:** • Summarize and interpret the quantitative results • Summarize and interpret the qualitative results • merge QUAN and QUAL results • triangulate QUAN results with QUAL results • Complement QUAN results with QUAL results • Interpret final findings • Derive conclusions
		Preparation	Step 1	Step 2	Step 3	Step 4

Figure 3.2 An overview of the procedural steps of the research methodology

(Points of integration between the quantitative and qualitative strand are highlighted in green)

3.5.1 Procedural Steps in Conducting Explanatory Sequential Mixed-Methods Design

Figure 3.2 illustrates an overview of the procedural steps used to conduct the typical two-phase explanatory design in this research. There are five procedural steps including a preparation step and four main steps. During the preparation step for this research, the use of the quantitative and qualitative strands were predetermined and planned. The researcher formulated both quantitative and qualitative research questions, determined the research design and methodology, developed the theoretical framework and foundation, prepared the research instruments and obtained Ethics approval from the institutional Ethics Review Board. Upon receiving the approval, the survey instruments were pilot-tested to ensure that they were appropriate and comprehensible as well as to confirm that the questions and the OLM graphics were appropriately displayed through the survey software application Opinio.

The first procedural step involved the quantitative data collection through an online survey questionnaire. It commenced after the permission from the faculty department chair was obtained. Participants were recruited through self-selection sampling. Invitation emails with the inclusion of survey link were sent to the teaching staff to invite them to participate in this study. Student participants were recruited by the teaching staff via an online announcement in the Blackboard Learning Management System. The survey link was included in the online announcement for students to access the survey questionnaire.

Data collected was analysed using SPSS software. The quantitative data which addressed the research questions gained a broad overview of user perceptions. The results obtained signified the progress to the second procedural step, where the qualitative strand was implemented. In this step, the integration between the quantitative and qualitative strands occurred. The researcher interpreted the results and decided which quantitative results needed further explanation. At the same time, the qualitative research questions were refined and developed based on the quantitative results. This was followed by the determination of the sampling procedure and modification of qualitative data collection protocols and plans. Modification approval was obtained from the Ethics Review Board before the interview plans were pre-tested.

Step 3 involved the qualitative data collection through the face-to-face interview, data analyses and result interpretation. Participants were recruited based on the recruitment process as described in Sections 3.5.3.2. Finally, in Step 4, the quantitative and qualitative results that had been interpreted were summarised and merged. The quantitative results were triangulated and complemented with the qualitative results to obtain the final findings and to

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derive conclusions. For example, quantitative results were compared with the patterns that emerged from the qualitative results.

It can be seen from Figure 3.2 that the Explanatory Sequential Mixed-Methods design involved two distinct, but connected phases. Two points of mixing occurred (highlighted in green in Figure 3.2) during qualitative data collection and final interpretation, as in Step 2 and Step 4. This allowed the researcher to better apply the qualitative strand so as to add insight into the quantitative results and to derive more comprehensive and in-depth conclusions in response to the research purpose. As both Study 1 and Study 2 were conducted based on Explanatory Sequential Mixed-Methods, the pilot testing of research instruments and data collection procedures for the quantitative and qualitative strands are similar in these two studies. They are discussed in the following subsections. The quantitative instruments for both studies that have been pilot-tested are presented in Chapter 5 and Chapter 7 respectively.

3.5.2   Quantitative Strand

The quantitative strand involves the collection of data that presents the counts and measures to describe the distribution of user perceived usefulness of visualisation formats and the users preferred formats, to examine the relationship between these variables, and to compare the use of various information visualisations by different user groups and to determine the factors affecting its use. Data were collected through an online survey questionnaire.

3.5.2.1 Questionnaire and Pilot Testing

The survey questionnaires for Study 1 and Study 2 consisted of close-ended questions with some open-ended questions to gather participant demographics and their comments. It is reasonable to collect some qualitative data in quantitative design and vice versa (Blackshaw & Crawford, 2009; Robson & McCartan, 2016). Questionnaires are a popular research tool in view of the key benefits of allowing researchers to gather information from a large number of subjects with little cost and time. It is specifically useful to obtain information related to demographic, , attitudinal and behavioural attributes of subjects (Blackshaw & Crawford, 2009). Different types of questions can be designed based on the purpose of study. A respondent can select or rank from the choices available in the close-ended questions. To ensure a better coverage of options and to have a balanced scale, the design of the questionnaire in this study also included noncommittal categories, such as 'other', 'did not use' or 'neither agree nor disagree'. While choices provided in the close-ended questions give a respondent a better understanding of the questions, their frustration or dropout rate is also reduced. The data collected can be easily coded and analysed by the researchers (Bailey,

2008). In this research, the survey questionnaire for Study 1 and Study 2 were developed and published online through the Opinio survey software application.

The questionnaires were pilot-tested with the target audiences at Swinburne University of Technology, Australia through the use of the Opinio survey software application. Study 1 involved 8 target end users that included 3 teaching staff and 5 students that formed the pilot-testing team. Study 2 involved 6 target end users that encompassed 4 teaching staff and 2 students. The purpose of pilot-testing is to ensure that the instruments are appropriate and comprehensible. Similar pilot testing procedure was applied in both studies.

A pilot test was conducted to evaluate the clarity of the scenarios and the items in the questionnaire. The survey questionnaire link was sent to each pilot-testing team member. The online questionnaire consisted of the draft questionnaire with a comment box in each question. Each member was encouraged to check various aspects of the questionnaire. This includes the wording, question order, redundant or missing questions, graphs, range of choices and response categories as well as recording of time taken to complete it (Van Teijlingen & Hundley, 2002). They were encouraged to comment if the questions and graphics were displayed appropriately from the software application. Participants were asked to make suggestions or restate questions that they felt confusing (Miller & Salkind, 2002) in the comment box provided.

The feedback received was quite positive with suggestions for some minor changes. The survey questionnaire was revised accordingly to reflect the changes. The revised questionnaire was presented again for further feedback before the main survey was conducted. It was confirmed that the time to complete the questionnaire was not more than 20 minutes for both Study 1 and Study 2 respectively.

3.5.2.2 Data Collection Procedures

After the questionnaire had been constructed, Ethics approval was sought from Swinburne University Human Research Ethics Committee (SUHREC) (Appendix A.1 for Study 1 and Appendix A.2 for Study 2). Permission was also obtained from the chair of the department and department head where the staff and students were from. Samples were obtained based on self-selection sampling method (see Section 3.6.1). Teaching staff were recruited through email invitation with the survey link included in it.

To recruit student participants, consent was sought from unit convenors and lecturers. Participants were recruited through the help of lecturers to advertise the research project to

their students in the class and through the online announcement. The survey link was included in the announcement. Interested teaching staff and students would click on this survey link. Once it was clicked, it brought the participants to the first survey page of the questionnaire that consisted of the online consent form (Appendix A.3 for Study 1 and Appendices A.4 and A.5 for Study 2).

Before the participants started the survey, they were asked to read the Project Information Consent Statements on the first page. Project Information Consent Statements introduced them to the research title and objectives, expectation from the participants, potential benefits gained, possible risks of participating, participant rights, assurance of a participant's anonymity, and contact information of the researchers and the Research Ethics Officer. They were warned that if the "Start" button in the page was clicked, this implied that they had read and understood the information provided about the research project and agree to participate in the research project. To decline, they could click on the "X" button to cancel the invitation.

At the end of the survey, after the participants had finished the survey and had submitted their responses, a note appeared to invite the participants for an interview (Appendix A.6). Participants who were interested to be interviewed or participate in focus groups could enter their name and contact information in the columns provided. The contact information captured in this page was separated from their previous responses. After the quantitative data had been collected and analysed, the participants were contacted through email to arrange for an interview.

3.5.2.3 Data Analysis Techniques

Statistical data analysis techniques used to address the research questions for Study 1 and Study 2 include Descriptive Statistics, Pearson Correlation Analysis, Independent Samples t-test and One-way Between-groups Analysis of Variance (ANOVA).

(a)   Descriptive Statistics

Descriptive Statistics are statistics in the form of numerical values, charts or tables that are used to provide summary to the data in a study (Pallant, 2013). There are a number of ways of using descriptive statistics in research. In this research, descriptive statistics is used to:

- Describe the characteristics of the samples under study.
- Test the research variables for any violation of assumptions underlying the statistical techniques used.
- Address the research questions.

(b)   Pearson Correlation Analysis

Pearson correlation analysis is used to determine the linear relationship between two variables. To conduct this analysis, it is important to ensure that there are no extreme outliers, and the assumption of linearity and homoscedasticity is not violated (Pallant, 2013). This can be done by exploring the distribution of all the data scores, the shape and trend produced by all the data points on a scatter plot with three simple steps:

- First, check the data points in the scatter plot for outliers. Any of the data points that are either very low or very high or away from the main cluster of points are called extreme outliers. They should be excluded from Pearson Correlation Analysis.

- Second, check the distribution of data points. Data points that spread all over suggest very low correlation whereas a curvature distribution suggests an invalid Pearson correlation. To conduct Pearson correlation analysis, data points should neatly arrange in a reasonably narrow cigar shape with the cluster of points reasonably distributed evenly from one end to the other. This means that the data is conformed to the assumption of homoscedasticity.

- Third, determine the trend formed by the cluster of points. An upward trend indicates linearity with positive relationship whereas a downward trend suggests linearity with negative relationship.

(c)   Independent Samples t-test

Independent samples t-test is used to compare the mean scores of two conditions or two different groups of people. It is important that the general assumptions associated with this parametric technique are not violated before conducting the test. For Study 1 and Study 2, data was collected using self-selection sampling. In this way, each individual in the population of interest had an equal chance to participate and approximate random sampling was assumed. The 5-point Likert scale, 1 to 5, that was used by the participants to rate their views and responses means that the dependent variables were measured at the interval level. For Study 1, participants had access to the proposed visualisation options through the Scenario-based design. For Study 2, the adoption of the visualisation in the unit means that each participant had their login account to interact with the prototype tool. Thus independence of observations could be assumed. The valid sample size of 222 and 134 for Study 1 and Study 2 denote that scores on the dependent variable could be assumed and were normally distributed based on the Central Limit Theorem (Mann, 2016). To ensure

homogeneity of variance, appropriate set of results was used based on Levene's test for equality of variances.

(d)   One-way Between-groups Analysis of Variance (ANOVA)

A one-way ANOVA test is used to compare the mean scores of more than two groups. ANOVA test compares the variance between the different groups (the independent variable) with the variability within each of the groups. One important assumption that applies to ANOVA test is the homogeneity of variance. SPSS supports this assumption by generating two sets of results. To ensure no violation to this assumption, appropriate sets of results had to be used. The ratio of the variance between the groups and the variance within the groups is called the F ratio. A large F ratio means there is more variability between the groups than within each group. That is, the variability is due to the independent variable. Meanwhile, a significant F test suggests that there is a significant difference among the groups and it does not indicate which two groups differ. This information is given by the Post-hoc Turkey HSD tests. ANOVA test was used in Study 2 to examine the difference in means between a specific user group and the self-regulation measurement scales.

3.5.3 Qualitative Strand

The qualitative strand was used to adequately answer the research questions. It commenced after the data collection and analysis of the quantitative strand were completed. Semi-structured open-ended interview questions were used to collect qualitative data. This enabled the researcher to explore the reasons why certain formats were perceived to be more useful and preferred to better understand the underlying nature of reality of the visualisation formats from user perspectives. Ways to enhance existing OLM visualisations and to better present student learning data were also explored. An interview plan was prepared and pilot-tested prior to the commencement of the interview session.

3.5.3.1 Interview Plan and Pilot Testing

An interview plan was prepared for Study 1 and Study 2 respectively. Both studies used semi-structured interview questions. Each of the interview plans used in Study 1 and Study 2 was pilot-tested with two participants respectively in order to gain a clear definition of the scope of the study and to time the interview session. The results helped the researcher to modify the interview plans and to focus on qualitative data collection by fine-tuning it to the projected analytical topics (Frankland & Bloor, 1999; Van Teijlingen & Hundley, 2002). It also helped to increase the researcher's confidence, especially the novice researcher on the

application of the interview technique in the qualitative strand (Holloway, 1997; Van Teijlingen & Hundley, 2002). The time required for conducting the interview for Study 1 and Study 2 was not more than 30 minutes and 45 minutes respectively.

3.5.3.2 Data Collection Procedures

Prior to the face-to-face individual and group interview sessions, the researcher contacted the participants who had volunteered to participate via an email. A copy of the Project Information Consent Statements (Appendix A.3 for Study 1 and Appendices A.4 and A.5 for Study 2) and a Consent Form (refer to Appendices A.7 and A.8 for Study 1 and Study 2 respectively) were attached in this email. All the interview sessions were recorded by using an electronic device with participants' permission. Notes were taken to supplement these audio recordings. Participants were asked to sign the consent form and return it prior to the interview session. At the end of the interview session, souvenirs and light refreshments were provided to the participants as a token of appreciation for their time and participation.

The interview data in the audio recordings were then transcribed to an electronic copy. Inductive Content Analysis was conducted by using Nvivo software. A detailed discussion of the findings of content analysis for Study 1 and Study 2 are presented in Chapter 5 and Chapter 7 respectively.

3.5.3.3 Content Analysis

Content analysis is a foundational method to analyse textual data collected from a qualitative strand. It applies a number of strategies including systematic coding and categorizing approach to explore a plethora of textual data (Grbich, 2013; Vaismoradi, Turunen, & Bondas, 2013). It enables a researcher to quantify the data and to analyse data qualitatively (Grbich, 2013). Any possible trends and patterns from the wordings, verbal expression, structures of conversation, discourses of communication as well as their frequency of use and correlation can then be identified through this method (Grbich, 2013; Vaismoradi et al., 2013).

Content analysis is used in this research in view of data that can be quantified through word frequency and to identify the common terms that the participants used to describe the representation formats. Through these descriptions, the researcher can gain insights about why a certain representational format was perceived useful and preferred and why some were not. Besides that, this method enables participants' verbal expressions to be extracted into fewer content related categories. This means that words, phrases or descriptions and the like that have the same meanings are grouped into the same categories (Cavanagh, 1997; Elo &

Kyngäs, 2008). That is, categories can be created from units of analysis to explore the reasons why a certain visualisation was perceived useful and preferred, and ways to enhance and enrich the visualisation options.

Content analysis has well-defined analytical stages to guide a researcher to identify, analyse and report categories within data in an easy, clear and user-friendly way besides involving rather low levels of interpretation (Vaismoradi et al., 2013). A researcher, especially novice researcher can gain core skills to analyse the qualitative data. Depending on whether there are previous similar studies or former knowledge related to the phenomenon under study, there are two modalities to conduct content analysis. They are known as inductive and deductive approach. Inductive approach is suitable for studies that do not have previous research exploring the phenomenon whereas a deductive approach operationalises based on prior knowledge (Vaismoradi et al., 2013). In view of insufficient theoretical or analytical interest that drives the researcher to the phenomenon under study, the inductive approach is used in this research. The inductive content analysis consists of three major phases. They are the preparation, organisation and reporting phases as illustrated in Figure 3.3. With the advancement in computing technology, these phases that used to be performed manually can now be conducted by using a software programme such as NVivo.
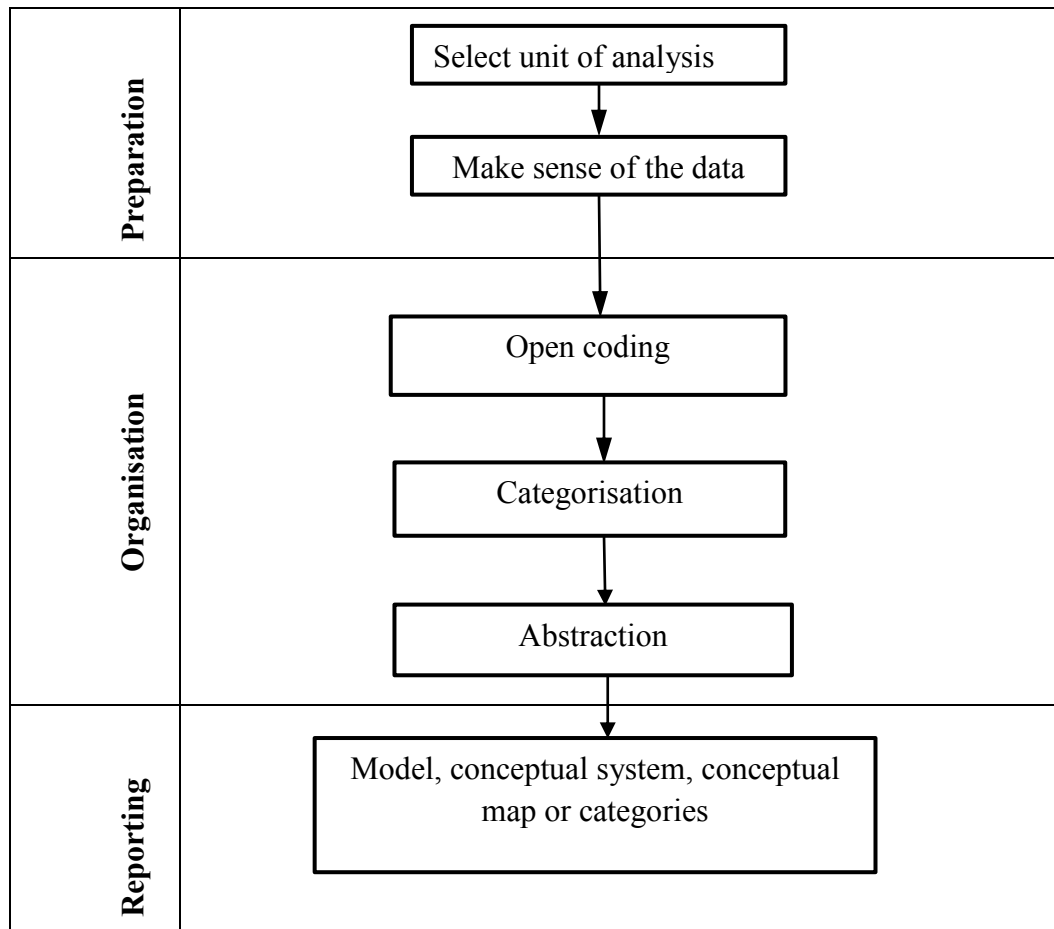
Figure 3.3 Content analysis phases

3.6 Sampling Method and Sample Size

A proper sampling method is required in both the quantitative and qualitative strands to ensure the quality of data and hence the findings. Unlike the qualitative strand, adequate sample size is essential in the quantitative strand to obtain statistically significant results and to generalise the findings. The following sub-sections explain the sampling method used in this research and the calculation of an adequate sample size that is required for the quantitative strand.

3.6.1 Sampling Method

Sampling refers to the process or technique of selecting a representative portion from the population under study (Mujere, 2016). It is an important process of any research study as it has great impact on the data quality and findings. There are two main sampling techniques, known as probability sampling techniques and non-probability sampling techniques (Neuman, 2011; Salant, & Dillman, 1994). Probability sampling techniques involve random selection

whereas non-probability sampling techniques are subjected to a researcher's judgment. Non-probability sampling techniques are more popular than probability sampling techniques because the whole process of selecting units for inclusion in a sample is easier, cheaper and faster (Mujere, 2016). This research study applied one of the non-probability sampling techniques known as self-selection sampling.

Self-selection or volunteer sampling refers to a sampling method in which individuals or organisations opt to participate in the research based on their own accord (Mujere, 2016). Self-selection sampling is applied in a wide range of research designs including the mixed-methods designs. The rationales for individuals to participate voluntarily in a study may include they having certain strong feelings or views on the topic of the study, immense interest in the research work or the outcomes, or simply to help a researcher (Henry, 1990; Mujere, 2016). Recruiting participants through this strategy involves two easy steps such as (i) the researcher publicizes the need for units and then, (ii) verify the relevance of the units to either invite or reject them.

The participants of this research were teaching staff and students from two tertiary institutions. Participants for Study 1 were teaching staff and students in Swinburne University of Technology, Australia and Multimedia University, Malaysia. Study 2 involved participants from Swinburne University of Technology, Australia only. It is the research goal that drives the selection of samples (Mujere, 2016) in both studies. Study 1 aims to obtain general ideas about user perceived useful OLM representational formats. Scenario-based design was used in this study to depict the sample scenarios of use for the proposed OLM visualisations. Participants did not require any prior knowledge or experience of use. Thus data was collected from these two institutions where the researcher is from. The goal of Study 2 is to gather data regarding the use of the OLM visualisation tool in which the target participants were users of the visualisation tool. The proposed OLM visualisation tool had been implemented in Swinburne University of Technology, Australia. Thus, participants were recruited from this institution only.

Based on the premise that participants who were chosen to participate in research voluntarily are likely to be more committed and are more willing to provide insight related to the topic being studied (Mujere, 2016), self-selection sampling was used to recruit participants for both studies. As each individual in the population of interest had an equal chance to participate, approximate random sampling was assumed.

Since participation on the online survey questionnaire was voluntary and participants could easily access the survey questionnaire by just clicking on the survey link, it was important to ensure that the participants in the quantitative strand were from the population of interest. This was done through the use of the filter out function in Opinio software application tool. Besides that, some of the interview questions were built on the quantitative results in which explanation had to be sought from a specific participant. To this end, a participant's demographic information was verified at the start of the interview session to make sure the topic of discussion was relevant to the participant.

In addition, the participants of the qualitative strand were recruited from participants in the quantitative strand. The questionnaire was designed so that when the questionnaire was completed and submitted by the participants, they (participants in the quantitative strand) were prompted with an invitation to participate in an interview (qualitative strand). This means that the participants for both the quantitative and qualitative phases were recruited from the same sample.

There are a few advantages of self-selection sampling. Besides providing the researcher with a quick way to get appropriate units that fulfil the selection criteria for inclusion in a sample, most importantly, the potential units are more likely to be committed to the study as well as provide greater insight to the topic of study. In contrary, the disadvantages include an unavoidable inherent self-selection bias reflected by the characteristics or traits of the participants that can lead to exaggeration of the research findings (Mujere, 2016). Cautious steps were taken to ensure validity of the research findings. Data was carefully analysed to uncover the paradoxes and contradictions that emerged from both the quantitative and qualitative results besides minimising biasness.

3.6.2 Sample Size

A sample is a subset that is drawn from a large population for a measurement, observation or questioning. It is important that a sample can provide accurate statistics about a population under study. For a quantitative study, adequate sample size is required to ensure that the results obtained from the study are statistically significant and that the findings can be generalized to the population as a whole (Jones, 1955; Mujere, 2016; Salant et al., 1994). Various propositions and formulas have been suggested to estimate the sample size required for a study. Smith (2013), for example, proposed the calculation of sample size as follows:

$$n = \frac{(z)^2 \sigma (1 - \sigma)}{e^2}$$

n is the desired sample size,

z is known as z-score

σ is the standard deviation

e is the margin of error

From the formula, the sample size is determined by the z-score, the standard deviation and the margin of error. The z-score value depends on the confidence level adopted by the researcher and can be obtained from a statistical table. Common confidence levels used in research are 90%, 95% and 99% and the corresponding z-scores are 1.645, 1.96 and 2.58 respectively. As for the standard deviation, it is suggested that 0.5 is used as it is the most forgiving number and it ensures that the sample would be large enough (Smith, 2013). Margin of error is expressed in percentage such as 1%, 5% or 10% to denote the amount of acceptable sampling error in a survey's results. In this research, the sample sizes of the quantitative strand for Study 1 and Study 2 were determined as the following:

z-score for 95% confidence level = 1.96

σ, standard deviation = 0.5 (as suggested in the literature)

e, margin of error = 0.1 (10%)

$$n = \frac{(z)^2 \sigma (1 - \sigma)}{e^2}$$

$$= \frac{(1.96)^2 (0.5)(1 - 0.5)}{(0.1)^2}$$

$$= 96.04 \text{ (at least 97 samples were needed in each study)}$$

3.7 Research Validity

Validity of research is an indication of whether the research is true and believable and that it evaluates the aspect that it is supposed to evaluate (Zohrabi, 2013). Validity is a crucial criterion for demonstrating credible, authentic, trustworthy, rigorous, confirmable and legitimate research findings (Creswell, 2013; Creswell & Miller, 2000; Onwuegbuzie & Johnson, 2006). It determines the overall quality and acceptability of research (Burns, 2003). Validity issues might occur during data collection, data analysis, and data interpretation

(Onwuegbuzie & Johnson, 2006). In mixed-methods design, apart from the validity issues associated with qualitative and quantitative strands, validity issues also relate to the mixed-methods approach (Creswell, 2013), especially when both sets of qualitative and quantitative inferences are combined as a coherent whole known as meta-inference (Tashakkori & Teddlie, 2003).

Among threats to validity include poor sampling in which data are collected from participants who are inappropriate for the research purpose and instrumentation changes from pre-test to post-test. Besides that, threats may be caused by a researcher's bias on the findings of one particular strand or participant's bias due to their background. Furthermore, the threats may be due to lack of definitions and measures of variables, and inadequate statistical power or the violation of the assumptions during statistical data analysis. In addition, problematic meta-inferences may occur when the inferences are pulled together from the qualitative and quantitative strands (Creswell, 2013; Onwuegbuzie & Johnson, 2006). Validity strategies are therefore important to enhance a researcher's ability to evaluate the accuracy of research findings and to convince readers of the research outcomes. To address the validity issues, a number of strategies were applied in this research project.

3.7.1 Construct Validity

Construct validity refers to the degree of a test and whether it actually measures the latent construct that it claims to measure (Netemeyer, Bearden, & Sharma, 2003). Various strategies were used to mitigate the threats to construct validity. The survey items were adopted and adapted from existing literature to ensure clear definitions and plausible measures of variables. Items were screened by experienced judges. A pilot test was conducted to evaluate the clarity of the survey items and the interview plan. Besides that, all the participants accessed the same questionnaire throughout the quantitative strand to avoid the instrumentation change issue. The qualitative phase applied semi-structured interview in which the topics and questions were specified and could be recast and expressed in different ways according to the situation (Zohrabi, 2013). The Explanatory Sequential Mixed-Methods design kept the instrumentation changes threat to a minimum. Furthermore, the same researcher was involved in data collection and data analysis for both strands.

3.7.2 Internal Validity

Internal validity is an assessment that verifies the extent to which causal conclusions can be made from an experiment (Seltman, 2012). The Explanatory Sequential Mixed-Methods design used in this research provided a greater internal validity. Through this research design, interviewees' perspectives and understandings of the world can be further accessed to compare and contrast the findings (Fraenkel, Wallen, & Hyun, 2003). At the same time, member checking strategy (Creswell, 2013) was applied in which follow-up interview was conducted with participants to enable them to comment on the qualitative findings. This helped to overcome the researcher's bias. However, the inherent self-selection bias could potentially affect the research results. Cautious steps were taken to ensure validity of the research findings. Data was carefully analysed to uncover the paradoxes and contradictions that emerged from both quantitative and qualitative results as well as to minimise the bias.

3.7.3 External Validity

External validity refers to the generalizability of the research inferences to other situations or people (Tran, 2016). In order to clarify a participant's bias, participant background information such as gender, user role, experience in information visualisation and etc. were collected in both the qualitative and quantitative phases. Thus, an open and honest narrative description of the research findings could be presented (Creswell, 2013) to justify the generalizability of the findings. However, as this research was a case study conducted in a specific place and time with a specific tool, the results may not be generalized more widely to other systems and other environments.

3.7.4 Statistical Validity

Statistical validity concerns the accuracy and reliability of conclusions derived from a statistical test including having sufficient data and applying an appropriate statistical test to analyse the data (Netemeyer et al., 2003). In order to overcome the threats to statistical validity in this research, various preliminary analyses were conducted to ensure adequate statistical power. Violation of assumptions for various statistical data analyses was also checked.

3.8   Summary

This chapter describes the selection of an appropriate research methodology to realise the research purpose. The mixed-methods approach to inquiry is selected based on the research questions that are descriptive, explanatory, and exploratory and to investigate the adoption of open learner model visualisations in supporting student learning. In this research project, the research problems are more quantitatively oriented. There is also a need to gain a general understanding of the problems and to seek causal explanation to the initial quantitative results in more depth. Therefore, Explanatory Sequential Mixed-Methods design is adopted to gain a more comprehensive view and complete picture of the research problems. Detailed implementations of both the quantitative and qualitative strands in two key studies (Study 1 and Study 2) in this research are discussed. Potential validity threats in the mixed-methods design are highlighted together with the strategies to effectively minimise these threats on the research findings. The subsequent chapters present OLM visualisation design and the data analysis results of the quantitative and qualitative strands obtained from the two key studies.

Chapter 4
Preliminary Open Learner Model Visualisation Design

4.1   Introduction

Many Open Learner Model (OLM) representational formats have been developed to expose students to their own learning progress. For example, skill meters have been used to show a student's knowledge level and misconception on a topic (Ahmad & Bull, 2009; Bull, Jackson, et al., 2010), and concept maps have been used to visualise the relationships among the domain concepts learnt (Mabbott & Bull, 2006; Maries & Kumar, 2008; Pérez-Marín & Pascual-Nieto, 2010). Supporting user exploration of learning data with suitable representations to present a learner model is one of the challenges in open learner modeling. The usefulness of a specific form of the representational formats is affected by many factors especially the purposes for opening the model and the stakeholders who will use it for information exploration. Current OLM research provides good reference of visualisation options to be adopted in this research project. However, they might not be sufficient to support the depth of user information needs and exploration in the Task-Oriented Portfolio teaching.

Task-Oriented Portfolio teaching based on the Constructive Alignment (CA) model requires students to learn in a self-regulated manner. Task List and Burndown Chart are two existing visualisations used in Doubtfire for the teaching staff to outline key learning tasks and to assist students in tracking their progress (Woodward et al., 2013). Although learning outcomes play the central role in this teaching approach, there is no feature to support student reflection of their achievements in terms of learning outcomes in Doubtfire. This research uses Doubtfire as a platform to explore various new visualisations for presenting learning task status and links between tasks and the learning outcomes.

In this way, both the teaching staff and students are kept aware of student progress in terms of task status as well as achievements in terms of learning outcomes. This would help students to work progressively and to manage the assessment tasks in a self-regulated manner so that the intended learning outcomes are achieved. The teaching staff would be able to monitor student progress and achievements.

This chapter illustrates various types of OLM visualisations that were proposed to serve the learning aspects in supporting the Task-Oriented Portfolio teaching. It then describes the implementation of scenario-based design to test a variety of visualisation options. The chapter is then concluded with a brief summary.

4.2   Proposed Open Learner Model Visualisations

Based on the nature of Task-Oriented Portfolio teaching, five key learning aspects have been identified in consultation with staff teaching portfolio-based units. Five key learning aspects for inspection are:

(i)   Inspecting learning task status

(ii)   Presenting an overview of learning task status statistics

(iii) Visualising individual learning outcome achievements

(iv)   Inspecting **group** learning outcome achievement statistics

(v)   Comparison of learning outcome achievements

The proposed representational formats for inspecting these learning aspects are as follows.

4.2.1   Key Learning Aspect 1: Inspecting Learning Task Status

Three different representational formats were proposed to enable users to keep track of student progress. The first two, the Task List and Burndown Chart, were adopted from (Woodward et al., 2013) and were designed to show the status of a student's learning task (i.e., Ready to Mark, Resubmit, Complete, etc). The third, the Task Completion Chart, was an alternative version of the Burndown Chart showing tasks that have been completed instead of tasks to be completed (remaining). The *y*-axis of the Burndown Chart shows the total task remaining against the time (in week) whereas the *y*-axis of the Task Completion Chart denotes the total number of tasks completed against the time (in week). The examples are as shown in Figure 4.1 (a) to (c).
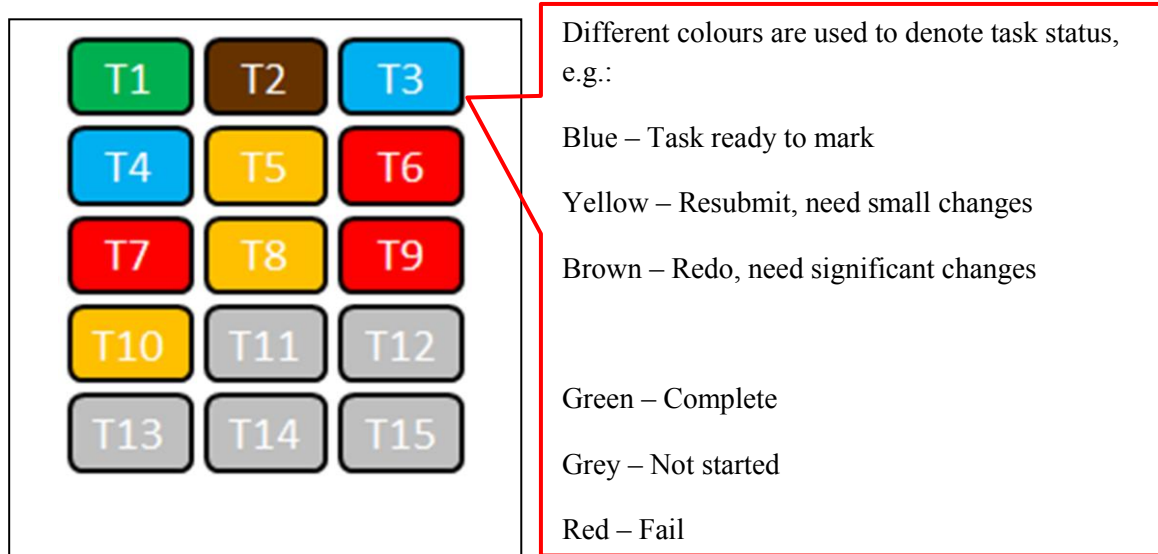
Figure 4.1 (a) Doubtfire Task List

The Task List shows the total tasks of a unit for a student (see Figure 4.1 (a)). Different colours are used to show the status of the task. For example, Blue designates that the task is ready to be viewed by the tutor, Yellow means that the the task has been reviewed by the tutor but still needs some work and green means that the tutor is happy with the work and it is considered complete. Grey shows that a student has not started working on the task yet. The Task List gives an immediate visual impression of the current status of all tasks.
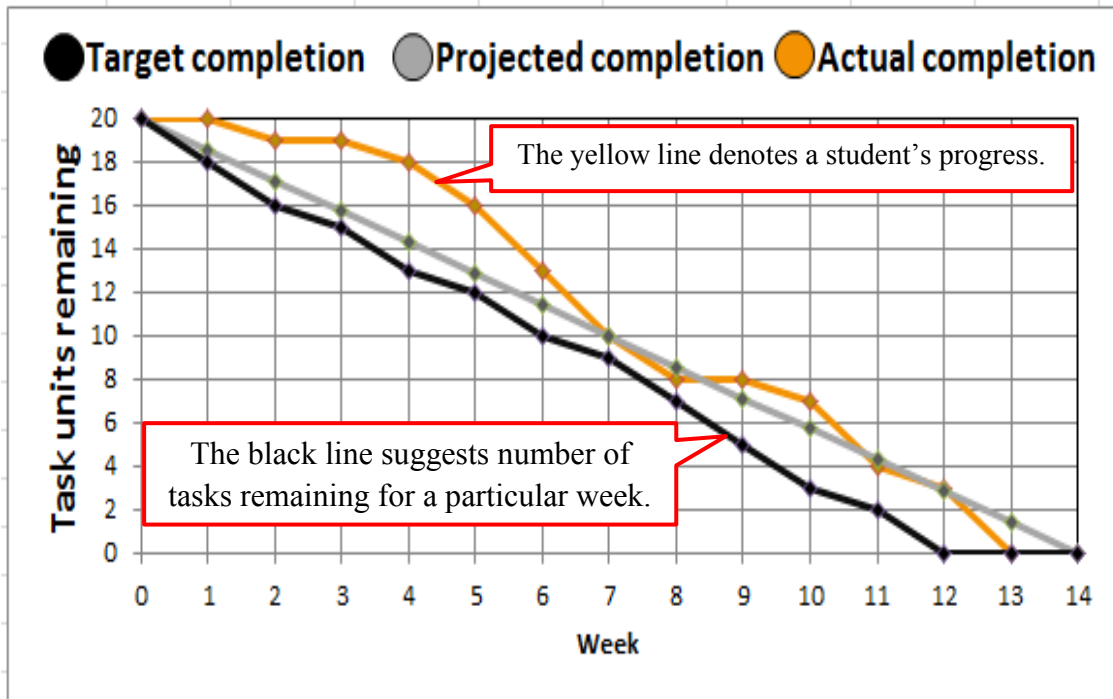
Figure 4.1 (b) Doubtfire Burndown Chart
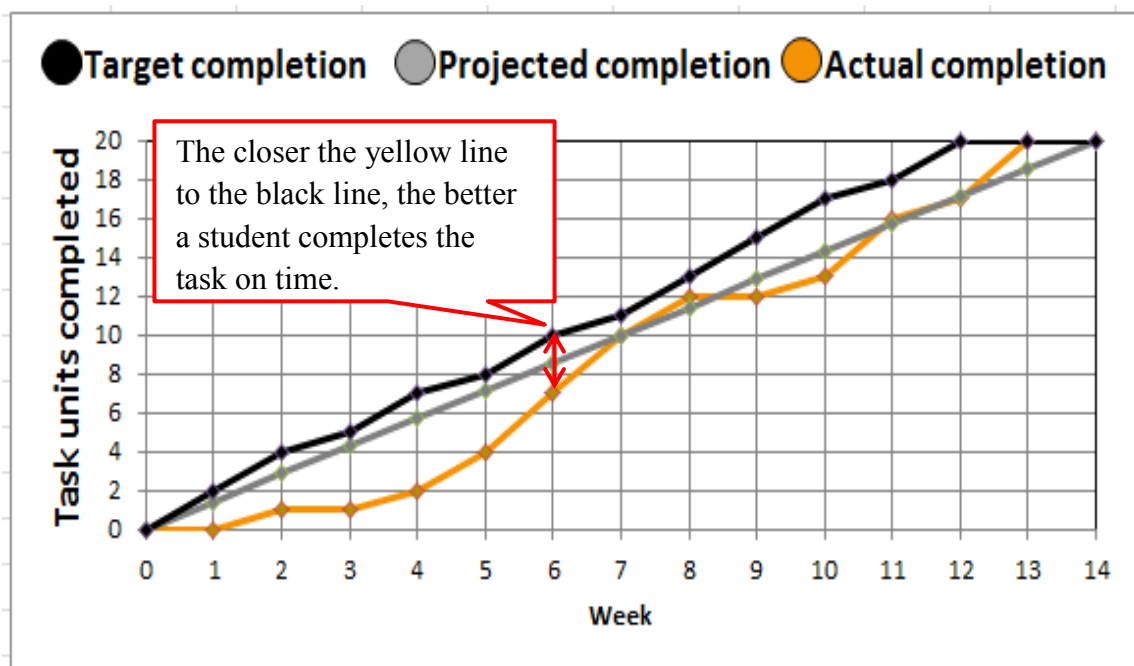
Figure 4.1 (c) Task Completion Chart

A Burndown Chart shows the backlog of tasks remaining by week (see Figure 4.1 (b)) whereas the Task Completion Chart shows the number of tasks completed by week (see Figure 4.1 (c)). The *x*-axis of these graphs shows the number of week. The *y*-axis of Burndown Chart and Task Completion Chart shows the number of tasks remaining and

completed by week respectively. In both charts, a student's progress is shown by the yellow line whereas the target completion is denoted by the black line. The closer the yellow line to the black line, the better a student completes the task on time. The grey line projects a student's completion time based on his/her current progress. This helps students to plan their time and their study load.

4.2.2   Key Learning Aspect 2: Presenting An Overview of Learning Task Status Statistics

Three types of graphical representations were proposed to provide a summary of a student's learning task status (see Figure 4.2 (a) to (c)). These were the Task Summary Table, Task Summary Bar Graph and Task Summary Pie Chart. These formats are popular graphical representations used in statistics. Each of the representations shows the total number of tasks for each task status. Task Summary Table describes the data with numbers. Task Summary Bar Graph and Task Summary Pie Chart use the height of the bars and the proportion of the circle to encode the number of tasks of each task status respectively. This allows users to check the current number, or proportion of learning tasks for each status. Students are able to visualise the number of tasks, especially those that need their further action such as redo or resubmit. They can then act on them accordingly in order to complete their learning tasks in a timely manner. The teaching staff are able to intervene when necessary based on what is captured in the visualisations.

	Number of tasks
Need help	4
Redo	6
Resubmit	10
Discuss	20
Complete	10
Total	50

Figure 4.2 (a) Task Summary Table
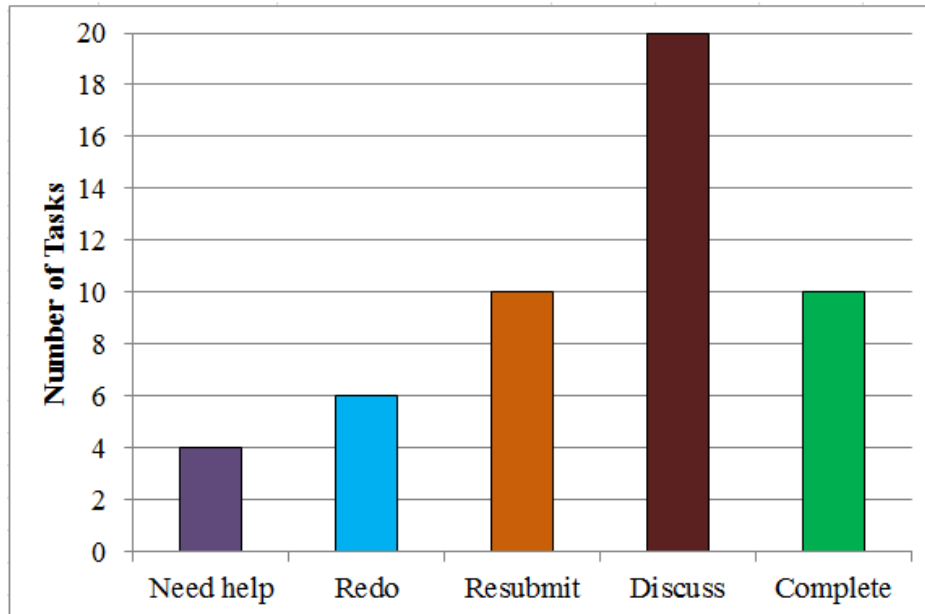
Figure 4.2 (b) Task Summary Bar Graph
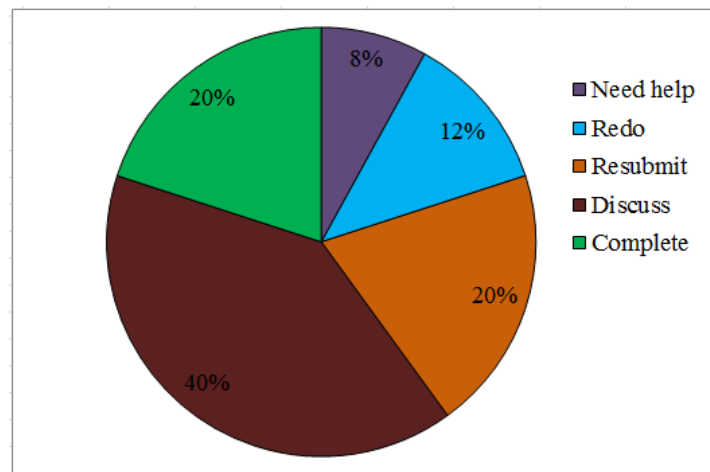
Figure 4.2 (c) Task Summary Pie Chart

4.2.3 *Key Learning Aspect 3: Visualising Individual Learning Outcome Achievements*

Visualisations in Figure 4.1 and Figure 4.2 display learning data in relation to task status whereas the visualisations in Figure 4.3 and Figure 4.4 present data about learning outcome achievements. One textual form and ten graphical representations for inspecting individual learning outcome achievements were proposed as in Figure 4.3 (a) to (k). Each of the representational formats presents the data in different ways by using text description, space, size, orientation, shape, quantity and/or colour. Out of the ten graphical representations, six of them – Skill Meter, Spider Plot, Tree Map, Smiley Face, Table and Word Cloud were

adopted from (Johnson et al., 2013), one – Grid Plot from (Albert et al., 2010), and the other three – Bar Graph, Target Plot and Star Pictogram were adopted from common statistical representations. In addition, Textual Form was proposed in view of its descriptive power (Bull et al., 2013). They were adopted and adapted to be used in this study.

Your achievement for LO1: Proficiently demonstrates communication in English is good.

Your achievement for LO2: Uses critical thinking in making judgements and decisions is good.

Your achievement for LO3: Executes tasks proficiently and on-time is weak.

Figure 4.3 (a) Textual Form
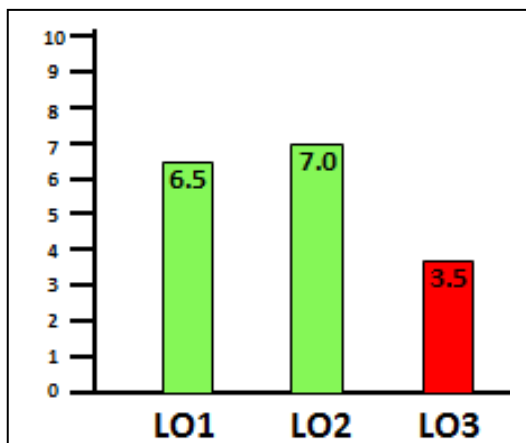
Figure 4.3 (b) Bar Graph   Figure 4.3 (c) Skill Meter
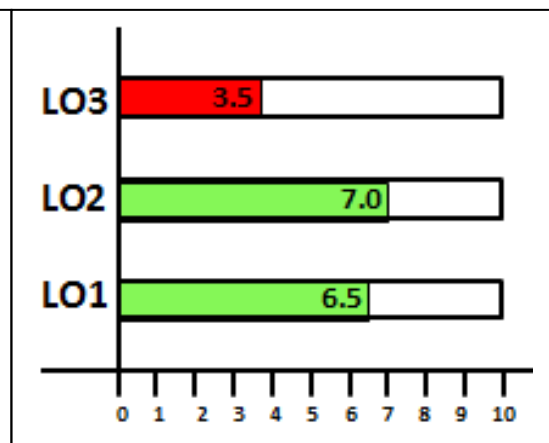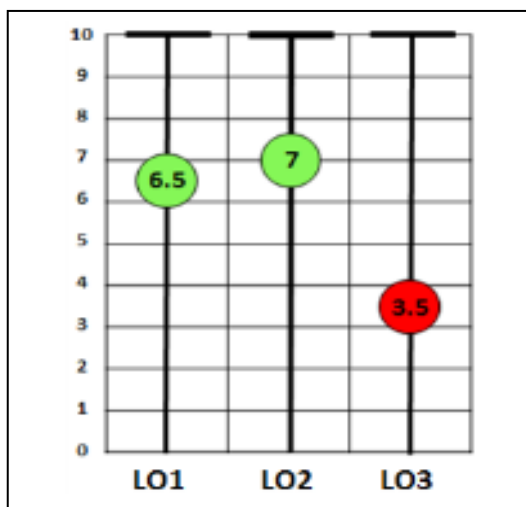
Figure 4.3 (d) Grid Plot   Figure 4.3 (e) Target Plot
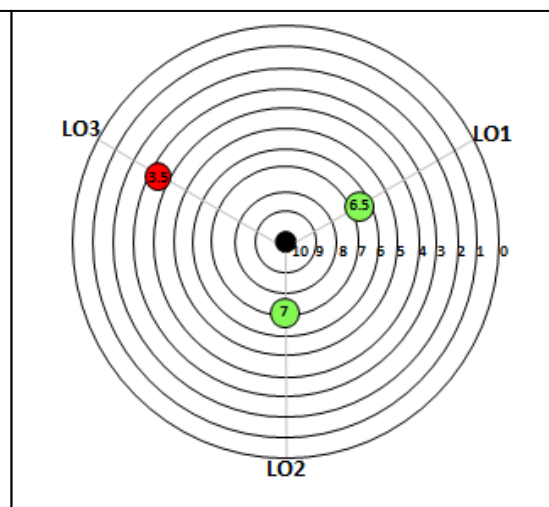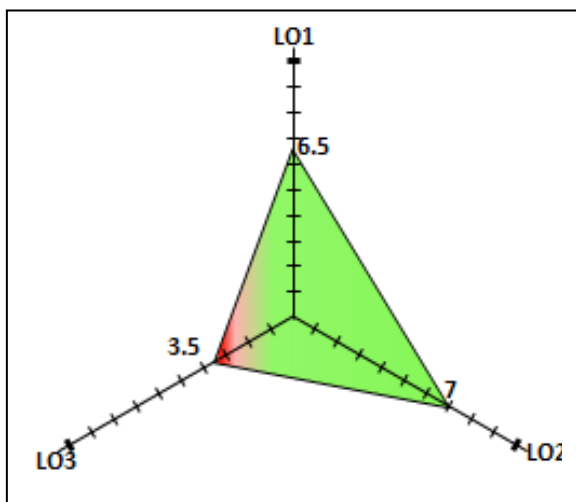
Figure 4.3 (f) Spider Plot
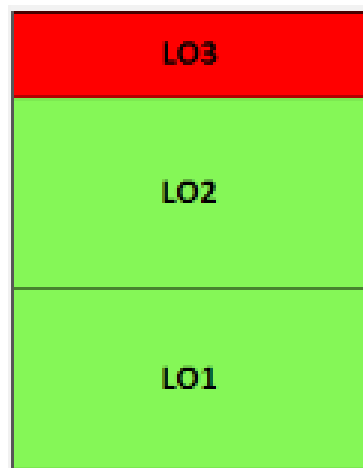
Figure 4.3 (g) Tree Map
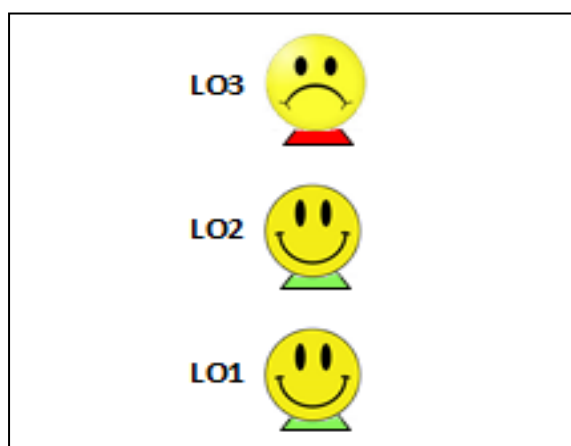
Figure 4.3 (h) Smiley Face

Figure 4.3 (i) Word Cloud

Figure 4.3 (j) Table

Figure 4.3 (k) Star Pictogram

Textual Form uses textual descriptions to convey a student's achievement level such as excellent, good, average or weak (see Figure 4.3 (a)). For all graphical representations, colours are used to denote if a student is making good progress in terms of grasping a particular learning outcome. For example, green indicates good progression and red indicates at risk. These are universal colours which have been extensively used in OLM to denote calmness and caution respectively (Johnson et al., 2013; Lloyd & Bull, 2006; Mabbott & Bull, 2004, 2006).

Data is presented vertically and horizontally in Bar Graph (Figure 4.3 (b)) and Skill Meter (Figure 4.3 (c)) respectively. The height and length of the bar in the Bar Graph and Skill Meter denote a student's achievement level. Positions of dots are used in Grid Plot (Figure 4.3 (d)) and Target Plot (Figure 4.3 (e)) to display a student's achievements. The higher dot position in the Grid Plot and closer dot position to the centre point of the Target Plot denote better achievement level and vice versa. This information is indicated by the area in the Spider Plot (Figure 4.3 (f)) and Tree Map (Figure 4.3 (g)) whereby a larger area denotes a better achievement level. Smiley Face (Figure 4.3 (h)) uses face expression with smiling face showing better achievement, neutral face for average and unamused face for weak achievement. Word Cloud (Figure 4.3 (i)) uses font size to show relative achievement level. The bigger font size for green text and red text denote higher and lower achievement level respectively. As for Table (Figure 4.3 (j)), the representation uses a combination of textual descriptions and graphics. The text describes the qualitative achievement ranges whereas the dot indicates a student's achievement level. In Star Pictogram (Figure 4.3 (k)), achievement level is displayed in pictorial form, indicated by the number of stars. Users are able to inspect the level of a student's learning outcome achievements through these representational formats.

*4.2.4   Key Learning Aspect 4: Inspecting **Group** Learning Outcome Achievement Statistics*
An exhaustive literature review related to OLM shows that most of the researchers in this field focus on representations of individual data instead of data statistics of a class. Inspection of class achievement data could be useful and motivating (Bull, 2004; Bull, Dimitrova, & McCalla, 2007; Kay, 1997). Four types of representational formats are proposed to display the learning outcome achievements of a class. They include the Boxplot, Ladder Scale, Fan Scale and Line Scale as shown in Figure 4.4 (a) to (d). The Boxplot has been widely used in exploratory data analysis to display visual summary of the data distribution which include minimum, first quartile, median, third quartile, and maximum (McGill, Tukey, & Larsen, 1978). Based on how a Boxplot can graphically depict a summary of the data distribution,

another three new types of representational formats, namely the Ladder Scale, Fan Scale and Line Scale have been proposed. While Ladder Scale presents data vertically, the same data is presented horizontally in Line Scale. Fan Scale resembles speedometer in which data is presented in a semi-circle form.
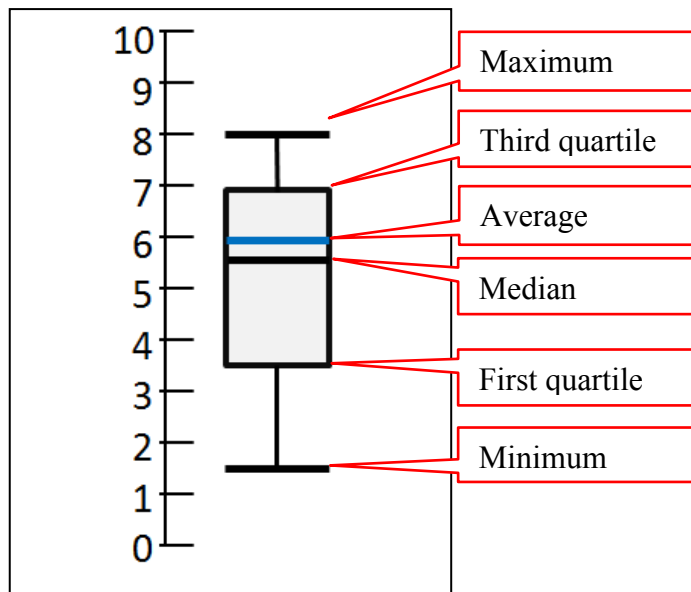
Figure 4.4 (a) Boxplot
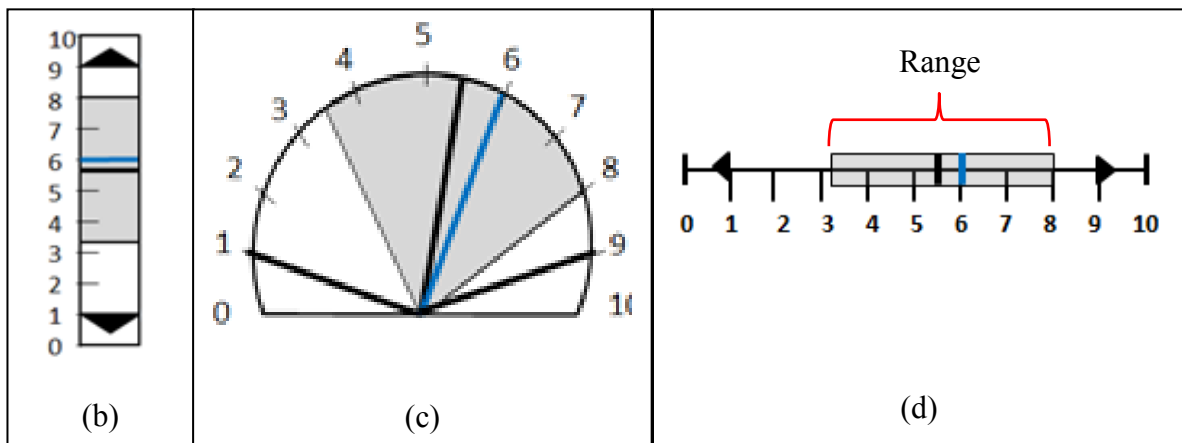
Figure 4.4 (b)   Figure 4.4 (c) Fan Scale   Figure 4.4 (d) Line Scale
Ladder Scale

These four representational formats are proposed to present the class achievement statistics data including class average, median score, maximum score, minimum score and the range score of fifty percent of the students. The range score is denoted by the grey shaded area on the visualisation whereas the average and median score are denoted by the blue and black lines that are in the shaded area respectively. The two lines or triangles outside the shaded range indicate the minimum and maximum values respectively. The statistics will be charted once a student's submitted work has been signed off as complete by the teaching staff. These representational formats are proposed as they could reveal comprehensive and insightful learning data to users. The teaching staff would be able to know how their class has performed. The analysis and visualisations would support staff reflection on teaching by identifying how well their teaching approach and strategies work for students. As for student users, they might be interested to know how their class has performed in achieving a particular learning outcome.

4.2.5 *Key Learning Aspect 5: Comparison of Learning Outcome Achievements*

Most existing OLMs focus on presenting the learning data of an individual student. In this research, various OLM visualisations were proposed to allow students to compare their achievements with the class achievement average and statistics. It also enables the teaching staff or students to compare between subgroups.

Based on the representational formats as discussed in Figure 4.3 and 4.4, different colours are used to display the comparison of the data, e.g., blue represents class achievement and green or red denotes individual achievements. Figure 4.5 (a) shows a comparison between individual achievement and group achievement. The height of the bars indicates achievement level, with a higher bar denoting a better achievement level and colour differentiates between group and individual achievements. For a comparison between individual achievement and class statistics as in Figure 4.5 (b), individual achievement is denoted by the red line if the achievement is low and green line for good achievement. A comparison between group achievements can be seen when the boxplots are placed side by side as in Figure 4.5 (c).
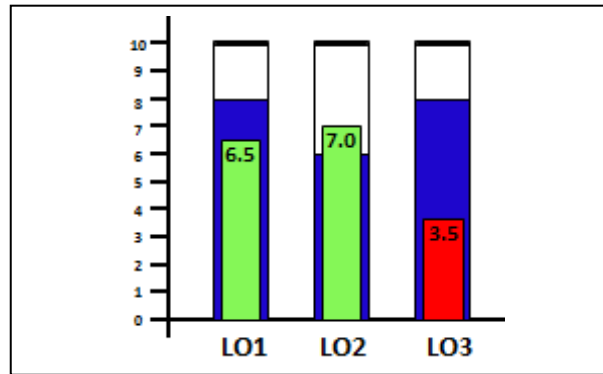
Figure 4.5 (a) Individual achievements versus group achievements
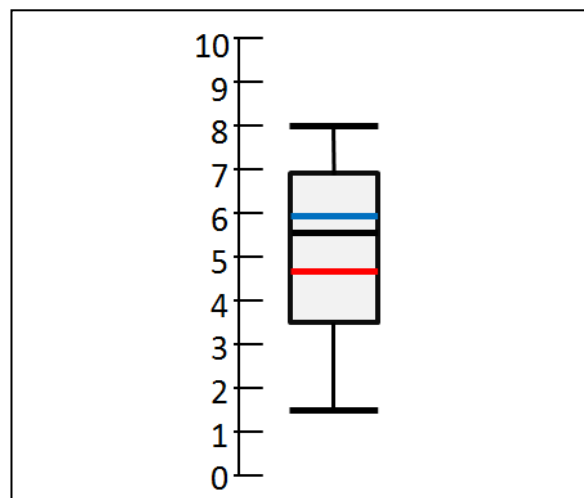
Figure 4.5 (b) Individual achievement versus group statistics
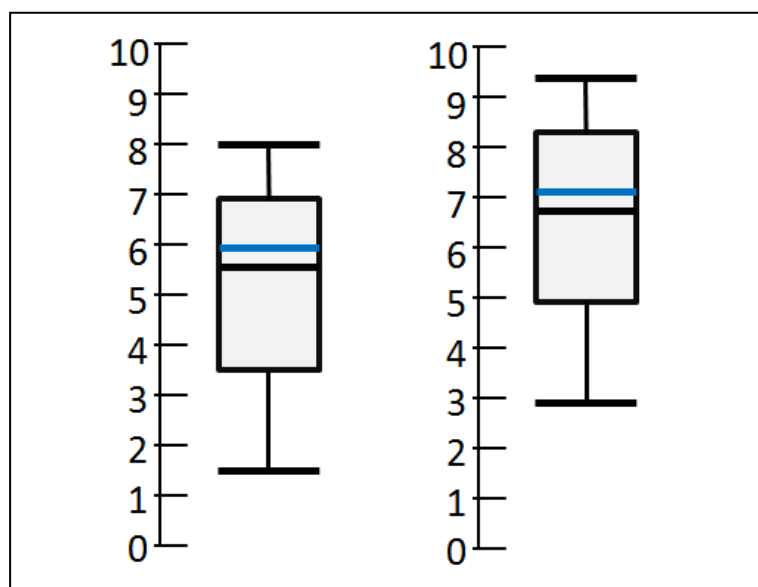
Figure 4.5 (c) Achievements of two subgroups

Through the OLM visualisations in Figure 4.5 (a), students are able to know if their achievement for a particular learning outcome is ahead or falling behind the class average. From Figure 4.5 (b), they can visualise how their class is performing as a whole. The visual data is especially helpful for student users to reflect on their own achievements, hence be motivated in improving their learning outcome achievements. Based on these visualisations, the teaching staff would be able to identify students who need help.

The visualisation in Figure 4.5 (c) would allow the teaching staff to know students' achievements by tutorial groups or different student cohorts. This would help the teaching staff to monitor student achievements by groups of student cohorts. It could be useful especially for a convenor who manages a unit or teaching staff who are in-charge of several tutorial groups. The representations could include visual analysis of a tutorial group, different student cohorts or with the whole unit. This data could be useful to help the teaching staff reflect on their teaching plan. If Figure 4.5 (c) is available to the students, they would be able to know the achievement of their class as compared to other classes.

The proposed tool that consists of the visualisations being reviewed will enrich existing OLMs with class-wide statistical data and comparison features. Students are expected to monitor their progress towards improving their learning outcome achievements relative to the progress and achievements made by their class or other classes. It is posited that this can better fulfil user information needs for inspecting their OLMs. Teaching staff can benefit from information about an individual student's achievements and also from information about the achievements of the class they are teaching. There are many ways visual analysis data can be explored. Some might be useful to all users and others may be useful to a certain user group. User perceived usefulness of the visualisations are sought from two main user groups, the teaching staff and student.

Based on these proposed visualisations, the next step is to seek target end user feedback and input regarding the support of each visualisation in facilitating their functional roles. The prototype design of the visualisations was built through the video simulation using Macromedia Captivate. Scenario-based design was used to allow the research participants access to the proposed visualisation options.

4.3   Scenario-based Design

Scenario-based design refers to techniques that are used to describe a future system during its early development process with the aim of envisioning and documenting its future use possibilities (Rosson & Carroll, 2002). Scenario-based design is a popular technique to guide the development of a system (Carroll, 2000). Scenario narratives can be presented in text, story-boards of annotated cartoon panels, video mock-ups or scripted prototypes to support user activities. The system use is represented as a series of planned scenarios. The main purpose of using scenario-based design is to make the intended use explicit. This enables the software designers to focus attention on the prospective users and their tasks that are implicit in systems and applications (Carroll, 2000). This helps them gain design rationale and make design decision for system design and the system development lifecycle (Carroll, 1997). From the insightful initial user requirements gained, they can better serve user needs and requirements for practical real-world applications.

Without user involvement, software designers can only envisage the software interface design. Ultimately, scenario-based design includes user involvement in the design process. It can increase interface success through gaining valuable user insights. Based on these positive advantages of scenario-based design, it was used in Study 1 of this research to depict the proposed visualisation options to the prospective users. Video mock-ups were used as the scenario narrative to form the foundation for the interface design rationale of the proposed OLM visualisation options. Initial user requirements for the prototype design were solicited in order to better serve prospective user needs, requirements and experience. This involved prospective users in the design process of the OLM prototype visualisation options. Users perceive usefulness of OLM representational formats, their preference toward specific graphical formats, potential problems and alternative representations to present data related to student learning progress and achievements are essential factors to be investigated.

In this research, various representational formats were proposed and developed for example scenarios of use to visualise the learner model (i.e. Figure 4.1 to 4.5). The charts used as OLM representational formats were constructed by using Microsoft Excel and Microsoft Power Point for examples of scenarios used. The prototype representation design was built through the simulation of the planned software by using Macromedia Captivate. Audio narration was incorporated in the video generated from Macromedia Captivate software. This video was uploaded in YouTube. Research participants accessed the video at http://youtu.be/Aa_7cisg1uo. This video link was included in the online survey questionnaire.

Before participants started answering the online questionnaire, they were introduced to OLM visualisations through this video simulation and example mock-up pictures. They were briefed about the visualisation options, the representation aspects and how they were intended to be used (see Appendix A.3). They were then invited to respond to an online survey. The purpose of the survey was to solicit initial user opinions, information visualisation needs and some interface design requirements of the OLM visualisation options. An Explanatory Sequential Mixed-Methods Design (see Section 3.4) was applied for collecting, analyzing, interpreting, and reporting both quantitative and qualitative data in Study 1. The results obtained are presented and discussed in Chapter 5.

4.4   Summary

Clear and easy to understand representational formats are important to facilitate user understanding of the information presented. This chapter presents the visualisation options proposed to capture student learning task status and their learning outcome achievements in supporting a Task-Oriented Portfolio teaching approach. Various representational formats are adopted and adapted from existing OLM and information visualisation research to support this approach. The proposed visualisation options aim to support user inspection of the status of the learning tasks, the task statistics, individual and group learning outcome achievements as well as achievements by subgroups. Scenario-based design is used to present sample scenarios of the mock-up implementations of each of the visualisation options to the research participants. There is a need to investigate from prospective end user perspectives about how the proposed visualisation options can support user needs and exploration of the intended learning data. The results obtained are presented in Chapter 5.

Chapter 5
Study 1 Instruments And Results

5.1   Introduction

A wide range of OLM visualisations have been developed to represent learning information and to suit user information needs (Bull & Kay, 2007; Johnson et al., 2013). This research adopted some existing OLM visualisations (e.g. Fig 4.4 (a)) and proposed some new visualisations (e.g. Fig 4.4 (b) – (d)) based on existing visualisations from other domains to support the Task-Oriented Portfolio teaching (Law, Grundy, Cain, & Vasa, 2015). OLM systems rely on clear and effective representation of the user model to facilitate user understanding on the display of the learning data (Girard, 2007; Reimann, Bull, Halb, & Johnson, 2011). It is important that the representation formats can be presented in an easy-to-read visual data for users to view, analyse and compare their learning progress and achievement data. Understanding user perceived usefulness and their preference for particular visual representational formats is essential in creating an effective OLM interface.

Study 1 aims to investigate user perceived useful and preferred OLM representation formats for presenting student progress and learning outcome achievements. To fulfil this aim, the Research Question (*RQ*) has been formulated as follows:

What are user perceived suitable OLM representational formats to present student learning data in terms of task status and learning outcome achievements?

To answer the primary research question, six secondary research questions were developed including:

RQ1: *What representational formats do users perceive as useful for the purpose of presenting learning data in terms of*

    (i)   learning task status?

    (ii)   learning task status statistics?

    (iii)   individual learning outcome achievements?

    (iv)   group learning outcome achievements, and

    (v)   comparison of learning outcome achievements?

RQ2: *What are user perceived preferred representational formats for the purpose of presenting learning data in terms of*

   (i)   learning task status?

   (ii)   learning task status statistics?

   (iii)   individual learning outcome achievements?

   (iv)   group learning outcome achievements, and

   (v)   comparison of learning outcome achievements?

RQ3: *Why is a certain representation perceived to be more useful and preferred?*

RQ4: *How can we enhance the visual representational formats?*

RQ5: *Is there a relationship between user perceived useful visualisations and their preferred visualisations?*

RQ6: *Is there a difference in perceived usefulness of visualisations between staff and students for user perceived most useful and preferred visualisations?*

Various prototype visualisations for capturing student learning task progress and learning outcome achievements were proposed (Section 4.2). The prototypes were tested with prospective end users using scenario-based design (Section 4.3). These visualisations were tested to confirm if they were likely to be useful and accepted by the stakeholders through a detailed survey and interviews. As discussed in the Research Methodology (Chapter 3), Study 1 was conducted in accordance with Swinburne's Human Research Ethics policies and procedures (Appendix A.1 and Appendix A.2). Staff participants were invited to participate in a survey through an email invitation. Student participants were recruited through the help of the teaching staff. The survey link was posted in an online announcement board. Interview participants were recruited from the survey participants in which interested participants could key-in their contact information at the end page of the survey (Appendix A.6). The contact information page was separated from a participant's responses to ensure anonymity. An Explanatory Sequential Mixed-Methods research design was adopted to adequately answer the research questions.

This chapter first presents the research instruments used to collect the data. This is followed by descriptive statistics analysis to describe the sample characteristics, both quantitative and qualitative samples. Next, the quantitative analysis techniques and results are presented together with the qualitative results (point of mixing) for a better interpretation of the findings.

A detailed discussion of the findings is then presented. Finally, this chapter highlights the potential threats to validity before it concludes with a brief summary.

5.2   Research Instruments

To adequately answer the research questions, both quantitative and qualitative strands were implemented. An online survey questionnaire and an interview plan were used as the instruments to collect the data needed.

5.2.1   Quantitative Instrument: Questionnaire Construction

There were two versions of survey questionnaires, one for the teaching staff and one for the students, both consisted of five parts with similar questions as shown in Appendix A.3. The only difference was participants perceived the usefulness of visualisations from either teaching perspectives or learning perspectives.

Part 1 presented the Project Information Consent Statement. Part 2 was designed to collect demographic information of the participants. Part 3 was used to identify participant perceptions on the types of OLM representational formats deemed useful to inspect their learner model. Each of the proposed visualisations was rated by the participants with a five-point Likert scale from 1=Not Useful to 5=Very Useful. The values from 1 to 5 were used to calculate the mean score for each of the representations and to identify the useful forms of representations.

Part 4 investigated participant preferred visualisations in exploring the OLM in five key learning aspects: (i) to view the learning task status; (ii) to check task status statistics; (iii) to inspect an individual student's learning outcome achievements; (iv) to view group learning outcome achievement statistics; and (v) to compare subgroups. To further understand participant opinions on why they prefer a specific visualisation, a textbox was provided for participants to provide additional comments where necessary. Open-ended questions in Part 5 aimed to identify potential barriers, solicit participant inputs for other visualisation formats to present student learning data and ways to improve it.

5.2.2   Qualitative Instrument: Interview Plan

The research questions for the qualitative strand consisted of fixed questions and questions that were built on the first quantitative phase. Apart from exploring the reasons why certain formats were perceived more useful and preferred and soliciting ways to enhance and enrich

the presentations of OLM visualisations, the qualitative strand aimed to explain the significant or unusual quantitative results in more depth.

Face-to-face individual interview sessions were held to collect the qualitative data through semi-structured open-ended interview questions. The interview questions were developed based on a comprehensive review of the related information visualisation and OLM literature together with data analysis results obtained from the quantitative strand.

The interview plan consisted of four parts. Part 1 gathered participants' demographic information. Part 2 was about how participants perceived the use of the proposed OLM visualisation options to present a student's learning data and their preferred visualisations. Part 3 solicited explanation on some significant quantitative results, including their opinions on OLM comparison features and reasons as to why certain OLM visualisations were perceived more useful and more preferred. Part 4 explored their views for other information visualisation approaches to better present a student's learning data and the possible barriers in using the visualisation tool. A sample of the semi-structured interview plan for staff and student is as attached in Appendix A.9 and A.10 respectively.

5.3   Samples

5.3.1   Preparation of Quantitative Data for Analysis

Statistical Package for the Social Sciences (SPSS) software was used to prepare data for quantitative analysis. It includes handling missing data, cleaning data, detecting outliers, testing the normality of the data set and performing reliability test. It was then used to analyse the quantitative data by generating descriptive statistics, exploring the relationship between variables, comparing mean scores and classifying OLM representational formats. SPSS is commonly used for generating descriptive statistics, tabulating reports, charts, and plots of distribution and trends (George, 2011; Pallant, 2013).

An important step in preparing the data set for analysis is to ensure that it is error free or with minimum errors due to data entry (Pallant, 2013). A researcher tends to commit such errors when a hardcopy survey questionnaire is used and when data collected is entered into the data analysis software. Thanks to Opinio survey software application that can automatically generate participant responses into a range of possible values set for a variable. The data set collected in this research was free from such errors. The data file that was generated in

various file extension formats including .xls and .sav could be readily imported to SPSS software for statistical analysis.

Adequate sample size is a major concern for quantitative data analysis. Missing data reduces the sample size for data analysis, thus ruining the research (Hair, Black, Babin & Anderson, 2014). It is, therefore, important to minimise the chance of having missing data and carefully handle the missing data from the data collected so as to obtain accurate research findings. Missing data occurs when the participants do not provide any answers or respond to the survey questions. Some survey software applications have built-in function to minimise the problem of missing data by requesting the participants to supply an answer for a particular question before they could proceed to the next question.

To minimise the possibility of missing data in this research, Opinio survey software application was used to ensure that the participants responded to the questions in a proper sequence. When a participant did not supply any answer to a particular question and the "Next" button in the survey page was clicked, a message prompted out to remind the participants to respond to the question. They could not proceed to the next question if the question was left blank. This implies that participants are required to answer a particular question before they could proceed to the next question. This causes the participants to either complete the questionnaire or abandon it. This has effectively reduced the missing data in the data set collected.

5.3.2 *Quantitative Sample Characteristics*

260 participants clicked on the survey link to start the survey. 38 abandoned the questionnaire while attempting the demographic questions and did not attempt any questions related to their perceived usefulness and preferred visualisations. These data were excluded from data analysis. The main reason could be that the participants were not interested in answering questions related to visualisation or they might not be familiar with information visualisation. Only one sample had missing data in the last question. To handle the missing data, a few suggestions have been proposed.

If no regular pattern can be noticed from the missing data in the survey questionnaires or if the missing data for an individual participant is less than 10%, the effect of the missing data on the research findings is small (Hair, Black, Babin & Anderson, 2014). Such missing data can generally be ignored or be replaced with appropriate values (Pallant, 2013). As there was only one sample that has missing data in the last question, it was reasonable to use the "Replace with mean" option in SPSS to replace the data with the mean value for the variable

(Pallant, 2013). This yielded a total of 222 valid samples. Once the data set was cleaned and the missing data was fixed, it was ready to be analysed with quantitative data analysis.

Descriptive statistics were used to describe the sample characteristics. Out of 222 valid samples, 64 were from Swinburne University of Technology, Australia whereas 158 were from Multimedia University, Malaysia. 34 of them were teaching staff and 188 were students. They were spread across a number of academic disciplines with a majority of them (150) from Information Technology (Info. Tech.), 57 from Engineering, and a minority of them (15) were from other disciplines such as Science, Business and Linguistics. 168 of them were male and 54 were female. Regarding participant familiarity with information visualisation (InfoVis), 17 reported being very familiar with information visualisation, 72 were somewhat familiar, 82 had heard about it and 51 were not familiar. Figure 5.1 illustrates the quantitative sample characteristics.
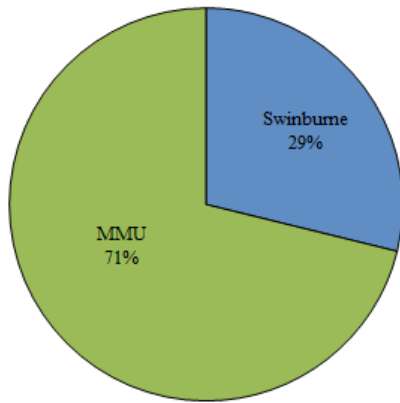
(a) Institutions   (b) User roles
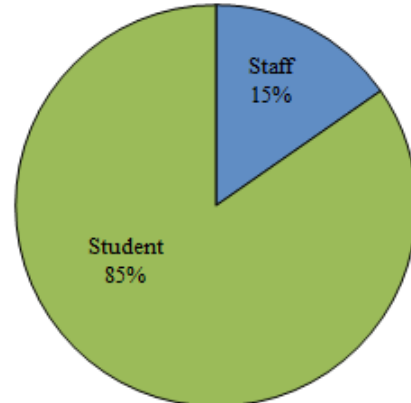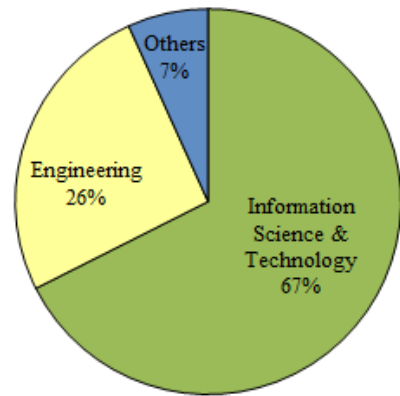
(c) Academic disciplines   (d) Gender
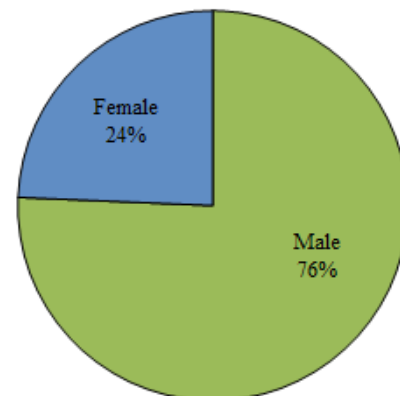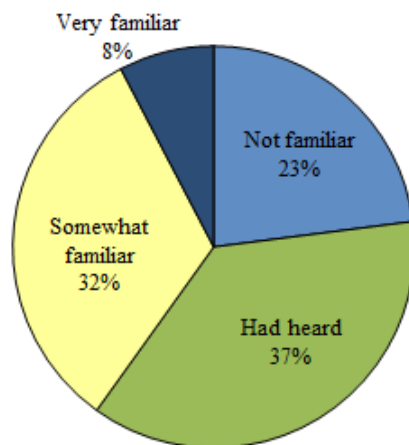
(e) Familiarity with InfoVis

Figure 5.1 Quantitative sample characteristics for Study 1

5.3.3 Qualitative Sample Characteristics

All the ten interview participants were males from the Faculty of Science, Engineering and Technology, Swinburne University of Technology. Seven of them were teaching staff and three were students. Two of them were from the Information Technology discipline and eight of them were from Engineering. In terms of experience with information visualisations, five were very familiar with information visualisation, four were somewhat familiar, and one had only heard about it. Figure 5.2 illustrates the characteristics of the qualitative samples.
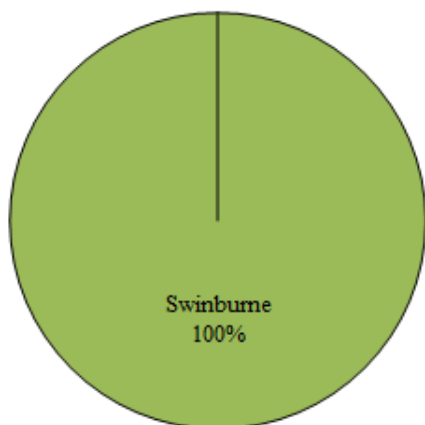
(a) Institution
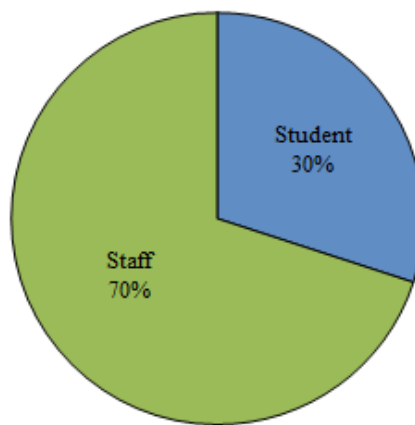
(b) User roles
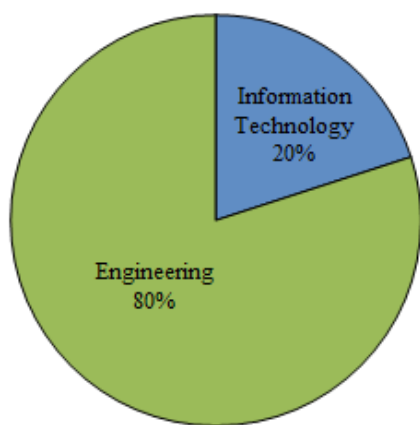
(c) Academic disciplines
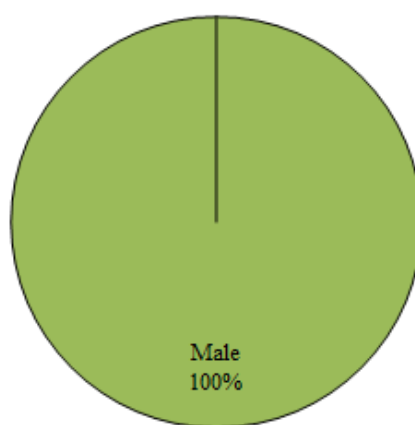
(d) Gender
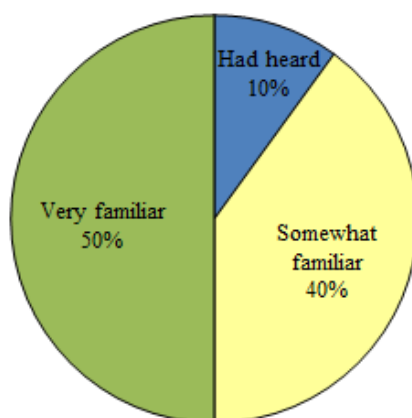
(e) Familiarity with InfoVis

Figure 5.2 Qualitative sample characteristics for Study 1

5.4   Quantitative Analysis Techniques and Mixed-Methods Results

Quantitative analysis techniques used in Study 1 include Descriptive Statistics analysis, Pearson Correlation, and Independent Samples t-test (Section 3.5.2.3). In Explanatory Sequential Mixed-Methods design, the point of mixing occurs during the final interpretation. This section reports on the analysis of the procedural steps of each of the quantitative analysis techniques. Content analysis (Section 3.5.3.3) was the qualitative analysis technique used to analyse the textbox comments in the survey questionnaire and face-to-face interview data. The quantitative results are presented together with the qualitative results for a better discussion and interpretation of the findings. 'He' is used as a pronoun for all the comments to retain the anonymity of participants. The following subsections present the results which address the research questions.

5.4.1   RQ1 to RQ4: User Perceived Useful and Preferred Visualisation Formats

Descriptive statistics analyses were used to answer *RQ1* and *RQ2* (i.e. to determine which representational formats the users perceived as useful and preferred). Qualitative analysis results based on content analysis were used to answer *RQ3* and *RQ4*. Comments were explored using word cloud format along with the original quotes obtained from the interviews. Word cloud is a type of word frequency analysis in which more common words or phrases appear in bigger font size. Word cloud is widely used and is a popular way to present data in a landscape view. It is a visual aid for providing a quick summary, especially for simplicity of the text. In this study, participant original responses (raw data) were categorised and coded. Word cloud analysis was used to present the coded data. The raw data and coded data for word cloud analysis are collated in Appendix A.13. The qualitative results provide causal explanation for user perceived useful and preferred representational formats found in *RQ1* and *RQ2* and ways to enhance the proposed visualisations. In this way, the data can be triangulated with the quantitative results to provide a more complete picture of the events under study.

Descriptive statistics measures such as number, percentage, mean and standard deviation are presented in table form to describe user views. Tornado charts are used to visualise the comparison between the percentage of participants who perceived the visualisations as useful and not useful. The percentage of participants who rated the visualisations as being moderately useful were divided equally into the perceived more useful and less useful views. This also eased the presentation in the Tornado charts. In other words, the ratings of 3 were

split evenly between more useful and less useful. This is to maintain the percentage of participants at 100%. The mixed-methods results are presented as follows.

5.4.1.1 Results for Key Learning Aspect 1: Inspecting Learning Task Status

Table 5.1 shows the proportion of the breakdown in terms of numbers and percentages (presented in parenthesis) of participants' responses for the representational formats that were perceived as useful for the purpose of inspecting the learning task status, including the mean value (μ) and standard deviation (SD) as well as their preferred view.

Table 5.1 Descriptive statistics results for inspecting learning task status

Format	Very useful			Not useful		μ	SD	Preferred view
	(5)	**(4)**	**(3)**	**(2)**	**(1)**			
Task List	43 (19.4)	69 (31.1)	50 (22.5)	39 (17.6)	21 (9.4)	3.33	1.24	132 (59.5)
Task Completion Chart	21 (9.5)	44 (19.8)	83 (37.4)	55 (24.8)	19 (8.5)	2.97	1.08	66 (29.7)
Burndown Chart	8 (3.6)	38 (17.1)	92 (41.4)	59 (26.6)	25 (11.3)	2.75	0.99	24 (10.8)

Task List (μ=3.33) was perceived as a more useful visualisation for inspecting learning task status whereas Task Completion Chart (μ=2.97) and Burndown Chart (μ=2.75) were perceived as slightly useful. As high as 59.5% (132) of the participants favoured Task List, 29.7% (66) and only 10.8% (24) liked Task Completion Chart and Burndown Chart respectively. The comparisons among these three visualisations based on user perceived usefulness and preferred view are charted in Figures 5.3 and 5.4 respectively.
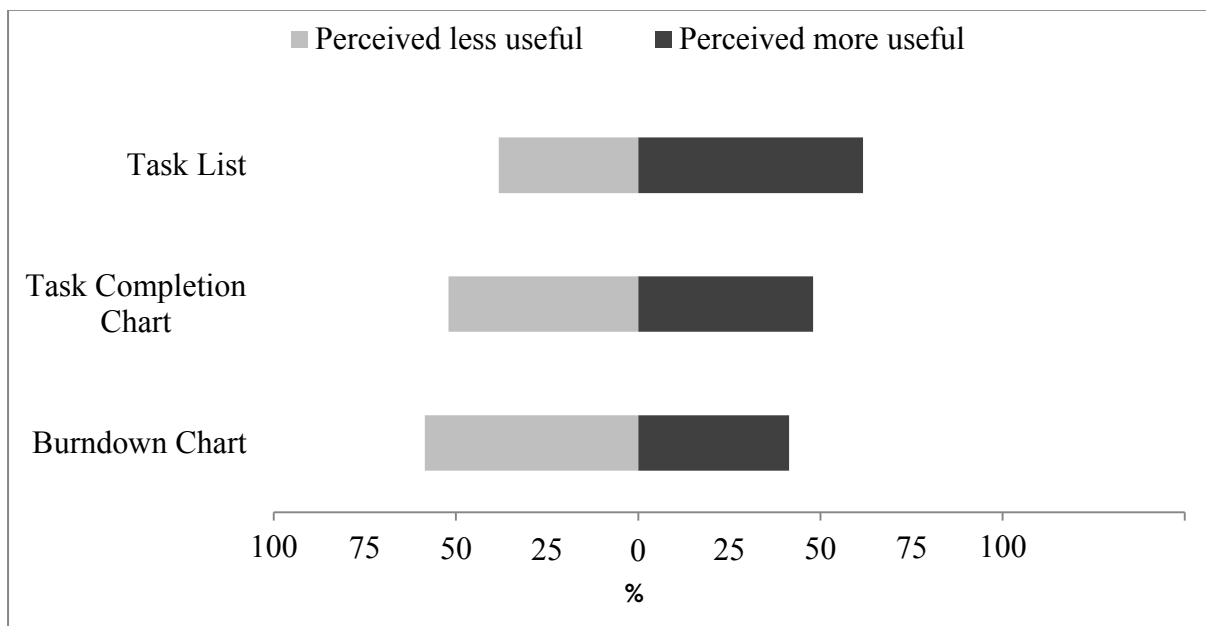
Figure 5.3 Usefulness ratings for each visualisation type for inspecting learning task status
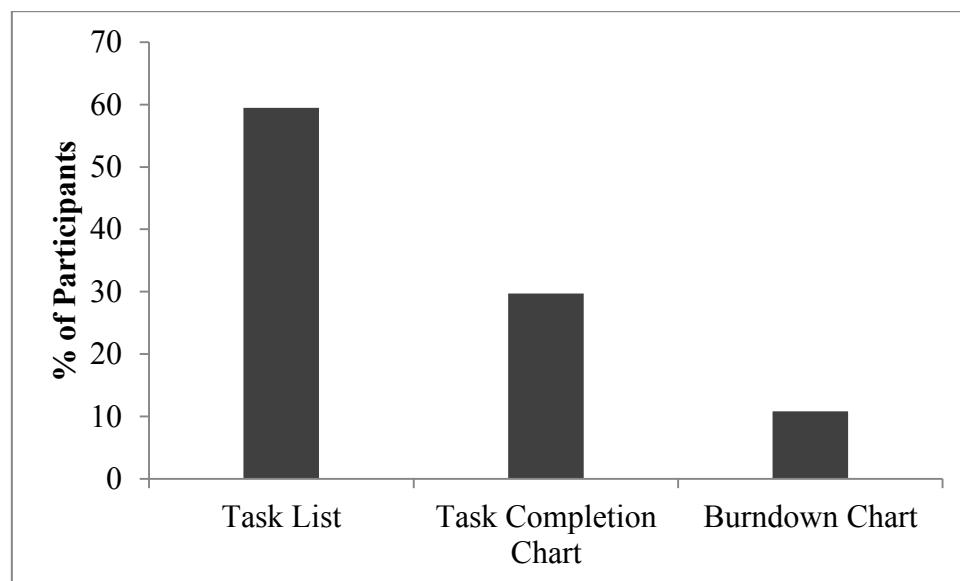
Figure 5.4 Participant preference for each visualisation to inspect learning task status

More participants perceived Task List as useful compared to Task Completion Chart and Burndown Chart. Task List was also the most preferred visualisation to inspect task status. To explore why participants preferred the Task List, a word cloud analysis was conducted on the comments that participants had provided when they were questioned as to why they preferred

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the Task List (see Figure 5.5). The main reason for their choice was because Task List helped them to easily track task status with distinct colour. Besides, it provides them with detailed, specific and actionable information of what to do next. Additionally, Task List was also perceived as simple, neat, clear, easy to understand, and it was a better visualisation as compared to the Burndown Chart and Task Completion Chart.

Figure 5.5 Word cloud analysis result for Task List

All these three visualisations convey information about task status. The Task List uses colour to show the status of each task. The Burndown Chart and the Task Completion Chart are quite similar. Both use line graphs to display the number of learning tasks with respect to time. While Burndown Chart displays the remaining tasks, Task Completion Chart shows the number of tasks completed. The interview results corroborate the quantitative results that Task List was generally perceived more useful by participants. It can be seen from the textual descriptions that the Task List appeared to be more popular and useful. Two students said:

> *Task List is really useful as I can see the status of each task in the list from the beginning to the end of the semester. I can focus my attention to complete the task that needs my further action.*
> *Task List has given a more sensing context. I can easily know which specific task and how many specific tasks I need to redo.*

A teacher expressed that:

> *Task List is good for both staff member and students to look at in terms of tracking progress. It gives quick analysis for identifying areas of concerns.*

However, Burndown Chart and Task Completion Chart each have their own descriptive and expressive power. Student comments include:

> *The Burndown Chart enables me to know my workload in total. It helps me to manage the backlog of the task and be aware of my past record.*

Tasks have to be deemed as the workload and not how many we have completed. Burndown Chart will straight away tell me how many tasks I need to complete and it is helpful because I can then manage my workload.

Task Completion Chart lets me see what I have done for the work I suppose to do. I prefer this tool than task Burndown Chart as I am more interested to know how much work I have completed as the time passes.

A teacher said:

I prefer Task Completion Chart because it gives more positive reinforcement of learning to students. I think the majority of students will take the positive impression.

Another teacher suggested having multiple views to inspect the learning tasks.

The line graphs tell how many tasks students have completed or still remaining whereas the Task List shows which one they have completed, submitted, need redo, etc.. They give different and complementary data so I think all are good. You need combination.

5.4.1.2 Results for Key Learning Aspect 2: Inspecting Learning Task Status Statistics

Table 5.2 shows participant perceived usefulness and individual preferences for inspecting learning task status statistics. All the three proposed visualisations were perceived to be moderately useful. With a small difference in the mean score, Task Summary Pie Chart (μ=3.69) and Task Summary Bar Graph (μ=3.64) were rated as the more useful visualisations to inspect learning task status statistics, as compared to Task Summary Table (μ=3.29).

Table 5.2 Descriptive statistics results for inspecting learning task statistics

Format	Very useful			Not useful		μ	SD	Preferred view
	(5)	**(4)**	**(3)**	**(2)**	**(1)**			
Task Summary Pie Chart	61 (27.5)	70 (31.5)	62 (27.9)	20 (9.0)	9 (4.1)	3.69	1.09	97 (43.7)
Task Summary Bar graph	48 (21.6)	91 (41.0)	49 (22.1)	22 (9.9)	12 (5.4)	3.64	1.09	81 (36.5)
Task Summary Table	37 (16.7)	61 (27.5)	75 (33.8)	28 (12.6)	21 (9.5)	3.29	1.17	44 (19.8)

Figure 5.6 and Figure 5.7 chart the comparison of participant perceived usefulness and preferred view to inspect learning task status statistics respectively.
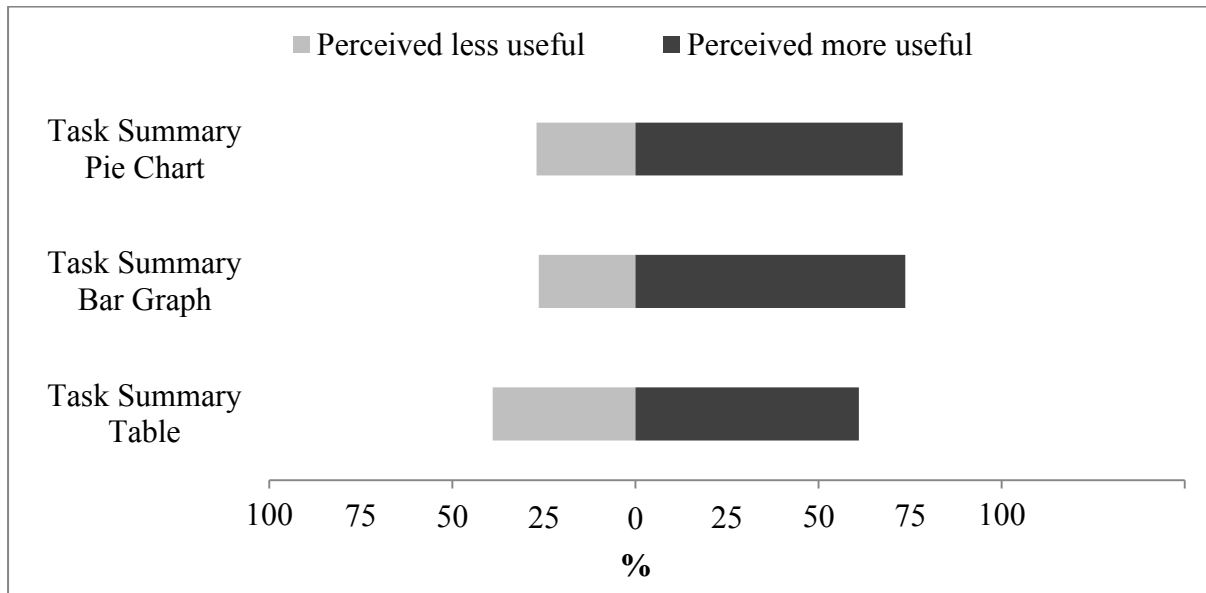
Figure 5.6 Usefulness ratings for each visualisation type for inspecting learning task status statistics

When asked which chart they preferred the most, more participants preferred the Task Summary Pie Chart (43.7%) than the Task Summary Bar Graph (36.5%) and that only 19.8% preferred the Task Summary Table (see Figure 5.7).
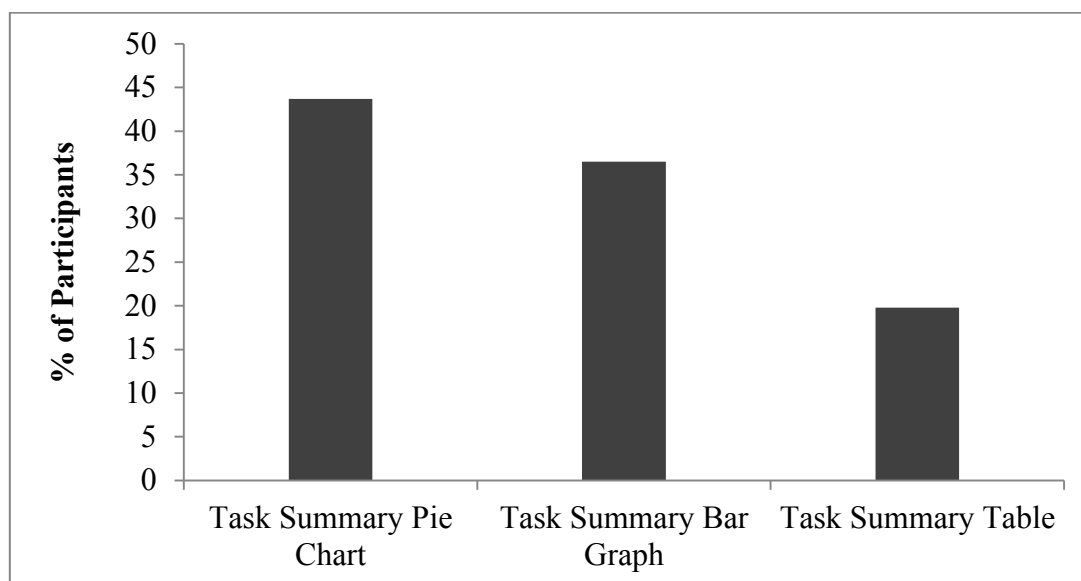
Figure 5.7 Participant preference for each visualisation to inspect learning task statistics

A word cloud analysis was conducted to explore why participants preferred the Task Summary Pie Chart (see Figure 5.8). The most frequent comments made by participants was that the Task Summary Pie Chart presents task breakdown and as a whole, it was easy to understand, easy to see as well as to compare the task statuses. Besides, it was also clear, familiar, attractive and motivating.

Figure 5.8 Word cloud analysis result for Task Summary Pie Chart

The interview data shed further light on why participants tended to prefer the graphical representations (particularly the Task Summary Pie Chart) over the textual Task Summary Table representation. A student indicated as follows:

Task Summary Pie Chart is very easy to see how much is left and how much is a concern. I like the colours. As compared to Task Summary Table, the visual impact is the colour coding of the data and the coding has a stronger influence to the reader. It motivates me to get the whole chart into green – complete.

Two teachers stated:

Task Summary Bar Graph is presenting the same thing as Task Summary Pie Chart. However, due to there is a complete 100% of the tasks that need to be done, I think Task Summary Pie Chart is a better chart to visualise the data.

In Task Summary Table, you can't get a proportion. There is no visual proportion. Presenting data in visual form like Task Summary Pie Chart is better.

A student pointed out a way to enhance the visualisation:

I suggest putting the number of tasks instead of percentages or a feature where a user can interchange between percentage and number.

5.4.1.3 Results for Key Learning Aspect 3: Inspecting Individual Learning Outcome Achievements

Table 5.3 illustrates the participants' perceived usefulness for presenting an individual student's learning outcome achievements. The table is colour scaled to show the degree of agreement with each level of perceived usefulness (green for useful, yellow for not useful, darker colour indicates higher percent of agreement). The visualisations rated as most useful, with mean scores of more than 3, were the Bar Graph (μ=3.74), the Pictogram (μ=3.54), the Skill Meter and the Table (each with μ=3.50). The visualisation formats rated as the least useful were the Tree Map (μ=2.52), Target Plot (μ=2.40) and Word Cloud (μ=1.97). It was also observed that while as many as 41% (91) participants rated Word Cloud as not useful, Tree Map and Target Plot were also rated as not useful by 19.8% (44) and 21.6% (48) participants respectively. The rest of the views including Textual, Grid Plot, Spider Plot and Smiley Face were rated as slightly useful to moderately useful with mean scores ranging from 2.83 to 2.99.

Figure 5.10 shows that 21.8% (145) participants had chosen the Bar Graph as their preferred visualisation. This is followed by 15% (100) who liked the table. 12.6% (84) favoured Skill Meter whereas 12.0% (80) liked Pictogram. The least preferred formats were Target Plot (3.3%), Tree Map (2.4%) and Word Cloud (1.8%).

Table 5.3 Descriptive statistics results for inspecting individual LO achievements

Format	Very useful				Not useful	μ	SD	Preferred view
	5	4	3	2	1			
Bar Graph	51 (23.0)	87 (39.2)	62 (27.9)	19 (8.6)	3 (1.3)	3.74	0.95	145 (21.8)
Pictogram	40 (18.0)	79 (35.6)	73 (32.9)	21 (9.5)	9 (4.0)	3.54	1.02	80 (12.0)
Table	31 (14.0)	83 (37.4)	78 (35.1)	25 (11.3)	5 (2.2)	3.50	0.95	100 (15.0)
Skill Meter	36 (16.2)	78 (35.1)	76 (34.2)	25 (11.3)	7 (3.2)	3.50	1.00	84 (12.6)
Grid Plot	20 (9.0)	51 (23.0)	74 (33.3)	61 (27.5)	16 (7.2)	2.99	1.08	31 (4.7)
Spider Plot	26 (11.7)	41 (18.5)	61 (27.5)	64 (28.8)	30 (13.5)	2.86	1.21	47 (7.0)
Smiley Face	26 (11.7)	49 (22.1)	60 (27.0)	39 (17.6)	48 (21.6)	2.85	1.31	64 (9.6)
Textual	10 (4.5)	46 (20.7)	86 (38.7)	57 (25.7)	23 (10.4)	2.83	1.02	65 (9.8)
Tree Map	9 (4.0)	31 (14.0)	71 (32.0)	67 (30.2)	44 (19.8)	2.52	1.08	16 (2.4)
Target Plot	7 (3.2)	25 (11.3)	66 (29.7)	76 (34.2)	48 (21.6)	2.40	1.05	22 (3.3)
Word Cloud	3 (1.3)	15 (6.8)	46 (20.7)	67 (30.2)	91 (41.0)	1.97	1.01	12 (1.8)

The comparison of participants' perceived usefulness and preferred view for the inspection of individual learning outcome achievements are as illustrated in Figures 5.9 and 5.10 respectively.

Figure 5.9 Usefulness ratings for each visualisation type for inspecting individual LO achievements
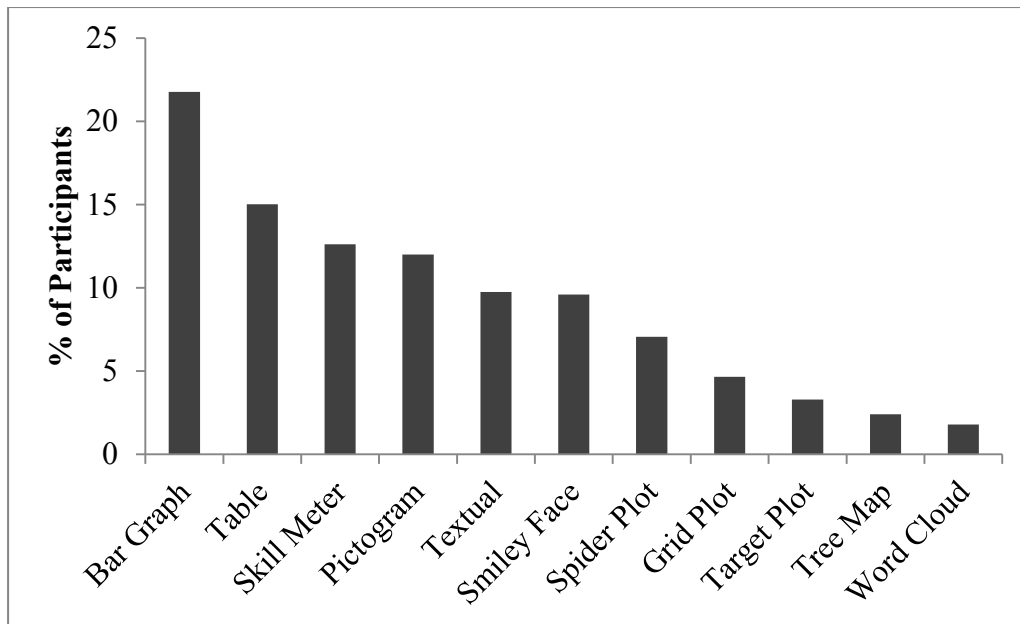
Figure 5.10 Participant preference for each visualisation to inspect individual LO achievements

Participants perceived the Bar Graph as the most useful representational format to present an individual's learning outcome achievements and most of them favoured this view too. The reasons for preferring the Bar Graph (as indicated by participants' comments) are visualised in the word cloud as shown in Figure 5.11. Participants perceived that the Bar Graph was easy to understand, see and compare. Besides, it was clear, simple and common. It also provided definite information and was a familiar visualisation.

Figure 5.11 Word cloud analysis result for Bar Graph

Following the quantitative results as shown in Table 5.3, the numerical data was triangulated with the narrative details from the qualitative results. Interview results were presented as to why Bar Graph, Skill Meter, Table and Pictogram were perceived useful and preferred in comparison to Target Plot, Tree Map and Word Cloud which were rated least useful and least

preferred. Participant views about other visualisation formats were also discussed. Their suggestions to improve the proposed visualisations were then presented.

Participant comments about Bar Graph, Skill Meter, Table and Pictogram:

Bar Graph and Skill Meter

A student said:

> *I like the vertical nature of a Bar Graph and it is easy to see my achievement level from the height.*

Two teachers stated:

> *The Bar Graph is good as it is accumulative and does not have a cap. Also, LO achievements are represented separately.*
>
> *Skill Meter and Bar Graph are simple and common. A lot of people know how to read them. Areas of problematic can easily be seen."*

Table

A teacher said:

> *Table is quite nice because it expresses LO achievement level in qualitative range.*

Pictogram

A teacher expressed:

> *Pictogram is easy and everyone is familiar with it, especially students. They can understand the ranking quite easily.*

Target Plot, Tree Map and Word Cloud were perceived least useful. This is interesting given their adoption in many domains. Reasons gathered from the interview details include:

Target Plot

> *As a teaching staff, I do not like Target Plot as I don't see why the LO should be in a spiral form. It looks complicated and difficult to interpret.*

Tree Map

A staff pointed out as follows:

Tree Map is not a good visualisation for this particular scenario as it assumes a cumulative of 100% of all LOs but in fact each LO is independent. It is easy to understand but it is not an appropriate application here.

Word Cloud

I can't justify my level of achievements from the font size of the word cloud. As a student, it didn't tell me how big is the font size for me to justify my skill as good or excellent.

Comments about other visualisations including Grid Plot, Smiley Face and Spider Plot are as follows:

Grid Plot

A teacher said:

Grid Plot looks crowded and complicated with the circles and the grid lines. It is confusing.

Smiley Face

Another teacher expressed that:

Smiley Face looks childish. It is very low resolution. It tells nothing.

Spider Plot

A student commented:

Spider Plot seems to relate each skill to another but that might not necessary be true.

Comments for improvement provided insightful input and aspects to be taken into consideration for the designing of appropriate representational formats to present an individual student's LO achievements. The comments are as follows:

A teacher said:

I would suggest denoting LO achievement level with qualitative range from very weak to excellent.

A student also expressed the similar view. Another teacher pointed out that:

Representational formats that have the max plot limit or some sort of uniform scale are not quite appropriate to represent learning outcome achievements as one learning outcome might not as important as the other in a unit.

A teacher suggested:

It is ideal to have combination of graphics and simple text for explanation to make the representation better and to ease interpretation.

A student also suggested the same point. A teacher proposed:

Stephen Few's bullet chart could be used to present student LO achievement data.

5.4.1.4 Results for Key Learning Aspect 4: Inspecting Group Learning Outcome Achievements

Table 5.4 presents the proportion of the breakdown of participants' responses according to their perceived usefulness of visualisations for the inspection of group learning outcome achievements, the mean value and standard deviation as well as their preferred view. Line Scale and Boxplot were both being rated as slightly to moderately useful with mean scores of more than 3.00, that is, μ=3.10 and 3.03 respectively. Although the mean score of Line Scale is slightly higher than Boxplot, more participants (32.9%) preferred Boxplot than Line Scale (29.3%). Ladder Scale and Fan Scale were perceived as slightly useful only with a mean score of 2.77 and 2.76 respectively. While 26.1% (58) liked Fan Scale, only 11.7% (26) liked Ladder Scale.

Table 5.4 Descriptive statistics results for inspecting group LO achievements

Format	Very useful			Not useful		μ	SD	Preferred view
	(5)	(4)	(3)	(2)	(1)			
Boxplot	22 (9.9)	58 (26.1)	68 (30.7)	52 (23.4)	22 (9.9)	3.03	1.14	73 (32.9)
Line Scale	20 (9.0)	59 (26.6)	78 (35.1)	53 (23.9)	12 (5.4)	3.10	1.04	65 (29.3)
Ladder Scale	13 (5.9)	36 (16.2)	82 (36.9)	70 (31.5)	21 (9.5)	2.77	1.02	26 (11.7)
Fan Scale	9 (4.0)	43 (19.4)	83 (37.4)	59 (26.6)	28 (12.6)	2.76	1.04	58 (26.1)

Figure 5.12 illustrates a comparison of the participants' perceived usefulness of the four proposed visualisations to inspect group learning outcome achievements while Figure 5.13 charts the comparison of participants' preferred view.
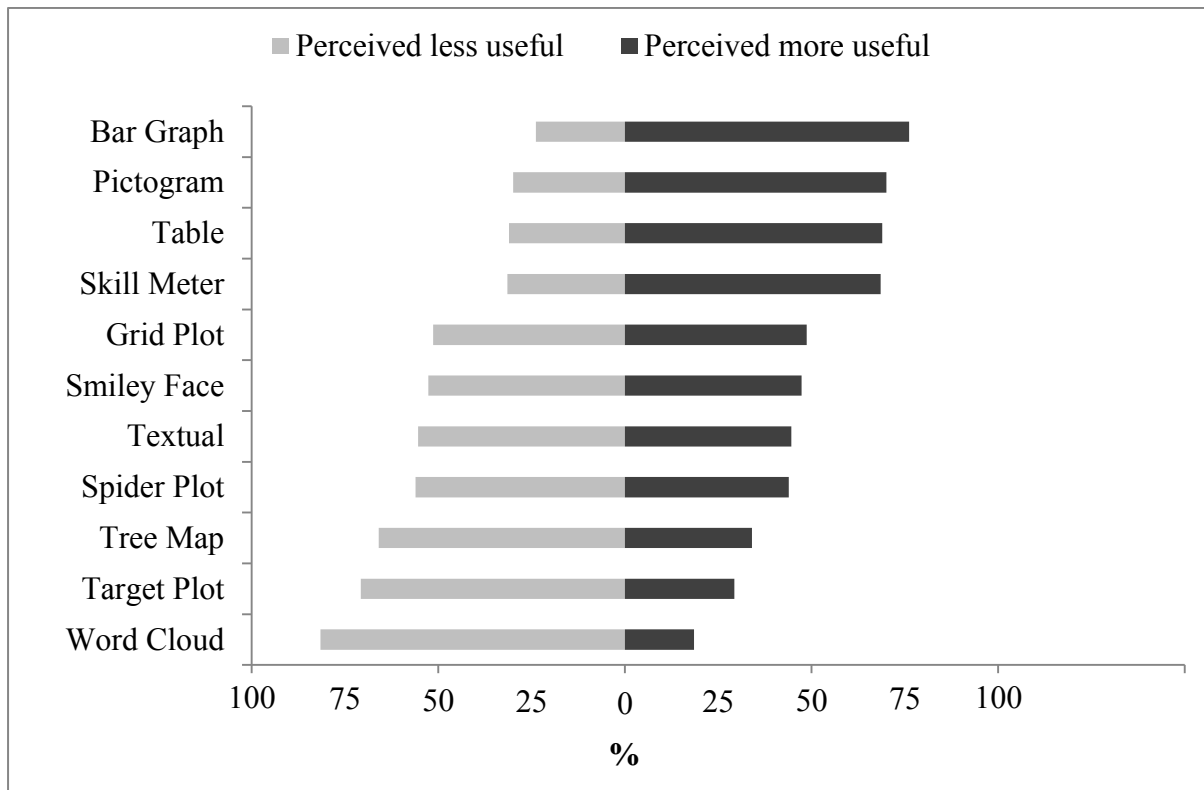
Figure 5.12 Usefulness ratings for each visualisation type for inspecting group LO achievements
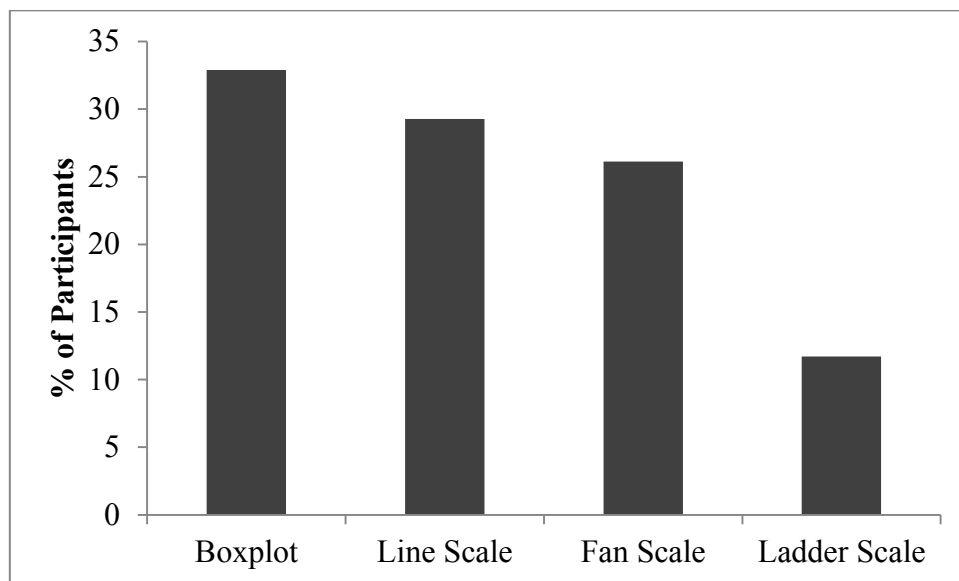
Figure 5.13 Participant preference for each visualisation to inspect group LO achievements

Although the mean score difference between Boxplot and Line Scale was quite close, with Line Scale was rated slightly higher than the Boxplot, but more participants preferred Boxplot. The word cloud analysis (see Figure 5.14) shows the most frequent reasons provided by participants as to why the Boxplot was perceived as more useful. Participants

reported that Boxplot was easy to understand, simple, clear, common, detailed and was a familiar visualisation. Besides that, they said that data set presented vertically was easy to see. Also, the representation was less cluttered and better than the other visualisations.
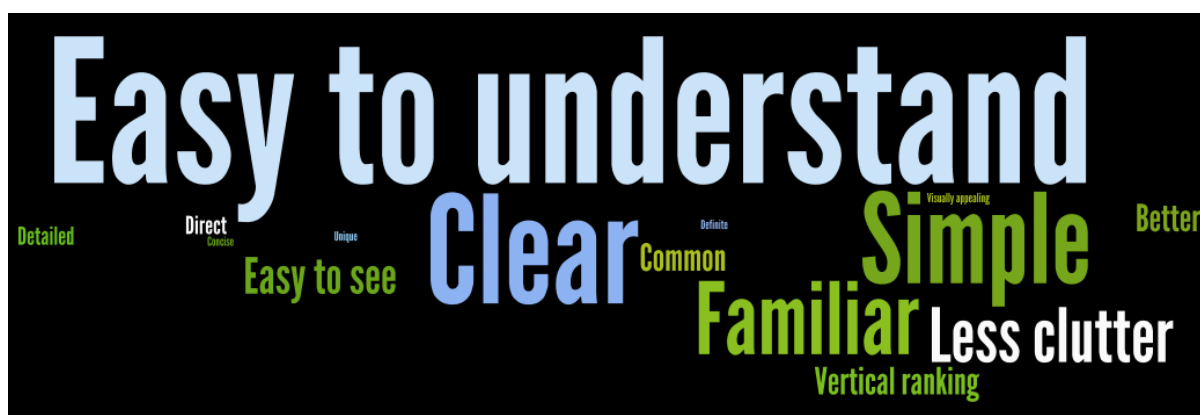
Figure 5.14 Word cloud analysis result for Boxplot

The interview results supported the quantitative finding that the Boxplot is the most useful and preferred visualisation. When interview participants were asked to select between Boxplot and Line Scale, 8 out of 10 participants chose the Boxplot. However, participants held different opinions on the Fan Scale. Their views about each of the representational formats are as follows:

Boxplot

Three teachers expressed the similar point that:

Boxplot is a familiar visualisation and easy to understand.

A student said:

I prefer Boxplot because it is going up rather than going side way. I can easily justify my achievement as higher means better.

Line Scale

A teacher indicated that:

Line Scale is useful because you can see the full scheme. It covers the boundaries and domain clearly.

When asked about comparing Boxplot and Line Scale, a student said:

Line Scale looks more complicated with the lines and triangles showing minimum and maximum. Boxplot is simple as each line clearly shows the statistics.

Fan Scale

A student stated:

Fan Scale is appealing, clear, easy to read and compare.

However, another student said:

Fan Scale is hard to understand. It is not normally used. I don't think it is very useful.

Ladder Scale

A teacher felt that:

Ladder Scale is not a common illustration. It is hard to understand.

These visualisations (Boxplot, Line Scale, Fan Scale and Ladder Scale) are different from the previous sections (Section 5.4.1.1 – 5.4.1.3). In the previous section, the visualisations are meant for inspecting the task status and learning outcome achievements of an individual student whereas the visualisations discuss in this section presents information about the group achievement such the class average, maximum and minimum. Participants held different views of having this visualisation. A teaching staff thought that:

For staff, the information is helpful. We can know if any particular group of students need help. However, exposing students to group achievement may motivate or not motivate the students. As a staff, I would like to see it but for the students probably I don't like them to see it.

Another teaching staff added:

These charts give an overview of the class. They are useful to the teaching staff but I don't think they are useful to students. For example, if I am a student and somebody tells me that your class is doing very good, I might feel proud but it doesn't say anything about me.

Students said:

I don't think the visualisations showing class statistics have any impact to me as a student. The class average will probably has some impact to me but other statistics such as the range score, I will pretty much ignore.

I would like to see the minimum, maximum, and other information about my class. I am interested to know how my class is doing.

Suggestions to improve the visualisations:

A teacher expressed that:

> *The charts are having the idea of distribution, so histogram may be a better representation.*

Another teacher added:

> *I would suggest having different visualisations for students and teaching staff.*

5.4.1.5 Results for Key Learning Aspect 5: Comparing Learning Outcome Achievements

Table 5.5 presents the proportion of the breakdown of participants' responses for the representational formats that were perceived as useful for the purpose of seeing a comparison of LO achievements and their preferred view. Participants felt that comparing individual achievements with group average (μ=3.44) was the most useful comparison view. Comparing individual achievements against group statistics (μ=2.82) and comparison between sub-groups (μ=2.69) were perceived least useful. Comparing with group average was also found to be the most preferred view among all with 66.2% (147) participants who favoured this view. Only 18.5% (41) and 15.3% (34) liked comparing against group statistics and subgroups features respectively.

Table 5.5 Descriptive statistics results for comparing group achievements visualisations

Format	Very useful			Not useful		μ	SD	Preferred view
	(5)	**(4)**	**(3)**	**(2)**	**(1)**			
Compare Group Average	36 (16.2)	77 (34.7)	68 (30.6)	31 (14.0)	10 (4.5)	3.44	1.06	147 (66.2)
Compare Group Statistics	17 (7.6)	42 (18.9)	71 (32.0)	67 (30.2)	25 (11.3)	2.82	1.10	41 (18.5)
Compare Subgroups	11 (5.0)	42 (18.9)	67 (30.2)	72 (32.4)	30 (13.5)	2.69	1.08	34 (15.3)

Figure 5.15 illustrates the comparison of participants' perceived usefulness for the comparison of learning outcome achievements while Figure 5.16 charts the comparison of participants preferred view.
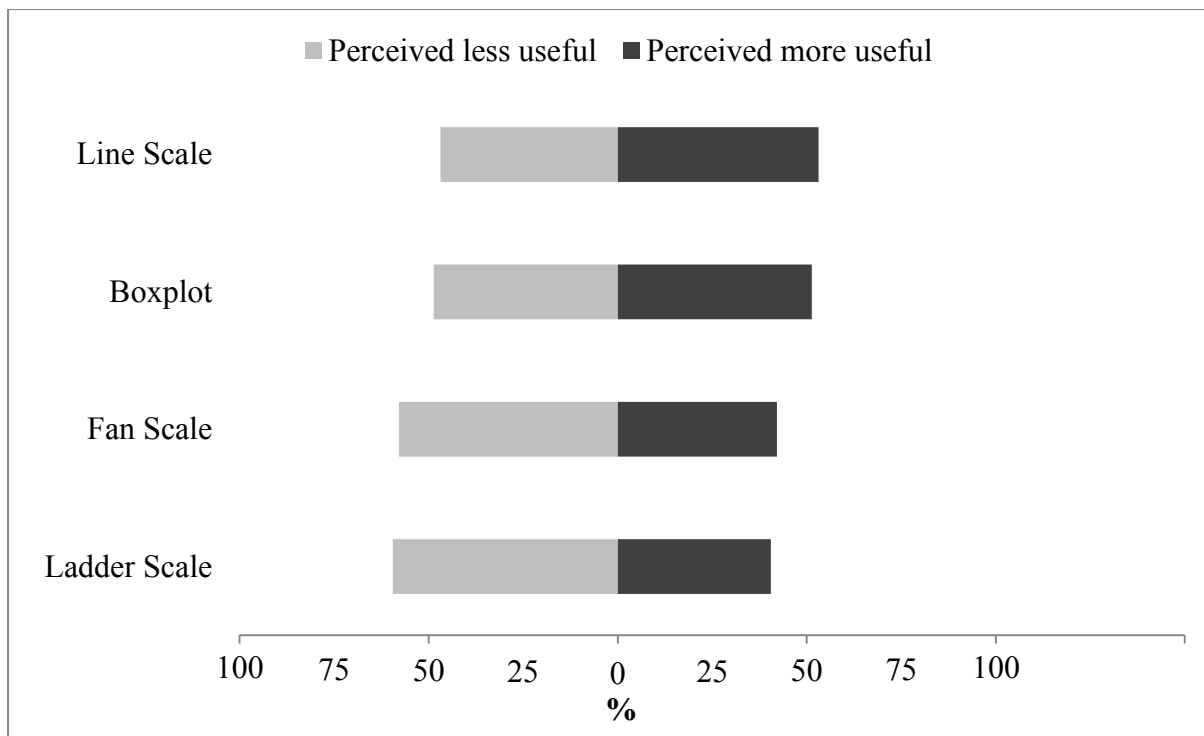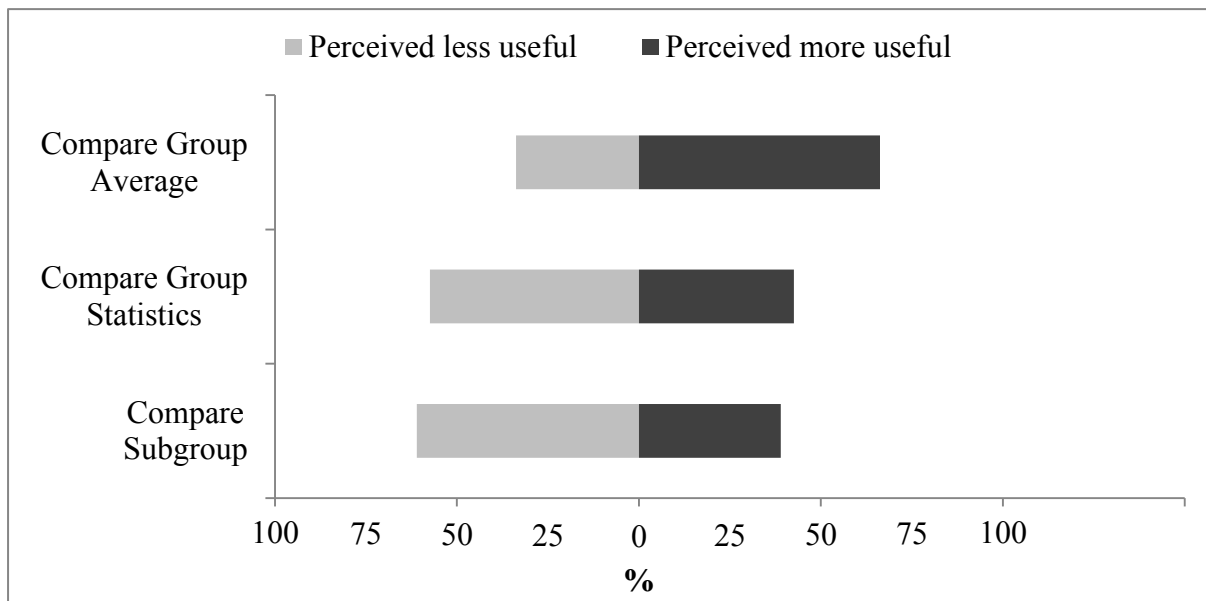
Figure 5.15 Usefulness ratings for each visualisation type for inspecting comparison of LO achievements
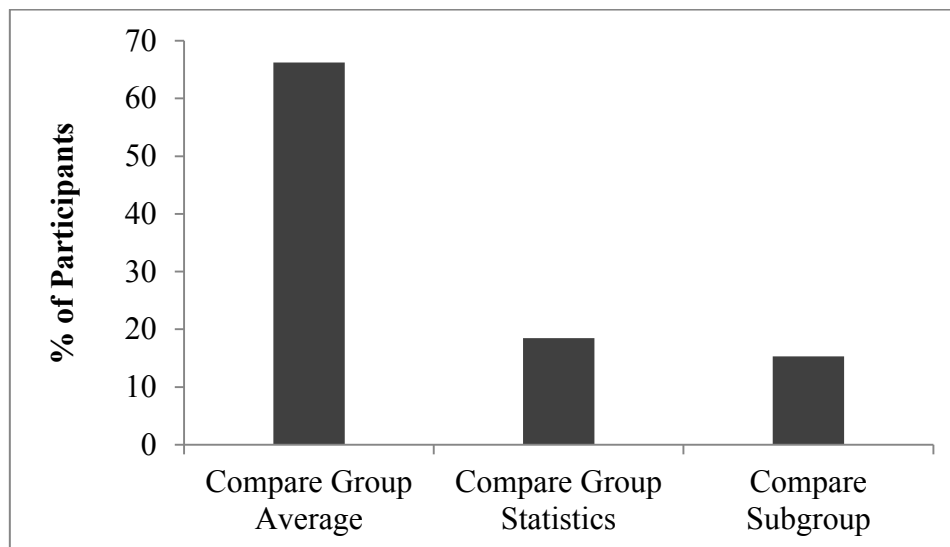
Figure 5.16 Participant preference for each visualisation to inspect comparison of LO achievements

Compare Group Average was perceived as the most useful and preferred comparison view. Figure 5.17 shows word cloud analysis results that explain the reasons as to why it was perceived useful. Participants perceived that this visualisation provided clear comparison, they could easily see and understand the data and comparison. Although simple, it provided

detailed and actionable information based on which learning outcomes need to be improved. It is discernible by colour and is a better visualisation than the others.

Figure 5.17 Word cloud analysis result for Compare Group Average visualisation

Combining individual, single group or multiple-groups achievement data allow users to see the comparison of an individual student achievement against the average achievement of their class and class statistics as well as comparison between subgroups. Such data could have both positive or negative effects on students and/or the teaching staff. The interview results further clarify this point. Teaching staff expressed as follows:

The comparative analysis helps to question student overstated confidence. We don't like the students to be shame in front of their classmates. With this feature, students can log into the system and see themselves. So, it is a "secret tool!"

It is human nature to know how they are ranked as compared to the rest of the class. In practice, it is irrelevant because all you really need to focus on is individually and which LOs are you learning more. The class performance has no impact to an individual's achievement. It is not needed for learning improvement. They are independent but human nature is competitive.

A student felt that:

The comparison features inspire competition in classroom in which we don't get an opportunity to do that much. It is motivating and may inspire me for better achievement. I can compare without invading others' privacy.

Two students indicated:

I only care for my own achievement so the comparison feature is not useful to me. But, it is nice to have it so that I can see how I perform as compared to my class.

I don't think this feature would help me or provide any positive outcomes to students. It may be more useful to the teaching staff for taking a necessary action towards improving the class performance.

The interview results corroborate with the quantitative results that compare individual achievement with group average was perceived as the most useful and preferred comparison view. Two teaching staff reflected:

Compare Group Average is useful because you get an idea about student performance. I can then know if a student needs help."

It is useful for a one-to-one discussion. We can use it to identify area for improvement and suggest ways how students can improve themselves.

Another teaching staff added:

This visualisation enables students to gauge their own performance in class, it advocates competitiveness among students. Also, it is a good way to have students to self-evaluate their performance against their class.

A student indicated:

As the visualisations are broken down into each specific LO with class average, they are easy to see and compare. I can quickly look at it and know which LO I am good at or need improvement. The visualisation gives me information of where I should do more work.

There were different opinions regarding Compare with Group Statistics and Compare Subgroups such as the following:

For Compare with Group Statistics, two teachers said:

It is only helpful to staff when trying to find students who are struggling or students who are doing really well that you want to give extra work.
The individual comparison using the Boxplot is quite hard for students to understand. Also, I don't think the statistics are very important to students.

For Compare with Subgroups, a teacher stated:

It is useful especially when a teaching staff has a few groups or sessions. It helps us to compare and conjecture why a particular group is performing better or worse."

A student indicated:

This feature is not useful for students because they may feel very bad and stressful if they found out that other class performs better than their own class.

Suggestions for improvement:

Two teaching staff pointed out:

In Compare Group Average visualisation, the bars are overlay, it is better to place the bars beside each other.

Boxplot could probably be used to visualise task progress.

A student suggested:

I would like to see comparison with the grading requirement for the subject.

Overall, Compare Group Average was perceived to be more useful than Compare with Group Statistic and Compare Subgroups. The reason could be that the data presented is more relevant to an individual student as the student would be better informed about their achievement in class.

5.4.2 *RQ5: Relationship between User Perceived Useful and Preferred Visualisation Formats Results*

Bivariate Pearson correlation analysis was used to answer the research questions:

RQ5: Is there a relationship between user perceived useful visualisations and their preferred visualisations?

Based on the mean values and the preferred view in percentage for all the proposed visualisations as presented in Table 5.1 to Table 5.5, a scatter plot was generated as shown in Figure 5.18. This is to identify any extreme outliers, and to ensure the assumption of linearity and homoscedasticity was not violated.
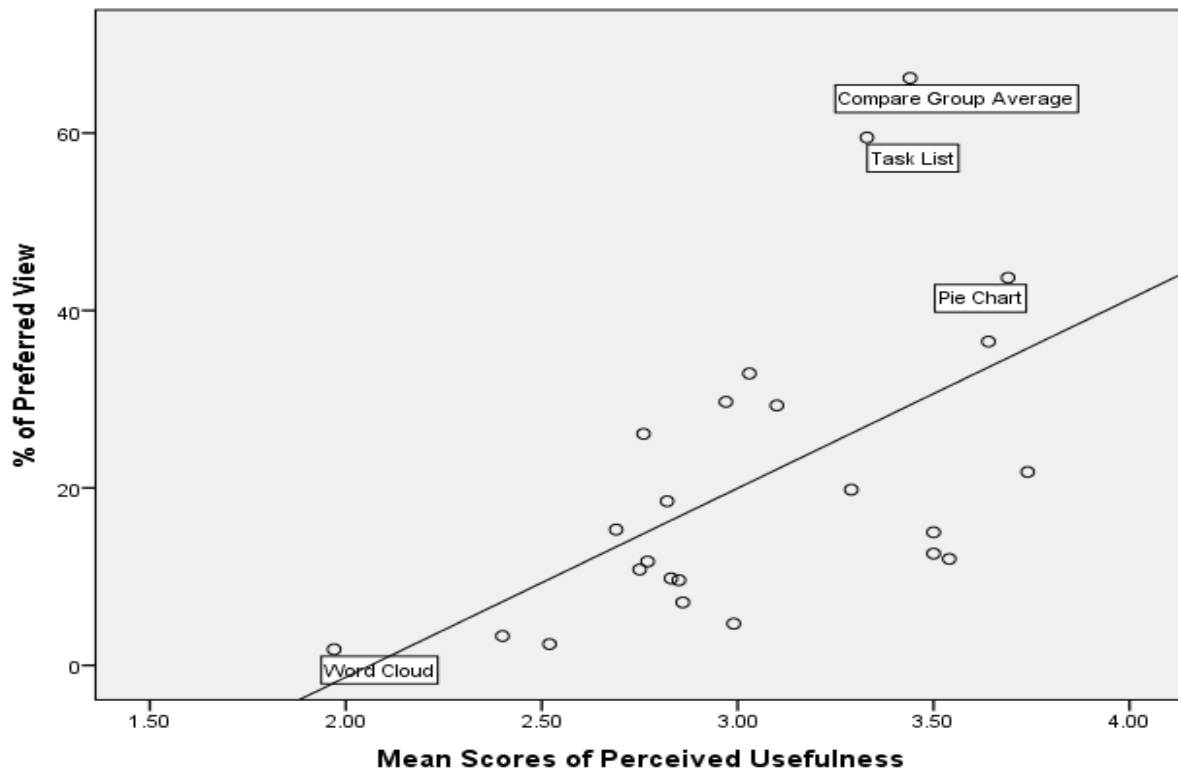
Figure 5.18 Scatter plot of participant perceived useful and preferred visualisation data set

From the scatter plot generated, two extreme outliers were identified. The data points were Task List and Compare Group Average. They were excluded from Pearson correlation analysis. The shape that was formed by the rest of the data points was checked. All data points were conformed to the assumption of homoscedasticity. Also, the cluster of points formed reasonably straight line with an upward trend indicated linearity with positive relationship. That is, high mean scores of perceived usefulness was associated with high percentages on user preference. In view of the fact that the data conformed to the assumptions of linearity and homoscedasticity, Pearson correlation analysis was conducted to investigate the relationship between the mean scores of perceived usefulness and preferred view in percentage. The following table shows the results.

Table 5.6 Correlations between perceived usefulness and preferred view

Pearson Correlation	.592**
Sig. (2-tailed)	.004
N	22

** Correlation is significant at the 0.01 level (2-tailed)

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Pearson product-moment correlation coefficient was obtained. There was a very strong, positive correlation between perceived usefulness and user preference, r=0.592, n=22, p<0.01 with higher perceived usefulness ratings correlated with most preferred views.

5.4.3 RQ6: Comparing Mean Scores of Staff and Students

The independent samples t-test was used to measure differences in means based on user role of either staff or students with their perceived usefulness of visualisations. A series of independent samples t-tests were performed to answer the research questions:

RQ6: Is there a difference in perceived usefulness of visualisations between staff and students for user perceived most useful and preferred visualisations?

Based on *RQ1* and *RQ2*, nine highly perceived useful and preferred visualisations were identified. The following table presents the highest perceived usefulness rating and most preferred visualisations by user roles. Table 5.7 and Table 5.8 present the statistics and t-test result by user roles (teaching staff and students) for the nine highly perceived useful and preferred visualisations. To ensure homogeneity of variance, an appropriate set of results was used based on Levene's test for equality of variances.

Table 5.7 Statistics by user roles for the highest perceived usefulness rating and most preferred visualisations

Scale	User roles	N	Mean	SD	Std. Error Mean
Task List	Teaching staff	34	3.38	0.95	0.16
	Students	188	3.32	1.29	0.09
Task Summary Pie Chart	Teaching staff	34	3.56	0.89	0.15
	Students	188	3.72	1.12	0.08
Bar Graph	Teaching staff	34	3.91	0.10	0.17
	Students	188	3.71	0.95	0.07
Boxplot	Teaching staff	34	3.38	1.28	0.22
	Students	188	2.96	1.10	0.08
Line Scale	Teaching staff	34	3.00	1.04	0.18
	Students	188	3.12	1.04	0.08
Compare Group Average	Teaching staff	34	4.15	0.56	0.10
	Students	188	3.31	1.08	0.08

Table 5.8 T-test results by user roles for the highest perceived usefulness rating and most preferred visualisations

		Levene's Test for Equality of Variances		t-test for Equality of Means						Effect size (η^2)
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	95% Confidence Interval of the Difference		
								Lower	Upper	
Task List	Equal variances assumed	6.353	0.012	0.250	220	0.803	0.06	-0.40	0.51	0.000
	Equal variances not assumed			0.307	57.16	0.760	0.06	-0.32	0.44	
Task Summary Pie Chart	Equal variances assumed	2.806	0.095	-0.782	220	0.435	-0.16	-0.56	0.24	0.003
	Equal variances not assumed			-0.916	53.76	0.364	-0.16	-0.51	0.19	
Bar Graph	Equal variances assumed	0.007	0.932	1.151	220	0.251	0.20	-0.15	0.55	0.006
	Equal variances not assumed			1.109	44.41	0.273	0.20	-0.17	0.58	
Boxplot	Equal variances assumed	4.529	0.034	1.993	220	0.048	0.42	0.01	0.84	0.014
	Equal variances not assumed			1.796	42.30	0.080	0.42	-0.05	0.89	
Line Scale	Equal variances assumed	0.001	0.982	-0.604	220	0.546	-0.12	-0.50	0.27	0.002
	Equal variances not assumed			-0.602	45.58	0.550	-0.12	-0.51	0.28	
Compare Group Average	Equal variances assumed	21.505	0.000	4.385	220	0.000	0.84	0.46	1.21	0.170
	Equal variances not assumed			6.722	86.06	0.000*	0.84	0.59	1.08	

* The mean difference is significant at the 0.05 level.

No significant difference in mean scores was found between teaching staff and students for all the nine highly perceived useful and preferred visualisations except the visualisations for Compare Group Average.

For Compare Group Average, significant difference in scores was found between teaching staff (*M*=4.15, *SD*=0.56) and students (*M*=3.31, *SD*=1.08; *t*(86)= 6.72, *p*=0.000, two-tailed). The magnitude of the differences in the means (mean difference=0.84, 95% *CI*: 0.59 to 1.08) was large ($ŋ^2$=0.170). While students perceived this visualisation as reasonably useful, teaching staff perceived it as quite useful to them.

5.5   Discussion

The results from Study 1 provide a general overview of the visualisations that were perceived useful and preferred by the research participants. Causal explanations from the user perspective were sought to better understand why a specific visualisation was perceived to be more useful and preferred. Ideas for representational formats were also solicited from the participants to improve the proposed visualisations. The quantitative results provided numerical measures of what were perceived useful and preferred. The qualitative results allowed the researcher to find out why a certain representation was perceived more useful or preferred and ways to better present the learning data. The quantitative results were triangulated and complemented with qualitative results to obtain final findings and to derive conclusions with the aim of unfolding the nature of relationships between users and the visualisation formats.

Various OLM representational formats were proposed to support five key learning aspects for facilitating student learning in a Task-Oriented Portfolio teaching and learning approach. The Burndown Chart and the Task Completion Chart provide details about the number of tasks that still remain or that have been completed by the students whereas the Task List shows the status of each task. The Task List was found to be the most useful format to present assessment task status (first key learning aspects). It was perceived as simple and specific in providing the level of detail needed to track learning task status as compared to Burndown Chart and Task Completion Chart. However, the interviews suggested that Task List together with Burndown Chart or Task Completion Chart gave different and complementary data to

each other. The results from the participant interviews suggested that providing multiple views to inspect learning task status would be beneficial.

Task Summary Pie Chart stood out as a more useful and preferred visualisation than Task Summary Bar Graph and Task Summary Table for displaying the second learning task aspect, i.e., for displaying assessment task statistics. The main reason was that the Task Summary Pie Chart provided task breakdown as well as full workload. It described workload status more accurately than Task Summary Bar Graph and Task Summary Table. In addition, the colour coding provided great visual impact to users. Students felt better informed about the proportional size of each task status and were motivated to get the whole chart into green – complete.

One textual form and ten graphical representations were proposed to support the third learning aspect – inspecting individual learning outcome achievements. Each of these visualisations makes use of wordings, space, size, orientation, shape, graphical icons and/or colour to present the data. The results obtained from Section 5.4.1.3 and Section 5.4.2 were integrated to gain thicker and richer data for designing suitable visualisations to present this learning aspect to the users. The results suggest that the Bar Graph, Skill Meter, Table and Pictogram are good options for use in any visualisation of individual learning outcomes. Participants wanted a visualisation that was simple and easy to understand, such as a Bar Graph, to inspect individual LO achievements.

Other OLM research have found that users have preference over a specific form of visualisation (Bull, Gakhal, et al., 2010; Duan et al., 2010) and the results presented in Table 5.3 corroborate this finding. In this case, more than 20% participants preferred Bar Graph to present individual LO achievements whereas less than 2% liked Word Cloud as an option. There is no empirical result to explain user preference in other OLM research. An investigation was carried out in this study to explore the correlation between user perceived usefulness and their preference. The strong positive relationship between participant perceived useful visualisations and their preferred views as presented in Section 5.4.2 provides a plausible explanation to user preference. It indicates that user preferred view is closely related to their perceived usefulness of the visualisations. Representational formats that are useful can increase user preference and thus their experience in using the tool. Creating user perceived useful and preferred representational formats to present the intended learning data is important to accommodate the user needs and exploration and hence their

experience in using the tool. This might improve user adoption and engage them in using the proposed visualisation tool in the future.

The results from Section 5.4.1.4 suggest that Boxplot is a credible option to support user inspection of group learning outcome achievements (fourth key learning aspect). Participants found it easy to understand the data presented. Each line clearly shows one piece of information and it is easy for user to comprehend the statistical information. Other visualisations such as Fan Scale and Ladder Scale were generally perceived as complicated and confusing.

The fifth key learning aspect supports users in comparing LO achievements. Compare Group Average visualisation was strongly recommended for presenting this learning aspect. Notable participant comments include it was simple, clear, and that they could gain detailed and actionable information from it as compared to other forms of visualisations.

The independent samples t-test results in Section 5.4.3 shows that the teaching staff perceived Compare Group Average to be more useful than what the students thought it would be. The teaching staff in general felt that this visualisation was useful to them and students as well. Teachers felt that they would benefit from visualisations that compare an individual's achievement with group data. One teacher reflected that this feature might keep the staff aware of student performance in the context of the class. This may help them to better understand the overall performance of their class and to identify if a particular student needs help. This is supported by another teacher who felt that this feature would help the teaching staff in one-to-one discussion in which they can suggest area for improvement to students.

Another teacher stated that this feature could advocate competitiveness in class and could help students to self-evaluate their own achievement. One student also reflected the same point. However, other student participants held different opinions regarding this feature. Some students were very positive towards the comparison feature. They said this feature could help to keep them stay competitive and they can compare their achievements without invading the privacy of others. In contrast, students who only care for their own achievements did not find this feature very useful or feel that it had any positive outcome to them. However, they did not oppose having this feature. They thought that it could be a "nice to have" feature.

In general, the teaching staff felt that comparison features may help students know how their performance is ranked. The features also could be used by the teaching staff as a 'secret tool' in keeping the students aware of their own performance. Although the teaching staff

envisaged a mostly positive opinion on providing students with comparison features, they held a negative view for exposing students to the class statistics and subgroups comparison. They did not think that the statistics was important to students. Hitherto, a student expressed his concern that the comparison features might cause unnecessary stress to students.

Some valuable inputs to enrich the visualisation options were also obtained. Stephen Few's bullet chart was proposed as a way of visualising an individual student's learning outcome achievements. This chart used various intensities of grey colour to make the qualitative ranges discernible by those who were color blind and it was perceived as a suitable way to present this learning aspect. Parallel Coordinate Plot was also proposed as a form of visualisation for users to have an overall view of all learning outcomes as well as all student achievements. Some useful comments received include:

(i)   Textual description is important in information visualisation to provide alternative support to graphical representations as the combination can have better descriptive power;

(ii)   Use combination of Burndown Chart and Task List as they give different and complementary data;

(iii)   Qualitative range is more appropriate than numerical value to indicate LO achievement level;

(iv)   Have comparisons feature to show comparison in the grading requirement of a subject;

(v)   Have different visualisations for different user roles, e.g., teaching staff and students;

(vi)   Comparison of subgroups might not bring positive effect to students.

While the participants suggested ways to improve the proposed visualisation options, they also highlighted a major issue regarding supporting colour blind users. Providing users with alternative visual support such as the use of mouse over hover text, single hue with different intensities and gradient to represent the qualitative ranges of learning outcomes were among the suggestions received to solve this issue. This issue will be seriously considered during the implementation of the final tool.

5.6 Threats to Validity

Careful steps were taken to mitigate the threats to validity (Section 3.7). However, there are some threats that could have affected the validity of the findings. They are listed below in terms of internal, external, construct and statistical validity.

5.6.1 Internal Validity

This research project applied Scenario-based design in which the prototype design of the visualisations tool was built through the video simulation. The video link was included in the online survey questionnaire to brief participants about the visualisation options and the intended use. There was a chance that the participants skipped the video and directly responded based on their own judgement of how the visualisation options would be used. Also, the colours, variation and resolution of the proposed visualisations could have caused a bias to the results. For example, the colours specifically chosen were green and red to indicate different achievement levels. This could be a major concern for accessibility of the visualisations for people with colour-blindness. Besides that, the visualisations for inspecting the class learning outcome achievements were minor variations on the Box Plot data. A more innovative set of visualisations may have resulted in different preferences. In addition, the resolution rather than the visualisation in the Smiley Face visualisation may have resulted in a significant factor in preference.

5.6.2 External Validity

There was a total of 222 valid samples collected from the online survey questionnaire and ten people were involved in the interview. Most teaching staff and students were from Engineering and Information Technology backgrounds. Generalising these results to others is not possible without further feedback from prospective users in other faculties who came from different backgrounds and courses. Using other kinds of courses and degrees may result in different visualisations being preferred for their learning outcomes and tasks. Also, there was an imbalance of gender proportion. For the survey, 168 were males with only 54 females. As for the interview, all were males. Thus, further feedbacks from more diverse end users from other faculties with more female participants are needed for generalising the results.

5.6.3 Construct Validity

The survey items and the interview plan used in this research study were reviewed by experienced judges and pilot-tested. The use of Explanatory Sequential Mixed-Methods design enabled the quantitative results to be triangulated and complemented with qualitative results. This means that the findings were supported by a more comprehensive and concrete

evidence. This increases the validity of findings. There is no construct validity issue identified.

5.6.4 Statistical Validity

Study 1 applied Pearson correlation and independent samples t-test to describe the relationship between two variables and to assess differences between the groups respectively. The valid sample size of 222 was adequate for the statistical analyses. The general assumptions were checked and there was no violation of assumptions on these two parametric techniques. There is no threat to the statistical validity.

5.7 Summary

Various OLM visualisations were proposed to facilitate five key learning aspects in supporting the Task-Oriented Portfolio teaching and learning. Based on the mixed-methods analysis results, five representation formats that user perceived useful and preferred visualisations in supporting these key learning aspects were identified. Besides that, various valuable inputs were also obtained to improve and enrich the proposed visualisation options. Potential issues and ways to overcome them will be seriously considered. As user perceived useful representational formats is closely related to their preferred view, creating user perceived useful representational formats may increase user adoption and engage them in using the proposed visualisation tool in the future. The finding could serve as a design and development guide to OLM visualisations. Understanding user perceived usefulness and preference of OLM visualisations could help OLM interface designers and developers make the learner model more visible and comprehensible. This can better support various stakeholders and encourage OLM use in supporting student learning. Based on the findings from Study 1, new visualisations will be developed for the Doubtfire tool (Chapter 6). The changes will be evaluated with users in Study 2 (Chapter 7).

Chapter 6

Open Learner Model Visualisation Prototype Design

6.1 Introduction

Following the data analysis results in Study 1 (discussed in Chapter 5), some Open Learner Model (OLM) representations were found to be more suitable for the presentation of the intended learning data. It was found that some visualisations were perceived to be easier to see, compare and understand as compared to other visualisations. Besides that, both user groups, the teaching staff and students wanted visualisations that are familiar, simple, clear, motivating, attractive, and yet provide detailed and actionable information for students to advance in their learning.

Based on these findings, five visualisations were identified as more preferred and useful to support the five key learning aspects for facilitating student learning in the Task-Oriented Portfolio teaching. This includes inspection of (i) learning task status, (ii) learning task status statistics, (iii) individual learning outcome achievements, (iv) group learning outcome achievements, and (v) comparison of learning outcome achievements.

Participants also provided some suggestions to expand the use of visualisations in the existing OLM research. They suggested the use of Stephen Few's bullet chart (Few, 2010) to visualise student learning outcome achievements. Also, learning outcome achievements were deemed more appropriate to be expressed in a qualitative range rather than in numerical measures. They wanted a comparison feature that enabled them to compare with the grading requirement. These are useful findings. They provide insightful initial user requirements to OLM designers and developers on the creation of visual encoding of data to fulfil user needs. They can better justify the design rationales and make more practical design decision. Although, numerous valuable inputs were obtained from Study 1, the development of the prototype tool was subjected to time and resources available. The visualisations were mostly developed based on the fundamental need to better support the Task-Oriented Portfolio teaching.

Based on our experience as software designers and developers in visual encodings, and with the findings from Study 1 (see Section 5.4), various OLM representational formats have been

designed and developed. While the results of Study 1 provide guidance to initial user needs and requirements, visual encoding is important to understand the way information is encoded. Due to different user roles, e.g., teaching staff and students, two groups of visualisations were developed. They are known as Teaching Support Visualisations and Shared Student-Centred Visualisations. The former is for teacher use only whereas the latter is for both user groups, the teaching staff and students. The next section introduces the visual encoding. This is followed by the illustration of Shared Student-Centred Visualisations and Teaching Support Visualisations to support student self-regulated learning in the Task-Oriented Portfolio teaching and learning. This leads to the illustration of Doubtfire++ before the chapter is concluded with a summary.

6.2   Visual Encoding

Two basic building blocks in visual encodings are known as marks and channels. Marks are graphical elements that are used to encode items or links whereas channels are visuals that are used to control their appearance (Munzner, 2014). Marks are classified based on the number of spatial dimensions. A zero-dimensional (0D) mark represents a point, a one-dimensional (1D) mark produces a line and a two-dimensional (2D) mark represents an area. Marks can be used to show individual items or links between items. The properties of a mark are defined by channel based on spatial position, colour, size, motion, angle, curvature and shape. The most common visual channels that are used to encode information in this research include visual channel of spatial position, colour and size. Appropriate use and matching between the graphical elements and visual channels form the design space of visual encodings.

6.3   Shared Student-Centred Visualisations in Supporting Student Self-regulated Learning

In embracing outcome-based learning, students have to be supported with the learning environments that provide them with the opportunities to become self-regulated learners. Self-regulated learners are conceptualised as active participants in engaging with their own learning. To this end, information visualisation techniques are used in this research to help learners plan, set goals, organise, self-monitor and self-evaluate their learning process. Visual representations can amplify user cognition through the formation of mental models of information (Liu et al., 2014). Learners direct involvement in modelling the development of

their learner models gives them a sense of accountability to take greater ownership of their own learning in becoming self-regulated learners (Bull & Kay, 2013). The formation of the mental models, in this case, through OLM visualisations, is posited to prompt users for further adjustment, planning and improvement. These OLMs could lead learners to be self-aware, determined and decisive in their own learning and hence become self-regulated learners. To achieve this, the following visualisation designs aim to support learner involvement in the three distinct phases in the self-regulation cyclical process: The Forethought, Performance Monitoring and Self-reflection phases (Section 2.5).

6.3.1 *Visualisations for Setting Learning Goals*

The first phase of the self-regulation cyclical process is known as the forethought phase. In this phase, a learner set the learning goals and plan for the tasks that are needed for learning. The plans made and goals set in this phase have an impact on the strategies to be used in the next phase, called the performance monitoring phase. Two visualisations, known as Target Grade Setting (Figure 6.1) and Task List (Figure 6.2) were used to support students for goal setting and task planning in this phase.
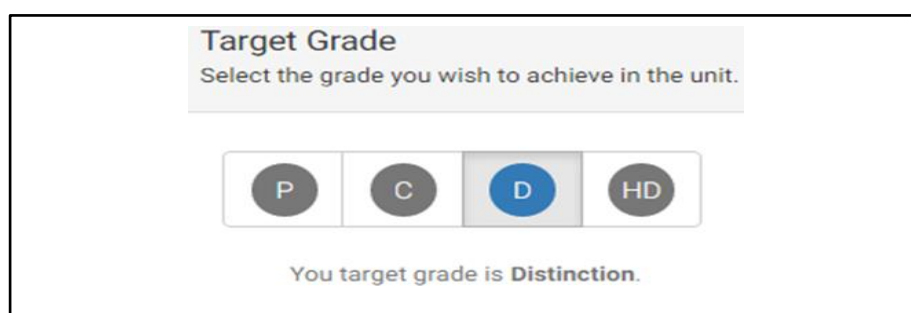
Figure 6.1 Target Grade Setting visualisation for setting target grade

The Target Grade Setting visualisation is designed to **accept a user's input for the target grade they wish to achieve in the unit**, as shown in Figure 6.1. A user's input is colour coded with vivid blue whereas other options are in grayscale. This makes the selection choice visually discernible. To make the selection clearer, the visual input is also supported by simple textual descriptions to denote a user's input. For example, the alphabet 'D' is used to indicate Distinction and the textual description dictates "Your target grade is Distinction." Each input grade is linked to the amount of work needed to be completed in order to obtain the desired grade. This means that while a specific target grade has been set by a student in the Target Grade Setting, the amount of work needed to demonstrate in order to achieve the

desired grade will be shown in the Task List. The Target Grade Setting provides flexibility to students to adjust the target grade and to see the workload required for different grades. Students can change it whenever they feel that they can target higher or adjust it to meet the workload they are able to cope with. This helps students to plan for their workload and learning schedule, and guide them to set a realistic target. Figure 6.2 (a) – (c) illustrate the Task List for a Pass, Credit and High Distinction respectively.
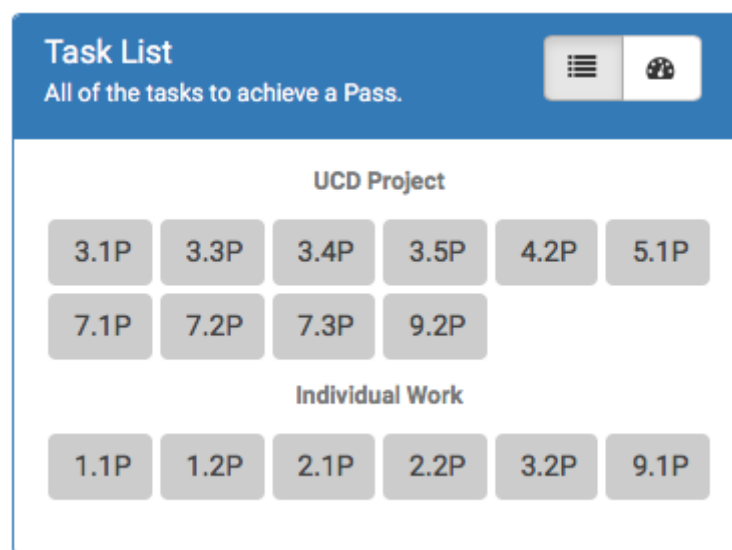
Figure 6.2 (a) Task List showing amount of workload for a Pass grade
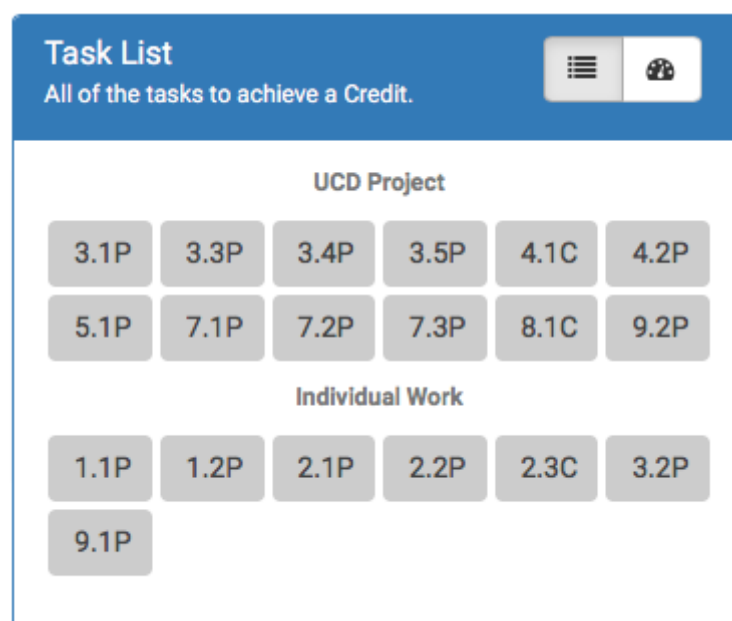
Figure 6.2 (b) Task List showing amount of workload for a Credit grade
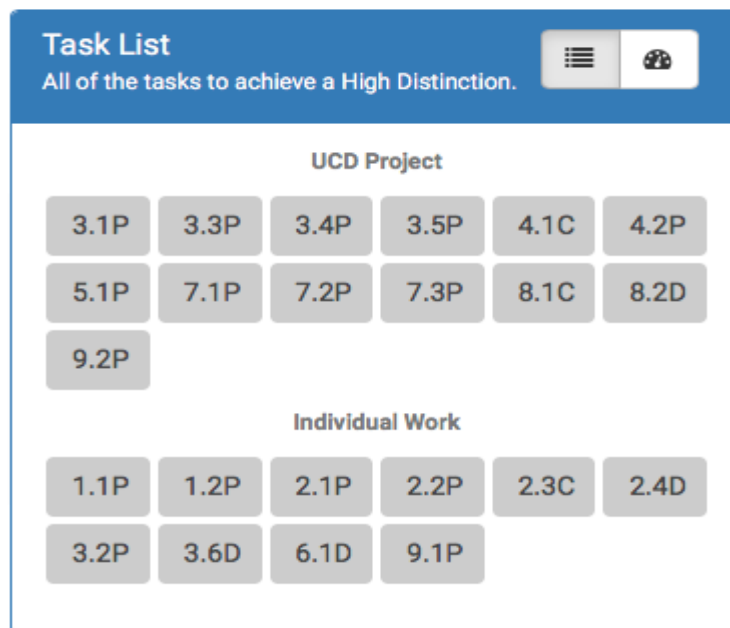
Figure 6.2 (c) Task List showing amount of workload for a High Distinction grade

6.3.2 *Visualisations for Monitoring Performance*

The next phase of the self-regulation cyclical process is the performance monitoring phase. This is a task implementation phase that involves the control of strategies and monitoring techniques that a student uses to engage in learning. In a Task-Oriented Portfolio teaching and learning, assessment tasks are decomposed into small, frequent tasks that firmly link to the intended learning outcomes to guide student learning. Task List and another six visualisations were used to support students in monitoring their performance in this learning environment. These visualisations were also viewable by the teaching staff.

Task List, Focus List, Task Summary Chart in pie chart form and Burndown Chart as shown from Figure 6.3 to Figure 6.6 **are used to keep students aware of their learning task status**. The Task List (Figure 6.3), apart from showing the amount of workload, was used to keep students informed about their task statuses. Task List provides an overview of the status of all tasks and support student engagement with frequent formative feedback on their tasks. Task status (i.e., Redo, Resubmit, Discuss, Complete) is categorical data. Colour hue is a reasonable choice to encode categorical data. A range of colour hues were exploited to show the status of a task such as brown for 'Redo', yellow for 'Resubmit', blue for 'Discuss', green for 'Complete' and so on.

Figure 6.3 Task List using colours to show task statuses

Focus List as shown in Figure 6.4 is part of the Task List. It **suggests tasks that students need to do next in order to stay on track to achieve the desired grade**. Different levels of revision or amendment are needed in attaining the required standard. The level of revision or amendment is a categorical data. Two types of visual encoding including colour hue and iconic representation are used to encode the data. The background colour of the iconic representation in Focus List is related to the Task List colour, that is, brown for 'Redo', yellow for 'Resubmit' and so on. Iconic representations are used to visually encode the kinds of actionable information to the students. For example, 'callout bubble icon' is used to inform students that they need to discuss their work with the tutor whereas 'spanner icon' is used to convey the information that a particular task needs to be completed in order to stay on track. This visualisation is especially useful for students who are lagging behind to catch up with their work. It is designed to help them visualise what is to be prioritised in their learning.
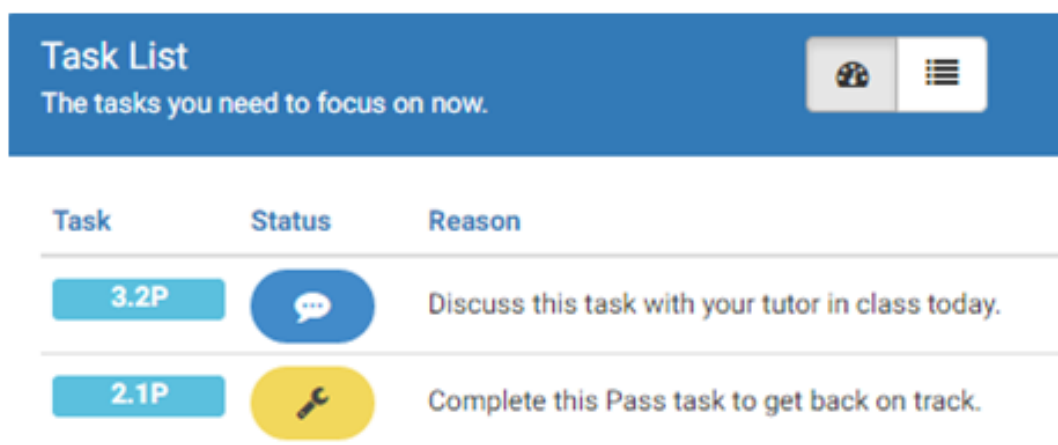
Figure 6.4 Focus List suggesting tasks to keep students on track

The **summary of task statuses** can be viewed through the pie chart as in Figure 6.5. The attribute in terms of percentage of tasks is encoded with area marks and the angle channel whereas the different task statuses are encoded by adding colours to the pie chart. In terms of judgement and accuracy, angle judgement is more difficult and less accurate as compared to the length judgement on line marks (Munzner, 2014). This is because the sector area changes along the radial axis, from smaller near the centre of the circle (pie chart) to bigger near the outside, causing users to make less accurate perceptual judgement (Munzner, 2014).

This is a disadvantage of the pie chart. However, pie chart is commended for providing clear relative contributions of parts to a whole using area judgement. It is the judgement of area that makes it a robust representation. This is supported by the notable comment made by both the teaching staff and students in Study 1 that pie chart presents task status breakdown and as a whole (Section 5.4.1.2). It is therefore appropriate to apply the proposed visualisation to present the proportion of complete versus incomplete tasks to users. The strong visual is the combination of area judgement and colour coding in which users can easily see if more effort is needed to complete the assessment tasks. **The visual also aims to motivate students in getting the whole pie into green – completing all the assessment tasks**.
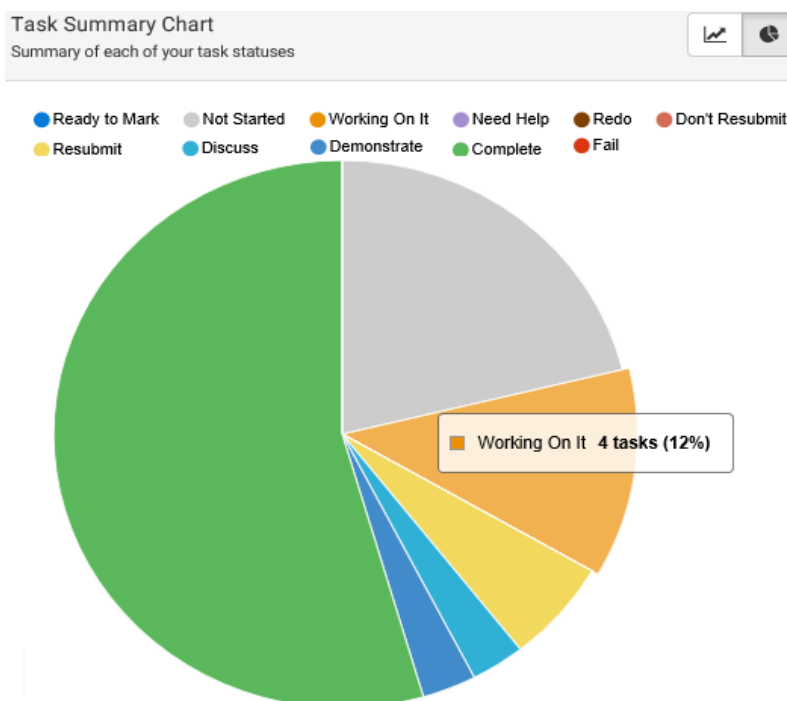
Figure 6.5 Task Summary Chart showing summary of task statuses for an individual student

As students progress through the semester, they are able to **track their progress by week via the Burndown Chart** as shown in Figure 6.6. The Burndown Chart is an Agile Scrum technique that shows work remaining versus time. The work remaining is represented by a line graph showing the backlog of work remaining by week. The backlog of work decreases as work is completed. This chart is adopted to present one key attribute (time) and one value attribute (total number of tasks required to complete), in a rectilinear spatial layout. The number of tasks to be completed is represented by the *y*-axis whereas time by week in a semester is denoted by the *x*-axis. Although the Task Completion Chart was found to be a more preferred visualisation over the Burndown Chart, it will not be developed at the current stage. This is because the Burndown Chart and Task Completion Chart were found to complement the Task List. Also, the Task Completion Chart and the Burndown Chart presented similar information. The Task Completion Chart will be included as an interchange with the Burndown Chart in the next development stage of the visualisation tool.
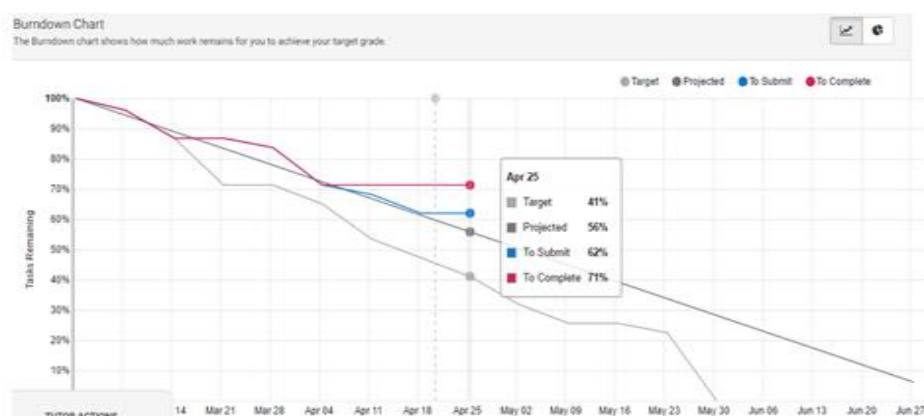
Figure 6.6 Burndown Chart is designed to help students to self-assess their progress

A line connects the total number of tasks completed in a particular week with the total number of tasks completed in the following week throughout the semester. The line emphasises the ordering of the items along the key axis. It is known as a connection mark. These connection marks form the slope and explicitly show the relationship from one week to another throughout the whole semester. A flat slope indicates that a student does not make any progress for that week whereas a steeper slope denotes that more tasks have been completed, indicating good progress. Through the slope formed by the connection marks within a timeframe, it gives a stronger implication of trend relationships that show how a student manages and approaches the assessment tasks throughout the semester.

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This chart is augmented by colour to show a second categorical attribute – students' actual progression, target progression and projected progression. The progression is presented with four different lines in four different colours. There are two lines showing the actual progression, the 'To Submit' and 'To Complete' lines. The former shows student progress based on a student's work that has been submitted whereas the latter shows the amount of submitted work that has been signed off as complete by the teaching staff. The 'Target' line indicates the expected progression based on target due date set by the teaching staff. The 'Projected' line predicts the end date based on a student's current progression. The Burndown Chart enables students to track their progress, showing target and projected completion time, percent of tasks submitted and completed. It keeps students aware of the number of tasks remaining at a certain point of time. Students can also estimate effort required to complete their tasks to meet the minimum requirement of their desired grade.

These visualisations are **designed to help students to self-monitor and self-assess their progress**. Students can estimate if they need to increase their effort and time exploiting support resources available in order to attain the required rate of progress. The teaching staff can access these visualisations to view a student's progress and achievements. Thus, these visualisations are posited to help both the teaching staff and student users to monitor an individual student's performance.

The Outcome Alignment and Achievement visualisation that resembles Stephen Few's bullet chart as shown in Figure 6.7 is **used to display student learning outcome achievements**. The charts use spatial region and colour hue to encode the attributes. The horizontal spatial position channel encodes the number of tasks being signed off by the teaching staff as complete for each grade standard. The vertical spatial position channel encodes the intended learning outcomes. The visual channel of colour hue is used to denote the ordinal data in terms of the achievement range of each grade standard. Four different colour hues are exploited to represent the qualitative range for different levels of achievement, indicating staff expectation for a Pass, Credit, Distinction and High Distinction.
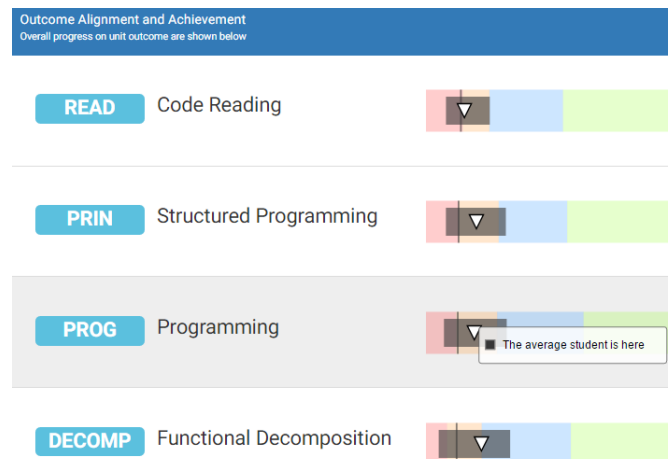
Figure 6.7 Outcome Alignment and Achievement visualisation presenting information about individual and group LO achievements

The other quantitative attributes, the class average, class achievement range, and an individual's achievement are encoded by adding a line mark, a grey shaded area, and a triangle respectively to the horizontal bars. Hover over text is exploited to depict the visual representation. Users are able to quickly grasp an overall understanding of their own achievement as well as their class achievement as compared to staff expectation. In this way, students are provided with a clear target to excel. The Outcome Alignment and Achievement is linked to all tasks that contribute to each learning outcome as in Figure 6.7. Students can easily click on the bar of the Outcome Alignment and Achievement visualisation to view the tasks that contribute to a specific learning outcome as shown in Figure 6.8. This visualisation is known as Outcome Alignment and Achievement Task View. Students can **identify tasks to be focused on from this visualisation in order to improve a specific learning outcome**.
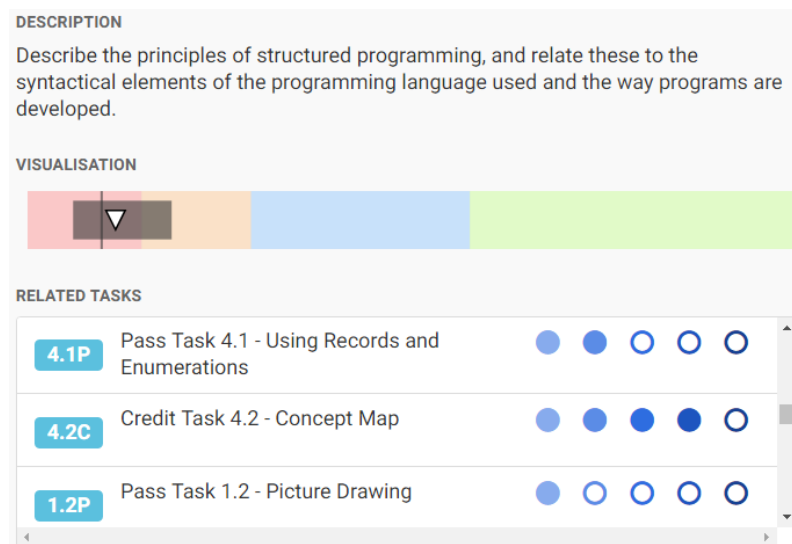
Figure 6.8 Outcome Alignment and Achievement Task View showing links between learning outcome and tasks

6.3.3   Visualisations for Facilitating Self-reflection

The last phase of self-regulation cyclical process is the self-reflection phase. In this phase, students **self-reflect to judge their learning outcome achievements** and react to consider revisions or adjustments that may be needed. This is a cyclical process. The result of self-reflection will impact learners' future task analysis and implementation to re-engage with the subsequent forethought phase and performance monitoring phase besides improving the existing task. The visualisation as in Figure 6.9 shows an example of the student reflection visualisation called Task Alignment Rating. This visualisation exploits multiple channels to encode the weighting of a particular learning outcome in an assessment task.

Point mark and colour saturation are used to encode the LO weighting. While the visual channel of horizontal spatial position denotes the assessment tasks, the vertical spatial position encodes the intended LOs. Through this visualisation, **students align unit tasks with the intended learning outcomes to demonstrate that they have achieved unit learning outcomes** in preparing their portfolio for final assessment. This visualisation encourages students to reflect on their progress and achievements based on the tasks completed by clicking on the ratings that best represent their knowledge gained. They can then upload their work to showcase or evidence their achievements. While the visualisation facilitates student self-reflection, the reflection data captured can provide insight about student learning. This helps **the teaching staff to examine any potential misalignment**

arising from mismatches between student reflections on learning and initial staff plans. The upload function helps students to retain their learning artefacts in evidencing their learning.

Figure 6.9 Task Alignment Rating for facilitating student self-reflection

6.4   Teaching Support Visualisations

In supporting Task-Oriented Portfolio teaching approach based on Constructive Alignment model, teaching staff play an important role. Ideally, the teaching staff create a supportive learning environment and provide frequent formative feedback to encourage students in becoming self-regulated learners. In this approach, students complete numerous small tasks and submit their tasks for feedback. The teaching staff then assess students' work to provide formative feedback aimed at helping the student improve their work and address any misconceptions. This means that the teaching staff need to track numerous student assessment tasks. They need to monitor student progress on a range of tasks and provide frequent formative feedback to all the students to ensure that their work is satisfactory.

To this end, it is essential to support the teaching staff with learning data in the form of multiple analyses and visualisations. This **helps them to intervene and support students whenever necessary**. Based on the software development team's experience and the findings from Study 1, the visualisations were developed to help the teaching staff to better understand their class and support student learning in the Task-Oriented Portfolio teaching environment. Teaching staff can visualise class target grade distribution, monitor student task assessment progress and LO achievements as well as provide feedback to students. The interaction data captured throughout the semester helps them reflect on their teaching.

6.4.1 *Visualising Student Target Grade Distribution*

The pie chart has been widely accepted as a powerful representation in presenting clear relative contributions of parts to a whole. In the proposed OLM tool, it is used to encode student Target Grade Distribution to the teaching staff as shown in Figure 6.10 (a) and (b). While the visual channel of size encodes the proportion of students, the visual channel of colour hue encodes the information of target grade. This encoded information is enhanced by hover over text that shows the target grade and the corresponding proportion in percentage. The Target Grade Distribution reveals the class aspiration grade in undertaking the unit. Target Grade Distribution is shown by an entire unit (Figure 6.10 (a)) and by tutorial groups (Figure 6.10 (b)). This **helps the teaching staff to better understand the characteristics of their students.** They would then be able to motivate students accordingly and intervene whenever necessary.
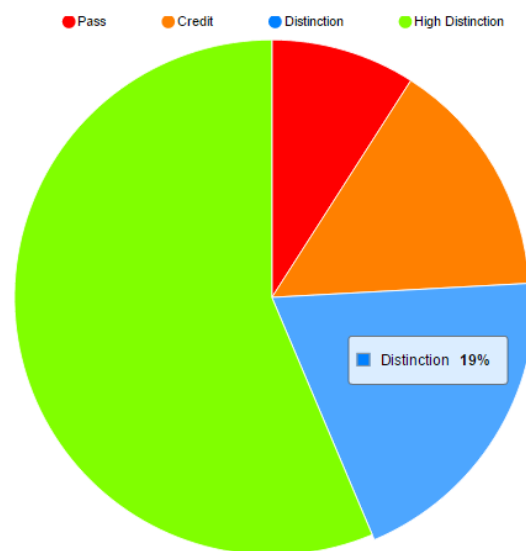
Figure 6.10 (a) Target Grade Distribution for visualising student target grade distribution in an entire unit
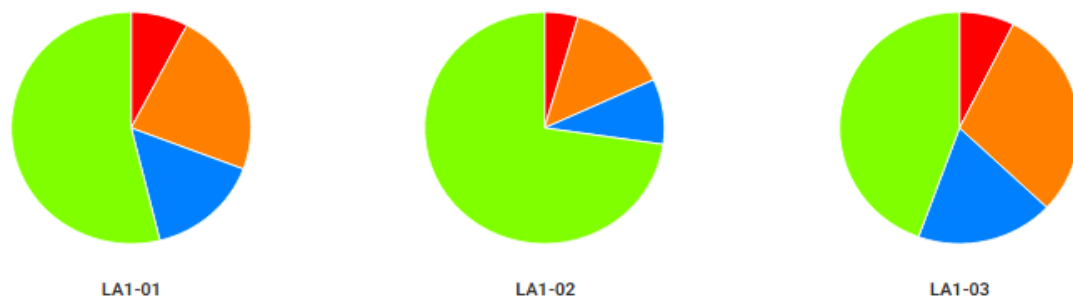
Figure 6.10 (b) Target Grade Distribution for visualising student target grade distribution over all tutorials

6.4.2   Visualisations for Monitoring Assessment Task Progress

The Progress Bar as shown in Figure 6.11 gives an overview of each student's assessment task statuses. The visualisation encodes a single quantitative attribute (proportion of tasks completed) and a categorical attribute (task status). The proportion of tasks completed is visually encoded by the length of the progress bar. The task status is encoded using visual channel of colour hues. The encoded information is enhanced by static text and hover over text. While the static text shows the proportion of each task status in percentage, the hover over text presents the task status and the corresponding percentage. This **allows the teaching staff to easily visualise the progress of each of the students in the class** without imposing extraneous cognitive load to interpret the data. Necessary actions can then be taken to help a particular student to catch up on.
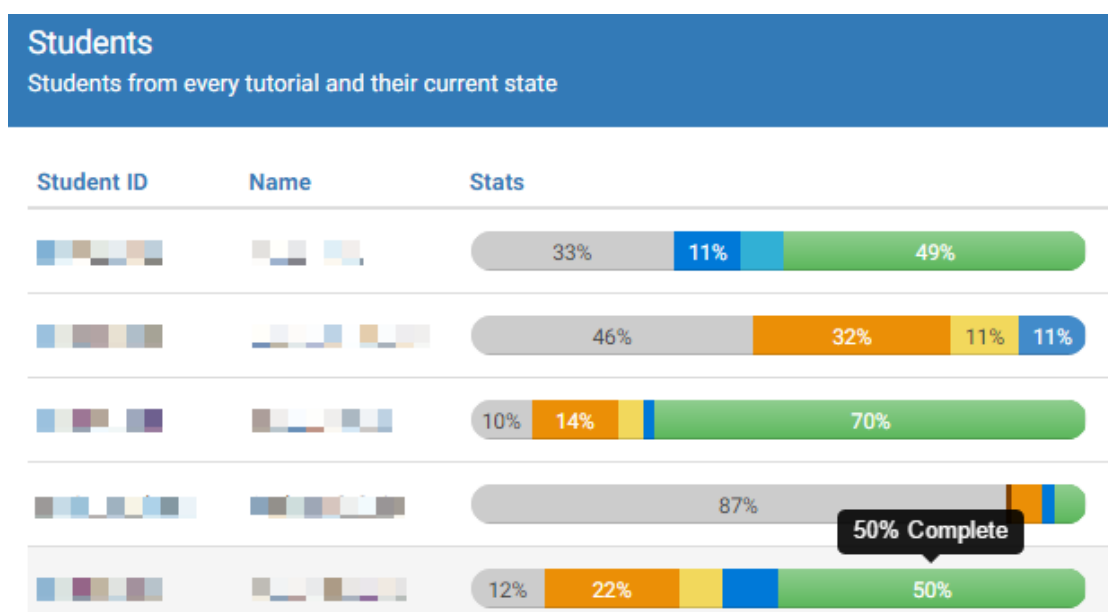
Figure 6.11 Progress Bar showing student task statuses by percentage

To know the task status of all students in a particular task, the visualisation in Figure 6.12 allows the teaching staff to select a particular task to view the submission information and the task status of each student on that task. The visualisation exploits common iconic representations of data to visually encode the information about task status of all students in a particular task. For example, the 'lightning icon' denotes that the student is 'Working on it' and the 'tick mark icon' indicates 'Task has been completed'. The iconic representations are enhanced with visual channel of colour hues. The colour hues are related to the colour hues used in the Task List in which the same colours are used consistently for the same status. In general, green indicates 'complete' status and other colours indicate 'incomplete' status. Teaching staff can gain a quick view if a particular student has completed the work or if it is

pending. This is especially helpful when a tutorial class is conducted to discuss a particular task. The visualisation **enables the teaching staff to easily identify students who need help in a particular assessment task**.

Figure 6.12 View by Specific Task visualisation showing tasks status for a specific task

The Pie charts in Figure 6.13 (a) – (c) encode similar information as in Figure 6.5. The Task Summary Chart (Figure 6.5) shows the proportion of complete versus incomplete tasks for a particular student. The Task Status Distribution enables the teaching staff to explore the proportion of different task statuses for an entire unit (Figure 6.13 (a)), by different tutorial groups (Figure 6.13 (b)) and by all tasks (Figure 6.13 (c)). The information **helps the teaching staff to identify which tutorial session and which task requires their most attention**. Hence, guidance and support can be provided accordingly.
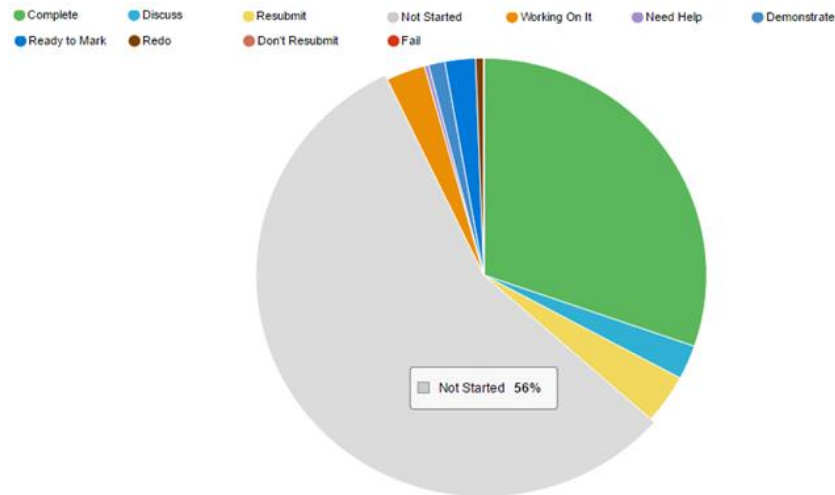
Figure 6.13 (a) Task Status Distribution showing proportion of different task status for an entire unit

LA1-01   LA1-02   LA1-03
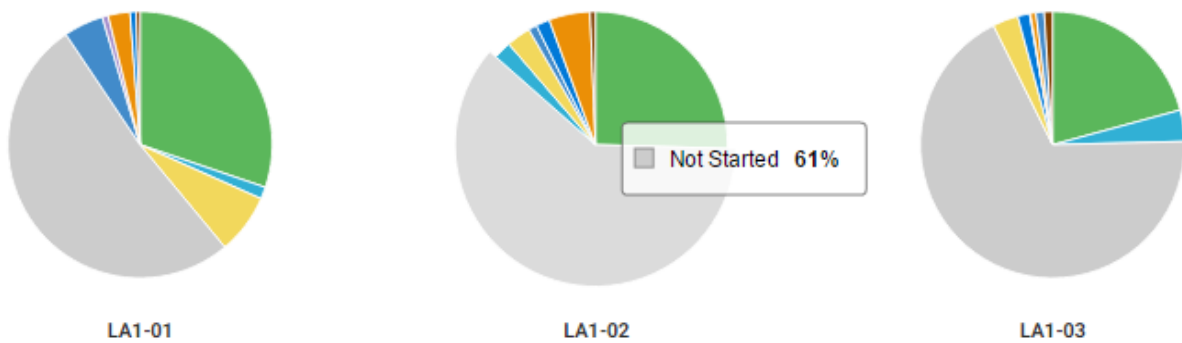
Figure 6.13 (b) Task Status Distribution showing proportion of different task status by different tutorial groups

1.1P   1.2P   1.3P
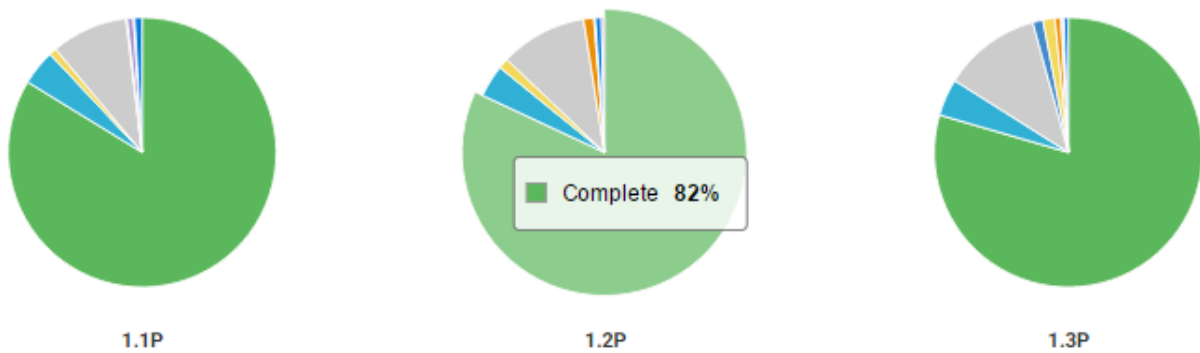
Figure 6.13 (c) Task Status Distribution showing proportion of different task status by all tasks

Task Completion Statistics presents information using boxplots as shown in Figure 6.14. Boxplot or box-and-whiskers plots is a popular visual representation for encoding the characteristics of a data distribution (Choonpradub & McNeil, 2005). Line and area are exploited in boxplots as marks to encode the data distribution. Boxplots provide a summary of five quantitative attributes including maximum, minimum, median, average and range. The position of line is used to encode the maximum, minimum, median, and average of the data distribution whereas area is used to encode the range value from the first (Q1) to the third (Q3) quartile of the distribution.

Bigger box area indicates that the data is distributed in a larger range. The lines across the box are encoded by colour hues to denote the median and average. The lines extending from Q1 and Q3 to the end points indicate the minimum and maximum value respectively (Krzywinski & Altman, 2014). Boxplots are used in this research project to present the Task Completion Statistics. A user is able to obtain information regarding the number of tasks that have been completed on average or by the majority of the students, the minimum and maximum number of tasks completed by a class. This information can be retrieved according to the entire unit (Figure 6.14 (a)), by tutorial group (Figure 6.14 (b)) and by target grade (Figure 6.14 (c)). The teaching staff **can gain an idea about the class progress for the unit they are teaching**, and compare class progress by tutorial group. They can also compare student progress against their aspiration grades and can intervene if they feel that the target set is not appropriate.
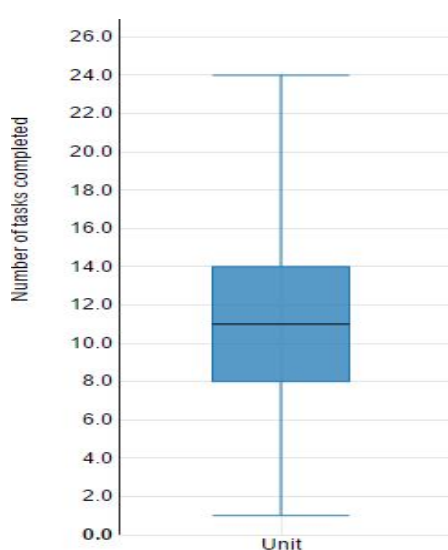
Figure 6.14 (a) Task Completion Statistics showing the completion statistics for an entire unit

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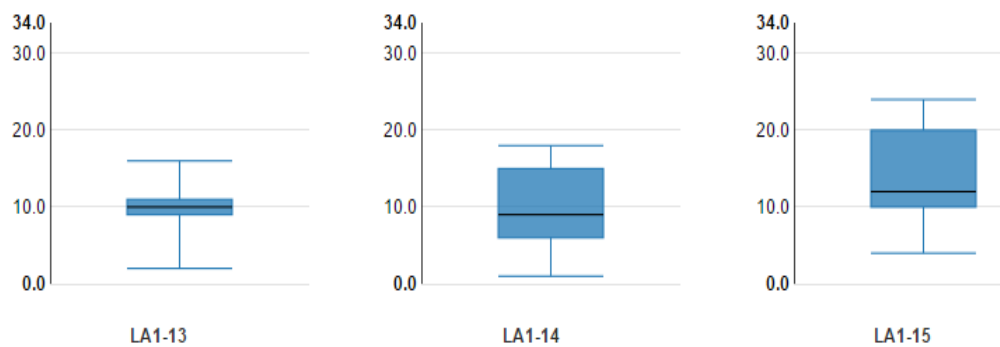
Figure 6.14 (b) Task Completion Statistics showing the completion statistics by tutorial groups
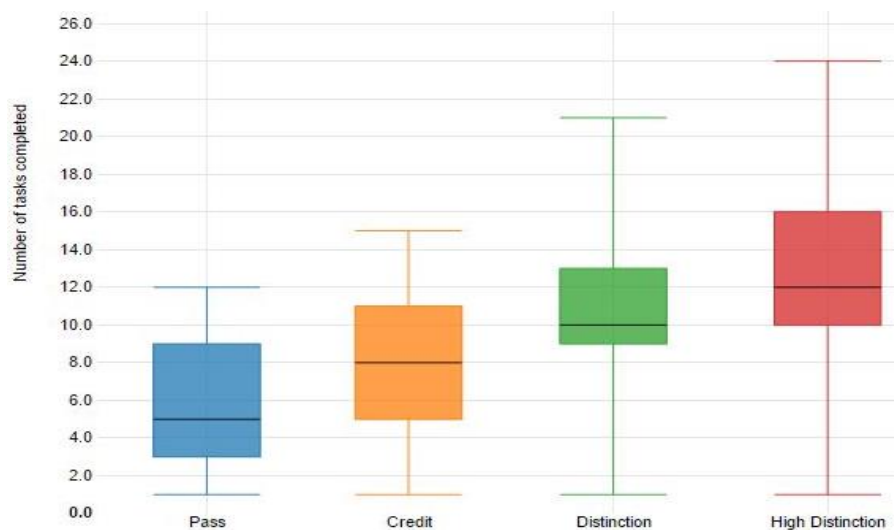
Figure 6.14 (c) Task Completion Statistics showing the completion statistics by student target grade

6.4.3   Visualisations for Monitoring Learning Outcome Achievements

Boxplot is also used to display student learning outcome achievement distribution. This visualisation is named LO Achievement Statistics. The teaching staff can gain information about student current performance in terms of learning outcome achievements in an entire unit (Figure 6.15 (a)) and by tutorial groups (Figure 6.15 (b)). At the end of the semester, the data **helps the teaching staff to reflect if the learning activities provided have led to the required level of learning outcome achievements** and if the achievements are in line with the unit requirement. This information can be used to guide staff future planning for the unit.

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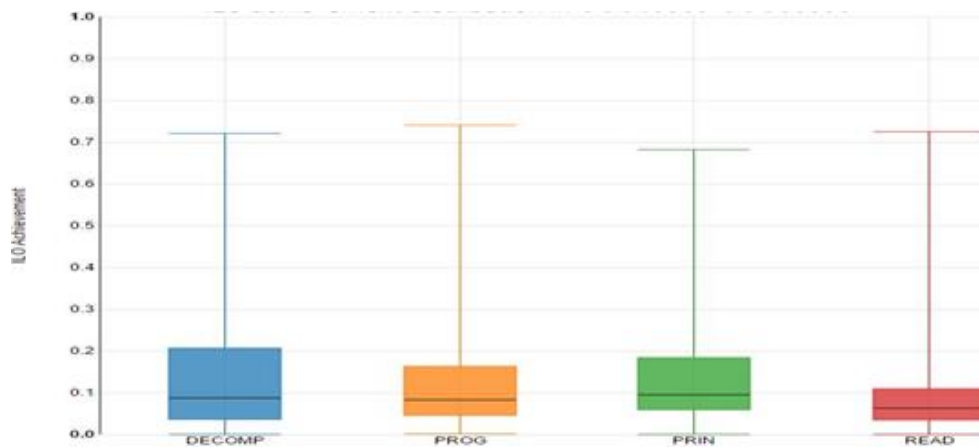
Figure 6.15 (a) LO Achievement Statistics visualisation by an entire unit
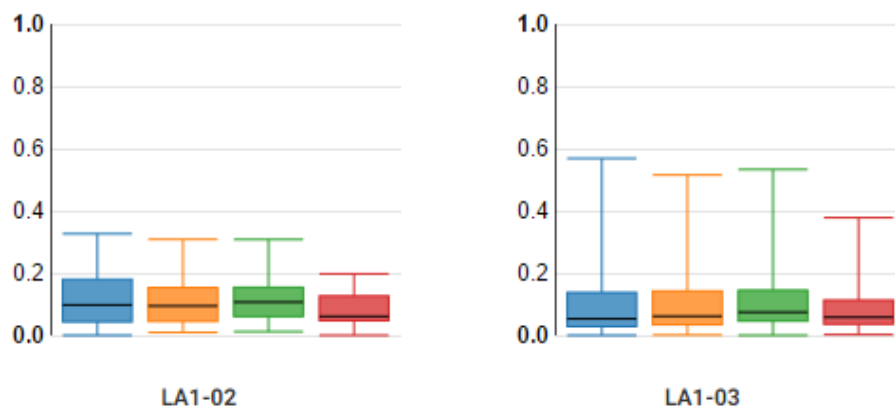
Figure 6.15 (b) Achievement Statistics visualisation by tutorial groups

6.4.4 Visualisations for Providing Feedback

Central to the Task-Oriented Portfolio teaching approach is providing formative feedback to help each student develop a portfolio of work to demonstrate that they have achieved the unit learning outcomes. This means providing frequent formative feedback is one of the important activities in this approach. The prototype tool was also designed to support the teaching staff interaction with the visualisations to sort, filter and obtain details on demand as well as to retrieve tasks awaiting feedback. The Task Requiring Feedback visualisation as shown in Figure 6.16 allows the teaching staff to view and provide feedback to student assessment tasks. The sorting function enables the teaching staff to sort according to Student ID, Name, Submitted date, and so on. This **enables the teaching staff to organise, plan and prioritise their workload.** A click on anywhere of a student's record row leads the users to a student's submitted task.

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Figure 6.16 Tasks Requiring Feedback visualisation showing tasks awaiting feedback

Once the task is assessed, feedback in textual description can be communicated to students. The feedback attribute is a categorical data. A combination of iconic representation, textual description and colour coding (Figure 6.17) is used for easy identification of what feedback is required. The multiple visual encodings are intended to reduce the teaching staff cognitive load when providing feedback to students. A staff user can either look at the iconic representation or colour hue rather than just read the textual description to select the feedback needed. This enables the teaching staff to provide a brief immediate feedback by a click on the Feedback Interface button. They also can leave some textual feedback in the comment textbox and send it to the students. Students can then visualise the task status and read the comment. They can act on the feedback received to improve their work. The Feedback Interface also keeps the comment history. This **helps both the teaching staff and students keep track of comments received and provided.**
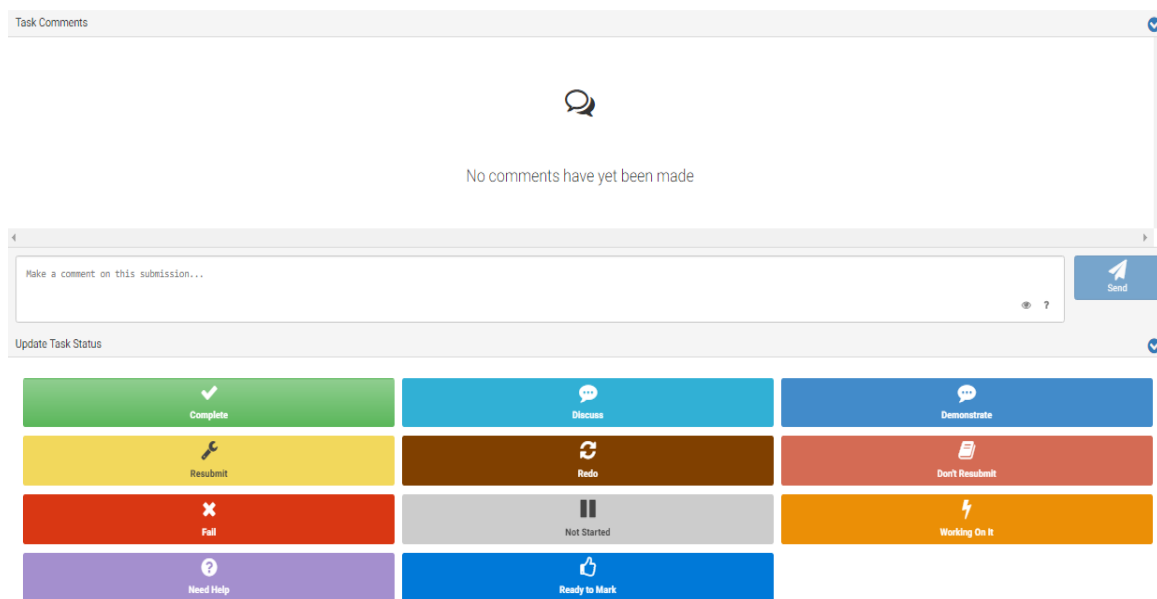
Figure 6.17 Feedback Interface enables a teaching staff to provide feedback to students

6.5   Doubtfire++

Doubtfire was enhanced with Shared Student-Centred Visualisations and Teaching Support Visualisations. The enhanced prototype tool is named Doubtfire++. These visualisations allow the teaching staff and students to explore the links between tasks and learning outcomes, and to monitor student progress and learning outcome achievements. Figure 6.18 illustrates the establishment of the links between tasks and learning outcomes in Doubtfire++. With the establishment of the links, Doubtfire++ could better support student reflections on task assessment in terms of learning outcomes.

It encourages them to think about what they want to achieve or what they have achieved in attempting or completing an assessment task. It is also posited that the visualisations can help the teaching staff to gain useful insights of how students learn in this new environment. In this way, staff can provide appropriate guidance to students on time as well as help them to reflect for any changes needed to further improve their practice in a CA approach. Doubtfire++ is believed to better support the frequent formative feedback in a Task-Oriented Portfolio teaching approach besides encouraging student self-regulated learning.
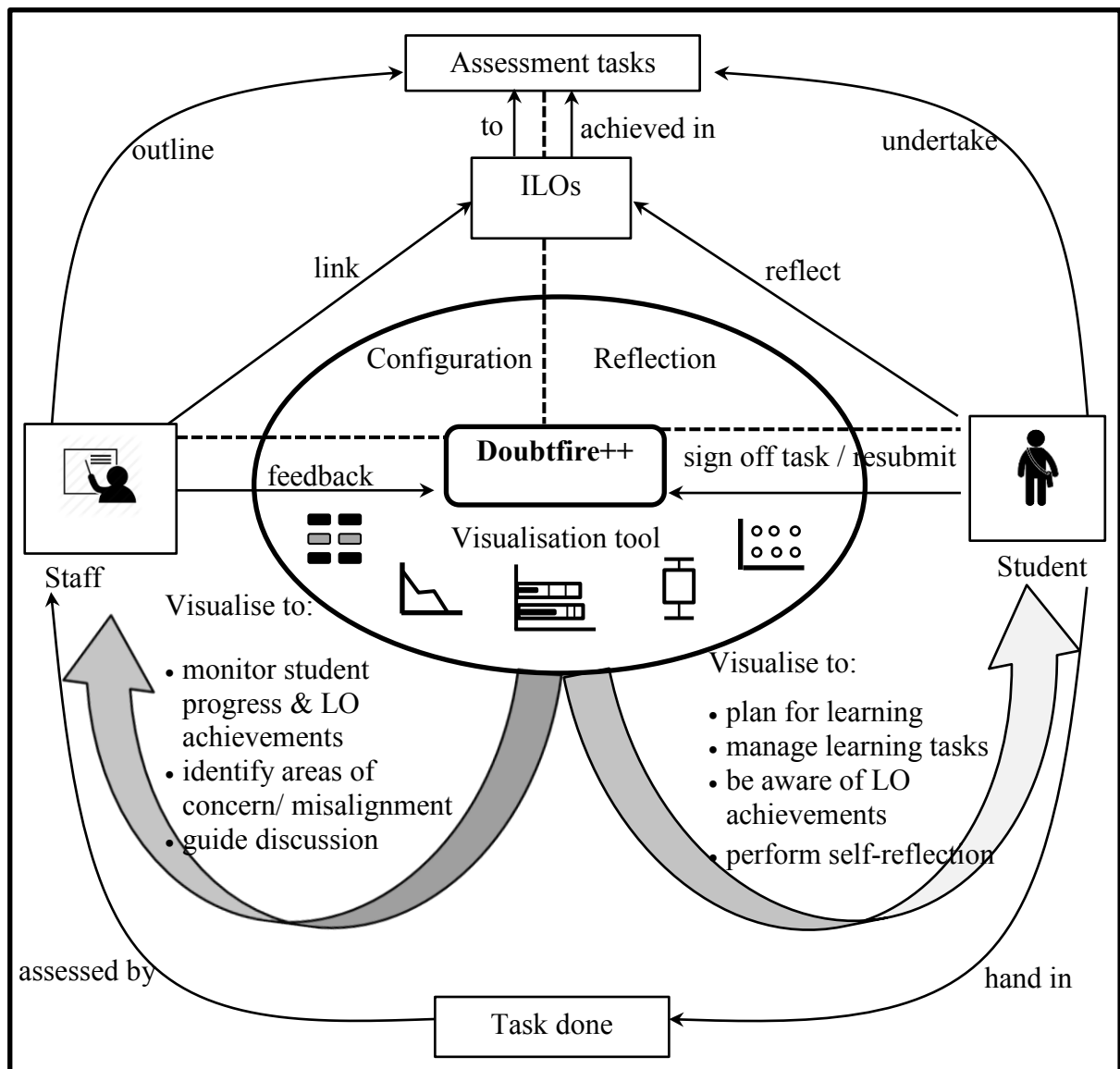
Figure 6.18 Doubtfire++ provides direct support for indicating the links between the learning tasks and the learning outcomes

6.6 Summary

This chapter discusses various OLM visualisations that have been developed based on software development team's experience in visual encodings and the findings obtained from Study 1 (see Chapter 5). The visualisations were developed to support outcome-based student-centred teaching and learning process known as Task-Oriented Portfolio teaching approach. Two major groups of visualisations have been designed and developed to support different user roles, i.e., teaching staff and students. The Shared Student-Centred

Visualisations are designed to facilitate students learning by taking greater ownership of their learning. The Teaching Support Visualisations are designed to help the teaching staff in creating a supportive learning environment to encourage students in becoming self-regulated learners. This includes supporting teaching staff to visualise student target grade, link the assessment tasks to the intended learning outcomes, and monitor task progress and learning outcome achievements. While the visualisations help the teaching staff to provide frequent formative feedback to students, students can visualise to act upon the feedback to advance in their learning. Users experience interacting with these visualisations prototype design is a valuable aspect to be studied. The instruments used to evaluate the prototype tool and data analysis results are reported in Chapter 7.

Chapter 7
Study 2 Instruments and Results

7.1   Introduction

Shared Student-Centred Visualisations and Teaching Support Visualisations are two groups of OLM visualisations that were developed to support students and teaching staff respectively (Chapter 6). The Shared Student-Centred Visualisations were developed to support students in taking greater ownership of their learning in the Task-Oriented Portfolio teaching. The Teaching Support Visualisations were developed to help the teaching staff support student learning.

Using Doubtfire as an evaluation platform, Study 2 aims to explore the teaching staff and student perceptions regarding the uptake and effective use of OLM visualisations in supporting Task-Oriented Portfolio teaching. For easy identification between previous Doubtfire version without links between tasks and learning outcomes and existing Doubtfire version (with OLM visualisations showing links between tasks and learning outcomes), the new tool is named Doubtfire++.

The key research questions for Study 2 have been formulated as follows:

How do users perceive the use of Doubtfire++ OLM visualisations in supporting Task-Oriented Portfolio teaching to encourage student self-regulated learning?

To adequately answer the primary research question, six secondary research questions (*RQ*) and the sub-research questions were developed as the follows:

RQ1: How do users with different roles perceive the usefulness of the OLM visualisation for Task-Oriented Portfolio teaching to support student self-regulated learning?

> *RQ1 (a): How do users with different roles perceive the use of Shared Student-Centred Visualisations as useful for the purpose of supporting student Self-regulated Phases?*

> *RQ1 (b): How do the teaching staff perceive the use of Teaching Support Visualisations as useful for supporting them in the Task-Oriented Portfolio teaching to encourage student self-regulated learning?*

RQ2: How do users perceive the use of Doubtfire++ OLM visualisations in supporting the following user roles in the Task-Oriented Portfolio teaching:

RQ2 (a): Facilitating student self-regulated learning in terms of

(i)   Goal setting?
(ii)   Performance monitoring?
(iii)   Self-reflection?

RQ2 (b): Supporting the teaching staff to facilitate student learning?

RQ2 (c): Supporting convenor in managing the unit?

RQ3: Do different user demographics impact user perceptions of using Doubtfire++ to support student Self-regulated Phases?

RQ4: Do any prior experiences in using Doubtfire++, frequency of use, and different teaching units impact users' perceptions of using Doubtfire++ to support student Self-regulated Phases?

RQ5: Does the use of Doubtfire++ have any impact on student final grades?

RQ6: What is user overall experience in interacting with Doubtfire++?

The Doubtfire++ prototype tool was deployed for one semester to support the Task-Oriented Portfolio teaching. It was evaluated with the end users (i.e., the teaching staff and students) through a detailed survey and interviews. As presented in Chapter 3, the study was conducted in accordance with Swinburne's Human Research Ethics policies and procedures (Appendix A.2). Staff participants, were invited to participate in this study through an email invitation. Student participants were recruited through the help of the teaching staff by posting the survey link in the online announcement in Blackboard Learning Management System. Interview participants were recruited from the survey participants. An invitation note appeared at the end page of the survey to invite participants for an interview in which interested participants could key-in their contact information. To protect anonymity, the contact information captured in the note (Appendix A.6) was separated from the participant's responses.

The next section describes the research instruments for collecting the data. This is followed by the presentation of the quantitative and qualitative sample characteristics. The chapter then reports the data analysis results of Study 2 in addressing the research questions. Threats to validity are presented before it is concluded with a summary.

7.2   Study 2 Instruments

The research instruments used in Study 2 include an online survey questionnaire and an interview plan.

7.2.1   Quantitative Instrument: Online Survey Questionnaire

Study 2 has two versions of survey questionnaires to seek user views from either teaching or learning perspectives as in Appendix A.4 and Appendix A.5 respectively. There were six parts in both the survey questionnaires with similar questions.

Part 1 consisted of project information statements. Part 2 was designed to collect a participant's demographic information. In Part 3, participants were requested to rate the usefulness of each of the visualisations based on a five-point Likert scale ranging from 1=Not Useful to 5=Very Useful. Participants rated each item from their perspective based on their user role as either teacher or student. To ensure a better coverage of user usage options, noncommittal categories, 'did not use' was included in each question.

Part 4 consisted of 27 items to examine OLM visualisations in supporting the students (fifteen items), teaching staff (eight items) and convenor (four items) in a Task-Oriented Portfolio teaching. These items were also rated by the participants with five-point Likert scale from 1=Strongly Disagree to 5=Strongly Agree.

Part 5 consisted of twelve items. Four items with five-point Likert scale were designed to investigate user overall experience interacting with the prototype tool including their attitudes and satisfaction. Eight items were used to examine an experienced user's opinions about the enhanced features in Doubtfire++ to support the Task-Oriented Portfolio teaching. Three-point Likert scale with 1=Worst, 2=Same, and 3=Better was used to rate Doubtfire++ as compared to the previous version, Doubtfire. Part 6 contained open-ended questions to identify problems encountered in using the visualisation tool and to seek for a participant's views for improving the visualisations and to better serve user need for information exploration.

7.2.2   Qualitative Instrument: Interview Plan

The interview plan consisted of fixed questions and questions that were built on the quantitative strand. Besides exploring how OLM visualisations were used by different users in supporting Task-Oriented Portfolio teaching and learning, user experience interacting with the prototype tool and ways to better support this approach, the qualitative strand was exploited to explain the significant or nonsignificant quantitative results in more depth.

Face-to-face individual and group interview sessions were held to collect the qualitative data through semi-structured open-ended interview questions. For teaching staff, their usage was related to their user role as convenor or tutor. They were invited to participate in an individual interview. For student participants, they were invited to group interview. The interview questions were developed based on its use to support the Task-Oriented Portfolio teaching and some follow-up questions from the results of the quantitative analysis.

The interview plan consisted of five parts. Part 1 was about a participant's demographic information and some screening questions to determine if the participant should be asked some of the questions that were built on the quantitative strand. Part 2 was related to how users used OLM visualisations in a Task-Oriented Portfolio teaching and learning. Part 3 aimed to address the quantitative results obtained such as how the prototype tool was used in different teaching units and the way students interacted with the goal setting visualisation to set their target. Part 4 gathered an experienced user's viewpoints on the additional visualisation features in the new prototype tool. Part 5 explored user experience in using the visualisation tool including the problems they encountered and ideas to enhance the OLM visualisation tool to better facilitate student learning in the Task-Oriented Portfolio teaching and learning. A sample of the semi-structured interview plans for the teaching staff and student is attached in Appendix A.11 and Appendix A.12 respectively.

7.3   Samples

The teaching staff modified their units to incorporate the use of Doubtfire++, including describing learning outcomes, goals, tasks, tasks linked to outcomes, and to focus on student-centred learning and reflection. Students interacted with Doubtfire++ to view unit tasks, submit their work for feedback, track their progress, visualise their learning outcome achievements as well as self-reflect on their learning. Through Doubtfire++, staff outlined assessment tasks, linked them to the intended learning outcomes, provided formative

feedback to students, signed tasks off by indicating the task status as well as monitored student progress and achievements. In Semester 1, in March 2016, Doubtfire++ was deployed in 12 teaching units in the Faculty of Science, Engineering and Technology at Swinburne University of Technology. A study was carried out to examine teaching staff and undergraduate student perceptions regarding the use of Doubtfire++ in supporting different user roles in a Task-Oriented Portfolio teaching and learning environment to encourage student self-regulated learning.

7.3.1 *Quantitative Sample Characteristics*

171 teaching staff and students from 12 units voluntarily accepted the invitation to participate in this study. Some did not answer any questions related to the graphical representations and some abandoned while answering the questionnaire. This could be due to the fact that the participants were not interested in answering questions related to visualisation. A total of 37 questionnaires that did not rate any questions related to the graphical representations or have missing data for more than 10% were excluded from data analysis. There were four samples with missing data that was less than 10%. As the missing data for an individual participant is less than 10%, the effect of the missing data on the research findings is small (Hair, Black, Babin & Anderson, 2014). The missing data was replaced with the mean value for the variable by using 'Replace with mean' option in SPSS (Pallant, 2013). This yielded a total of 134 valid samples.

The valid samples consisted of 15 teaching staff and 119 students. Out of the 15 teaching staff, nine of them were tutors whereas four of them played a multiple role as convenor, lecturer and tutor. They were spreading across seven Programming (Prog.) units, three Software Engineering (SE) units and two Information Technology (IT) units. All of the Programming units fully adopted portfolio assessment while other units either adopted partial or full use of portfolio assessment. There was an imbalance of gender proportion. That is, 110 were males with only 20 females. Four did not disclose their gender. The imbalance of gender proportion could be due to the fact that data was collected from one faculty (Faculty of Engineering, Science and Technology) in which there were more males in this faculty. The majority (94) were familiar with visualisation techniques. That is, 21 were very familiar and 73 were somewhat familiar, 32 had heard about them, and eight were not familiar. 113 of them were frequent users of Doubtfire++ (used it every day or at least twice in a week) whereas 21 of them occasionally or rarely used it (less than two times in a week). 43 of them had experience using both versions, Doubtfire and Doubtfire++ whereas 91 were new users.

While 85 used it in a Programming unit only, 19 users were from only a Software Engineering unit, 28 users used it in at least one Programming unit and at least one other unit including Information Technology units. Two did not disclose this information. Figure 7.1 (a)–(f) illustrate participant demographics by user roles, gender, familiarity with Information Visualisation (InfoVis), frequency of use, user types, and teaching units respectively.
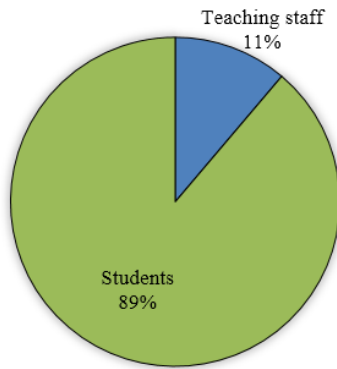
(a) User roles
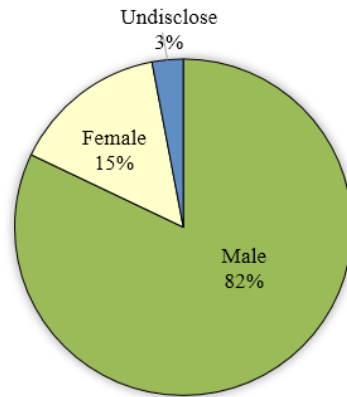
(b) Gender
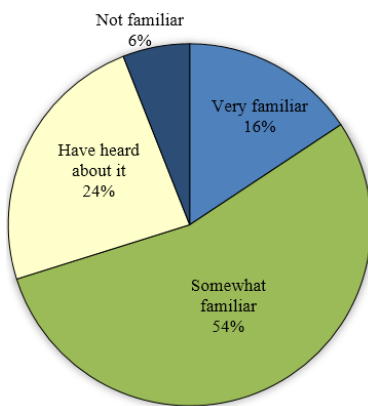
(c) Familiarity with InfoVis
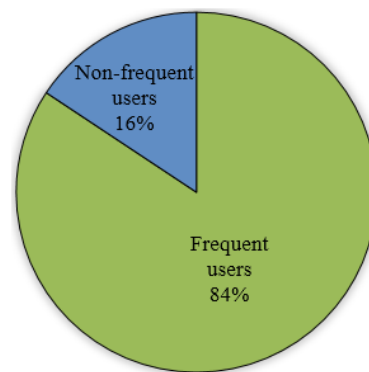
(d) Frequency of use
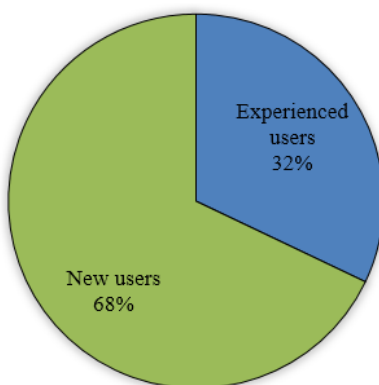
(e) User types
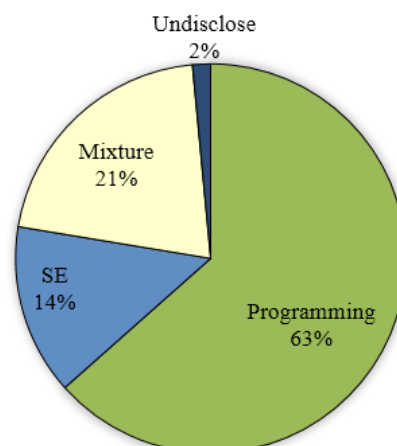
(f) Teaching units

Figure 7.1 Quantitative sample characteristics for Study 2

7.3.2 Qualitative Sample Characteristics

Three focus group discussions and seven face-to-face interview sessions were conducted with students and the teaching staff respectively. Nine of them were students and seven of them were teaching staff with eleven males and five females. All of them were Doubtfire++ frequent users who used it every day or at least twice in a week. Nine were experienced users who had used both Doubtfire and Doubtfire++ versions and seven were new users who used only Doubtfire++. Thirteen of them used it in Programming units only, two used it in Software Engineering (SE) units only and one used it in both programming unit and SE unit (mixture). Fourteen of them used it for fully portfolio assessment unit while three used it in partial portfolio assessment unit. As a student participant had two units that used Doubtfire++, one of the unit adopted fully portfolio assessment and the other unit adopted partial portfolio assessment, the total number of fully and partial portfolio assessment was seventeen instead of sixteen. Figure 7.2 (a)–(f) illustrates the qualitative sample demographics by user roles, gender, frequency of use, user types, teaching units, and assessment types.
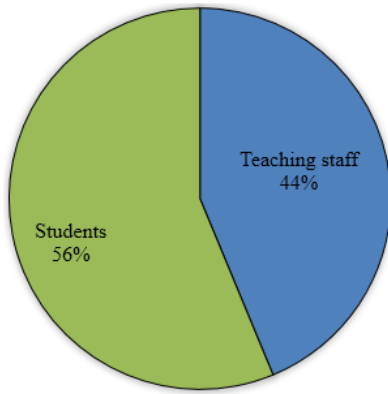
(a) User roles
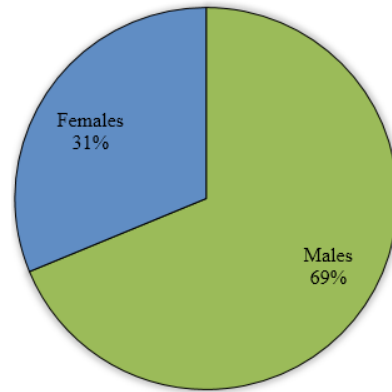
(b) Gender
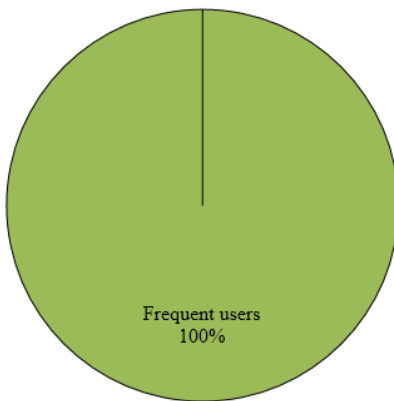
(c) Frequency of use
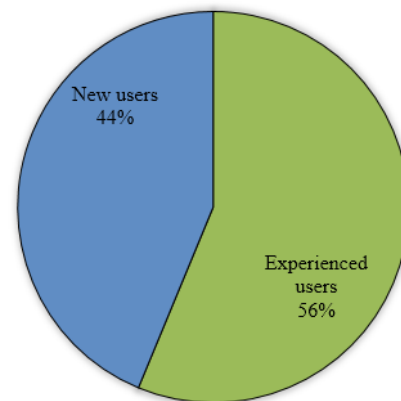
(d) User types
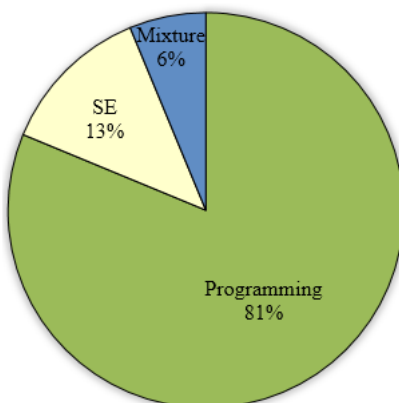
(e) Teaching units
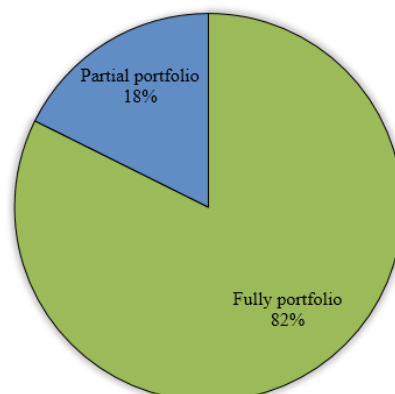
(f) Assessment types

Figure 7.2 Qualitative sample characteristics for Study 2

7.4 Quantitative Analysis Techniques and Mixed-Methods Results

Study 2 applied Descriptive Statistics analysis, Independent Samples t-test and a One-way Between-groups Analysis of Variance (ANOVA) (Section 3.5.2.3) to analyse the quantitative data. Content analysis (Section 3.5.3.3) is used to analyse the qualitative data collected from the face-to-face interview. This research project adopts an Explanatory Sequential Mixed-Methods approach to adequately answer the research questions. The quantitative analysis results are presented first followed by the qualitative results. The qualitative results are used to describe, compare, confirm or juxtapose the quantitative results obtained to better address the research questions. To retain anonymity of the interview subjects, 'he' is used as a pronoun for all the comments. This section presents the analysis results according to the sequence of the research questions, *RQ1* to *RQ6*.

7.4.1 Research Question 1 (RQ1)

RQ1: How do users with different roles perceive the usefulness of the OLM visualisation for Task-Oriented Portfolio teaching to support student self-regulated learning?

> *RQ1 (a): How do users with different roles perceive the use of Shared Student-Centred Visualisations as useful for the purpose of supporting student Self-regulated Phases?*

> *RQ1 (b): How do the teaching staff perceive the use of Teaching Support Visualisations as useful for supporting them in the Task-Oriented Portfolio teaching to encourage student self-regulated learning?*

To answer *RQ1*, descriptive statistics analysis was conducted to obtain the counts of usage of all participants and their perceived usefulness of OLM visualisations in supporting the Task-Oriented Portfolio teaching. The Shared Student-Centred Visualisations were developed to help students engage in their learning through the three cyclical phases in self-regulation learning, (i.e., setting learning goals, monitoring performance and performing self-reflection). These visualisations were accessible by all user groups. Data was collected from all users (both teaching staff and student) to find out to what extend a specific Shared Student-Centred Visualisation was perceived useful for the purpose of supporting student Self-regulated Phases. For the Teaching Support Visualisations, data was collected from the teaching staff. The following subsections present the results for Shared Student-Centred Visualisations and Teaching Support Visualisations respectively.

7.4.1.1 RQ1 (a): Results for Shared Student-Centred Visualisations

The results are presented in the sequence according to visualisations that support student in three key phases of self-regulated learning, i.e., (i) Goal setting, (ii) Performance monitoring, and (iii) Self-reflection phases.

(i)   Shared Student-Centred Visualisation for Supporting Goal Setting Phase

The Target Grade Setting visualisation (Figure 6.1) was designed for users to visualise all target grades. It links the amount of assessment tasks and the learning outcomes to each of the target grades. It was designed to keep students informed about the unit requirement for each grade including the amount of work to be completed as well as learning outcomes to be demonstrated in the assessment tasks. Figure 7.3 illustrates user usage and their perceived usefulness of the visualisation to set their target grade.
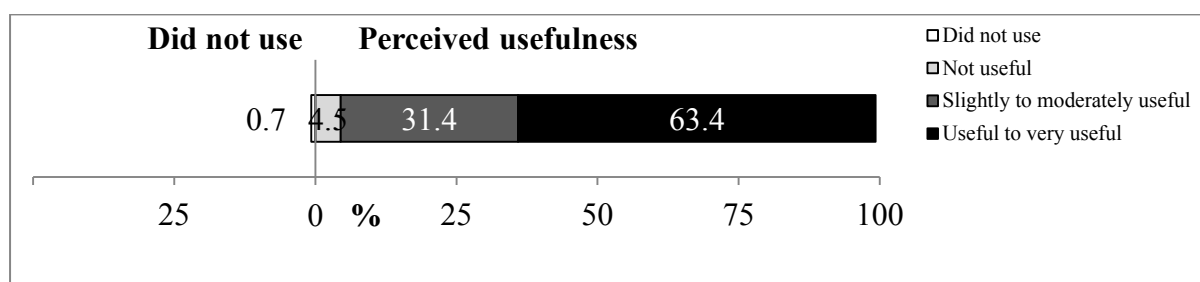
Figure 7.3 User usage and usefulness rating for the Target Grade Setting

The result indicates that it was a popular visualisation. Only 1 participant (0.7%) reported not using it. Many participants (63.4%) found it useful for setting their learning goals whereas 31.4% rated it as slightly to moderately useful. Only 6 participants (4.5%) rated it as not useful.

The qualitative results corroborate with the quantitative findings. The teaching staff felt that:

> *It helped me understand the expectation of the students and allowed me to monitor student progress based on their expectations and their progress on a weekly basis.*

Another teacher also held a positive view:

> *It helped me see what a student was aiming for and guided my one-to-one discussions with them. It also allowed me to give them sufficient advice and warnings about managing their time and some pitfalls that they would likely encounter, especially with the higher grades.*

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However, one teacher said:

The way it was used was the top students used it correctly. The people in the middle used it correctly but all the people were really weak would either just keep putting HD or left the default grade – 'Pass' there.

Two teaching staff said that they had to intervene in the middle of the semester. One told the class:

You have few weeks to go, you might need to re-consider changing to a new target grade depending on how much you have done so far.

Student participants generally perceived that it was useful. Some of their comments included:

This visualisation helped me to set goals and view the required tasks to reach the desired grade. It made the necessary workload for each grade easier to see and judge. This helped me manage my schedule.

Initially, I really wanted a good grade. In the week when I was really busy, I felt stressed over the overwhelming tasks. I changed it to a 'Pass'. All the sudden, the number of tasks reduced. It really calmed me down. I completed the 'Pass' tasks and then adjusted it to see if I could target high again.

Being able to change my desired grade to view the tasks, it made me felt very rewarding. It was like selecting a difficulty in a game! Tasks seemed more achievable this way.

Three of the students, who targeted for a 'High Distinction' grade, said that they didn't really use it after the initial setting up of their target grade as that was the grade they strive for.

(ii) OLM Visualisations for Supporting Performance Monitoring Phase

Six visualisations were designed to facilitate users in monitoring student performance. Although they provided information about different learning aspects, some appeared to be more popular than others. The results are illustrated in Figure 7.4.
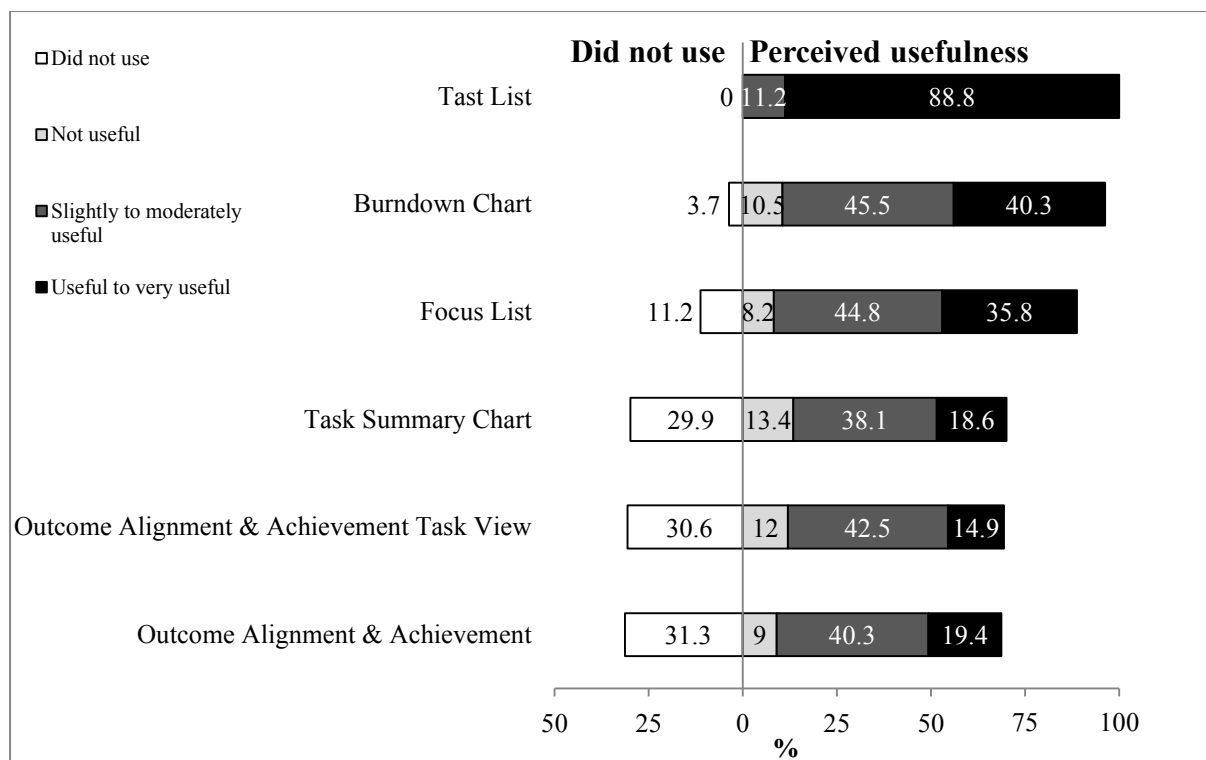
Figure 7.4 User usage and usefulness rating for OLM visualisations in monitoring performance

The Task List was designed for users to inspect the status of each assessment task and it was the most popular visualisation, followed by Burndown Chart and Focus List. Other visualisations such as visualisations for inspecting task status summary and learning outcomes were less popular. About 30–32% participants did not use them. Although they were less popular, quite a number of the participants (10%–20%) who used them found them useful. About an equal number of participants, that is 9%–14% found them not useful. All participants found Task List as the most useful visualisation for monitoring their performance. Burndown Chart and Focus List were also found useful. Only a small number of participants found Burndown Chart and Focus List to be not useful, that is, 10.5% and 8.2% respectively.

The qualitative results from the interview supported the quantitative findings. Most teaching staff felt that Task List helped them the most. Comments include:

> *It told me if my students had any issues with any specific tasks. I could see which tasks they stuck on, which tasks they needed help. I could then help them.*
> *I referred to it when I started a discussion with a particular student. It was particularly useful when I counselled those struggling students. I used to it to advise students for tasks to catch up on.*

The most notable student comments on Task List were related to its use to monitor their performance and plan for their learning. Comments included:

> *I checked it frequently to make sure I was on track. It gave me a quick big picture of what I needed to work ahead and planned my time to achieve what I aimed for.*
>
> *It was the most influential visualisation to my learning because it basically devoted the goals. When I saw my goal on High Distinction or Distinction, I actually learnt out the tasks I needed to do to achieve my goal.*

Colour was pointed out by student participants as an effective visual encoding method in Task List. The colours make it easy for tracking progress as well as to motivate students to complete the tasks. A teacher said:

> *The colour coding made it easy to know which task was awaiting my feedback and I could respond to it quickly.*

Student comments included:

> *I aimed for all blue and green. It was a fantastic overview of where you were at and what you needed to work on. I felt super satisfying when I have it all green at the end!*
>
> *Filling up the list with green was an incredibly satisfying thing to watch. It helped me to visualise quickly and easily knew how close I was in completing the unit!*

As the Focus List was part of the Task List that was designed to help those who lagged behind to stay on track, its use was not as popular as the Task List. Most staff felt that it was more useful for students. While a small number of students found it was useful, some students found it redundant. Comments include:

> *I used this view to get a brief summary of all my upcoming tasks. It was helpful if I fell behind as it was a constant reminder of the work left to complete in order to catch up.*
>
> *I prefer Task List that showed the overall task view than this view. So, I personally didn't use it much.*

The following comment reveals how staff perceived and used the Burndown Chart:

> *It was very useful to gauge if a student's rate of doing tasks was sufficient enough to reach their desired grade during the semester. Based on the shape of the line, student progress can easily be reviewed at the end of the unit. This helps in portfolio assessment.*

Students had different opinions about the Burndown Chart. Students who were able to interpret the graph found it to be very useful in helping them to stay on track. However, some students found it hard to understand the line graphs. They commented:

> *It provided the timeline measurement as well as the percentage values. This gave more meaning to the percentages. I was able to visualise the required 'velocity' of work needed to stay on track. It helped me juggling the workload over my four units!*
>
> *I had a really flat line for not submitting the tasks for weeks. I was motivated to get back on track and brought the line back near to the target line.*
>
> *I had never really got a good idea of how I was going by looking at this chart. It was just a bunch of lines that were sometimes above the dark grey line and sometimes below it...*

The following statement shows how the Task Summary Chart was used by one of the teaching staff.

> *It gave me a general overview of my class. I used it occasionally to get a general sense of the class progress.*

Some student participants felt the positive effect of having Task Summary Chart. However, some of them pointed out that the Task List and the Burndown Chart gave more detailed information. This could be the reason why it was perceived to be not so popular and many of them did not pay much attention to it. They commented:

> *It helped me to self-reflect on my progression through the unit. It gave me good visual of summary about my progress in the unit at a certain point of time.*
>
> *It was a good progress breakdown of task statuses. As the pie chart gradually turned greenish, I gained a sense of progress to get the pie chart into 100% green.*
>
> *I didn't use this very much. Instead, I used the Burndown Chart and Task List.*

The Outcome Alignment and Achievement Task View showed that all tasks contributed to each learning outcome. These links will be displayed only if a convenor has set them up. It is important to note that a unit convenor reported that he did not set up the links in Doubtfire++. Another convenor said that he was new to the unit and the links were being set up at the end of the semester. This had some impact to the user responses in this visualisation, for example one teacher said:

> *This was useful in reviewing task and outcome alignment for me, and I expect that students reviewed this when creating their portfolios.*

Some students appreciated the information it presented whereas some misused it. Their comments include:

> *It gave me a rough idea of the intended links between the tasks and the LOs. It helped me to justify what to include in my portfolio.*
>
> *It helped me to know what tasks needed to be completed to grasp a better LO achievements in attaining my learning goal.*
>
> *I only used it to fulfil my obligation to pointlessly number the tasks when filling out the portfolio.*
>
> *I don't care about learning outcomes. This is because the learning outcomes had been in-built in the course. If the tutor said you were doing good for a task, this means you had achieved the learning outcomes.*

Outcome Alignment and Achievement was designed to display student learning outcome achievements, reflecting this, one teacher said:

> *It helped me to see the LO coverage and to ensure my unit has a good coverage of the intended LOs.*

For units that have the links set up between the tasks and learning outcomes, not many teaching staff used it. They felt that it was more useful to students. The following comments show that it has different impact to students with different achieving levels. Comments included:

> *It was useful to see the breakdown of each grade level for each outcome. I used this to measure myself against my class and against each grade level. It helped me to monitor my own performance.*
>
> *I am a competitive person. I enjoyed seeing my triangle ahead of the average student block. It rewarded my nature to be good and be better. It motivated me the most.*
>
> *I don't care about LOs.*
>
> *While it was nice to be able to see how the rest of my class had gone with the tasks, coming from a relatively tough and disappointing semester, it did not help me when I saw how behind I was.*

(iii)   OLM Visualisation for Supporting Self-reflection Phase

The Task Alignment Rating was designed for students to reflect on their learning by indicating the level of the learning outcome they demonstrated in each of their assessment tasks. Figure 7.5 illustrates user usage and their perceived usefulness of Task Alignment Rating.
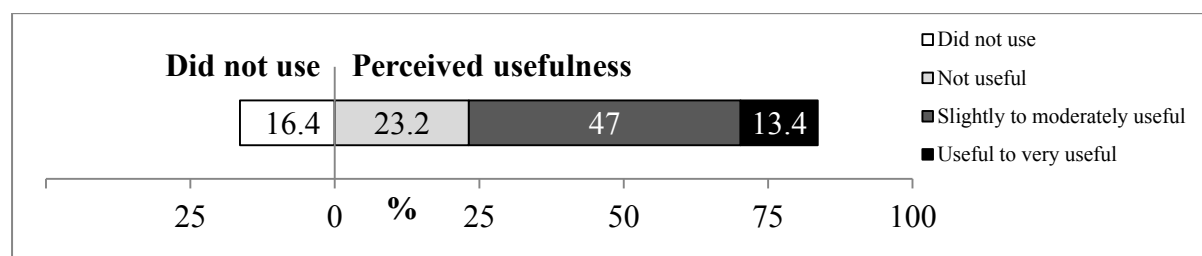
Figure 7.5 User usage and usefulness rating for the Task Alignment Rating

The result indicates that quite a number of the participants (16.4%) did not use it whereas 23.2% who used it did not find it useful at all. Only 13.4% said it was useful. The majority of them (47%) rated it as slightly to moderately useful.

From the teacher perspective, they felt that:

> *It was perhaps useful to reflect on, and perhaps could have guided students in selecting a range of tasks to include in the portfolio.*
> *The data captured was actually very interesting as an exercise to think through how the tasks I had planned relate to the unit learning outcomes.*

A tutor suggested:

> *It would be more useful to students if they used it to reflect upon each task submission rather than during portfolio submission. This is because their mind is still fresh with the task and can better justify their work.*

Depending on students' attitudes towards learning outcomes and self-reflection, divergent comments were received from the student participants. They said:

> *It made you think about what you had learned from each task. It was good to reflect on your learning but it was not always used to its full purpose. This is because everyone was busy at the end of the semester and tended to put less effort on it.*
> *I am more task-oriented rather than outcome-oriented. I only used this tool simply because it has to be used for the portfolio.*

Although the results from Section 7.4.1.1 (a) show that the visualisations had been designed to support student self-regulated learning according to goal setting, performance monitoring and self-reflection phases, in practice, students used a combination of the visualisations from all the phases to manage their learning. One of the students said:

> *The combination of Task List and Burndown Chart helped me to set an appropriate goal in the Target Grade Setting visualisation. Through that combination, I could flexibly allocate my time to go for each of the task. When I found myself sleeping behind from the Burndown Chart, I would look at Task List to see tasks for catch up in order to bring it back to where it should be.*

Another student stated:

> *I regularly used the Target Grade Setting visualisation, Task List, Focus List, Task Summary Chart, Burndown Chart and Outcome Alignment and Achievement. It was handy for gaining a sense of task counts, workload, and overall how much I had progressed and achieved through the unit for the target grade I had chosen. They were related. They helped me to see, reflect and improve my work.*

One student added:

> *I used the Task Alignment Rating and Outcome Alignment and Achievement Task View for self-reflection. They were helpful for me to decide the work that I should include in my portfolio.*

7.4.1.2 RQ1 (b): Results for Teaching Support Visualisations

Eight visualisations were designed to support teaching staff in a Task-Oriented Portfolio teaching and learning. Figure 7.6 shows the proportion of the teaching staff usage and their perceived usefulness of each of these OLM visualisations in supporting Task-Oriented Portfolio teaching approach.
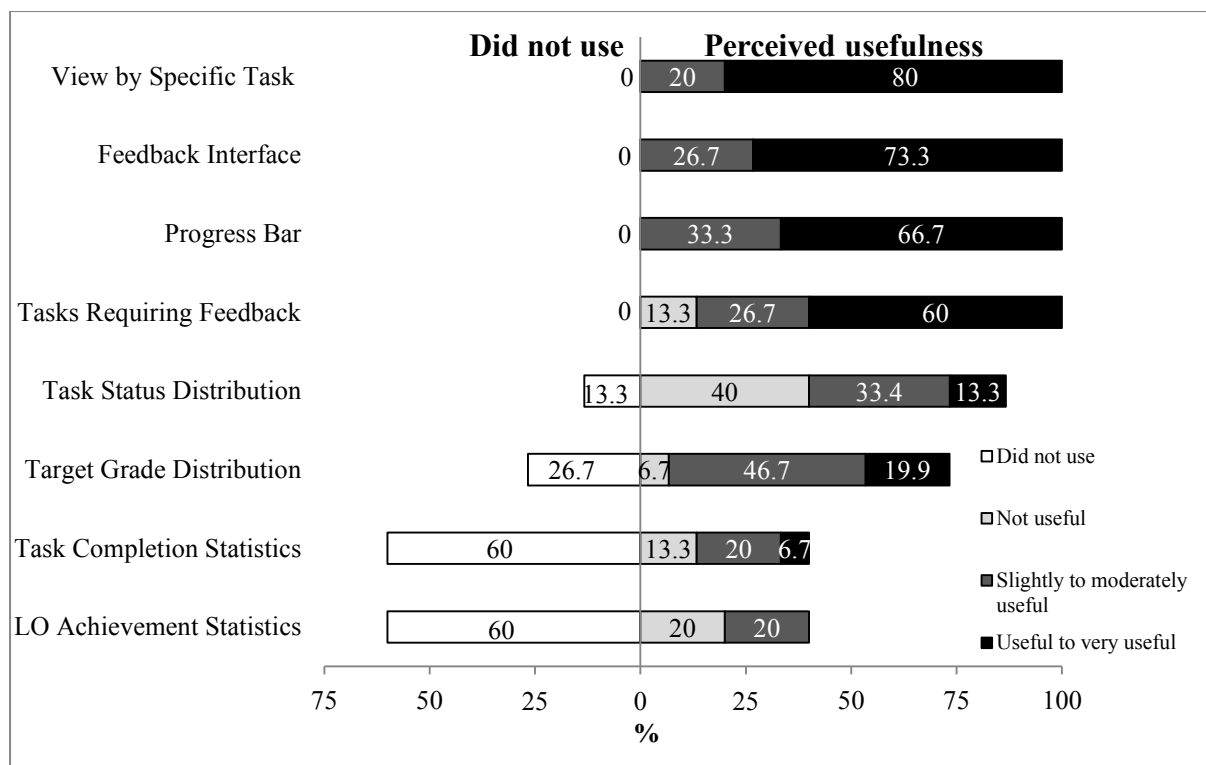
Figure 7.6 Teaching staff usage and usefulness rating for Teaching Support Visualisations

Four popular visualisations were View by Specific Task, Feedback Interface, Progress Bar and Task Requiring Feedback. Task Status Distribution and Target Grade Distribution were less popular. 13.3% and 26.7% of the participants did not use them respectively. The least popular visualisations were Task Completion Statistics and LO Achievement Statistics. As many as 60% participants did not use them.

All staff participants found that View by Specific Task, Feedback Interface and Progress Bar were useful visualisations in supporting them in a Task-Oriented Portfolio teaching and learning. At least 66% of them rated each of these three visualisations as useful to very useful. This is followed by Task Requiring Feedback, in which 60% said it was useful but 13.3% said it was not useful. While as high as 40% participants rated the Task Status Distribution as not useful, 33.4% said it was slightly to moderately useful while 13.3% rated it as useful to very useful. Quite a number of participants (26.7%) did not use Target Grade Distribution. However, it was perceived by 66.6% of participants as a useful visualisation with only 6.7% stating that it was not useful.

The narrative descriptions provide some insights of how View by Specific Task was used. Two tutors pointed out:

It helped me sort out what kind of feedback to give quickly. It formed the mental model for me to plan my feedback to student tasks.

It was useful as I could sort by tasks. I used it to organise and prioritise my marking workload.

Two staff participants indicated that they used it to catch up with people. One elaborated:

The sorting function helped me to easily confirm if students had completed their task in a timely manner. I used it to track students who have not done their work.

A convenor who used it all the time suggested a way to better serve user needs:

I am using it all the time to sort for tasks that are 'Ready to mark'. As the sorting function sorts the blue ones (Ready to mark) after the green ones (Complete), I wonder if the sorting function can sort the blue ones to the top according to what a user wants.

The Feedback Interface was rated useful. A tutor expressed that:

It was the main means of communication between the teaching staff and students. We could easily click to indicate the level of revision that required. We also could leave comments to students.

The following comments give examples of how the Progress Bar was used by the teaching staff:

It gave a simple overview about the progress of all students. I could sort by the task status to get an idea of where each student was up to.

Based on the proportion of colours, I can decide if I need to have a discussion with a particular student.

Task Requiring Feedback was popular and perceived useful by most participants. Participant comments explained the reasons:

It really helped when I have got a lot of 'Ready to mark' assignments. Based on what came out, I could then try to structure the way I did the marking.

I referred to it for tracking student submissions before I went to the lab. I looked at the assignment and prepared for the lab.

The Task Status Distribution was rated by 40% of participants as not useful. The following comment could be the main reason. A convenor said:

Due to the optional tasks in my unit, it was not quite accurate.

However, most qualitative results juxtapose with the quantitative findings. The comments show how it was used to support the teaching staff, both tutor and convenor in a Task-Oriented Portfolio teaching.

A tutor said:

This visualisation was the most beneficial to me. I could check to make sure every student finished their Week 1 tasks before Week 3. I also could check from task to task. It let me see which task that needed more help or too easy.

Another tutor indicated that:

I used it to help gauge if I was behind in marking or on track compared with the rest of the tutors.

A tutor added:

I used this visualisation periodically to compare my tutorial group with other groups. I took snapshot of the group that was progressed well to encourage my own students.

A convenor expressed that:

I used the pie chart to see where my tutors or tutorial groups were at. I referred to it during tutor meeting. The pattern gave me some sense of what was going on in the tutorials and how tutors were responding.

The Target Grade Distribution used a pie chart to present the data. Task Completion Statistics and LO Achievement Statistics encoded the data distribution with a boxplot. The qualitative results corroborated the quantitative findings that they were less popular and were perceived less useful.

Two tutors said that they had never looked at these two visualisations. Two convenors commented:

I can better understand a student cohort and their aspiration grade from the Task Status Distribution and Target Grade Distribution.

The Target Grade Distribution was not useful if student just left the default option there. I did not look at it. I was more concern about how an individual student went along with a specific task.

7.4.2 Research Question 2 (RQ2)

RQ2: How do users perceive the use of Doubtfire++ OLM visualisations in supporting the following user roles in the Task-Oriented Portfolio teaching:

RQ2 (a): Facilitating student self-regulated learning in terms of

(i)   Goal setting?

(ii) Performance monitoring?

(iii) Self-reflection?

RQ2 (b): Supporting the teaching staff to facilitate student learning?

RQ2 (c): Supporting convenor in managing the unit?

The results are presented according to user perceptions on how Doubtfire++ OLM visualisations support different user roles including students, teaching staff and convenors in the Task-Oriented Portfolio teaching as follows.

7.4.2.1 RQ2 (a): Results for Facilitating Student Self-regulated Learning

Table 7.1 presents the Cronbach's alpha coefficients for Goal setting, Performance monitoring and Self-reflection scales. The Cronbach's alpha values ranged from 0.834 to 0.852. This indicates that each construct exhibited strong internal reliability. Nunnally and Bernstein (1994) suggested a satisfactory range between 0.70 and 0.90 for the items in each scale to be a valid measure of their underlying construct. Thus, the reliability of all scales was acceptable. The following subsections present the results for the use of Doubtfire++ OLM visualisations in facilitating student self-regulated learning according to the three key phases: (i) Goal setting, (ii) Performance monitoring and (iii) Self-reflection.

Table 7.1 Internal consistency reliability coefficients

Scale	Cronbach's alpha (α)
Goal setting	0.852
Performance monitoring	0.834
Self-reflection	0.834

(i) *Goal Setting*

As suggested by Bolliger and Shepherd (2010) and Wetzel and Strudler (2005), keeping students informed and aware of course learning outcomes can assist them in setting their learning goals. Two items were used to examine student perceptions regarding how OLM visualisations in Doubtfire++ can assist them to set their learning goals as follows: "Doubtfire++ helped me…"

(1) see the links between tasks and learning outcomes.

(2) engage with the leaning outcomes.

56.7% of the participants agreed or strongly agreed that Doubtfire++ helped them see the links between tasks and learning outcomes (μ=3.54, SD=0.99) whereas 46.3% of them felt that it helped them to engage with the leaning outcomes (μ=3.38, SD=0.96). While 26.9% and 35.8% expressed their neutral view on these items respectively, only 16.4% and 17.9% strongly disagreed or disagreed with these items respectively. Figure 7.7 illustrates the proportion of participants' responses to each of the items.
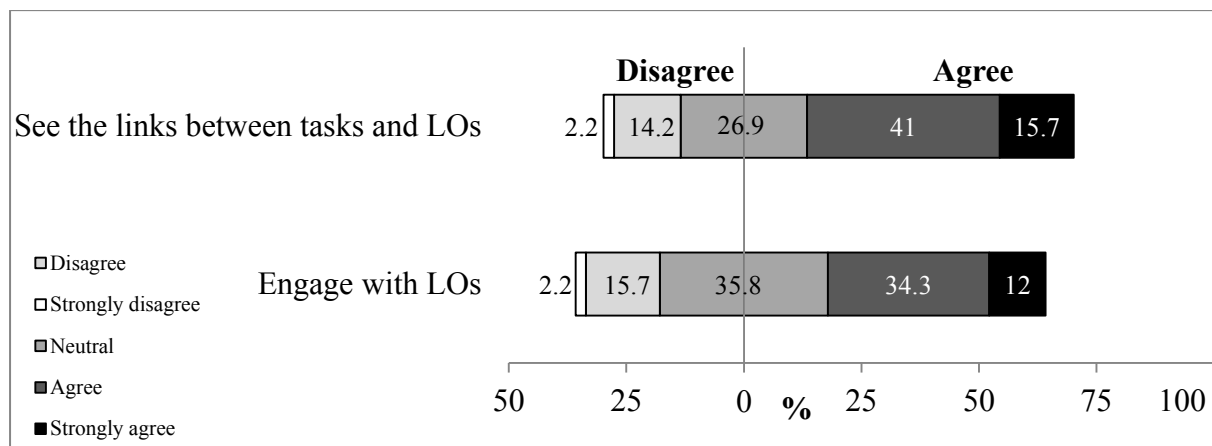
Figure 7.7 Participant responses to each of the items about Doubtfire++ helped students for goal setting

(ii) *Performance Monitoring*

In performance monitoring, seven items were used to investigate user perceptions on how Doubtfire++ OLM visualisations helped them monitor student performance. This includes the way students managed their learning tasks and how they acted upon the feedback received through frequent formative feedback (Cain & Woodward, 2012). Data was collected from all users (both teaching staff and student). Both user groups rated the items according to how

these visualisations helped the students manage their learning tasks, from student and teaching staff perspectives respectively. The items were: "Doubtfire++ helped…"

(1) motivate me/students to complete tasks.

(2) me/students to engage with learning.

(3) me/students to manage my learning.

(4) me/students keep on track.

(5) make it easy for me/students to access tasks.

(6) make it easy for me/students to submit work for feedback.

(7) me/students to act upon feedback I/they received.

90.3% highly valued that Doubtfire++ had made it easy for them to submit their work for feedback (μ=4.51, SD=0.76) and to access learning tasks (μ=4.49, SD=0.75) respectively. 82.9% agreed that it helped them to manage their learning (μ=4.17, SD=0.95) and to keep their learning on track (μ=4.13, SD=0.90) respectively. While 76.1% found that Doubtfire++ helped them act upon feedback they received (μ=4.07, SD=1.00), 70.2% said that it motivated them to complete their learning tasks (μ=3.84, SD=0.85) with 60.4% strongly agreed or agreed that Doubtfire++ engaged them with learning (μ=3.70, SD=0.97). Only less than 10% of participants strongly disagreed or disagreed with all items. Figure 7.8 illustrates the participant responses to all items in performance monitoring.
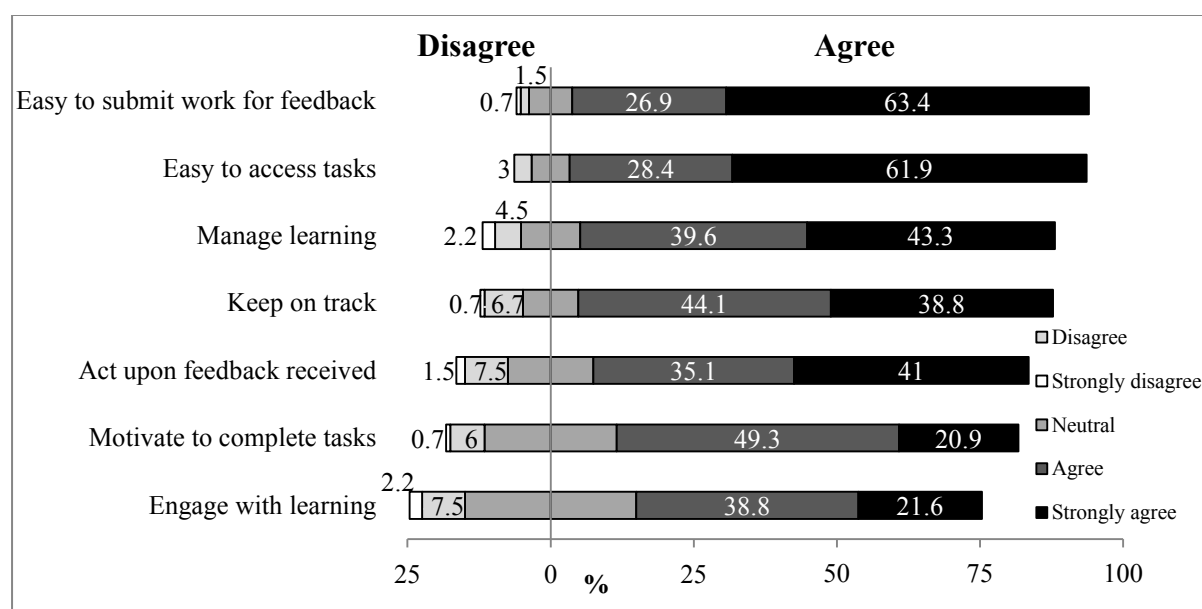
Figure 7.8 Participant responses to each of the items about Doubtfire++ helped students for performance monitoring

(iii)   Self-reflection

Reflection is one of the purposes of portfolio and e-portfolio development (Bolliger & Shepherd, 2010). According to Hinett (2002), reflection is a way of helping learners to think about learning, including what, how, and why they learn. In this way, learners develop the capacity to make judgments and self-evaluate where learning might take them. Doubtfire++ has been enhanced with OLM visualisations to facilitate reflection upon their learning through multiple visualisations and analytics in supporting Task-Oriented Portfolio approach.

Six items were used to examine user perceptions on how OLM visualisations in Doubtfire++ can facilitate their reflection in the Task-Oriented Portfolio teaching and learning environment. The reflection aspects enable students to self-evaluate and make self-judgement on their progress and achievement. In this teaching approach, they were provided with more control to determine if any action can be taken to improve their learning in preparation of summative assessment and for future planning. Data was collected from the teaching staff and students. The items included: "Doubtfire++ helped me/students…"

(1)   gain self-satisfaction to construct knowledge.

(2)   make self-judgement to retain learning artefacts.

(3)   self-evaluate to showcase achievements in portfolios.

(4)   self-evaluate own progress.

(5)   self-evaluate to prepare for final assessment.

(6)   make self-judgement to attain greater achievement.

80.6% of the participants felt that Doubtfire++ helped students self-evaluate to showcase achievements in portfolios (μ=4.10, SD=0.88) and 71.6% said that it helped students to prepare for final assessment (μ=3.85, SD=0.99). In addition, 67.1% agreed that Doubtfire++ helped them to make self-judgement in attaining greater achievement (μ=3.82, SD=0.98), 66.4% agreed it assisted them to retain their learning artefacts (μ=3.74, SD=0.95) and 53.8% agreed it motivated them to construct their knowledge (μ=3.56, SD=1.00). However, fewer than half of the participants (47.8%) felt that Doubtfire++ helped them to self-evaluate their own progress against others (μ=3.33, SD=1.23). While this item also recorded the highest percentage of disagreement (24.6%), followed by 13.4% who disagreed that "Doubtfire++ helped students to gain self-satisfaction in constructing knowledge". 10.4% held negative opinions on "Doubtfire++ helped me/students make self-judgement to retain learning artefacts.". Only a small percentage of the participants (less than 10%) strongly disagreed or disagreed with the rest of the items. The highest percentage of disagreement for "Doubtfire++

helped me self-evaluate own progress against others" could be due to the fact that some students only cared for their own achievement and thus did not really value the comparison feature (Law, Grundy, Cain, & Vasa, 2016). Figure 7.9 illustrates the proportion of participant responses to each of the items for self-reflection.
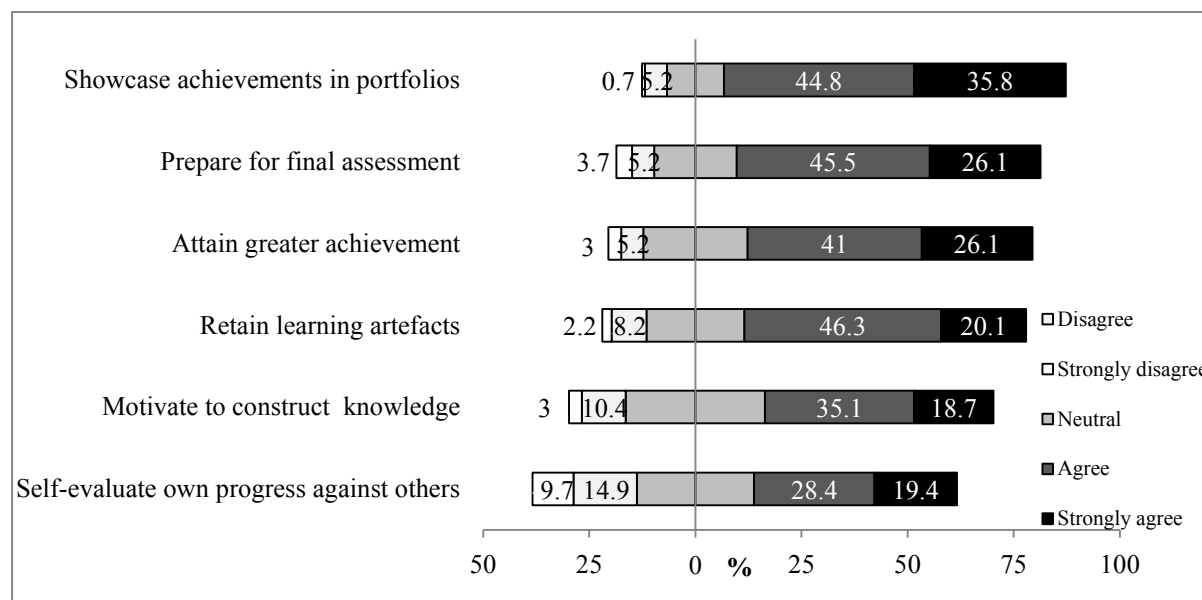
Figure 7.9 Participant responses to each of the items about Doubtfire++ helped students for self-reflection

Overall, the participants were quite receptive that Doubtfire++ encouraged student self-regulated behaviour. One of the staff participants reflected the use of Doubtfire++ as follows:

> *It was very useful for formative assessment supporting Task-Oriented Portfolio approach. Doubtfire++ has made the formative assessment easy with various visualisations to support task submission, feedback, and tracking. Embracing formative assessment, students enjoyed more flexibility to improve and resubmit their work. At the same time, the teaching staff could see the learning data by students, by tasks and by tutorials for their unit through different visual analytics. It facilitated the 2-way communication between the teaching staff and students. This is especially helpful for students to monitor their performance and for the teaching staff to support students in this aspect. It is a good tool to support portfolio-based assessment.*

7.4.2.2 RQ2 (b): Results for Supporting The Teaching Staff to Facilitate Student Learning

Eight items were used to investigate the teaching staff perceptions of the use of OLM visualisations in supporting them to facilitate student learning in a Task-Oriented Portfolio teaching and learning. Cronbach's alpha coefficient for the scale was 0.723 indicating a valid measure of the underlying construct (Nunnally & Bernstein, 1994).

In general, the use of OLM visualisation in Doubtfire++ positively impacted most staff participant perceptions of supporting Task-Oriented Portfolio teaching and learning. None of the participants strongly disagreed with any of the items. The mean scores for all items were above 3.00, ranging from 3.60 to 4.60. All participants strongly agreed or agreed that Doubtfire++ helped them to monitor student progress (μ=4.60, SD=0.51) and eased the process of assessing student portfolio in the final assessment (μ=4.27, SD=0.46). As high as 93.3% stated that it was easy to see task awaiting feedback (μ=4.20, SD=0.78), and it helped them guide discussion with students (μ=4.53, SD=0.64).

The majority of them (86.7%) expressed that it was easy to provide feedback to students through Doubtfire++ (μ=4.20, SD=0.86) with only a small number (6.7%) who disagreed. 80% found that the grade aspiration visualisation in Doubtfire++ helped them understand student needs (μ=4.00, SD=1.00) with 13.3% who disagreed. Quite a number of them (66.7%) indicated that it helped them to reflect on their teaching (μ=3.73, SD=0.59). 60% strongly agreed or agreed that understanding grade aspirations helped them guide student learning (μ=3.60, SD=0.91). Figure 7.10 illustrates staff participant responses to each of the items.
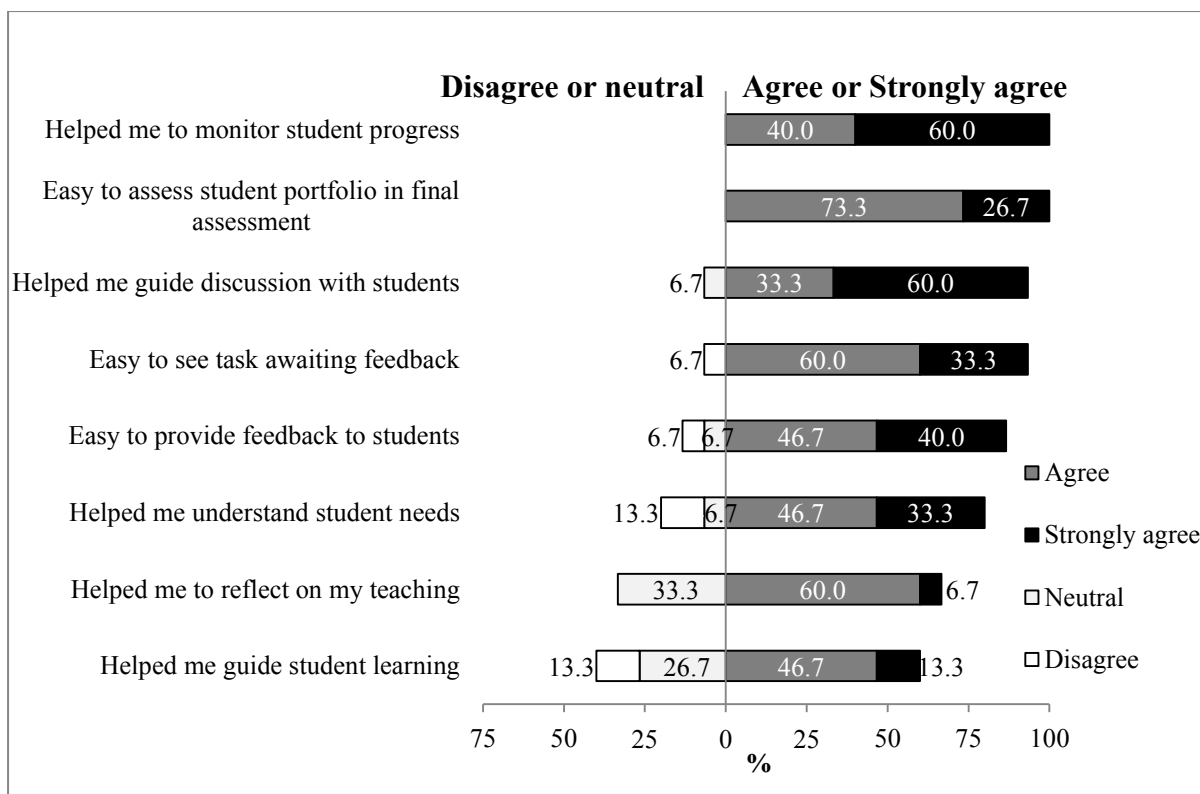
Figure 7.10 Staff responses to each of the items about the use of Doubtfire++ for supporting them in a Task-Oriented Portfolio teaching

The quantitative results are supported by the comments provided by three teaching staff as the follows:

A tutor said:

> *I like Doubtfire++ as I could easily access student tasks and gave them feedback. It worked quite efficiently in providing continuous support for the feedback process between the staff and students. The visualisations helped me effectively track if students had improved on those small parts of task incrementally. It was a great tool in keeping track of student progress.*

A convenor pointed out:

> *The visualisations showed where students were up to, what they were working on, and what they needed to fix quite quickly. We can have comments so the students know where they were up to and acted upon. The comment history helped us keep track of student work very well.*

Another convenor further added:

> *The visualisations in Doubtfire++ helped the teaching staff in accessing and organising their marking load for portfolio-based assessment very effectively. Using the system,*

tracking and marking process could be easily and quickly be done for large cohorts of students.

7.4.2.3 RQ2 (c): Results for Supporting Convenor in Managing The Unit

Four items were used to investigate convenor views about the use of OLM visualisations in supporting their roles in the Task-Oriented Portfolio teaching and learning. Out of a total of 134 valid samples, only four were convenors. As the sample size was small, frequency was used to present the results. Table 7.2 shows the number of convenors and their responses as well as the mean score (μ) and the standard deviation (SD).

Table 7.2 Results of using OLM visualisations in supporting a convenor's role

Items	Strongly agree			Strongly disagree			μ	SD
	(5)	**(4)**	**(3)**	**(2)**	**(1)**	**Did not use**		
Linking tasks to outcomes helped me reflect on how the tasks aimed to develop student learning.	1	1	1	0	0	1	4.00	1.00
Easy to setup the unit (its tasks, outcomes, etc)	0	3	1	0	0	0	3.75	0.50
Analytic data helped me track progress of the student cohort.	0	3	1	0	0	0	3.75	0.50
Analytic data helped me guide others teaching in the unit.	0	1	2	1	0	0	3.00	0.82

The mean score for all the four items ranged from 3.00 to 4.00. This indicates that the convenors were quite receptive that OLM visualisations in Doubtfire++ supported their role as a convenor. Three convenors felt that OLM visualisations in Doubtfire++ had made it easy for them to set up the units and the analytic data helped them to track progress of student cohort respectively. One convenor held a neutral view for these two items. A convenor reported not using the visualisation for linking tasks to outcomes. Two convenors agreed that linking tasks to outcomes helped them reflect on how the tasks aimed to develop student learning and one convenor expressed a neutral view. While one convenor agreed that the analytic data helped to guide others teaching in the unit, a convenor disagreed with this item. Two other convenors neither agreed nor disagreed with it.

The qualitative results provide some insights to the quantitative results. A convenor said:

Doubtfire++ helped me to manage my unit that has portfolio-based assessment. It kept records for each formative feedback and communication between the teaching staff and students. The visual analytics that provided information about all tutorials and entire unit enabled me to track different cohorts of students and tutors as well. You can see different patterns. You gained better understanding of student cohorts. You can also find out if the tutor was keeping up with the 'Ready to mark' tasks and their feedback.

Another convenor stated:

Initially I was new to portfolio assessment. After a semester engaging with Doubtfire++ to support portfolio-based assessment, I felt the need to revise and re-develop the assessment tasks, including linking between tasks and learning outcomes. I felt that the linking is important to guide students to demonstrate their achievements in their portfolio submission. Also, it helped me to check if I have completely covered the intended learning outcomes.

Other comments include:

We have changed to certain tasks this semester because of how things went last semester which was certainly captured in Doubtfire++. So I would say Doubtfire++ was part of the information that we used to gauge the effectiveness and gained the rationale if we needed to change the tasks.

However, a convenor cautioned:

It is important to note that when tasks are firmly linked to the intended learning outcomes, it has to also be flexible to accommodate the inclusion of any possible learning outcomes so that the task is not just within that bound.

7.4.3   Research Question 3 (RQ3)

RQ3: Do different user demographics impact user perceptions of using Doubtfire++ to support student Self-regulated Phases?

RQ3 aims to investigate the difference in means between user demographics (user role, gender, familiarity with InfoVis) and all self-regulation measurement scales (goal setting, performance monitoring and self-reflection). A series of independent samples t-tests (see Section 3.5.2.3 (c)) were conducted to measure differences in means for user roles and gender. A one-way ANOVA analysis (Section 3.5.2.3 (d)) was used to determine the

differences between participant familiarity with information visualisation techniques. The following sub-sections present the analysis of the results based on user roles, gender and user familiarity with InfoVis.

7.4.3.1 RQ3(a): User Role

Table 7.3 and Table 7.4 present the statistics and t-test result by user roles (teaching staff and students) for all the measurement scales respectively.

Table 7.3 Statistics by user roles for all self-regulated measurement scales

Scale	User roles	N	Mean	SD	Std. Error Mean
Goal setting	Teaching staff	15	2.90	0.74	0.19
	Students	119	3.53	0.91	0.08
Performance monitoring	Teaching staff	15	3.97	0.44	0.11
	Students	119	4.15	0.65	0.59
Self-reflection	Teaching staff	15	3.47	0.57	0.15
	Students	119	3.77	0.76	0.07

Table 7.4 T-test results by user roles for all self-regulated measurement scales

		Levene's Test for Equality of Variances		t-test for Equality of Means						Effect size (η^2)
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	95% Confidence Interval of the Difference		
								Lower	Upper	
Goal setting	Equal variances assumed	1.540	0.217	-2.567	132	0.011*	-0.63	-1.11	-0.14	0.048
	Equal variances not assumed			-3.029	19.84	0.007	-0.63	-1.06	-0.20	0.065
Performance monitoring	Equal variances assumed	1.580	0.211	-1.039	132	0.301	-0.18	-0.52	0.16	0.008
	Equal variances not assumed			-1.404	22.63	0.174	-0.18	-0.44	0.08	0.015
Self-reflection	Equal variances assumed	1.851	0.176	-1.469	132	0.144	-0.30	-0.70	0.10	0.016
	Equal variances not assumed			-1.844	20.96	0.079	-0.30	-0.64	0.04	0.025

* The mean difference is significant at the 0.05 level.

No significant difference was found between teaching staff and students for performance monitoring and self-reflection. The only significant difference in scores was found for goal setting. The significant difference in scores was found between teaching staff (M=2.90, SD=0.74) and students (M=3.53, SD=0.91; t(132)= –2.57, p=0.01, two-tailed). The magnitude of the differences in the means (mean difference=0.63, 95% CI: –1.11 to –0.14) was small (η^2=0.048). Although teaching staff marginally disagreed that Doubtfire++ helped students in setting their learning goal, students generally agreed that it did. Students reflected in the open-ended question how they had been using the goal setting visualisation in Doubtfire++ to assist them in managing their learning (Refer teaching staff and student comments in Section 7.4.1.1 (a.i).

7.4.3.2 RQ3(b): Gender

Tables 7.5 and 7.6 present the statistics and t-test results by gender for all the measurement scales respectively. An appropriate set of results was used based on Levene's test for equality of variances to ensure homogeneity of variance for this test.

Table 7.5 Statistics by gender for all self-regulated measurement scales

Scale	User roles	N	Mean	SD	Std. Error Mean
Goal setting	Male	110	3.44	0.91	0.09
	Female	20	3.60	0.94	0.21
Performance monitoring	Male	110	4.11	0.63	0.06
	Female	20	4.33	0.60	0.13
Self-reflection	Male	110	3.74	0.77	0.07
	Female	20	3.80	0.63	0.14

Table 7.6 T-test results by gender for all self-regulated measurement scales

		Levene's Test for Equality of Variances		t-test for Equality of Means				95% Confidence Interval of the Difference		Effect size (η^2)
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Lower	Upper	
Goal setting	Equal variances assumed	0.217	0.642	-0.737	128	0.463	-0.16	-0.60	0.28	0.004
	Equal variances not assumed			-0.720	25.87	0.478	-0.16	-0.63	0.30	0.004
Performance monitoring	Equal variances assumed	0.302	0.583	-1.467	128	0.145	-0.22	-0.52	0.08	0.017
	Equal variances not assumed			-1.517	27.19	0.141	-0.22	-0.53	0.08	0.018
Self-reflection	Equal variances assumed	0.186	0.667	-0.347	128	0.729	-0.06	-0.43	0.30	0.001
	Equal variances not assumed			-0.399	30.35	0.692	-0.06	-0.39	0.26	0.001

Although generally females rated each scale higher than males, there was no significant difference between male and female. Gender had no effect on all the measurement scales. The mean scores for all scales for both males and females were more than 3.00, ranging from 3.44 to 4.33. This indicates that both males and females were quite receptive that Doubtfire++ helped students in goal setting, performance monitoring and self-reflection.

7.4.3.3 RQ3(c): Familiarity with Information Visualisation

A one-way ANOVA test was used to compare measurement scales (goal setting, performance monitoring and self-reflection) for four groups of users (independent variable) with different levels of experience in Information Visualisation (InfoVis) (Group 1: Not familiar with information visualisation at all; Group 2: have heard about it; Group 3: somewhat familiar; Group 4: very familiar). Table 7.7 and Table 7.8 present the descriptive statistics and the significant level of F test ANOVA results respectively.

Table 7.7 Descriptive statistics by familiarity with InfoVis for all self-regulated measurement scales

Scale	Group	N	Mean	SD	Std. Error	95% Confidence Interval for Mean	
						Lower	Upper
Goal setting	1	8	3.44	0.94	0.33	2.65	4.23
	2	32	3.55	0.79	0.14	3.26	3.83
	3	73	3.42	0.92	0.11	3.21	3.64
	4	21	3.45	1.09	0.24	2.95	3.95
Performance monitoring	1	8	4.16	0.43	0.15	3.80	4.52
	2	32	4.13	0.55	0.10	3.93	4.33
	3	73	4.16	0.66	0.08	4.01	4.31
	4	21	4.01	0.72	0.16	3.69	4.34
Self-reflection	1	8	3.60	0.68	0.24	3.03	4.18
	2	32	3.84	0.64	0.11	3.61	4.07
	3	73	3.68	0.81	0.09	3.50	3.87
	4	21	3.78	0.72	0.16	3.45	4.11

Table 7.8 ANOVA results for familiarity with InfoVis for all self-regulated measurement scales

		Sum of Squares	df	Mean Square	F	Sig.	Effect size (η^2)
Goal Setting	Between Groups	0.338	3	0.113	0.132	0.941	0.003
	Within Groups	110.686	130	0.851			
	Total	111.024	133				
Performance Monitoring	Between Groups	0.360	3	0.120	0.299	0.826	0.007
	Within Groups	52.067	130	0.401			
	Total	52.427	133				
Self-reflection	Between Groups	0.736	3	0.245	0.434	0.729	0.010
	Within Groups	73.543	130	0.566			
	Total	74.279	133				

The significant level of F test ANOVA results indicates that there is no significant difference among the mean scores on the dependent variable (Goal setting, Performance monitoring, and Self-reflection) for the four groups of users. This implies that experience in information visualisation had no effect on all the measurement scales.

7.4.4 Research Question 4 (RQ4)

RQ4: Do any prior experiences in using Doubtfire++, frequency of use, and different teaching units impact users' perceptions of using Doubtfire++ to support student Self-regulated Phases?

RQ4 aims to investigate the difference in means between prior experience of using Doubtfire++, frequency of use, and different teaching units and all the self-regulation measurement scales (goal setting, performance monitoring and self-regulation). A series of independent samples t-tests and a one-way ANOVA analysis were used to determine the mean differences. To ensure homogeneity of variance in t-tests, appropriate set of results was used based on Levene's test for equality of variances. The following subsections present the analysis of the results.

7.4.4.1 RQ4(a): Experience of Using Doubtfire++

Table 7.9 and Table 7.10 present the statistics and t-test result by user experience of using Doubtfire++ for all the measurement scales.

Table 7.9 Statistics by user experience in using Doubtfire++ for all self-regulated measurement scales

	Experience using Doubtfire++	**N**	**Mean**	**SD**	**Std. Error Mean**
Goal Setting	Experienced user New user	61 73	3.29 3.60	0.99 0.82	0.13 0.10
Performance Monitoring	Experienced user New user	61 73	3.98 4.25	0.68 0.56	0.09 0.07
Self-reflection	Experienced user New user	61 73	3.62 3.83	0.86 0.63	0.11 0.07

Table 7.10 T-test results by user experience of using Doubtfire++ for all self-regulated measurement scales

		Levene's Test for Equality of Variances		T-test for Equality of Means						Effect Size (η^2)
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	95% Confidence Interval of the Difference		
								Lower	Upper	
Goal Setting	Equal variances assumed	2.290	0.133	-2.016	132	0.046*	-0.32	-0.63	-0.01	0.030
	Equal variances not assumed			-1.982	116.38	0.050	-0.32	-0.63	0.00	0.029
Performance Monitoring	Equal variances assumed	2.029	0.157	-2.560	132	0.012*	-0.27	-0.48	-0.06	0.047
	Equal variances not assumed			-2.516	116.20	0.013	-0.27	-0.49	-0.06	0.046
Self-reflection	Equal variances assumed	4.459	0.037	-1.600	132	0.112	-0.21	0.46	0.05	0.019
	Equal variances not assumed			-1.557	107.43	0.122	-0.21	-0.47	0.06	0.018

* The mean difference is significant at the 0.05 level.

A significant difference in scores was found for goal setting between experienced Doubtfire++ users (*M*=3.29, *SD*=0.99) and new Doubtfire++ users (*M*=3.60, *SD*=0.82; *t*(132)=2.02, *p*=0.046, two-tailed). The magnitude of the differences in the means (mean difference=0.32, 95% *CI*: –0.63 to –0.01) was small (η^2=0.030). A significant difference in scores was also found for performance monitoring between experienced Doubtfire++ users (*M*=3.98, *SD*=0.68) and new Doubtfire++ users (*M*=4.25, *SD*=0.56; *t*(132)=2.56, *p*=0.01, two-tailed). The magnitude of the differences in the means (mean difference=0.27, 95% *CI*: –0.48 to –0.06) was small (η^2=0.047). Interestingly, new users perceived Doubtfire++ was significantly more helpful to support students in goal setting and performance monitoring than the experienced users.

7.4.4.2 RQ4(b): Frequency of Using Doubtfire++

Table 7.11 and Table 7.12 present the statistics and t-test result by user usage frequency for all the measurement scales.

Table 7.11 Statistics by usage frequency for all self-regulated measurement scales

Scale	Usage Frequency	N	Mean	SD	Std. Error Mean
Goal setting	Frequent user	113	3.48	0.87	0.08
	Non-frequent user	21	3.36	1.13	0.25
Performance monitoring	Frequent user	113	4.20	0.57	0.05
	Non-frequent user	21	3.73	0.79	0.17
Self-reflection	Frequent user	113	3.78	0.69	0.06
	Non-frequent user	21	3.45	0.97	0.21

Table 7.12 T-test results by usage frequency for all self-regulated measurement scales

		Levene's Test for Equality of Variances		t-test for Equality of Means						Effect size (η^2)
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	95% Confidence Interval of the Difference		
								Lower	Upper	
Goal setting	Equal variances assumed	3.191	0.076	0.555	132	0.580	0.12	-0.31	0.55	0.002
	Equal variances not assumed			0.464	24.61	0.647	0.12	-0.42	0.66	0.002
Performance monitoring	Equal variances assumed	2.502	0.116	3.254	132	0.001*	0.47	0.18	0.75	0.074
	Equal variances not assumed			2.585	23.92	0.016	0.47	0.09	0.84	0.048
Self-reflection	Equal variances assumed	1.493	0.224	1.889	132	0.061	0.33	-0.02	0.68	0.026
	Equal variances not assumed			1.494	23.86	0.148	0.33	-0.13	0.79	0.017

* The mean difference is significant at the 0.05 level.

There was a significant difference in scores for performance monitoring between frequent users (*M*=4.20, *SD*=0.57) and users who rarely used Doubtfire++ (*M*=3.73, *SD*=0.79; *t*(132)=3.25, *p*=0.00, two-tailed). The magnitude of the differences in the means (mean difference=0.47, 95% *CI*: 0.18 to 0.75) was medium (η^2=0.074). The mean values indicated that frequent users perceived Doubtfire++ was significantly more helpful for them to monitor their performance than users who rarely used it.

7.4.4.3 RQ4(c): Different Teaching Units

A one-way between-groups analysis of variance (ANOVA) was performed to explore the impact of different teaching units on each of the measurement scales (goal setting, performance monitoring and self-reflection). Participants were divided into 3 groups according to their deployment of Doubtfire++ in different teaching units (Group 1: Used in Programming units only; Group 2: Used in Software Engineering (SE) units only; Group 3: Used in Programming (Prog.) units and at least 1 other unit). The division in comparison of the teaching units was based on types of portfolio-based assessment. All programming units used Doubtfire++ to support fully portfolio-based assessment whereas it was used to support partially portfolio-based assessment in other teaching units. Also, as programming units are mostly core units for the courses in this faculty, students could have enrolled in both fully and partially portfolio-based units. Tables 7.13 and 7.14 show the descriptive statistics and the significant level of F test ANOVA results respectively.

Table 7.13 Descriptive statistics by different teaching units for all self-regulated measurement scales

Scale	Teaching units	N	Mean	SD	Std. Error	95% Confidence Interval for Mean	
						Lower	Upper
Goal setting	Prog. only	85	3.53	0.92	0.10	3.33	3.73
	SE only	19	3.21	0.84	0.19	2.80	3.61
	Mixture	28	3.38	0.95	0.18	3.01	3.74
Performance monitoring	Prog. only	85	4.23	0.56	0.06	4.11	4.35
	SE only	19	3.83	0.69	0.16	3.50	4.17
	Mixture	28	4.03	0.74	0.14	3.74	4.32
Self-reflection	Prog. only	85	3.84	0.70	0.08	3.68	3.99
	SE only	19	3.42	0.84	0.19	3.02	3.82
	Mixture	28	3.68	0.79	0.15	3.37	3.98

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Table 7.14 F test ANOVA results by different teaching units for all self-regulated
measurement scales

		Sum of Squares	df	Mean Square	F	Sig.	Effect size (η^2)
Goal Setting	Between Groups	1.783	2	0.892	1.063	0.348	0.016
	Within Groups	108.147	129	0.838			
	Total	109.930	131				
Performance Monitoring	Between Groups	2.732	2	1.366	3.548	0.032*	0.052
	Within Groups	49.670	129	0.385			
	Total	52.402	131				
Self-reflection	Between Groups	2.810	2	1.405	2.567	0.081	0.038
	Within Groups	70.600	129	0.547			
	Total	73.409	131				

* Significant difference at 0.05 level

The Sig. value of 0.032 is less than 0.05. This indicates that there was a statistically significant difference at the $p<0.05$ level in the mean score for the performance monitoring measurement scale for the three groups: $F(2, 129)=3.55$, $p=0.032$. Despite the statistical significance, the effect size that showed the difference in mean scores between the groups was small ($\eta^2=0.05$). Post-hoc tests were conducted to find out the groups that differ. The results are presented in Table 7.15.

Table 7.15 Post-hoc Tukey HSD test results by different teaching units for all self-regulated measurement scales

Tukey HSD			Multiple Comparisons				
Dependent Variable	Group					95% Confidence Interval	
			Mean Difference	Std. Error	Sig.	Lower Bound	Upper Bound
Performance monitoring	1	2	.39230*	.15746	.037*	.0189	.7657
		3	.19628	.13521	.318	-.1243	.5169
	2	1	-.39230*	.15746	.037*	-.7657	-.0189
		3	-.19603	.18444	.539	-.6333	.2413
	3	1	-.19628	.13521	.318	-.5169	.1243
		2	.19603	.18444	.539	-.2413	.6333

* The mean difference is significant at the 0.05 level.

Post-hoc comparisons using the Tukey HSD test indicated that the mean score for Group 1 (*M*=4.23, *SD*=0.56) was significantly different from Group 2 (*M*=3.83, *SD*=0.69). Group 3 (*M*=4.03, *SD*=0.74) did not show any significant difference from either Group 1 or 2. This means users who used Doubtfire++ in programming units only and in software engineering units only differ significantly in terms of their perceived usefulness score for performance monitoring.

The interview results as follows explain some of the reasons.

A student who had 2 units that used Doubtfire++ in that semester provided feedback that there was a difference in the way Doubtfire++ was deployed in these two units. He said:

> *Their engagement was not as good as the other people in the programming unit who I thought they used the system properly. This is because tasks were split into every tiny little sub-task like 5 tasks per week. This caused the Task List looked really 'cumbersome' with many tasks and colours. Also, they didn't make use of the commenting function.*

Another student participant agreed and stated:

> *It depends on how the teaching staff engaged with the system. This includes how they outlined each task, mapped the tasks, and properly planned for details of what specific tasks will help student learning or achieve the learning outcomes.*

Another student added:

Unit has to be well-structured in order to guide students from the fundamental towards excelling in the units. For example, the pass tasks to explore the fundamental of the unit, credit tasks for students to go further from the fundamental, distinction and high distinction for more creative and innovative work that are more time consuming and need more effort.

7.4.5 Research Question 5 (RQ5)

RQ5: Does the use of Doubtfire++ have any impact on student final grades?

RQ5 examines the impact of using Doubtfire++ on student performance grade. The unit grade distributions for all the 12 units that deployed Doubtfire++ in Semester 1, 2016 and the prior year results were retrieved to examine the impact. Due to staff movement, some prior year (2015) data was not available. Also, a unit had only three students and was excluded from data analysis. This yields six valid samples with complete set of grade distributions for both years. The analysis of the unit grade distributions (in percentage) aims to compare the units as a whole with the results of the prior year. The average number of students (in percentage) for each grade for all the six units was calculated for both academic years, 2015 and 2016. A line graph was plotted to visualise the change of grade distribution between the academic year 2015 and 2016 as in Figure 7.11.
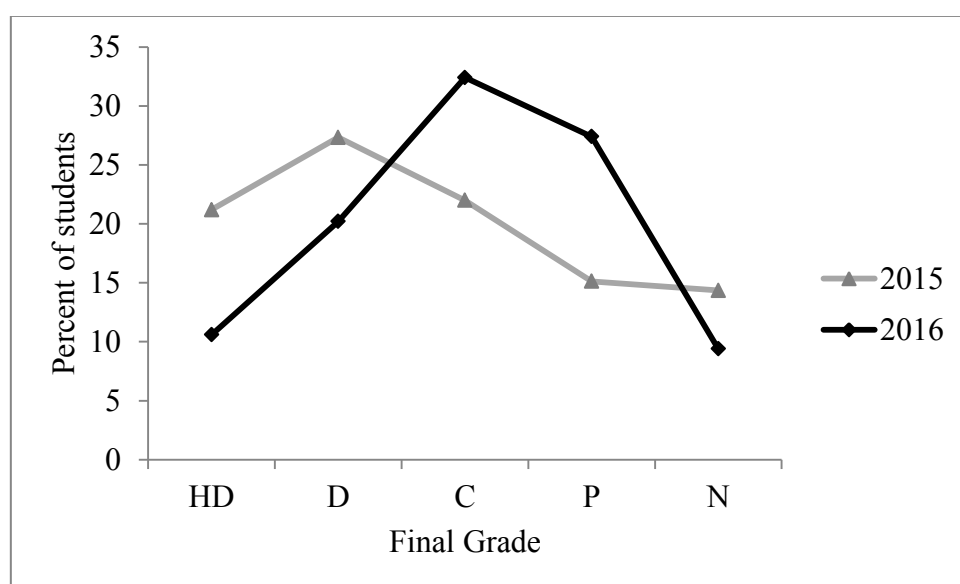

Figure 7.11 The change of grade distribution between the academic year 2015 and 2016

It is interesting to see a higher percent of HD and D in 2015 in comparison to 2016 and more C and P with lower failure rate in 2016 than 2015. The use of Doubtfire could have impacted the students' final grades.

A series of independent samples t-tests were conducted to measure the differences in means between the academic year 2015 and 2016 with the grade distribution (High distinction (HD), Distinction (D), Credit (C), Pass (P) and fail (N)).

Tables 7.16 and 7.17 present the statistics and t-test results by the academic year 2015 and 2016 for different grade distributions.

Table 7.16 Statistics by academic year 2015 and 2016 for different grade distributions

Grade Distribution	Year	N	Mean	SD	Std. Error Mean
% HD	2015	6	21.19	15.41	6.29
	2016	6	10.59	4.98	2.03
% D	2015	6	27.34	8.08	3.30
	2016	6	20.20	10.41	4.25
% C	2015	6	22.00	12.44	5.08
	2016	6	32.42	5.27	2.15
% P	2015	6	15.13	12.57	5.13
	2016	6	27.40	12.10	4.94
% N	2015	6	14.35	5.18	2.11
	2016	6	9.41	5.15	2.10

Table 7.17 T-test results by academic year 2015 and 2016 for different grade distributions in percentage

		Levene's Test for Equality of Variances		t-test for Equality of Means							Effect size (η^2)
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	95% Confidence Interval of the Difference			
								Lower	Upper		
%HD	Equal variances assumed	2.128	0.175	1.605	10	0.140	10.608	-4.121	25.338		0.205
	Equal variance not assumed			1.605	6.033	0.159	10.608	-5.547	26.763		
%D	Equal variances assumed	0.558	0.472	1.327	10	0.214	7.140	-4.850	19.130		0.150
	Equal variance not assumed			1.327	9.421	0.216	7.140	-4.951	19.231		
%C	Equal variances assumed	2.245	0.165	-1.890	10	0.088	-10.425	-22.713	1.863		0.263
	Equal variance not assumed			-1.890	6.741	0.102	-10.425	-23.568	2.718		
%P	Equal variances assumed	0.014	0.909	-1.723	10	0.116	-12.270	-28.137	3.597		0.229
	Equal variance not assumed			-1.723	9.986	0.116	-12.270	-28.141	3.601		
%N	Equal variances assumed	0.000	0.993	1.658	10	0.128	4.943	-1.699	11.586		0.216
	Equal variance not assumed			1.658	10.000	0.128	4.943	-1.699	11.586		

The results from independent-samples t-test show that there was no significant difference in the mean scores in percent of grade distribution (dependent variable) for all the grades between the academic year 2015 and 2016. The magnitudes of the differences in the means for all grade distributions were large with η^2 values ranging from 0.150 to 0.263. This implies that the use of Doubtfire++ had no effect on all the grade distribution in 2016 as compared to the previous year, 2015. The enhanced features in Doubtfire++ appeared to have no effect on students' performance grade.

However, it is important to note that this is just a crude measure because there are numerous factors and variables that can affect students' final grades such as teaching resources, teaching staff, student background, programming language used in a particular semester, learning activities, mode of assessment, assessment criteria, and many more. This is an interesting aspect to investigate. Future research can be conducted with a careful control of other variables as mentioned above especially the assessment mode and criteria, and the programming mode being used. In this way, the impact of Doubtfire++ on student final grades can be justified in a better way.

7.4.6 Research Question 6 (RQ6)
RQ6: What is user overall experience in interacting with Doubtfire++?

User overall experience interacting with Doubtfire++ is one of an important measure for investigating its use in supporting the Task-Oriented Portfolio teaching approach. It reflects users' entire range of experience including their attitudes and satisfaction in using it, problem encountered and suggestions for improvement. The following subsections present the results.

7.4.6.1 User Attitudes and Satisfaction to Using Doubtfire++
Four items were used to examine user attitudes and satisfaction in using Doubtfire++. Cronbach's alpha coefficient was calculated to determine the internal consistency of the scale. The Cronbach's alpha value of 0.945 indicates that each item is a valid measure of the underlying construct. The reliability of the scale was acceptable.

An independent samples t-test was conducted to compare the mean satisfaction scores for teaching staff and students. Table 7.18 and Table 7.19 present the statistics and t-test result for mean satisfaction scores by user roles.

Table 7.18 Statistics by user roles for mean satisfaction scores

User role	N	Mean	SD	Std. Error Mean
Teaching staff	15	4.317	0.658	0.170
Student	119	4.273	0.789	0.072

Table 7.19 T-test results by user roles for mean satisfaction scores

	Levene's Test for Equality of Variances		t-test for Equality of Means						Effect size (η^2)
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Diff.**	**95% Confidence Interval of the Difference**		
							Lower	**Upper**	
Equal variances assumed	0.171	0.680	0.206	132	0.837	0.0438	-0.377	0.465	0.0003
Equal variances not assumed			0.237	19.466	0.815	0.0438	-0.342	0.430	0.0004

There was no significant difference in scores for teaching staff (M=4.32, SD=0.66) and students (M=4.27, SD=0.79; t(132)=0.21, p=0.84, two-tailed). The magnitude of the differences in the means (mean difference=0.04, 95% CI: -0.38 to 0.46) was very small (η^2=0.0003). Figure 7.12 illustrates the proportion of users and their responses to each of the items related to their attitude and satisfaction in using Doubtfire++.
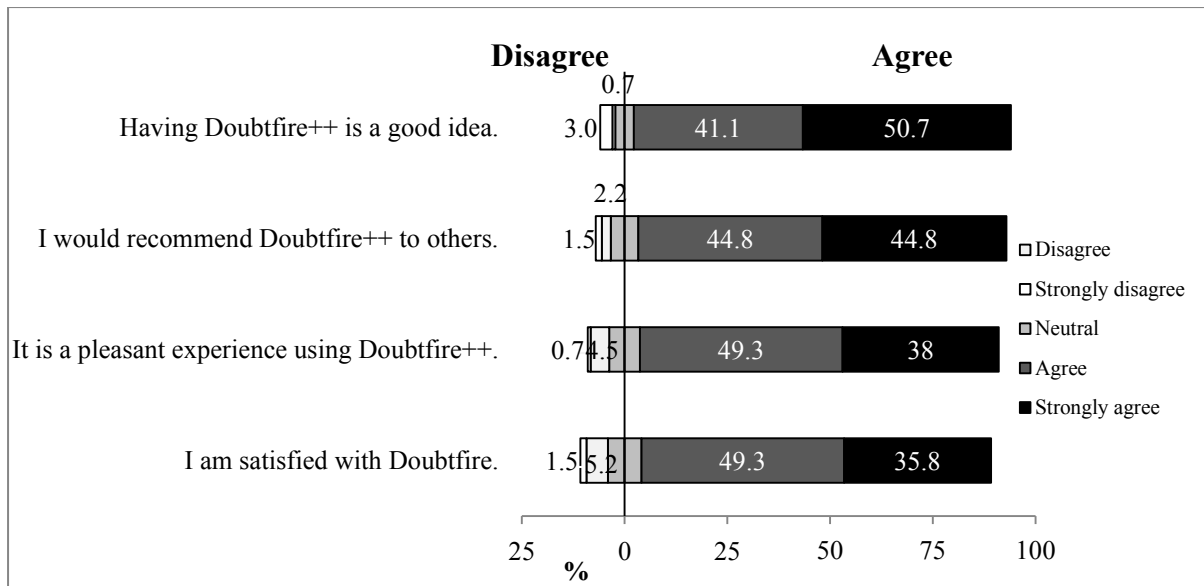
Figure 7.12 Participant responses to each of the items about their attitude and satisfaction in using Doubtfire++

The results show that the majority of the users (more than 85%) had a very positive experience using Doubtfire++ in a Task-Oriented Portfolio teaching. This result is supported by the qualitative findings. The narrative descriptions provide insightful explanation about user attitude and satisfaction.

A convenor stated that:

> It was so cool and very useful. I like it very much. It was well-designed. I will keep using it.

A tutor said:

> It made the work so much easier for the tutor. I would prefer doing task submission and feedback through Doubtfire++ instead of doing it manually. Doubtfire++ has made the marking and feedback process very easy and straight forward. Overall this is a really good learning management system for the teaching staff and students.

Students in general had a very pleasant experience using Doubtfire++. One of them said:

> Doubtfire++ is one of the best tools I used at university so far. This is because it does one thing and does really well. It shows uploaded submission and feedback received for students to improve and keep track of their work. I will recommend it to others.

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Another student commended:

It was very visual. I like how it simplified the task statuses. It kept everything contain in one area along with tutor's comments. You knew where you were at the unit for every stage. If you were far behind, you knew how much work you needed to do. It engaged students.

Students liked the way Doubtfire++ supported them in the Task-Oriented Portfolios teaching approach. One mentioned:

As the whole mass of tasks was broken down into smaller tasks, they were more approachable. In this way, you felt better about how well you were doing and it motivated you to do better. Students won't suffer straight away from the overwhelming task or exam that set them back from putting effort.

Two students appreciated the flexible way to manage their learning being supported by Doubtfire++. A student remarked:

With Doubtfire++, you actually engaged. It gives you a quick overview of the tasks and let you plan for your time to cope with the tasks. You actually put in effort and then you get your time in. You manage your own timing and learning. Students are responsible for their own grade and learning. That is why I like it.

Students also valued the visualisations in Doubtfire++ that provide them with essential information to guide their learning. A student indicated:

Doubtfire is a wonderful tool to keep students aware of and engage in their learning. It has got depth of information available in different graphs. At a glance you first log in, you see the Burndown Chart. Task List and Focus List are nice, the simple upfront view. If you want more information, you can dig down further to visualise progress statistics and outcome achievements.

Another student reflected:

Doubtfire++ is very clean, nice to look at, and easy to navigate. The visualisations helped me to engage in my self-pace learning. I really enjoyed working with Doubtfire++.

A student said the tool has a great potential in educational setting and recommended to commercialise this tool. Student participants in the interview sessions found it very useful in helping them track their progress and manage their learning. They wish Doubtfire++ is available for other units. One of them said:

It is a great system and definitely helped me a lot to achieve the grade I decided to get. I wish it will be used in every subject I am doing because it just made the learning experience so much easier!

43 out of 134 participants had experience using both versions, Doubtfire and Doubtfire++. They were quite receptive to the enhanced features in Doubtfire++. All items have mean scores more than 3.00, ranging from 3.47 to 3.72. 55.8% of them felt that Doubtfire++ had better support to help them align learning with learning outcomes ($\mu=3.72$, SD=1.05) and better helped them prepare for final assessment ($\mu=3.67$, SD=1.02) respectively. This is followed by 53.5% who agreed that it better helped them to reflect on learning ($\mu=3.63$, SD=0.98). 51.2% said that Doubtfire++ had better support for them to track ($\mu=3.65$, SD=1.07) and guide their learning ($\mu=3.58$, SD=0.91) respectively. More than 40% of them, i.e., 44.1%, 41.9% and 41.9% agreed it better helped them manage their learning ($\mu=3.60$, SD=0.88), better connected them to teaching staff ($\mu=3.47$, SD=0.94) and had better access to learning artefacts ($\mu=3.53$, SD=0.94) respectively. Only a small number of the participants (less than 12.0%) held a negative view of Doubtfire++ in supporting their learning. Figure 7.13 depicts their opinions.
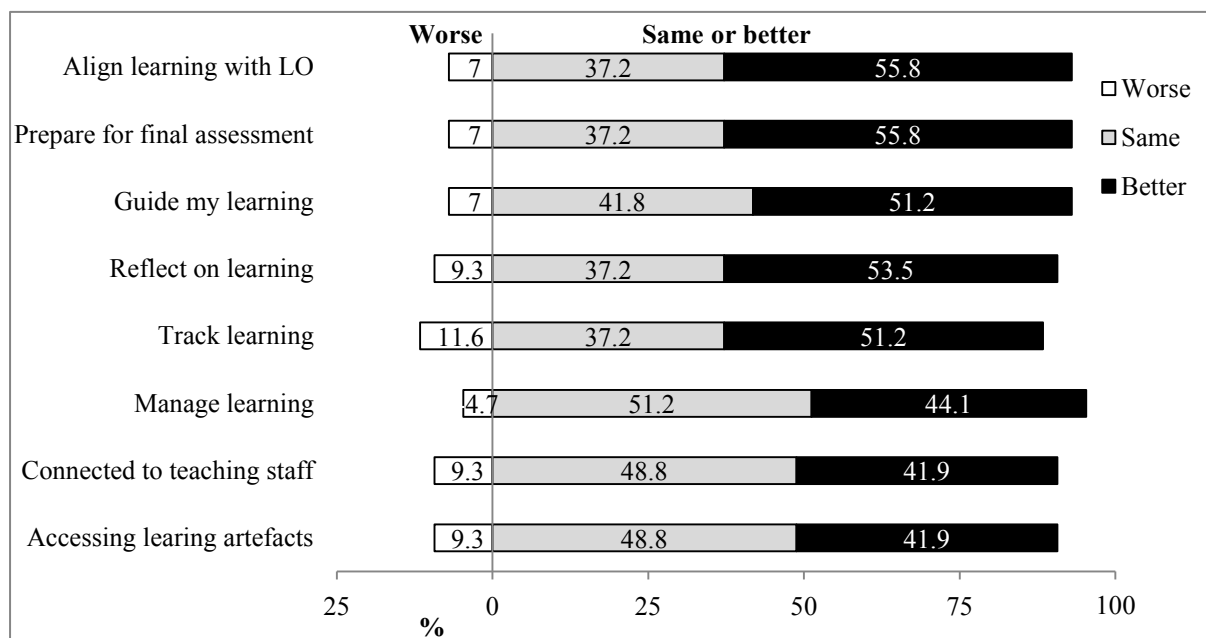

Figure 7.13 Experienced user responses to each of the items about Doubtfire++

All interview participants agreed that Doubtfire++ with enhanced features is better than the previous version of the tool. One staff participant directly stated that:

The best new feature I found was the visual analytics. They gave particular statistical information to the teaching staff to better support student learning. Besides that, the feedback process field had improved. One of the useful new features was the Focus List to guide the weak student to stay on track.

Another staff indicated:

The new feature captured the unit learning outcomes. While this feature made the teaching staff to think about how the tasks they had got link up to the outcomes they had created, it gave students the opportunities to reflect and link up the assessment tasks with their learning outcome achievements.

A student participant said:

I used it last year as well as this year. The new visualisation for seeing unit learning outcomes was nice.

7.4.6.2 Problems Encountered in Using Doubtfire++

Figure 7.14 shows the summary of problems highlighted by participants in the survey. In this open-ended question, students were free to express the problems they encountered when using Doubtfire++.
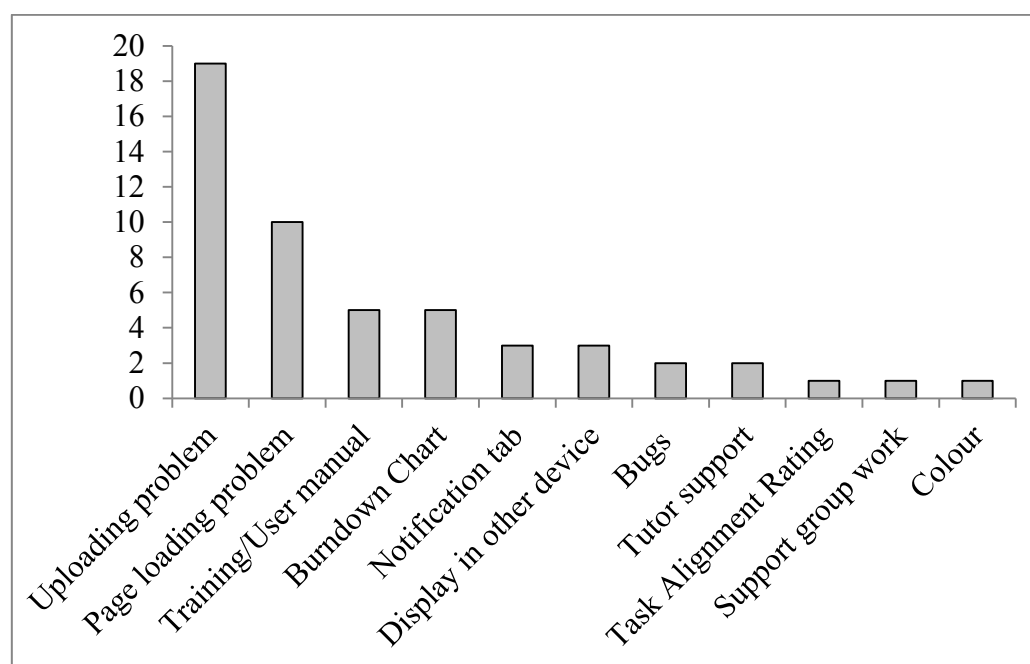

Figure 7.14 Problems encountered

Uploading files in Doubtfire++ was the main issue highlighted. This is because the current system only accepted certain file types for upload. The second problem is the page loading issue that was mainly due to slow page loading and it took some time to reflect the new task status when updating. Five participants suggested including a video or an online user manual to explain Doubtfire++ features. Similarly, interview participants who were new users or first time users convened the unit using Doubtfire++ saying that it was essential to have an introduction session to demonstrate how to use it. Burndown Chart was the visualisation that some participants were keen to know especially on how each line encoded data. Participants also proposed having notification tab for each new update, submission or feedback available. This was also mentioned by two of the interview participants. One said:

> *As students interacted with Doubtfire++ to submit or resubmit their work, there was no notification panel to notify the teaching staff about the submission.*

The other one stated:

> *Also, when a tutor had provided feedback, students were unaware of it.*

They also wanted to use Doubtfire++ in other devices such as an iPad. Two participants reported about some bug issues. They also highlighted that tutor support was important for the effective use of Doubtfire++.

One student interviewee said:

> *My tutor was pretty on the ball. Since he was quick in giving feedback, the visualisations captured my latest progress most of the time, especially the Burndown Chart. I felt engaged in my learning.*

Another student added:

> *I had never had any issues with Doubtfire++. I guess in this case I had a good tutor to constantly give feedback throughout the process and I think that helped a lot.*

Other problems include problem using Task Alignment Rating, no support for group work submission and too similar colours between different task statuses ('Discuss' and 'Ready to mark').

Other problems highlighted by the interview participants included:

> *The plagiarism support was not there for the written tasks.*
> *As more units are using Doubtfire++, the university would need to have a support team to maintain the system.*

7.4.6.3 Suggestions for Improvement

When users have a real experience using the tool, they provided more insightful suggestions on what are actually needed and propose more practical ways on how to improve the tool to better serve their needs and exploration. Based on the content analysis results, suggestions for improvement encompass four main aspects including: (i) ways to enhance the visualisations, (ii) have better support features, (iii) make the system more adaptive to encourage or alert the users, and (iv) institutional support to establish a technical team for maintaining the system. Each of these categories are known as 'Visualisation enhancement', 'Support feature', 'Adaptive system', and 'Institutional support' for easy presentation of participant suggestions in a table form. Table 7.20 shows the suggestions to improve the tool.

Table 7.20 Suggestions to improve Doubtfire++

Category	Suggestions for Improvement
1. Visualisation enhancement	• Have a 'Global Burndown Chart' showing a student's progress for all units in different colours • Have a leaderboard or score card ranking on Outcome Alignment and Achievement to show an individual student's progress or achievements in relation to the class • Make it flexible for students to perform self-reflection with the Task Alignment Rating either upon each task submission or at the end of the semester • Have students to self-reflect based on learning outcomes such that for each outcome, students select the tasks that help them learn the most with a comment box to explain the reasons • Have a progression map for showing the whole degree course
2. Support feature	• Include an introduction video or a user manual in Doubtfire++ to show its features • Have a notification tab to track the number of new submission/feedback upon log in the system • Allow image file to be attached along with the comments given for a task

	• Have plagiarism checking software for written task • Allow users to personalise the setting such as users can customise the theme color for different semester and save their preferred visualisations in the front page
3. Adaptive system	• System intervenes students to reflect on their progress and guide them for setting an appropriate target grade based on their progress and time remaining or invite those who have met the 'Pass tasks' to the next level • System generates auto-notification if students have not submitted the task after the task due date • Have motivating feature for the system to motivate those high achiever to excel further by complimenting their achievements such as giving achievement badge and persuade those lower achiever to engage in their learning
4. Institutional support	• The system requires Information Technology (IT) infrastructure support to maintain and enhance the system • Allocate space to archive student learning artefacts for future reference • Integrate Doubtfire++ with university learning management system and email all together in one page

7.5   Threats to Validity

A number of measures have been taken to reduce the threats to validity as discussed in Section 3.7. However, there are several threats that could have affected the validity of the findings. The threats are listed according to internal, external, construct and statistical validity.

7.5.1   Internal Validity

As some units did not set up the links between the tasks and learning outcomes, this could have affected the results obtained and final interpretation of the results. Also, the research participants were recruited from self-selection sampling. They could be users who liked the visualisation tool hence leading to exaggeration of the research findings. In addition, nine of the fifteen teaching staff were tutors. While the context of institutions varies, in most

institutions the tutors were graduate students with very little experience, and very little oversight responsibility for the course overall. They could have used the visualisations in different ways, or have different goals for the use of the information. Furthermore, in retaining anonymity of the participants, it is unclear to what extent students had used the Doubtfire++ features. These aspects have caused a potential threat to the internal validity.

7.5.2 External Validity

So far there were 134 valid responses obtained from the online survey questionnaire. Most teaching staff and students were from the same faculty with more than 60% of them using it in programming units. It is also important to note that there was an obvious gender imbalance in this faculty in which more than 80% were males. The gender imbalance in the respondents could be representative of the gender proportions in the student groups surveyed. This potentially creates a bias that would limit the generalisation of the findings.

7.5.3 Construct Validity

To ensure the clarity of the survey items and the interview plan, they were reviewed by experienced judges and pilot-tested. Besides that, the explanatory sequential mixed-methods design has kept the construct validity threat to a minimum. The quantitative results helped the researcher to modify the interview plans to focus qualitative data collection by fine-tuning it to the projected analytical topics. Therefore, there is no construct validity issue.

7.5.4 Statistical Validity

RQ3 to RQ6 in Study 2 applied an independent samples t-tests and/or a one-way between-groups analysis of variance (ANOVA) to assess differences between groups. The valid sample size of at least 130 used for *RQ3, RQ4* and *RQ6* was sufficient to perform these two statistical analyses. The general assumptions that apply to these two parametric techniques were checked. There is no violation of assumptions and calculation problem that threatens the validity for *RQ3, RQ4* and *RQ6*. However, the small sample size ($n=12$) used in *RQ5* that compared the units using Doubtfire++ for the years 2015 and 2016, could have introduced bias to the results obtained.

7.6   Summary

Doubtfire++ was used as an evaluation platform to test the use of various open learner model visualisations in supporting Task-Oriented Portfolio teaching and learning to encourage student self-regulated learning. Doubtfire++ was perceived simple, appealing and easy to navigate as well as having depth of information available in different graphs. The visualisations play a key role in supporting various user roles in a Task-Oriented Portfolio teaching approach. The convenors especially valued the trends and patterns exhibited from the visualisations that helped them to reflect on their teaching approach to better manage the unit. The tutors were impressed by the effective way of providing frequent formative feedback and tracking student progress. Students in general felt that the system helped them to flexibly manage their learning. They were able to choose their desired grade to achieve, visualise their progress and self-evaluate their achievements. OLM visualisations kept the students cognisant of their learning pace. With tutor support, the majority of the students felt that the visualisations provided good support to guide them towards achieving their desired grade. That is, they felt supported and rewarded learning in a self-regulated manner. Their overall experience using Doubtfire++ was quite positive. A detailed discussion of the results will be presented in Chapter 8.

Chapter 8
Discussion

8.1 Introduction

Sixteen OLM representations supporting student learning in a Task-Oriented Portfolio teaching and learning approach have been developed. The visualisations for presenting five key learning aspects included visualisations that keep users informed about:

(i) learning task status,

(ii) learning task status statistics,

(iii) individual learning outcome achievements,

(iv) class learning outcome achievements, and

(v) comparison of learning outcome achievements.

These visualisations are distributed into two main groups known as Shared Student-Centred Visualisations and Teaching Support Visualisations. Shared Student-Centred Visualisations encode different aspects of student learning including:

- student desired achievement target (Target Grade Setting),

- task status (Task List, Focus List, Task Summary Chart),

- progression rate (Burndown Chart),

- student learning outcome achievements (Outcome Alignment and Achievement, Outcome Alignment and Achievement Task View), and

- student self-reflection (Task Alignment Rating).

The Teaching Support Visualisations support the teaching staff in:

- viewing student grade aspiration (Target Grade Distribution),

- visualising student submission (Progress Bar, View by Specific Task, Task Requiring Feedback),

- providing feedback and comments (Feedback Interface),

- inspecting visual analytics for tracking student progress (Task Status Distribution, Task Completion Statistics) and

- inspecting achievement by an individual student and different student cohorts (LO Achievement Statistics).

Doubtfire++ has additional features to support student learning in a Task-Oriented Portfolio teaching to encourage student self-regulated learning. Study 2 was conducted to investigate the deployment of Doubtfire++ in teaching units in the Faculty of Science, Engineering and Technology at Swinburne University of Technology for one semester. The results have been presented in Chapter 7. This chapter discusses the results obtained from Study 2.

Section 8.2 discusses the Shared Student-Centred Visualisations, including their support of user needs and user perceived usefulness of the visualisations. The use of these visualisations in facilitating student self-regulated learning is also discussed. Section 8.3 discusses the Teaching Support Visualisations including user perceived useful visualisations and their use in supporting frequent formative feedback. This is followed by an extensive discussion about the use of Doubtfire++ in supporting different user roles including convenors, teaching staff and students in Section 8.4. Factors that could have impacted their perceptions are also discussed. User overall experience interacting with Doubtfire++ is then discussed in Section 8.5. The discussion also includes experienced user views on the enhanced features in Doubtfire++. Lastly, the chapter is concluded with a summary.

8.2   Shared Student-Centred Visualisations

Shared Student-Centred Visualisations were developed to support students in the Task-Oriented Portfolio teaching and learning environment. The visualisations were designed to encourage students in becoming self-regulated learners. Among the visualisations include one visualisation for facilitating students in setting target grade, three for inspecting task progress, three for inspecting learning outcome achievement and one for performing self-reflection. The following subsections discuss how these visualisations were perceived useful by the teaching staff and students.

8.2.1 Visualisation for Setting Target Grade

The Target Grade Setting was **perceived quite useful by both teaching staff and students**. It helped the teaching staff to understand a student's expectation in the unit. This enabled them to guide student work and discussion. Not all students set their desired target grade in Doubtfire++. A teaching staff felt that the Target Grade Setting visualisation was not fully utilised by students as some just left the default view – 'Pass' in the system. While some high achieving students set it to 'High Distinction' and left it there for the whole semester to be the goal to strive for, some students actively adjusted it based on their current status and progress. This means some students used it to help them plan for their workload and time to achieve their aspiration grades. They felt engaging and rewarding for being able to control their own learning pace. It is important to note that students have to utilise this visualisation to set their desired grade so that the teaching staff are able to motivate and intervene students when necessary.

Unfortunately, not all students utilised it to set a realistic goal. Some teaching staff took the initiative to motivate the students to target high at the start of the semester and some intervened in the middle of the semester to remind students in setting an appropriate target to achieve. It was suggested to have a more adaptive open learner model system to motivate, challenge and guide students to target high and set a realistic learning goal. This would be beneficial to both sets of user groups. This finding leads to future research for integrating adaptive learning technology in this system.

8.2.2 Visualisations for Inspecting Task Progress

Task List was perceived to be **the most useful visualisation by both the teaching staff and students** in Study 2 to monitor student learning. Task List displayed a detailed view for each assessment task. The teaching staff stated that it helped them to easily track any specific task that students required help. It was used as a reference to counsel struggling students. Students used it to track their progress and identify tasks to be completed for achieving their target. The colours used to encode different task statuses were perceived to be very motivating by the students for completing their tasks.

Focus List is the list that is extracted from the Task List to show tasks that need student immediate attention. Although it was not popular as compared to Task List, it was perceived useful to guide weak students to stay on track. Burndown Chart was perceived useful by the teaching staff for helping them to visualise student rate of doing tasks throughout the semester and to review a student's overall progress at the end of the semester. It provided

students with timeline measurement to effectively manage their tasks. It motivated students to stay on track, engage students with the assessment tasks and help those who had a packed schedule and who juggle multiple units to manage their learning. Quite a number of students found it useful. However, some students had difficulties interpreting the line graphs shown in the Burndown chart and did not use it at all. This indicates that improvement is needed to help users interpret the visual encoding of the Burndown Chart.

The teaching staff found that the Task Summary Chart **provided them a useful overview** about their class progress. The students found that it **gave them a good visual of progress summary**. The colour coding especially had a strong visual impact to motivate the students to complete the tasks. They gained a sense of satisfaction as their Task Summary Chart turned green. While some students felt that it gave them a sense of their progress breakdown as a whole that complements the more detailed view in Task List and Burndown Chart, some students found it redundant.

8.2.3 *Visualisations for Inspecting LO Achievements*

For visual analytics related to learning outcomes (Outcome Alignment and Achievement and Outcome Alignment and Achievement Task View), data will only be available if the links between the assessment tasks and the intended learning outcomes are in place, preferably at the start of the semester. As two units did not have the links set up in Doubtfire++ and one unit only set it up at the end of the semester, these visualisations were being ignored in some units. Also, for the units that have the links set up, not many were aware of this visualisation as it was not in the first login page. This could be the reason for lower usage rate. **Some students valued these visualisations** for helping them to identify tasks to complete for improving a specific LO and to prepare for their portfolios.

The Outcome Alignment and Achievement displayed staff expectation for students to achieve the required grade outcomes and a particular student's achievement level. In general, **the teaching staff were unsure or thought that students had never looked at it to inspect their learning outcome achievement**. However, some students, especially those high achieving students, **found that it had provided a good measure for them to gauge their achievements** against their class and the expected grade level. Some students who always strived to stay competitive found it to be very useful, rewarding, motivating and engaging. They thought it was a great way for having Outcome Alignment and Achievement to present the learning outcome achievements. They wanted more detailed information about how competitive they were in their class. They suggested having leaderboard or score card ranking

to indicate, for example the top 10% achievers in the class. This signifies that the Outcome Alignment and Achievement provides a good mental model to motivate those high achieving students to engage and excel further. This is an exciting finding. However, a struggling student indicated that it was not helpful to him. These findings suggest that future research should be conducted to explore further in this aspect, for both high achieving students to excel and for low achieving students to engage in their learning.

The Outcome Alignment and Achievement Task View visualisation informs students about the tasks planned by the lecturer to achieve the learning outcomes. The teaching staff found that it **helped them to review the task and outcome alignment.** It was perceived to help in guiding students to prepare their final portfolio and to demonstrate their learning outcome achievements. Students found that it gave them rough ideas about the intended links between the assessment tasks and the outcomes. They also found that it had helped them to select learning artefacts for their portfolio. Some felt that it had helped them to identify tasks that they could focus for the purpose of improving their LO achievements.

However, some misused it. They copied the links into their Portfolio submission instead of performing self-reflection based on what they had gained from doing the assessment tasks. This indicates that the Constructive Alignment practice had not been fully integrated in some of the units and it had not been fully understood and embraced by the students. Staff guidance and encouragement is required to fully engage students in the CA environment.

Also, in any event, **some students reflected that they did not care about learning outcomes**. They only cared about task submission. Some students perceived that the learning outcomes were outside their control. They felt that the lecturer had designed the learning outcomes of a unit. Completing the tasks means that they had achieved the intended learning outcomes planned by the lecturer. Thus, visualisations presenting student progress related to task status were perceived more central than visualisations showing student learning outcome achievements. This signifies the need to create the awareness among students in the university level about the importance of learning outcomes in guiding them to build their strengths and identify areas for their personal and future career growth.

As discussed, **visualisations that were used to track learning task status and progress** such as Task List, Focus List and Burndown Chart **were more popular and perceived more useful** than visualisations for presenting learning outcome achievements. Participants generally perceived that this set of visualisations (Task List, Focus List and Burndown Chart)

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were essential to guide and drive student task completion. Following task completion, they perceived that they had attained the planned learning outcomes. Visualisations for presenting learning outcome achievements such as Outcome Alignment and Achievement and Outcome Alignment and Achievement Task View were perceived to be useful as a complementary view to gain a more complete picture about student progress and achievements.

8.2.4   *Visualisation for Facilitating Student Self-reflection*

Study 2 results showed that **not many teaching staff and students found Task Alignment Rating useful**. Majority of them rated it as slightly to moderately useful. Two main reasons could be the way it was designed and the time the reflection practice was conducted. The total number of tasks that could be linked to the number of the intended learning outcome produced a large matrix for students to reflect, think, and click to link them up. The reflection practice became tedious for students as it was scheduled at the end of the semester when students were busy preparing for their final assessment. It was suggested by tutors and some students that the rating should be done upon submission of each assessment task. This is because it helps students to reflect more when their minds are still fresh with the work they have just completed. They could also reflect on all the tasks throughout the whole semester rather than the 'overwhelming' whole lot of tasks at the end of the semester.
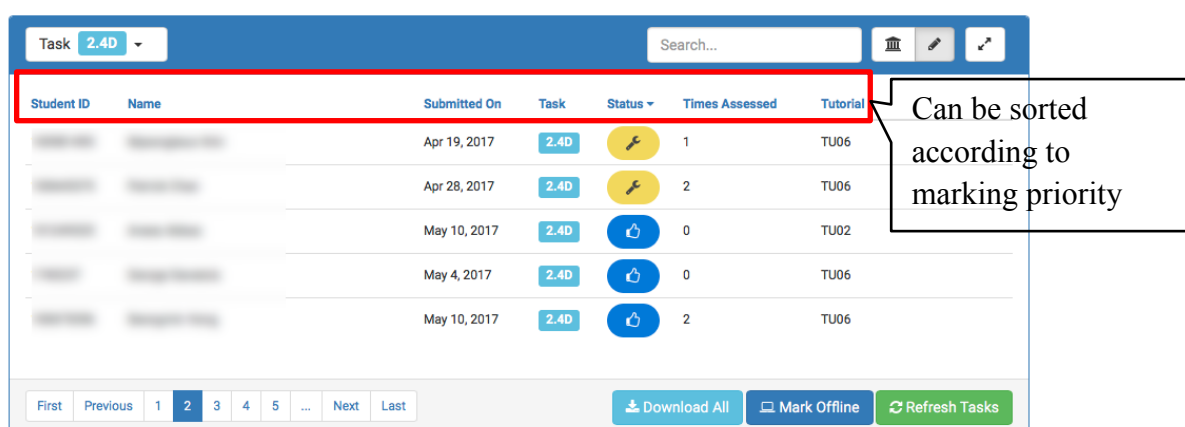
From the findings, **both staff and students were receptive to the idea of having the Task Alignment Rating to guide student self-reflection**. A teaching staff said that the data helped him to reflect on unit intended LOs. This was supported by a student participant who used it to reflect on his learning. These are useful findings. They help to advise how current self-reflection practice can be facilitated by open learner model visualisations. Further research is needed to explore how to conduct the self-reflection practice to benefit both the students and staff. The finding also prompts for simpler visualisation design to ease the self-reflection process.

8.3 Teaching Support Visualisations

Close monitoring and feedback are two essential activities in the Task-Oriented Portfolio teaching approach. The teaching staff are involved in monitoring student progress and providing frequent formative feedback to support student learning. There were eight visualisations designed to support teaching staff in this teaching approach. Four were used to support the teaching staff in marking and providing feedback to students. Another four were used to inspect class progress and achievements.

8.3.1 *Visualisations for Supporting Staff Marking And Feedback*

The visualisations were View by Specific Task, Feedback Interface, Progress Bar and Task Requiring Feedback. Through the View by Specific Task (Figure 8.1), the **teaching staff gained a quick view for all student task statuses of a specific task**. They appreciate the sorting function as they were able to easily sort according to Student ID, Student Name, Submitted Date, Task, Times Assessed and Tutorial Group. It was perceived useful by the teaching staff for it helped them to organise their marking workload and prepare for feedback to students for a specific task. Some used it to catch up with students who lagged behind. Although **it was rated as one of the most popular and useful visualisations,** one of the teaching staff commented that it was hard to find the students who have not done their work. This is because a few students were displayed at a time and one has to sort for status and then advance the list until the students who have not done it were found. This implies that there is room for improvement to better serve the user needs.

Figure 8.1 Sorting features in View by Specific Task

The Task Requiring Feedback (Figure 8.2) has a similar sorting function as the View by Specific Task. Unlike View by Specific Task that presents a specific task only at a time, Task Requiring Feedback presents all the tasks that are awaiting feedback. The **teaching staff found that it helped them track student submission**s and **easily identify student work that was awaiting for them to mark**. They liked the way they could interact with the visualisation to sort and structure their marking. It helped them to plan and prioritise their marking workload. It also helped them to prepare their feedback to students and to guide the discussion during the lab session.

Figure 8.2 Sorting features in Tasks Requiring Feedback

The Feedback Interface (Figure 8.3) encodes feedback attributes using a combination of iconic representations, textual description and distinct colours. The **teaching staff found it useful to convey their comments and indicate the level of revision needed for students to improve their work**. The comment history helped them follow-up with the pending tasks. It provided good future reference and helped them to progressively track a student's work.
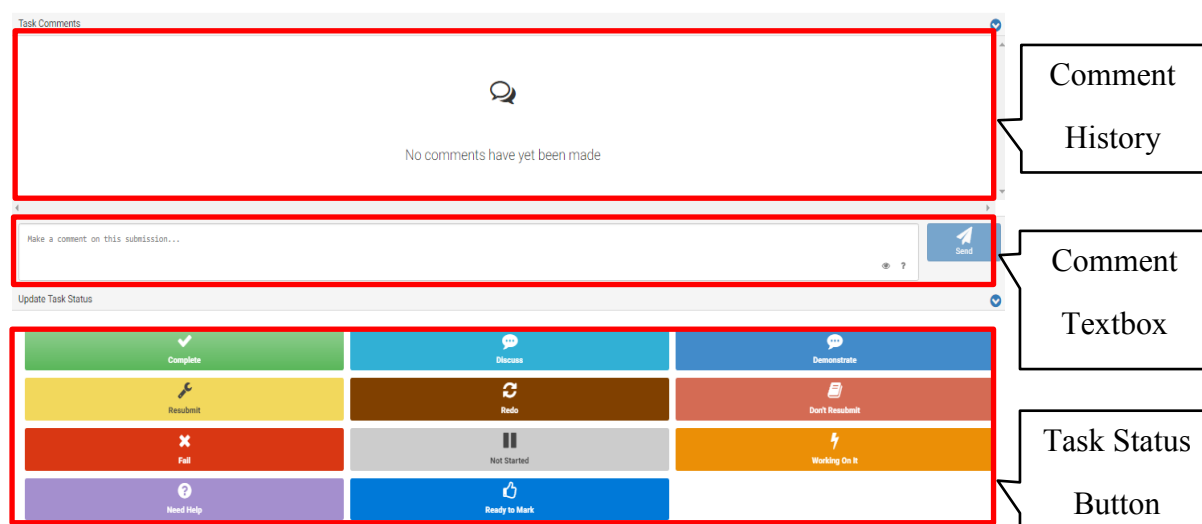
Figure 8.3 Features in Feedback Interface

The teaching staff commended Progress Bar (Figure 8.4) for its simple overview of the progress of each of the students in the class. The teaching staff liked the vivid colours and the length of the Progress Bar that encoded the proportion of the different task statuses. They could directly identify students who were ahead or lagged behind. It helped them to sort and identify students who needed their attention and help.
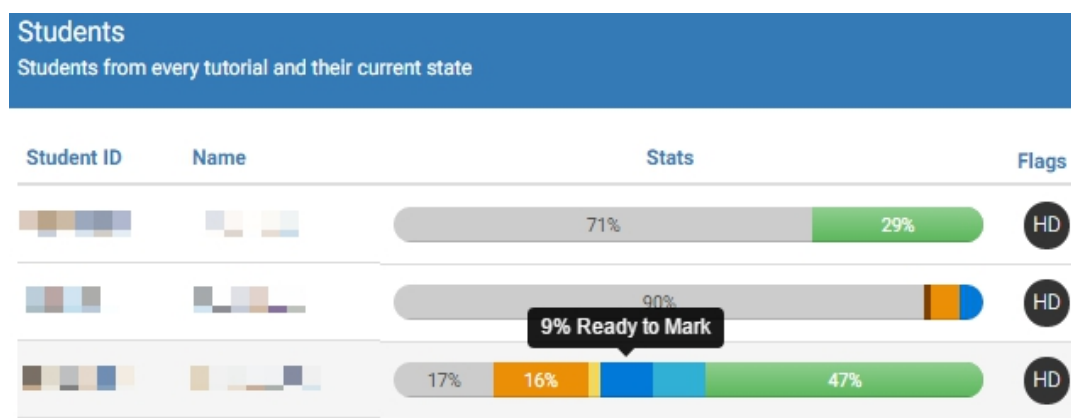

Figure 8.4 Progress Bar showing students who target for HD with different progressing rate

8.3.2   *Visualisations for Inspecting Class Progress and Achievements*

Another four visualisations enabled the teaching staff to inspect class progress and achievements by their own class and other student cohorts. The visualisations were Task Status Distribution, Target Grade Distribution, Task Completion Statistics and LO Achievement Statistics. Task Status Distribution and Target Grade Distribution used a pie chart to encode the data distribution. Student progression trend and aspiration grade

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proportion could easily be tracked by different student cohorts and among different tutorial groups. The Task Completion Statistics and LO Achievement Statistics were displayed as a boxplot. Student progress and achievement statistics could easily be viewed by a particular tutorial group or by all students in the unit.

The Task Status Distribution **was perceived inaccurate if a unit had optional tasks**. However, for units without optional tasks, the teaching staff used it to track task completion rate. They also used it to compare task completion by tutorial groups to gauge the progress of their own group. While a teaching staff stated that Target Grade Distribution helped him to understand the grade aspiration of a student cohort, a teaching staff doubted the data presented. He felt that students did not devote a realistic target grade to achieve in Doubtfire++. The LO Achievement Statistics was idle if the links between tasks and LOs were not set up in Doubtfire++. Both Target Grade Distribution and LO Achievement Statistics were not popular and not many teaching staff used them.

The findings indicated that the visualisations that facilitated marking and giving feedback were more popular and perceived to be more useful than visualisations meant for inspecting class progress and achievements. This could be due to the fact that providing frequent formative feedback is the central to the Task-Oriented Portfolio teaching approach. The visualisations include View by Specific Task, Progress Bar, Feedback Interface, and Task Requiring Feedback visualisations. These visualisations **helped the teaching staff to plan for feedback, give feedback, structure and prioritise their marking workload** as well as to initiate discussion with students who seemed to be lagged behind. They supported the teaching staff to monitor an individual student's progress to help students construct knowledge and develop a portfolio of work. From the feedback received, **students could make self-judgement and select learning artefacts to demonstrate their learning outcome achievements in their portfolios**. They can better support teaching staff in their role and their needs in providing frequent formative feedback. In fact such support is essential in a Task-Oriented Portfolio teaching approach for students to advance in their learning. This could be the main reason that facilitating marking and giving feedback were perceived to be more popular and useful than visualisations for inspecting class progress and achievements.

Although **visualisations for inspecting class progress and achievements were found less popular and were perceived less useful**, they provided some insights about overall student performance. Some teaching staff pointed out that they used a combination of both sets of

visualisations to help them gain a more complete picture of their students and class as well as other student cohorts. This gave them a better understanding of whether the assessment tasks planned had worked for the students during unit delivery. For example, they were able to know if any one task needed more help, whether their class was on track as compared to other tutorial groups, and the overall student performance. Overall, the combination of these visualisations provided the teaching staff some insights about the progress and achievements of an individual student as well as the whole class. They found it interesting to be able to monitor the performance of an individual student, to conjecture about classes and motivate their students and class.

8.4 The Use of Doubtfire++ in Supporting Different User Roles

The following subsections discuss the use of Doubtfire++ in supporting three main user groups in the Task-Oriented Portfolio teaching.

8.4.1 Students

Portfolio-based approaches encourage students to take greater ownership of their learning. Learning outcome plays an essential role to assist students in setting their learning goals and work progressively by collecting learning artefacts to showcase their achievements in a portfolio. Doubtfire++ has been designed to encourage student self-regulated learning in supporting the Task-Oriented Portfolio teaching.

8.4.1.1 Doubtfire++ OLM Visualisations in Facilitating Student Self-regulated Learning

The results in Section 7.4.2.1 show that in general, all user groups were quite favourable to the use of Doubtfire++ in supporting student self-regulated learning. **They marginally agreed that it helped students see the links between tasks and LOs and engage with LOs to set their learning goals. They were also receptive to its use to monitor student performance.** The majority of them agreed that it made it easy for students to submit their work for feedback and students could also easily access the tasks. It helped students to manage their learning, act upon feedback received and kept them on track. They also marginally agreed that it motivated students to complete tasks and engage with learning. They were quite favoured to its use in supporting student self-reflection. **They agreed that it helped students to self-evaluate and to showcase their achievements in portfolios.** They were also quite agreeable that it helped students to self-evaluate and to prepare for the final assessment, make self-judgement to attain a greater achievement and retain learning artefacts.

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They marginally agreed that it helped them gain self-satisfaction to construct their knowledge and help them to self-evaluate their own progress.

Also, from the discussion in Section 8.2, it can be seen how each of the Shared Student-Centred Visualisation had helped students form appropriate mental models of information. The visualisations had helped them understand and analyse their learning status, progress and achievement in the Task-Oriented Portfolio teaching approach. The following subsections discuss how various visualisations were used to support student in three key phases of self-regulated learning.

(i)   Goal Setting

The first phase of self-regulated learning is setting a learning goal. The favourable results from Study 2 (Section 7.4.1.1 (a.i)) demonstrated that **the Target Grade Setting in combination with the Task List visualisation was effective in assisting students to set and work towards appropriate goals.** For some students, the Outcome and Alignment Achievement Task View was also helpful although many students did not interact with this visualisation until they prepared their portfolios at the end of semester.

These visualisations provided students with flexibility to adjust the target grade and to see the workload required for different grades and learning outcome achievements. Figures 8.5 and 8.6 are the Task Lists for a struggling student going for a D Grade and C grade respectively. It can be seen that the number of tasks and the pending tasks (grey color) are significantly reduced. It directly conveys the required tasks and expected level to achieve a particular target grade. In this way, the responsibility lies within the students to decide for their desired grade and plan to allocate time and effort needed for achieving a realistic learning goal. Figure 8.7 shows how a student who aimed for a C grade had progressed well. The colour coding had provided a great visual impact and had kept the students informed about their progress level. The results indicate that students generally agree that Doubtfire++ facilitated them in setting appropriate learning goals. However, some teaching staff did not think that it benefited all the students. The reasons have been explained in Sections 8.2.1 and 8.2.3.
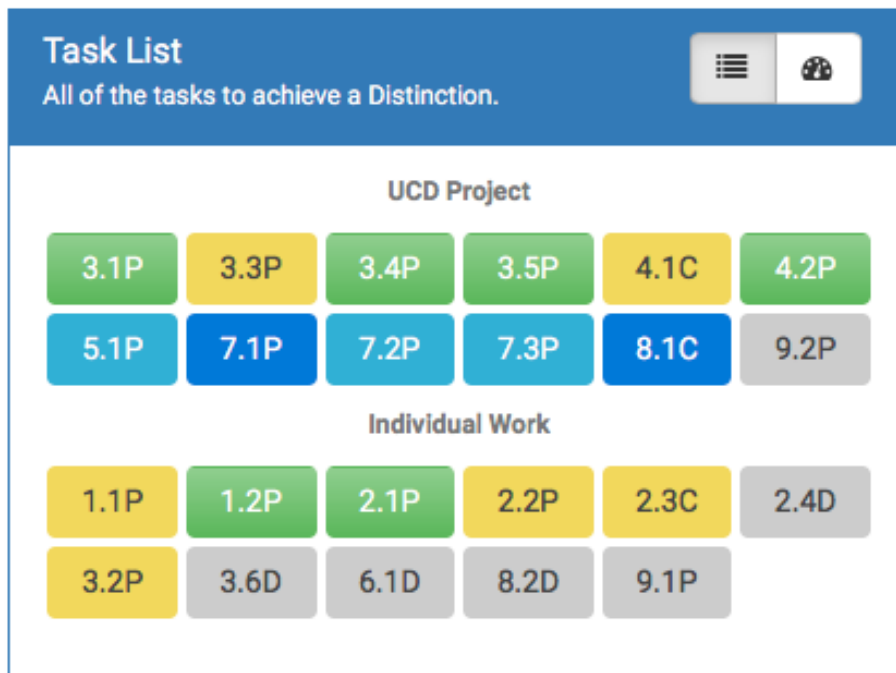
Figure 8.5 Week 10 Task List Visualisation showing struggling student going for a D grade
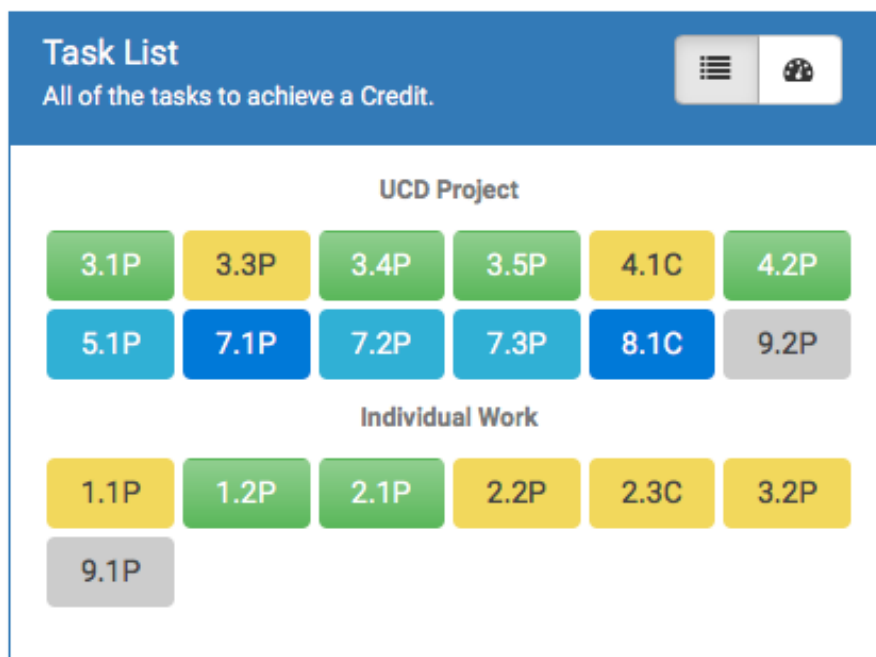

Figure 8.6 Week 10 Task List Visualisation showing same struggling student who had selected a C grade
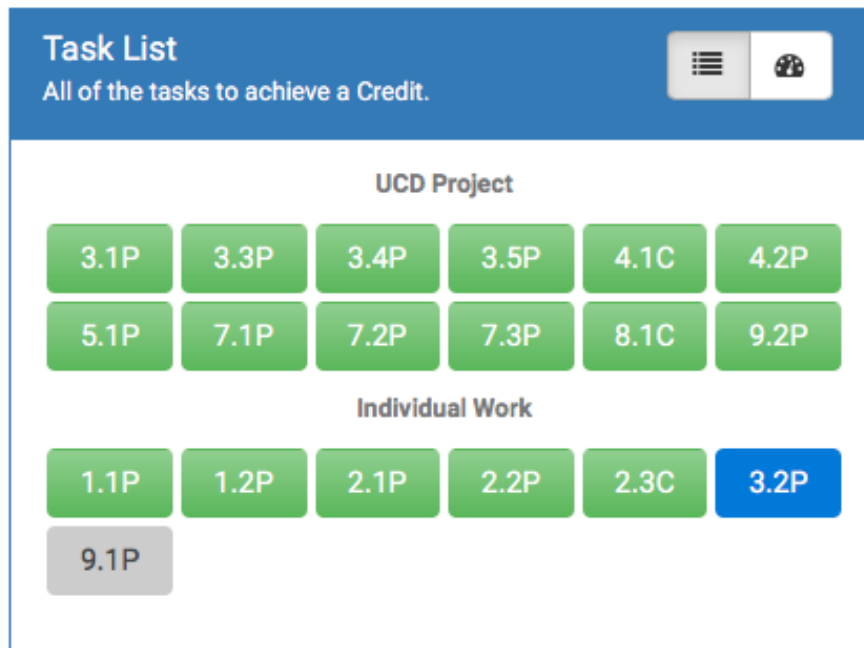
Figure 8.7 Week 10 Task List Visualisation showing student aiming for a C grade and doing well

(ii)   *Performance Monitoring*

The second phase of self-regulated learning is performance monitoring. **Students especially valued the Task List as it provided an easy way for them to track their task statuses**. The colour coding used in the Task List and Task Summary Chart (Figure 8.8) motivated them to complete the tasks for these visualisations to look 'Green'. The Focus List was perceived by some participants to direct students to focus and prioritise on the tasks. Figure 8.9 illustrates the Focus List for the struggling student in Figure 8.5 who had set a 'Distinction' in Doubtfire++. The Burndown Chart was perceived to assist students to gauge their progress in relation to the remaining time to complete the tasks. Figure 8.10 illustrates the Burndown Chart for a struggling student who felt that it had helped them to estimate time and effort needed to complete their tasks and to stay on track in order to achieve their desired grade.
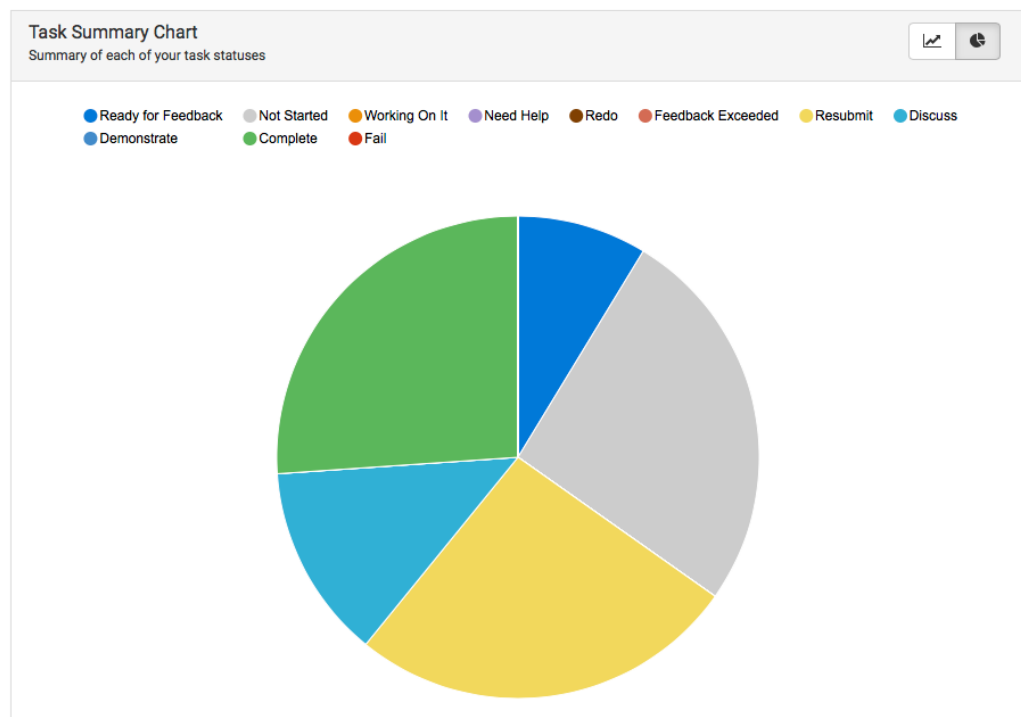
Figure 8.8 Task Summary Chart for the struggling student in Figure 8.5 above

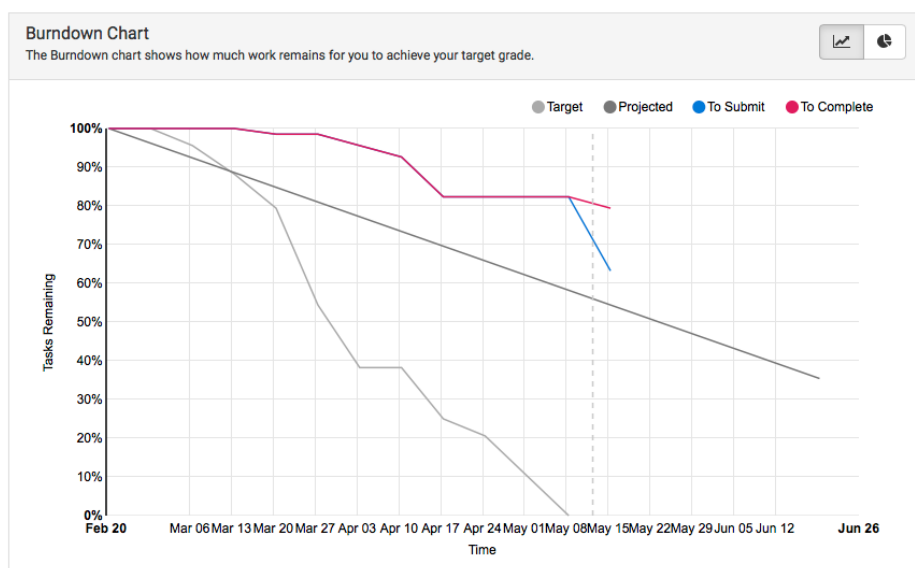Figure 8.9 Focus List for the struggling student in Figure 8.5 above

Figure 8.10 Burndown Chart for the struggling student in Figure 8.5 above

The Outcome Alignment and Achievement displayed staff expectation for students to achieve the required grade outcomes and a student's achievement level. **Some students used it to self-assess their achievements against the required grade standard and class achievements**. They commended it for motivating them to stay competitive and to strive for the best. A click on the Outcome Alignment and Achievement enabled students to drill down to see the Outcome Alignment and Achievement Task View. **Some students felt that this task view helped them to visualise the intended links between the assessment tasks and the outcomes.** Together these visualisations in Doubtfire++ (Task List, Focus List, Burndown Chart, Outcome Alignment and Achievement and Outcome Alignment and Achievement Task View) played an essential role in helping students monitor their performance.

(iii) Self-reflection

The third phase is self-reflection. In Doubtfire++, the Task Alignment Rating (see Figure 6.9) worked together with the Outcome Alignment and Achievement (see Figure 6.7) and Outcome Alignment and Achievement Task View (see Figure 6.8) to help students reflect their LO achievements. They can evidence their learning by uploading their learning artefacts through Task Alignment Rating. **Students who utilised it found that it assisted them to see the relevance between the assessment tasks and the learning outcomes**. This helped them to think about what they have learnt from each assessment task. They found that the combined use of the Task Alignment Rating, Outcome Alignment and Achievement and

Outcome Alignment and Achievement Task View were helpful for preparing the Portfolio. **However, most students did not make full use of the Task Alignment Rating as they were not aware of it**. They only used it at the end of the semester when they were required to prepare the Portfolio for final assessment.

An important finding is that users actually interacted with multiple visualisations (Target Grade Setting, Task List, Focus List, Burndown Chart, Task Summary Chart and Outcome Alignment and Achievement) to help them learn in a Task-Oriented Portfolio teaching to develop self-regulatory skills. This corroborates with the findings from other OLM research that multiple representations are helpful (Bull, Gakhal, et al., 2010; Bull et al., 2013; Mabbott & Bull, 2004). With the application of different visual encodings, each of the visualisations has its own descriptive and expressive power. They complement each other to provide a complete picture of student progress and achievements. Students not only could easily access learning tasks and submit their work for feedback, but they could also obtain a quick view on their task status and LO achievements that directed their focus to stay on track. **This helped them to self-evaluate their progression rate and leveraged their time and effort towards meeting their learning goals.** They were also encouraged to self-reflect on their learning outcome achievements through the use of Task Alignment Rating at the end of the semester when they prepared the Portfolio.

The majority of the participants found that these visualisations helped them manage their learning. They also agreed that it engaged students with learning. The Shared Student-Centred Visualisations kept students conscious about their time, workload, progress rate and achievement requirements in monitoring their performance and helped them make decisions to advance in their learning. The Shared Student-Centred Visualisations had positively impacted perceptions of most users in the way Doubtfire++ guided students through self-regulation learning phases, that is, the goal setting, performance monitoring and self-reflection phases.

8.4.1.2 Factors Impacting User Perceptions of The Use of Doubtfire++ in Supporting Student Self-regulated Learning

The impact of Doubtfire++ OLM visualisations on different user groups in facilitating student self-regulated learning was investigated. The measurement scales of self-regulated learning include goal setting, performance monitoring and self-reflection. Gender and familiarity with information visualisation had no effect on all the measurement scales. **This means that in general, both males and females were receptive to the use of Doubtfire++.**

The use of OLM visualisations were not more favoured by one gender. Also, experience and knowledge in information visualisation techniques were not required to comprehend the visual data encoded in Doubtfire++. This is supported by the finding that the visualisations in Doubtfire++ were simple, easy to understand and provided depth of information for user inspection and exploration (Section 7.4.6.1). The following subsections discuss the impact of Doubtfire++ to different user groups according to the goal setting, performance monitoring and self-reflection measurement scales.

(i)   *Goal Setting Measurement Scale*

A significant difference in scores was found between the teaching staff and students for the goal setting measurement scale, **with students finding it more useful than the teaching staff**. The use of visualisations has formed a mental model that guides students in setting a realistic goal by providing them flexibility to adjust their time and effort to meet their desired grade and vice versa. However, the teaching staff, who managed groups of students, have a different view. This is because they interacted with all students in the unit and thus held a more comprehensive view.

A significant difference in scores was also found between new users and experienced users for goal setting. New users perceived Doubtfire++ more helpful than experienced users for setting learning goals. New users were more impressed with this feature. This could be an indication of the potential of Doubtfire++ in attracting new users. It also could be due to its widely known novelty effect, a fundamental characteristic of any information technology innovation. It refers to the newness or freshness from the perspective of an adopter (Wells, Campbell, Valacich, & Featherman, 2010). This suggests that the goal setting feature initially seems useful, but the effect gradually diminishes after using it a while, as in the case of the experienced users.

(ii)   *Performance Monitoring Measurement Scale*

Frequent Users (used it every day or at least twice in a week) perceived it more useful than Non-Frequent Users (less than twice in a week). This could be due to users who perceived it useful and used it more frequently to monitor student performance. It can also be attributed to Frequent Users who perceived that Doubtfire++ was significantly more helpful for them to monitor their performance than Non-frequent Users. Due to this, Frequent Users could have valued Doubtfire++ more than Non-frequent Users to monitor their performance.

The result also shows that while Experienced Users (used in year 2016 or earlier) had ideas about some of the Doubtfire++ features, New Users (used in year 2016 only) were more impressed with the way it can help them to monitor their performance. This aspect was also influenced by its deployment in different teaching units. For example, the Programming unit users felt that it was of great value to them in monitoring their performance than in Non-programming units. Depending on the adopted teaching and assessment approaches, the unit deliveries were different in terms of whether the links between tasks and LOs were set in Doubtfire++, the frequency of formative feedback and if the unit adopted partial or full use of portfolio-based assessment. Different units used Doubtfire++ in different ways and at different usage rates. The Programming units had both teaching activities and assessments aligned to the intended learning outcomes with links set up at the start of the semester and had adopted full use of the Portfolio assessment. This could have influenced user usage as they were able to make extensive use of the visualisation tool to monitor their performance.

(iii) *Self-reflection Measurement Scale*

For self-reflection measurement scale, **there were no significant differences in means between all factors** (user role, gender, familiarity with InfoVis, experience using Doubtfire++, usage frequency and teaching units) under study. The mean scores for self-reflection were above 3.00, ranging from 3.42 to 3.82 across all factors implying that users marginally agreed that Doubtfire++ was useful for students to perform self-reflection. Specific group of users did not have any impact on user perceptions of using Doubtfire++ to perform self-reflection.

From the discussion regarding the impact of Doubtfire++ to different user groups in facilitating student self-regulation, more users perceived that it helped students in performance monitoring than goal setting and self-reflection. This implies that there is room for improvement in these two aspects to better support student self-regulated learning.

8.4.2   *The Use of Doubtfire++ in Supporting the Teaching Staff*
In a Task-Oriented Portfolio teaching, students are engaged with small frequent tasks throughout the unit delivery. The final assessment requires students to submit a portfolio to demonstrate their learning outcome achievements. To support students in this learning environment, the teaching staff play an essential role in providing continuous support to facilitate student learning towards achieving the intended learning outcomes. The Teaching Support Visualisations as discussed in Sections 8.3 and 8.4 show how different OLM visualisations were used by the teaching staff in supporting their role to facilitate student

learning in the Task-Oriented Portfolio teaching. For example, the Feedback Interface, Task Requiring Feedback, and View by Specific Task were used by the teaching staff to check task awaiting their feedback, plan for feedback and prioritise marking workload. Task List, Progress Bar, Task Status Distribution, and Task Completion Statistics were used to track a student's assessment task status whereas Burndown Chart was used to visualise a student's progression rate. Student learning outcome achievements were inspected through the Outcome Alignment and Achievement and LO Achievement Statistics. They also gained useful data from student input in Task Alignment Rating to reflect on tasks and LOs alignment. It is the combination of these visualisations that provide effective use to a teaching staff in facilitating student learning to encourage student self-regulated learning.

The encouraging results obtained from Study 2 (Section 7.4.2.2 (b)) indicated **that the most beneficial effect that Doubtfire++ brought to the teaching staff is that it helped them to track and monitor student progress.** They also highly valued Doubtfire++ for making it easy to assess student portfolio in the final assessment and to guide discussion with the students. They valued Doubtfire++ for making it easy to see task awaiting feedback. They commended it as an easy way to provide feedback to students. The majority of them agreed that being able to see student grade aspiration helped them understand student needs. They also marginally agreed that it helped them to reflect on their teaching and guide student learning. Overall, they felt that they were supported by Doubtfire++ in the Task-Oriented Portfolio teaching approach.

8.4.3   *Doubtfire++ in Supporting A Convenor's Role*

Convenors generally agreed that Doubtfire++ made it easy for them to set up the unit, including outlining tasks and linking the tasks to the intended learning outcomes for Portfolio-based assessment units (See Section 7.4.2.3). They also agreed that linking tasks to outcomes in Doubtfire++ helped them reflect on how the tasks aimed to develop student learning. The visual analytics especially the Task Status Distribution enabled them to track the progress of the student cohorts and tutor responses. They could see the trend of tutors responding to tutorials. They found that different patterns exhibited from the visualisations provided them with a better understanding of student cohorts and tutor activities in supporting students with formative feedback. Outcome Alignment and Achievement was found helpful to a convenor to verify the coverage of the intended learning outcomes in the unit.

A convenor participant indicated that the Target Grade Distribution helped him to conjecture about the student cohorts. Although they only marginally agreed that the analytic data helped them guide others teaching in the unit, some expressed that the visual analytics data captured in Doubtfire++ at the end of the semester had prompted some convenors to reflect on how the tasks aimed to develop student learning. Besides that, the data captured in Doubtfire++ helped them to reflect on the unit delivery and guide their future planning. They gained rationale for making changes to the assessment tasks and existing practice.

Besides that, data captured in Doubtfire++ was used by convenors to gauge the effectiveness of the assessment tasks and to ensure that the learning outcomes were sufficiently covered in the unit. It helped the convenors to make decision for revising the teaching approach, resources and materials to convene future units. In addition, it had also guided others teaching especially a new convenor who was new to portfolio-based assessment in the unit.

It was pointed out that in supporting the concept of constructive alignment, the links between the assessment tasks and the intended learning outcomes in Doubtfire++ has to be made easy to accommodate any changes made. The system has to be made flexible for the inclusion of any additional learning outcomes or break-up of the assessment tasks to better align the tasks with the intended learning outcomes. Also, a convenor has to accept the fact that when the links between assessment tasks and learning outcomes are set, the task is not just within the bound set.

8.5 User Overall Experience Interacting with Doubtfire++

Study 2 results (Section 7.4.6.1) show that **both teaching staff and students had a very positive experience interacting with Doubtfire++**. They liked it for its clean, clear and easy to navigate interface. They also liked the visuals that gave them an overview of information needed. They could drill down further for more specific information as well as the depth of information presented in different graphs. They valued the flexibility that students could choose their grade and work all the way to achieve the desired grade. More importantly, they commended Doubtfire++ for supporting both the teaching staff and students with an effective 2-way communication. Doubtfire++ makes the process of receiving task submission and providing feedback to students easy and straight forward for the teaching staff. It provides a platform for students to submit their assessment tasks and receive feedback.

Doubtfire++ allows the teaching staff to align the assessment tasks with the intended learning outcomes. Supported by various OLM visualisations, both teaching staff and students can easily track the task status and learning outcome achievements. Students commended it for helping them keep all assessment tasks together along with tutor comments. While staff felt it was useful for them to plan for their marking workload and identify students that needed help, students expressed that they had a better control over their learning pace, engaged in learning and were more readily responsible for their own learning in this highly supportive learning environment.

With regards to its impact to student achievement, Tongchai (2016) reported that the use of OLM in blended learning environment supports learning achievement. However, Study 2 results (Section 7.4.5) **indicated that Doubtfire++ did not have any impact on student final grades**. It is important to note that this is just a rough measure because there are numerous factors and variables that can affect student final grades such as teaching resources, learning activities, assessment criteria, and many more. Although there was no evidence that Doubtfire++ support student gain in this aspect, users generally felt rewarding using it. Also, despite some problems that had been identified in Section 7.4.6.2, there was no major problem that affected the use of Doubtfire++. Some plausible ways to improve it have been presented in Section 7.4.6.3.

Both students and staff with prior experience using Doubtfire felt that Doubtfire++ was better than the previous version. Previous Doubtfire version has limited features to keep students informed about task status and learning progress. There was also no direct support for indicating the links between the tasks and the intended learning outcomes. The teaching staff and students were left to guess student learning outcome achievements and the teaching staff were always left to reckon by themselves if student learning outcomes have matched their expectation.

Study 2 results (Section 7.4) were encouraging. The majority of users **found that the new version has better features to support student learning** including aligning their learning with the learning outcomes, and tracking their learning progress. They also felt that the additional features could better guide student learning and help them to reflect on their learning. While experienced Doubtfire users felt that the new features were better, new users were impressed of the way Doubtfire++ supported students in goal setting and performance monitoring. Overall, users were very receptive in using Doubtfire++ for supporting the Task-Oriented Portfolio teaching. They were impressed by its simple and yet useful interface. They

enjoyed working with Doubtfire++. In addition, they highly recommended its use in other units and felt it was suitable for commercialisation.

8.6   Summary

Two important groups of OLM visualisations have been developed to support both the teaching staff and students in a Task-Oriented Portfolio teaching approach. Teaching Support Visualisations facilitate the teaching staff in creating a supportive learning environment. This provides students with great opportunities in becoming self-regulated learners. While the Shared Student-Centred Visualisations guide students in taking greater ownership of their learning, they provide useful information about student grade aspiration, learning progress and self-reflection data to the teaching staff. Visualisations supporting inspection of student task progress were perceived more useful than visualisations showing student learning outcome achievements. For Teaching Support Visualisations, the visualisations that support the teaching staff in marking assessment tasks and providing feedback were perceived more useful than visualisations for inspecting class progress and achievements by unit or by other student cohorts. Although these visualisations were perceived less useful, they were found to provide different and complementary data to give the teaching staff and students a more complete view about student learning and unit delivery in this teaching approach. For the purpose of facilitating student self-regulation, both user groups perceived that it helped students in performance monitoring more than goal setting and self-reflection. More research work is needed to improve these two aspects to better support student self-regulation learning. Overall, both the teaching staff and students had a very positive experience interacting with Doubtfire++. From the discussion, the results are promising. In summary, the visualisations provided in Doubtfire++ to support student learning in the Task-Oriented Portfolio teaching environment were viewed positively by both sets of user groups.

Chapter 9
Conclusions and Future Work

Use of an independent open learner model exposes users to many important source of student learning information to promote student self-regulated learning. It is an emergent research field. It has extensively been used to prompt learner autonomy in their learning processes (Bull & Kay, 2013). This research project investigated the design and use of Doubtfire++, an independent open learner model visualisation tool.

9.1 Conclusions

Chapter 2 reviewed the application of an outcome-based student-centred teaching approach known as the Task-Oriented Portfolio teaching. Students in this teaching approach were granted with flexibility and opportunities to take greater ownership of their learning. We found that it is therefore important to promote and develop student potential to self-regulate their learning in this teaching approach. The review revealed the need for an independent open learner model to encourage student self-regulated learning in this teaching approach.

This PhD thesis research project was built around two key studies, Study 1 and Study 2 to design and evaluate Doubtfire++. Chapter 3 presented an Explanatory Sequential Mixed-Methods research methodology that was used to conduct these studies. It consisted of two distinct phases, the quantitative and qualitative phases.

As Doubtfire++ is a specific application with specific target end users, this research methodology is suitable to be used in this research project to investigate problems related to target real-world applications to describe, explain and explore the aspects of events under study. Data collected from these two phases was analysed independently and connected during final interpretation. While the quantitative data provided an initial interpretation of the events under study, the qualitative data explained the statistical results in more depth with multiple viewpoints and interpretations. The merging between quantitative and qualitative results provided more comprehensive and convincing evidence to the research questions.

OLM systems rely on clear and effective representational formats to facilitate user information exploration and understanding. Study 1 solicited initial user requirements for designing suitable representational formats in Doubtfire++. Chapter 4 illustrated the proposed visualisation options that were adopted and adapted from existing OLM research and common graphical representations used in Statistics. These visualisation options were used to facilitate five key learning aspects in supporting Task-Oriented Portfolio teaching and learning. The analyses of results in Study 1 were presented in Chapter 5. A set of user perceived useful and preferred visualisations in supporting user exploration of these key learning aspects have been identified. The results also provided valuable inputs for improving and enriching the proposed visualisations as well as potential issues and ways to tackle them. The overall findings guided the design and development of OLM visualisations to support the Task-Oriented Portfolio teaching approach. They provided useful initial user requirements that helped the software development team to gain design rationales and to make more practical design decision for Doubtfire++.

Based on the software development team's experience in visual encoding and with these insightful findings, various OLM visualisations have been designed and developed. Chapter 6 illustrated two groups of these visualisations in supporting different user roles, the teaching staff and students. The Teaching Support Visualisations aim to support the teaching staff in creating a supportive learning environment to guide student learning in the Task-Oriented Portfolio teaching.

The Shared Student-Centred Visualisations prompted students learning in a self-regulated manner. Multiple visualisations have been designed and developed to guide students through the self-regulated phases including goal setting, performance monitoring and self-reflection. These visualisations were designed to support students set their aspiration grade, visualise workload, inspect their learning progress and achievements, and perform self-reflection on their learning in terms of learning outcomes. They could visualise to plan for their time and effort toward achieving their aspiration grade set. In this way, students gained the autonomy to decide and undertake the learning activities to construct their knowledge toward achieving their aspiration grade. They were guided to learn in self-regulated manner.

The analyses of results on how these two groups of visualisations were used to support the Task-Oriented Portfolio teaching to facilitate student self-regulated learning were reported in Chapter 7. Various quantitative statistical analysis techniques were used to investigate the use of each of the visualisations in specific and the use of Doubtfire++ independent open

learner model system in supporting the Task-Oriented Portfolio teaching approach in general. Qualitative analysis results were used to complement, compare, confirm, contrast and triangulate the quantitative results obtained. To identify ways to improve Doubtfire++, problems encountered by users were presented in counts to determine the prevalence of the problem in order to tackle them based on priority. Content analysis was used to categorize suggestions to improve Doubtfire++ system into four categories for future enhancement.

As discussed in Chapter 8, Doubtfire++ has been shown to positively impact user perceptions in supporting different user roles in a Task-Oriented Portfolio teaching and learning environment. Together the software development team's experience in visual encoding and the results of Study 1 had provided an insightful design requirement to develop the visualisations. Study 2 results provided strong support that these visualisations facilitated the teaching staff in creating a supportive learning environment that provides students with opportunities in becoming self-regulated learners. The majority of the students felt that they were supported in taking greater ownership of their learning.

Additional visualisations in Doubtfire++ were found better than the previous Doubtfire version. They offered specific information as well as the depth of information for user inspection. Each of the visualisations has its own descriptive and expressive power to support user information exploration and needs. They were found to provide different and complementary data for users to gain a more complete view about student learning and unit delivery in this teaching approach. Although there were a few problems to be rectified, Doubtfire++ indeed had offered students with data-rich and evidence-based learning opportunity to encourage student self-regulated learning. It had also provided the teaching staff with valuable learning data in the form of multiple analyses and visualisations to help them guide student learning during unit delivery and for future planning.

9.2 Key Contributions

The research work in this thesis has contributed to the field of open learner modelling, computer education and software development. The following subsections present the contributions made to these fields.

9.2.1 Open Learner Modelling

This research project has made three main contributions to open learner model research. Firstly, it has produced a set of effective representational formats to model student learning progress and achievements in the Task-Oriented Portfolio teaching. It enriched current OLM research with more visualisation options, learning aspects for inspection, served wider user groups and purposes of data exploration. Secondly, the visualisations were ideally designed to guide students through self-regulated learning cyclical phases. This can be a guide to help other similar OLM systems to better support student learning or become a reference to other OLM empirical research. Thirdly, the empirical findings suggest the feasibility of extending OLM use in outcome-based student-centred teaching environment so that students are supported to learn in this environment.

9.2.2 Computer Education

This research has made significant contributions to two aspects in computer education in terms of the stakeholders and the teaching approach. It supported different stakeholders including the convenors, tutors and students. The visualisation tool helped the convenors to plan, convene and manage computer education units in outcome-based student-centred learning environment. Tutors were supported with more effective communication platform to facilitate student learning and organize their tutorial class, and manage their marking workload. Students were guided with a more systematic way to self-regulate their learning including planning, organizing, monitoring, and self-evaluating their learning. Also, this research demonstrated ways to better support the adoption of constructive alignment approach in computer education. The use of OLM visualisations helped to create awareness of the pedagogical value among the students in the deployment of Portfolio-based teaching. The research findings also revealed the potential of OLM visualisation in supporting CA approach by inviting students to involve in the alignment process and to tackle the potential misalignment issues.

9.2.3   Software Development

This research project also contributed to software development. The contribution is the tool developed to support student self-regulated learning in the Task-Oriented Portfolio teaching approach. Besides that, through the applicability of the scenario-based design and the mixed-methods research design, the two common software development methodologies, initial user requirements for designing the prototype tool can be identified to better support the needs of the end users. The research design provided empirical findings about user information exploration and needs to encourage student self-regulated learning in this teaching approach. It is an example that supports the viability of mixed-methods research and scenario-based design in the context of this domain.

9.3   Future Work

Future work involves expanding the use of Doubtfire++ for more diverse units, courses and institutions, and serving wider user roles with more robust information visualisation techniques to better support student self-regulated learning. The following subsections detail four key future directions.

9.3.1   Application of Doubtfire++ in A Broader Context

The participants in Study 2 were from the same faculty in the same university with majority of them using Doubtfire++ in programming units. Also, there was an obvious gender imbalance in the research sample in which majority of them were males. Future work may involve the adoption of Doubtfire++ in other faculties and educational institutions that include further feedback from more diverse end users and female respondents. More data can be collected and comparative statistics can be generated. The results can then be used to triangulate and cross-validate the findings obtained from this research project. Besides that, the choices of colours selected to be used in the visualisation tool would have to include colours with sufficiently high contrast or saturation to cater people with colour-blindness. This is to ensure the application of Doubtfire++ in a broader context.

9.3.2   Adaptive Doubtfire++ System

Doubtfire++ is an independent open learner model that supports student inspection of their learning progress and achievement. As discussed in Chapter 8, although both user groups were receptive to the use of Doubtfire++, they wanted more adaptive open learner model system. Current system is quite static in which the learner model data is presented without

further intervention from the system. The system could be made more dynamic by enhancing it with technology-based personalisation intervention, an adaptive learning technology. Such technology adapts instruction to learner characteristics and needs such as backgrounds and preferences (Koedinger & Corbett, 2006; Walkington, 2013). As the target grade set is linked to the number of assessment tasks required to achieve it, technology-based personalisation intervention can be used to adapt the provision of assessment tasks to student progress.

For example, the system negotiates with the students who target high but could not cope with the amount of work required. In such cases, the system could intervene to prompt the students to reconsider their nominated target grade. For students who target low or have met the target grade, the system could challenge them to target higher or automatically move them to the next grade level. In this way, the adaptive system can guide students in setting a realistic target grade or motivate students to engage with their learning. The inclusion of system intervention such as the use of leaderboard or score card ranking in the Outcome Alignment and Achievement was also suggested. This is to encourage both high achieving students to excel and for low achieving students to engage in their learning. This is feasible with the intervention of technology-based personalisation intervention.

Future work can look into the impact of technology-based personalisation intervention in Doubtfire++ to support student self-regulated learning. The work can then be extended to investigate the impact of Doubtfire++ on student final grades with a careful control of other variables such as the assessment mode and criteria, and the programming mode being used.

9.3.3 Expanding Doubtfire++ Support

The analysis of results demonstrated three key prospects for expanding Doubtfire++ support:

(i)   Although the results showed the potentials of Doubtfire++ visualisations in supporting student self-regulated learning that consists of three cyclical phases, the results also indicated that more users perceived that it helped students in the performance monitoring phase than in the goal setting and self-reflection phases. The shortcomings in these phases require further research to improve them.

(ii)   This research project has also shown the potential of OLM visualisations in supporting the role of the convenor in managing a unit. Its use can be expanded to help wider user roles in the educational setting. For example, supporting the course administrator to manage the degree course. This relates to the expansion of its use with the inclusion of class-wide and course-wide statistical data and comparison

features. In this way, learner model can be opened to users in the form of 'Course Progression Map'. The progression map resembles the train track station map that can help users to visualise all units for the degree courses that a student undertakes, show student progress and learning outcome achievements through the course with key learning artefacts. It can also support the course administrator to oversee the course implementation.

(iii) For graduates to be competitive and sustainable in the current job market, many Higher education institutions, in preparing undergraduates for the workforce, are embracing outcome-based student-centred teaching approach. Constructive alignment is an example of such teaching approach in which learning outcome plays the central role to guide the learning activities. The teaching staff align assessment tasks with the intended learning outcomes for each of the assessment tasks. Self-reflection is an essential activity to guide students plan and self-evaluate their learning gain especially their achievements in terms of learning outcomes. Study 2 results showed that both staff and students were receptive of having Task Alignment Rating to guide student self-reflection toward achieving the intended learning outcomes. However, visualisations for presenting learning outcome achievements such as Outcome Alignment and Achievement were perceived less useful than visualisations that support task status inspection such as Task List.

The qualitative results showed that most student participants solely relied on the teaching staff to perform the alignment process. Students perceived that learning outcomes were in-built in the unit. It was the teacher's full responsibility to determine and embed the learning outcomes in the assessment tasks. Most students in general thought that upon completion of a task, they had achieved the intended learning outcomes. This indicates a dire need to communicate the importance of learning outcomes clearly to the students to reflect on the learning outcomes achieved upon completion of a task. While the job market requires competent employees, it is important that the learners who are the centre of the teaching activities and as the future workforce, need to be aware of the importance of learning outcomes for their personal and future professional growth and development.

Together these three prospects lead to future research work to integrate more robust information visualisation techniques to expand Doubtfire++ support to wider users and scopes. Two fundamental components that form the core of Information Visualisation

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(Infovis) are the representation component and the interaction component. The representation component is underpinned by the field of computer graphics, for data to be mapped with representation in order to display it in an understandable format to the users. The interaction component that is built upon Human-Computer Interaction (HCI) opens up the communication loop between the user and the system for the user to explore and gain better insights of the data set (Yi et al., 2007).

The integration of more robust information visualisation representations and interaction techniques could potentially enhance Doubtfire++ to better support student self-regulated learning, especially in goal setting and self-reflection phases, and accommodate wider user roles and scopes of application as well as learning outcome awareness. Longitudinal studies could be conducted to investigate the effective use and uptake by different user roles in different units, courses and institutions as well as ways to invite students to involve in the alignment process.

9.3.4 Integration with Learning Management System (LMS)

A Learning Management System (LMS) refers to a software program that is used for delivering, documenting, tracking and managing training programmes or education courses (Mahnegar, 2012). Examples of LMS include Blackboard and Moodle. LMSs consist of systems to manage training and educational records and software to deliver courses through Internet for distance learning (Mahnegar, 2012) as well as providing features for online interaction and collaboration (Whitley-Grassi & Hoefler, 2012). LMSs have also been used to link learning activities with institutional missions and program goals for outcomes assessment purposes (Tello & Motiwalla, 2010).

However, the linking of learning activities to program goals is mainly to fulfil the reporting purposes as requested by the professional accreditation agency (Tello & Motiwalla, 2010) and it has limited support for student learning. Doubtfire++ supports both teaching staff and students in frequent formative feedback to encourage student self-regulated learning in outcome-based student-centred teaching and learning environment. The research work can be extended to investigate the possibility of integrating Doubtfire++ with LMS to support student learning.

In summary, this empirical study has shown the potential of Doubtfire++ visualisation tool in supporting two user groups, the teaching staff and students in the outcome-based student-centred teaching and learning environment. The visualisations support the teaching staff in the creation of a supportive learning environment that guides students in becoming self-

regulated learners. This research work raises a number of implications for expanding its application to a broader context, enhancing it with a more powerful system and with robust information visualisation techniques as well as the possibility to integrate with other learning management system to support the outcome-based student-centred teaching and learning.

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Appendices

Appendix A.1

SHR Project 2014/308 Ethics Clearance (Study 1)

From: Kaye Goldenberg
Sent: Friday, 19 December 2014 11:05 AM
To: John Grundy; Check Law
Subject: SHR Project 2014/308 Ethics Clearance

To: Prof John Grundy, FSET/Ms Law Check Yee

Dear Prof Grundy,

SHR Project 2014/308 A study of convenor and student opinions on open learner model visualisations
Prof John Grundy, FSET/Ms Law Check Yee
Approved Duration: 19/12/2014 to 31/08/2017 [Adjusted]

I refer to the ethical review of the above project protocol by a Subcommittee (SHESC3) of Swinburne's Human Research Ethics Committee (SUHREC) at a meeting held 28 November 2014. Your response to the review, as emailed on 15 December was reviewed by a SHESC3 delegate.

I am pleased to advise that, as submitted to date, the project may proceed in line with standard on-going ethics clearance conditions here outlined.

-    All human research activity undertaken under Swinburne auspices must conform to Swinburne and external regulatory standards, including the current *National Statement on Ethical Conduct in Human Research* and with respect to secure data use, retention and disposal.

-    The named Swinburne Chief Investigator/Supervisor remains responsible for any personnel appointed to or associated with the project being made aware of ethics clearance conditions, including research and consent procedures or instruments approved. Any change in chief investigator/supervisor requires timely notification and SUHREC endorsement.

-    The above project has been approved as submitted for ethical review by or on behalf of SUHREC. Amendments to approved procedures or instruments ordinarily require prior ethical appraisal/clearance. SUHREC must be notified immediately or as soon as possible thereafter of (a) any serious or unexpected adverse effects on participants any redress measures; (b) proposed changes in protocols; and (c) unforeseen events which might affect continued ethical acceptability of the project.

-    At a minimum, an annual report on the progress of the project is required as well as at the conclusion (or abandonment) of the project. Information on project monitoring, self-

audits   and   progress   reports   can   be   found
at:http://www.research.swinburne.edu.au/ethics/human/monitoringReportingChanges/

- 	A duly authorised external or internal audit of the project may be undertaken at any time.

Please contact the Research Ethics Office if you have any queries about on-going ethics clearance. The SHR project number should be quoted in communication. Researchers should retain a copy of this email as part of project recordkeeping.

Best wishes for the project.

Yours sincerely,

Kaye Goldenberg
Acting Secretary, SHESC3

Kaye Goldenberg
Research Ethics Executive Officer (Acting)
Swinburne Research (H68)
Swinburne University of Technology
Level 1, SPS, 24 Wakefield Street
Hawthorn, VIC 3122
Tel: +61 3 9214 5218
Fax: +61 3 9214 5267
Email: kgoldenberg@swin.edu.au

Appendix A.2

SHR Project 2015/309 Ethics Clearance (Study 2)

From: Keith Wilkins on behalf of RES Ethics
Sent: Monday, 21 December 2015 5:00 PM
To: John Grundy; Check Law
Cc: RES Ethics; Astrid Nordmann; Rajesh Vasa; Andrew Cain
Subject: SHR Project 2015/309 - Ethics Clearance

To: Prof. John Grundy/Ms Check Law - FSET

Dear John and Law

SHR Project 2015/309 – Evaluation of Doubtfire++ Open Learner (OLM) Prototype Tool
Prof. John Grundy, Ms Law Check Yee (Student), Dr Rajesh Vasa, Dr Andrew Cain - FSET
Approved Duration: 18-12-2015 to 30-06-2017

I refer to the ethical review of the above project revised protocol by a Subcommittee (SHESC1) of Swinburne's Human Research Ethics Committee (SUHREC). Your response to the review, as emailed on 15 December 2015 with attachments, were put to the Subcommittee delegate for consideration.

I am pleased to advise that, as submitted to date, the project may proceed in line with standard on-going ethics clearance conditions here outlined.

- All human research activity undertaken under Swinburne auspices must conform to Swinburne and external regulatory standards, including the current *National Statement on Ethical Conduct in Human Research* and with respect to secure data use, retention and disposal.

- The named Swinburne Chief Investigator/Supervisor remains responsible for any personnel appointed to or associated with the project being made aware of ethics clearance conditions, including research and consent procedures or instruments approved. Any change in chief investigator/supervisor requires timely notification and SUHREC endorsement.

- The above project has been approved as submitted for ethical review by or on behalf of SUHREC. Amendments to approved procedures or instruments ordinarily require prior ethical appraisal/clearance. SUHREC must be notified immediately or as soon as possible thereafter of (a) any serious or unexpected adverse effects on participants any redress measures; (b) proposed changes in protocols; and (c) unforeseen events which might affect continued ethical acceptability of the project.

- At a minimum, an annual report on the progress of the project is required as well as at the conclusion (or abandonment) of the project. Information on project monitoring and modifications/additions, self-audits and progress reports can be found on the Research Intranet pages.

- A duly authorised external or internal audit of the project may be undertaken at any time.

Please contact the Research Ethics Office if you have any queries about on-going ethics clearance. The SHR project number should be quoted in communication. Researchers should retain a copy of this email as part of project recordkeeping.

Best wishes for the project.

Yours sincerely,

Keith Wilkins for
Dr Astrid Nordmann
Secretary, SHESC1

Keith Wilkins
Secretary, SUHREC & Research Ethics Officer
Swinburne Research (H68)
Swinburne University of Technology
P O Box 218
HAWTHORN VIC 3122
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Appendix A.3

Online Survey Questionnaire (Study 1)-Staff & Student

PART 1: PROJECT INFORMATION CONSENT STATEMENTS

Research Supervisor
Professor John Grundy
Dean, School of Software and Electrical Engineering
Faculty of Science, Engineering and Technology (FSET)
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Email: rvasa@swin.edu.au

Research Supervisor
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Deputy Director (Teaching Practice) of STEMed
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Australia
Ph **+61 3 9214 5324**
Email: acain@swin.edu.au

Researcher
Law Check Yee
PhD Candidate
Faculty of Science, Engineering and Technology
Swinburne University of Technology
PO Box 218, Hawthorn VIC 3122
Australia
Ph +61 413 852 324
Email: claw@swin.edu.au

You are invited to participate in this research study as part of the PhD research of Law Check Yee, supervised by Professor John Grundy, Dr. Rajesh Vasa and Dr. Andrew Cain in the Faculty of Science, Engineering and Technology (FSET) of Swinburne University of Technology. The project is approved by the Swinburne University Human Research Ethics Sub Committee (SUHREC) and conducted under the privacy policy followed by Swinburne University of Technology (http://www.research.swinburne.edu.au/ethics/forms/). Individual responses will not be released or shared. Results from the analysis will be published in collective form. Information provided will be stored electronically on a password protected computer and server in Swinburne University of Technology and will be accessible to the researchers only.

The Research Project
Since e-portfolios have emerged in the nineties as a pedagogical strategy, many higher education institutions are beginning to adopt and deploy e-portfolio systems in the teaching and learning process. However, some researchers have pointed out that some students have been struggling to create e-portfolios. The main reason reported is students have difficulty aligning personal and program goals. This research project aims to close this gap through the development of a visualisation tool. This visualisation tool will help students to manage their learning tasks and display students' achievements in terms of learning outcomes. This tool can guide students in setting and aligning their learning with the learning goals and can help the teaching staff to plan for their teaching.

The Procedure
If you agree to participate in this survey, please visit the following link:
  http://opinio.online.swin.edu.au/s?s=16351 (Staff)
  http://opinio.online.swin.edu.au/s?s=16739 (Student)

You will be introduced to the prototype of this visualisation tool through a video simulation that will show you the features of this tool and how to use it. It will take around 3 minutes to watch this video. The survey questionnaire contains 30 questions and will take, at most, 20 minutes to answer.

Anonymity
No identifying information about the participant will be recorded. If you wish to be informed of the results of the survey, you may provide an email address that we will use to contact you with a report of the results once the study is completed. This address will be stored independently and will NOT be associated with your survey responses.

Voluntary Participation
Your participation in this research is voluntary. You may discontinue participation at any time during the survey without penalty.

Privacy & Confidentiality
The responses provided will be kept confidential and will be used for academic research purposes only. Individual responses will not be released or shared. The signed consent forms will be kept secure in a locked file cabinet for seven years and will be destroyed after that. The archived data can be accessed only by the principal investigator and student investigator. Results from the collective analysis of responses will be published in a publicly available PhD thesis and may be published in journal articles and conference papers.

Research Output
Results from the analysis will be published in a publicly available PhD thesis and may be published in peer-reviewed academic conferences and journals.

Research Ethics
This project has been approved by Swinburne's Human Research Ethics Subcommittee (<SHESC3>) on behalf of Swinburne's Human Research Ethics Committee (SUHREC).

Right to Ask Questions
If you would like further information about the project, please do not hesitate to contact:

Principal Investigator	: Professor John Grundy
Swinburne Contact Address	: Faculty of Science, Engineering and Technology, Swinburne University of Technology, PO Box 218 Hawthorn, Victoria 3122 Australia
(Swinburne) Tel No (s)	: +61 3 9214 8731
(Swinburne) Email (s)	: jgrundy@swin.edu.au
Student Investigator	: Law Check Yee
Swinburne Contact Address	: Faculty of Science, Engineering and Technology, Swinburne University of Technology, PO Box 218 Hawthorn, Victoria 3122 Australia
(Swinburne) Tel No (s)	: +61 4 1385 2324
(Swinburne) Email (s)	: claw@swin.edu.au

Concerns/Complaints
This project has been approved by or on behalf of Swinburne's Human Research Ethics Committee (SUHREC) in line with the *National Statement on Ethical Conduct in Human Research*. If you have any concerns or complaints about the conduct of this project, you can contact:

Research Ethics Officer, Swinburne Research (H68),
Swinburne University of Technology, P O Box 218, HAWTHORN VIC 3122.
Tel (03) 9214 5218 or +61 3 9214 5218 or resethics@swin.edu.au

Online Consent Form

Should you agree to participate, you need to click on the "Agree" button indicating your agreement to participate at the bottom of this page. This will take you to the survey page. Once you have responded to the survey, you need to click on the "Submit" button. By clicking the submit button you are implying your consent for the researchers to use the data for research purposes and that you understand that the submitted data cannot be withdrawn after this.

Agree
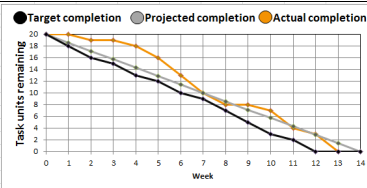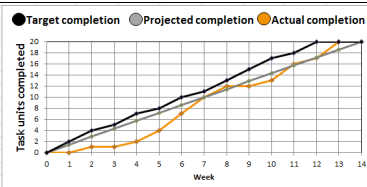
Cancel

PART 2: DEMOGRAPHIC INFORMATION
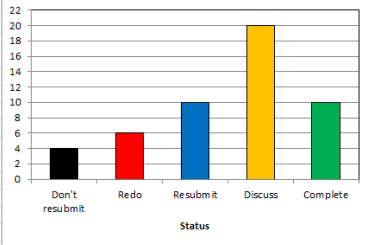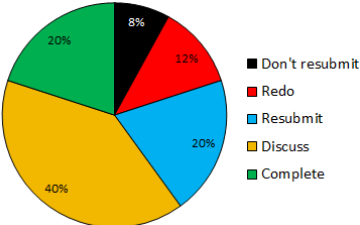
1. Please specify your institution.
    - ○ Swinburne University of Technology
    - ○ Multimedia University

2. What best describes your area?
    - ○ Information Technology
    - ○ Engineering
    - ○ Computer Science
    - ○ Science
    - ○ Other (Please specify _____)

3. Are you:
    - ○ Male
    - ○ Female

4. How familiar are you with data visualisation?
    - ○ Not familiar at all
    - ○ I have heard about it
    - ○ Somewhat familiar
    - ○ Very familiar

PART 3: VISUALISATIONS: RATE BY PERCEIVED USEFULNESS

5. Displaying assessment task status: Assume that in Blackboard you are able to see an individual student's assessment task status displayed by the following visualisations. By using the scale of 1 to 5, indicate the extent to which you think the following representation is useful to present the learning data.
[1-Not useful, 2-Slightly useful, 3-Moderately useful, 4-Useful, 5-Very useful]

Visualisations	**Explanation**	**Rating**				
 Task List	The task list shows the total tasks of a unit for a student. Different colour are used to show the status of the task such as: Green for Complete Grey shows student has not working on this task yet.	1	2	3	4	5
 Burndown Chart	The graph shows the backlog of tasks remaining by week. The yellow line represents a student's progress versus the target completion (black line). The closer the yellow line to the black line, the better the student in completing his/her task on time. The grey line projects a student's completion time based on his/her current progress.	1	2	3	4	5
 Task Completion Chart	The graph shows the number of tasks completed by week. The yellow line represents a student's progress versus the target completion (black line). The closer the yellow line to the black line, the better the student in completing his/her task on time. The grey line projects a student's completion time based on his/her current progress.	1	2	3	4	5

6. Displaying assessment task status statistics: Assume that in Blackboard you are able to see an individual student's assessment task status statistics displayed by the following visualisations. By using the scale of 1 to 5, indicate the extent to which you think the following representation is useful to present the learning data.
[1-Not useful, 2-Slightly useful, 3-Moderately useful, 4-Useful, 5-Very useful]

Visualisations	Explanation	Rating
Task Summary Table Number of students Don't resubmit 4 Redo 6 Resubmit 10 Discuss 20 Complete 10 Total 50	Assume that in a group of 50 students, the status of their task is presented in a table form.	1 2 3 4 5
Task Summary Bar Graph	The status of students' tasks in your group is presented in a bar graph.	1 2 3 4 5
Task Summary Pie Chart	The status of students' tasks in your group is presented in a pie chart.	1 2 3 4 5

7. Displaying an individual student's achievements: Consider that there are 3 learning outcomes, LO1, LO2, and LO3 for your course as follows:
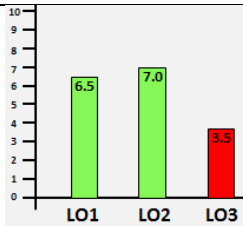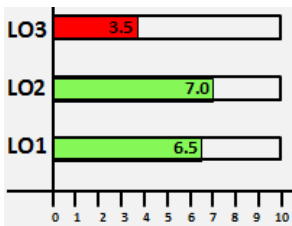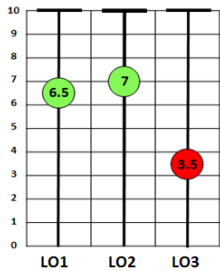
LO1: Proficiently demonstrates communication in English, including listening, speaking, reading and writing.
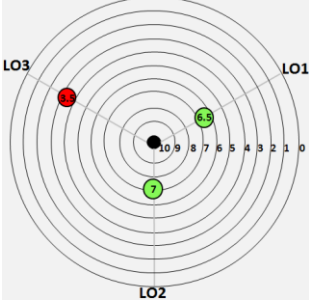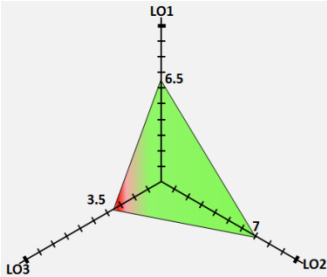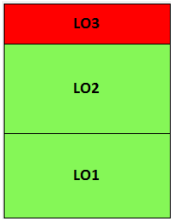
LO2: Uses critical thinking in making judgements and decisions.

LO3: Executes tasks proficiently and on-time.

Assume that in your class, a student's current achievements of **LO1, LO2,** and **LO3** are **6.5, 7.0,** and **3.5** respectively on a scale of 10. In Blackboard you are able to see various visualisations displaying his/her achievements as follows.

By using the scale of 1 to 5, please rate each of the visualisations to the extent you think the following representation is useful to present a student's achievement.
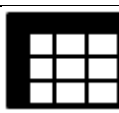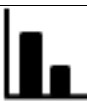[1-Not useful, 2-Slightly useful, 3-Moderately useful, 4-Useful, 5-Very useful]
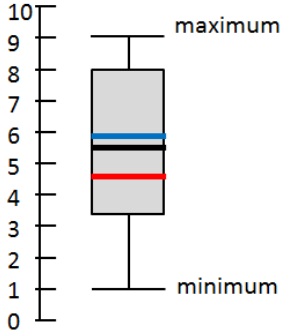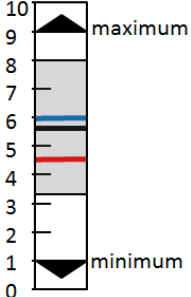
Visualisations	**Explanation** [Green indicates good progression, red for at risk.]	**Rating**
Your achievement for LO1: Proficiently demonstrates communication in English is good. Your achievement for LO2: Uses critical thinking in making judgements and decisions is good. Your achievement for LO3: Executes tasks proficiently and on-time is weak. **Textual Form**	A student's achievement is described by using text: Very good, good, average, weak, and very weak	1 2 3 4 5
 Bar Graph	The height of the bar represents your student's current achievement. Green indicates good progression, red for at risk.	1 2 3 4 5
 Skill Meter	The length of the bar represents your student's current achievement.	1 2 3 4 5
 Grid Plot	The position of the dot represents your student's current achievement.	1 2 3 4 5
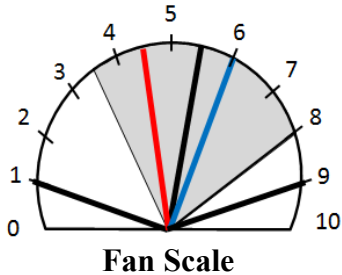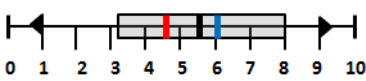
Target Plot	The position of the dot represents your student's current achievement. The closer the dot to the centre (the black dot), the better the achievement is.	1	2	3	4	5
Spider Plot	The plot on the axis represents your student's current achievement. The greater the area formed by the plots, the better the achievement is.	1	2	3	4	5
Tree Map	The area of the rectangle represents your student's current achievement. Bigger areas denote that the student has a better achievement for that competency.	1	2	3	4	5
Smiley Face	A smiley face indicates good achievement, no smile 😐 for average, sad face for at risk.	1	2	3	4	5
Word Cloud	Bigger text size indicates better achievement.	1	2	3	4	5

Visualisation	Explanation	Rating
<table>...</table> **Table**	The dot in the column of the table denotes your student's current achievement.	1 2 3 4 5
Star Pictogram	The number of stars represents your student's current achievement.	1 2 3 4 5

The first visualisation (Table) shows a grid with columns: Very weak, Weak, Average, Good, Excellent. LO1 has a green dot under Good, LO2 has a green dot under Good, LO3 has a red dot under Weak.

The Star Pictogram shows: LO1 with 6.5 green stars, LO2 with 7 green stars, LO3 with 3.5 red stars.
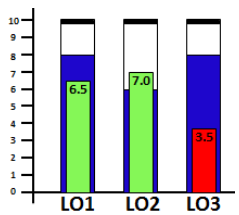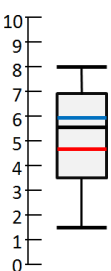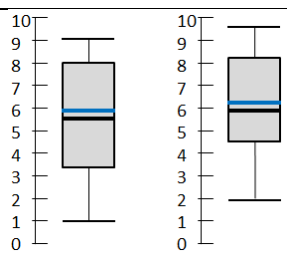
8.   Displaying group achievement: Assume that in Blackboard you are able to see group achievement of LO1 displayed by the following visualisations. By using the scale of 1 to 5, indicate the extent to which you think the following representation is useful to present group learning outcome achievement.
[1-Not useful, 2-Slightly useful, 3-Moderately useful, 4-Useful, 5-Very useful]

These visualisations will show the data for average, maximum, minimum, median, and range score of most of the students (50%) in a group/class. Individual achievement will only be shown if an individual student is selected.

Visualisations	Explanation	Rating
Boxplot	■ group achievement ■ individual achievement ■ median □ 50% of the students falls in this range	1 2 3 4 5
Ladder Scale	■ group achievement ■ individual achievement ■ median □ 50% of the students falls in this range ▲ maximum ▼ minimum	1 2 3 4 5

Visualisation	Legend	Rating
Fan Scale	■ group achievement (blue) ■ individual achievement (red) ■ median □ 50% of the students falls in this range	1 2 3 4 5
Line Scale	■ group achievement (blue) ■ individual achievement (red) ■ median □ 50% of the students falls in this range ▶ maximum ◀ minimum	1 2 3 4 5

9. Displaying comparison of learning outcome achievements: Please indicate the extent to which you think the following representation is useful to present the comparison of a student's learning outcome achievements.
[1-Not useful, 2-Slightly useful, 3-Moderately useful, 4-Useful, 5-Very useful]

Visualisations	**Explanation**	**Rating**
	Blue represents class achievement. Green or red denotes individual achievement. The comparison can be seen from the height of the bars.	1 2 3 4 5
	The blue indicates class achievement, black denotes class median score, the red line denotes an individual student's achievement.	1 2 3 4 5
	Compare 2 subgroups.	1 2 3 4 5

PART 4: VISUALISATIONS: RATE BY PREFERENCE
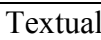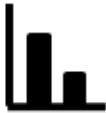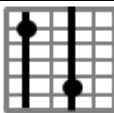
10.   Select 1 of your most preferred visualisation to view the assessment task status.

Visualisations	Select 1 of your most preferred view.	Why do you prefer this specific visualisation?
Task List	☐	
Burndown Chart	☐	
Task Completion Chart	☐	

11.   Select 1 of your most preferred visualisation to view the assessment task status statistics.

Visualisations	Select 1 of your most preferred view.	Why do you prefer this specific visualisation?
Task Summary Table	☐	
Task Summary Bar Graph	☐	
Task Summary Pie Chart	☐	
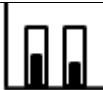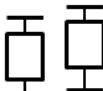
12. Select 3 of your preferred visualisations to view an individual student's learning outcome achievements.

Visualisations	Select 3 of your most preferred views.	Why do you prefer this specific visualisation?
Textual Textual Form	☐	
Bar Graph	☐	
Skill Meter	☐	
Grid Plot	☐	
Target Plot	☐	
Spider Plot	☐	
Tree Map	☐	
Smiley Face	☐	
Word Cloud	☐	
Table	☐	
Star Pictogram	☐	

13. Select 1 of your most preferred visualisation to view the group achievements.

Visualisations	Select 1 of your most preferred view.	Why do you prefer this specific visualisation?
Boxplot	☐	
Ladder Scale	☐	
Fan Scale	☐	
Line Scale	☐	

14. Select 1 of your most preferred visualisation to view the comparison of learning outcome achievements.

Visualisations	Select 1 of your most preferred view.	Why do you prefer this specific visualisation?
Compare Group Average	☐	
Compare with Group Statistics	☐	
Compare Subgroups	☐	

PART 5: OPEN ENDED QUESTIONS

15.   Please suggest improvements to the visualisations that you think would help you/students.

_____
_____

16.   Are there any other information visualisation approaches that you think could assist you/students to better understand your/student progress and achievements?

_____
_____

17.   In your opinion, do you see any barriers in using these visualisations?

_____
_____

18.   Other comments.

_____
_____

THANK YOU

Reminder

This is the end of the questionnaire. Please be reminded that by clicking on the "Submit" button, you are implying your consent for the researchers to use the data for research purposes and understand that the data cannot be withdrawn after submission.

Submit

Cancel

Appendix A.4

Online Survey Questionnaire (Study 2)-Staff

PART 1: PROJECT INFORMATION CONSENT STATEMENTS

Research Supervisor
Dr Andrew Cain
Deputy Director (Teaching Practice) of STEMed
Senior Lecturer
Faculty of Science, Engineering and Technology (FSET)
Swinburne University of Technology

Research Supervisor
Professor John Grundy
Professor of Software Engineering
Faculty of Science Engineering & Built Environment
Deakin University

Research Supervisor
Dr Rajesh Vasa
Deputy Director, Deakin Software and Technology Innovation Laboratory
Faculty of Science Engineering & Built Environment
Deakin University

Researcher
Law Check Yee
PhD Candidate

Project Title: <u>Evaluation of Doubtfire++ Open Learner Model (OLM) Prototype Tool</u>

You are invited to participate in this research study as part of the PhD research of Law Check Yee, supervised by Dr Andrew Cain in the Faculty of Science, Engineering and Technology (FSET) of Swinburne University of Technology, Professor John Grundy and Dr. Rajesh Vasa in Deakin University. The project, SHR Project 2015/309, has been approved by the Swinburne University Human Research Ethics Sub Committee (SHESC1) and will be conducted in Swinburne University of Technology, Australia, under the privacy policy followed by Swinburne University of Technology. Individual responses will not be released or shared. Results from the analysis will be published in collective form. Information provided will be stored electronically on a password protected computer and server in Swinburne University of Technology and will be accessible to the researchers only.

The Research Project
A new Open Learner Model (OLM) prototype tool, Doubtfire++ has been designed and developed to track learning tasks. This tool may be able to help students to manage their learning tasks and facilitate them in reflecting on their achievement in terms of learning outcomes. For teaching staff, this tool may be able to help them to monitor student progress

and achievements and to plan their teaching. Users can gain insights about learning task activities, student progress and learning outcome achievements from this tool.

When users interact with a tool or product to perform their tasks or to achieve their goals, their personal experience using it will be formed. Their experience has a great impact on the success or failure of a product or a tool. Thus, user experience that closely relates to usability issues is an important aspect to study. Besides that, user attitude and behaviour toward using the prototype tool that characterize their acceptance of the tool is also a valuable aspect to be evaluated, in order to better understand the overall performance of the tool.

We seek your help in giving us feedback on our Doubtfire++ prototype tool to help us understand the potential benefits and any drawbacks of the tool for supporting student learning. We will ask you to carry out a survey to indicate the importance of the tool in addressing your teaching and learning related needs and issues as well as to rate your experience interacting with it. Four open-ended questions that follow will solicit your input to describe your experience, any problems encountered and your recommendations on how to improve the tool.

The Procedure
If you agree to participate in this survey, please visit the following link:

http://opinio.online.swin.edu.au/s?s=17562

The survey questionnaire contains 18 questions and will take around 10-15 minutes to answer.

Anonymity
No identifying information about you will be recorded. If you wish to be informed of the results of the survey, you may provide an email address that we will use to contact you with a report of the results once the study is completed. This address will be stored independently and will NOT be associated with your survey responses.

Voluntary Participation
Your participation in this research is voluntary. You may discontinue participation at any time during the survey without any penalty.

Privacy & Confidentiality
The responses provided will be kept confidential and will be used for academic research purposes only. Individual responses will not be released or shared. The signed consent forms will be kept secure in a locked file cabinet for a minimum period of five years post-publication and will be securely destroyed after that. The archived data can be accessed only by the principal investigator and student investigator. Results from the collective analysis of responses will be published in a publicly available PhD thesis and may be published in journal articles and conference papers.

Research Output

Results from the analysis will be published in a publicly available PhD thesis and may be published in peer-reviewed academic conferences and journals.

Right to Ask Questions

If you would like further information about the project, please do not hesitate to contact:

Principal Investigator : Dr Andrew Cain
Swinburne Contact Address : Faculty of Science, Engineering and Technology,
    Swinburne University of Technology, PO Box 218
    Hawthorn, Victoria 3122 Australia
(Swinburne) Tel No (s) : +61 3 9214 5324
(Swinburne) Email (s) : acain@swin.edu.au

Student Investigator : Law Check Yee
Swinburne Contact Address : Faculty of Science, Engineering and Technology,
    Swinburne University of Technology, PO Box 218
    Hawthorn, Victoria 3122 Australia
(Swinburne) Tel No (s) : +61 4 1385 2324
(Swinburne) Email (s) : claw@swin.edu.au

Concerns/Complaints

This project has been approved by Swinburne's Human Research Ethics Subcommittee on behalf of Swinburne's Human Research Ethics Committee (SUHREC) in line with the *National Statement on Ethical Conduct in Human Research*. If you have any concerns or complaints about the conduct of this project, you can contact:

Research Ethics Officer, Swinburne Research (H68),
Swinburne University of Technology, P O Box 218, HAWTHORN VIC 3122.
Tel (03) 9214 5218 or +61 3 9214 5218 or resethics@swin.edu.au

Online Consent Form

Should you agree to participate, you need to click on the "Start" button indicating your agreement to participate at the bottom of this page. This will take you to the survey page.

Start

Cancel

PART 2: DEMOGRAPHIC INFORMATION

1.   How familiar are you with data visualisation?
        ○ Not familiar at all
        ○ I have heard about it
        ○ Somewhat familiar
        ○ Very familiar

2.   Are you:
        ○ Male
        ○ Female

3.   Have you ever used Doubtfire++ in any of your units?
        ○ Yes
        ○ No

4.   In which years have you used Doubtfire++?
        ○ 2016 only
        ○ 2016 and earlier

5.   For units using Doubtfire++, which of the following functions did you perform in 2016? Select all that apply.
        ○ I setup units (Convenor)
        ○ Delivered lectures
        ○ Conduct tutorials
        ○ Other, please specify.

6.   How frequent did you access Doubtfire++?
        ○ Always (Almost everyday)
        ○ Often (A few times in a week)
        ○ Sometimes (at least 2 times in a week)
        ○ Occasionally (less than 2 times in a week)
        ○ Rarely (1-2 times throughout the semester)

7.   In which of the following units did you use Doubtfire++ in this semester? Select all that apply.
        ○ Concurrent Programming (COS40003)
        ○ Creating Data Driven Mobile Applications (COS80020)
        ○ Database Implementation (INF30011)
        ○ Database Implementation (INF80033)
        ○ Development Project 1: Tools and Practices (SWE20001)
        ○ Development Project 2: Design, Planning and
        ○ Management(SWE30010)
        ○ Enterprise Development (SWE80005)

○ Enterprise Development (UG) (SWE40003)
○ Interface Design and Development (COS30043)
○ Introduction to Programming (COS10009-COS60006)
○ Object Oriented Programming (COS20007)
○ Object Oriented Programming (COS70006)
○ Problem Solving With ICT (ICT10001)
○ User-Centred Design (COS20001-COS70004)
○ I prefer not to disclose

8. Which of the following assessment types can best describe your unit?
    ○ Fully portfolio assessment.
    ○ Partial portfolio assessment.
    ○ No portfolio assessment.
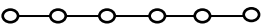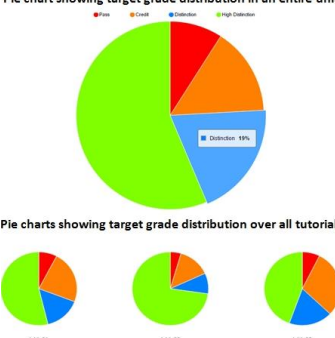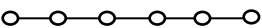
PART 3: VISUALISATIONS: RATE BY PERCEIVED USEFULNESS
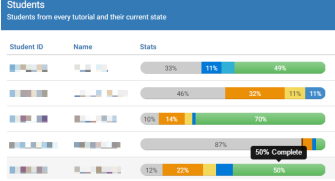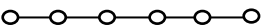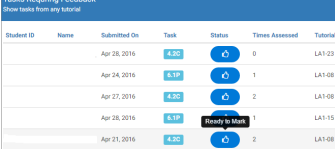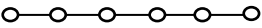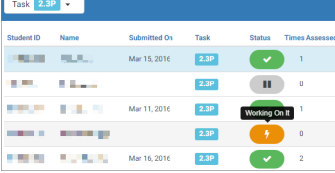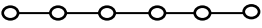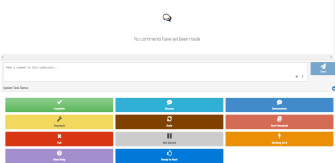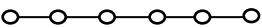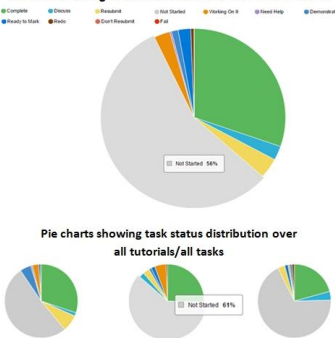
9. Doubtfire++ exploits various visualisations to communicate student progress and achievement. Please rate each of the following visualisations to the extent that it would be useful to you/students. Briefly explain how you used this visualisation, and why it was useful / not useful.
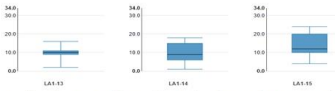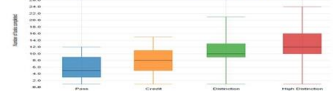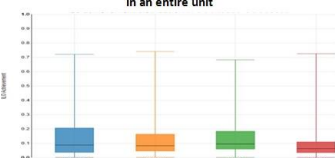   [1-Not useful, 2-Slightly useful , 3-Moderately useful, 4-Useful, 5-Very useful, 6-Did not use]

    ```
    O——O——O——O——O——O
    1   2   3   4   5   6
    Not useful          Very useful   Did not use
    ```

Visualisations	Rating	Briefly explain how you used this visualisation, and why it was useful / not useful.
Target Grade Select the grade you wish to achieve in the unit. P C D HD You target grade is **Distinction**. Target Grade Setting	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	
Task List	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	

Focus List	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	
Burndown Chart	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	
Task Summary Chart	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	
Outcome Alignment and Achievement	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	
Outcome Alignment and Achievement Task View	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	
Task Alignment Rating	For me: 1 2 3 4 5 6 For student: 1 2 3 4 5 6	

Progress Bar	For me: 1 2 3 4 5 6	
Task Requiring Feedback	For me: 1 2 3 4 5 6	
View by Specific Task	For me: 1 2 3 4 5 6	
Feedback Interface	For me: 1 2 3 4 5 6	
Task Status Distribution	For me: 1 2 3 4 5 6	
Target Grade Distribution	For me: 1 2 3 4 5 6	

  Task Completion Statistics	For me: 1 2 3 4 5 6 ○—○—○—○—○—○	
  LO Achievement Statistics	For me: 1 2 3 4 5 6 ○—○—○—○—○—○	

PART 4: ADDRESSING OLM SUPPORT TO DIFFERENT USER ROLES

10. Please indicate to what extent you agree or disagree with the following statements about your usage of Doubtfire++ for supporting student learning.
     [1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree]

Doubtfire++ helped students…

#	Items	Strongly disagree				Strongly agree
1	…see the links between tasks and learning outcomes.	1	2	3	4	5
2	…to engage with learning outcomes.	1	2	3	4	5
3	…to easily submit work for feedback.	1	2	3	4	5
4	…to easily access tasks.	1	2	3	4	5
5	…to manage their learning.	1	2	3	4	5
6	…to keep on track.	1	2	3	4	5
7	…to act upon feedback they received.	1	2	3	4	5
8	…to be motivated to complete tasks.	1	2	3	4	5
9	… to engage with learning	1	2	3	4	5
10	…self-evaluate to showcase achievements in portfolios.	1	2	3	4	5
11	…self-evaluate to prepare for final assessment.	1	2	3	4	5
12	…make self-judgement to attain greater achievement.	1	2	3	4	5
13	…make self-judgement to retain learning artefacts.	1	2	3	4	5
14	…gain self-satisfaction to construct knowledge.	1	2	3	4	5
15	…self-evaluate own progress.	1	2	3	4	5

11. Please indicate to what extent you agree or disagree with the following statements about your usage of Doubtfire++ for supporting student learning.
[1-Strongly disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly agree]

#	Items	Strongly disagree				Strongly agree
1	Helped me to monitor student progress.	1	2	3	4	5
2	Easy to assess student portfolio in final assessment.	1	2	3	4	5
3	Task statuses helped me guide discussion with student.	1	2	3	4	5
4	Easy to see task awaiting feedback.	1	2	3	4	5
5	Easy to provide feedback to students.	1	2	3	4	5
6	Grade aspiration helped me understand student needs.	1	2	3	4	5
7	Helped me to reflect on my teaching.	1	2	3	4	5
8	Grade aspiration helped me guide student learning.	1	2	3	4	5

12. Please indicate to what extent you agree or disagree with the following statements about your usage of Doubtfire++ as a convenor.
[1-Strongly disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly agree]

#	Items	Strongly disagree				Strongly agree
1	Linking tasks to outcomes helped me reflect on how the tasks aimed to develop student learning.	1	2	3	4	5
2	Doubtfire++ made it easy to setup the unit (its tasks, outcomes, etc).	1	2	3	4	5
3	Analytic data helped me track progress of the student cohort.	1	2	3	4	5
4	Analytic data helped me guide others teaching in the unit.	1	2	3	4	5

PART 5: USER EXPERIENCE INTERACTING WITH DOUBTFIRE++

13. Please indicate the extent to which you agree or disagree with the statement about your experience interacting with Doubtfire++ on a scale of 1 to 5.
    [1-Strongly disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly agree]

#	Items	Strongly disagree				Strongly agree
1	Having Doubtfire++ is a good idea.	1	2	3	4	5
2	It is a pleasant experience using Doubtfire++.	1	2	3	4	5
3	I am satisfied with Doubtfire++.	1	2	3	4	5
4	I will recommend Doubtfire++ to others.	1	2	3	4	5

14. In comparison to previously, please rate the effect of the additional features in Doubtfire++ on the following aspects to student learning:
    [1-Worse, 2-Same, 3-Better]

#	Items	1 Worse	2 Same	3 Better
1	Manage learning.	1	2	3
2	Track learning.	1	2	3
3	Guide student learning.	1	2	3
4	Connected to teaching staff.	1	2	3
5	Align learning with LOs.	1	2	3
6	Reflect on learning.	1	2	3
7	Access learning artefacts.	1	2	3
8	Prepare for final assessment.	1	2	3

PART 6: OPEN ENDED QUESTIONS

15. Describe your experience in using Doubtfire++.

   _____

   _____

16. List out the major problems that you encounter when using this tool, if any.

   _____

   _____

17. Please suggest improvements to Doubtfire++ that you think would help you/students.

   _____

   _____

18. Other comments.

   _____

   _____

THANK YOU

Reminder

This is the end of the questionnaire. Please be reminded that by clicking on the "Submit" button, you are implying your consent for the researchers to use the data for research purposes and understand that the data cannot be withdrawn after submission.

Submit

Cancel

Appendix A.5

Online Survey Questionnaire (Study 2)-Student

PART 1: PROJECT INFORMATION CONSENT STATEMENTS

Research Supervisor
Dr Andrew Cain
Deputy Director (Teaching Practice) of STEMed
Senior Lecturer
Faculty of Science, Engineering and Technology (FSET)
Swinburne University of Technology

Research Supervisor
Professor John Grundy
Professor of Software Engineering
Faculty of Science Engineering & Built Environment
Deakin University

Research Supervisor
Dr Rajesh Vasa
Deputy Director, Deakin Software and Technology Innovation Laboratory
Faculty of Science Engineering & Built Environment
Deakin University

Researcher
Law Check Yee
PhD Candidate

Project Title: <u>Evaluation of Doubtfire++ Open Learner Model (OLM) Prototype Tool</u>

You are invited to participate in this research study as part of the PhD research of Law Check Yee, supervised by Dr Andrew Cain in the Faculty of Science, Engineering and Technology (FSET) of Swinburne University of Technology, Professor John Grundy and Dr. Rajesh Vasa in Deakin University. The project, SHR Project 2015/309, has been approved by the Swinburne University Human Research Ethics Sub Committee (SHESC1) and will be conducted in Swinburne University of Technology, Australia, under the privacy policy followed by Swinburne University of Technology. Individual responses will not be released or shared. Results from the analysis will be published in collective form. Information provided will be stored electronically on a password protected computer and server in Swinburne University of Technology and will be accessible to the researchers only.

The Research Project
A new Open Learner Model (OLM) prototype tool, Doubtfire++ has been designed and developed to track learning tasks. This tool may be able to help students to manage their learning tasks and facilitate them in reflecting on their achievement in terms of learning outcomes. For teaching staff, this tool may be able to help them to monitor student progress and achievements and to plan their teaching. Users can gain insights about learning task activities, student progress and learning outcome achievements from this tool.

When users interact with a tool or product to perform their tasks or to achieve their goals, their personal experience using it will be formed. Their experience has a great impact on the success or failure of a product or a tool. Thus, user experience that closely relates to usability issues is an important aspect to study. Besides that, user attitude and behaviour toward using the prototype tool that characterize their acceptance of the tool is also a valuable aspect to be evaluated, in order to better understand the overall performance of the tool.

We seek your help in giving us feedback on our Doubtfire++ prototype tool to help us understand the potential benefits and any drawbacks of the tool for supporting student learning. We will ask you to carry out a survey to indicate the importance of the tool in addressing your teaching and learning related needs and issues as well as to rate your experience interacting with it. Four open-ended questions that follow will solicit your input to describe your experience, any problems encountered and your recommendations on how to improve the tool.

The Procedure
If you agree to participate in this survey, please visit the following link:

http://opinio.online.swin.edu.au/s?s=17563

The survey questionnaire contains 15 questions and will take around 10-15 minutes to answer.

Anonymity
No identifying information about you will be recorded. If you wish to be informed of the results of the survey, you may provide an email address that we will use to contact you with a report of the results once the study is completed. This address will be stored independently and will NOT be associated with your survey responses.

Voluntary Participation
Your participation in this research is voluntary. You may discontinue participation at any time during the survey without any penalty.

Privacy & Confidentiality
The responses provided will be kept confidential and will be used for academic research purposes only. Individual responses will not be released or shared. The signed consent forms will be kept secure in a locked file cabinet for a minimum period of five years post-publication and will be securely destroyed after that. The archived data can be accessed only by the principal investigator and student investigator. Results from the collective analysis of responses will be published in a publicly available PhD thesis and may be published in journal articles and conference papers.

Research Output

Results from the analysis will be published in a publicly available PhD thesis and may be published in peer-reviewed academic conferences and journals.

Right to Ask Questions

If you would like further information about the project, please do not hesitate to contact:

Principal Investigator	: Dr Andrew Cain
Swinburne Contact Address	: Faculty of Science, Engineering and Technology, Swinburne University of Technology, PO Box 218 Hawthorn, Victoria 3122 Australia
(Swinburne) Tel No (s)	: +61 3 9214 5324
(Swinburne) Email (s)	: acain@swin.edu.au
Student Investigator	: Law Check Yee
Swinburne Contact Address	: Faculty of Science, Engineering and Technology, Swinburne University of Technology, PO Box 218 Hawthorn, Victoria 3122 Australia
(Swinburne) Tel No (s)	: +61 4 1385 2324
(Swinburne) Email (s)	: claw@swin.edu.au

Concerns/Complaints

This project has been approved by Swinburne's Human Research Ethics Subcommittee on behalf of Swinburne's Human Research Ethics Committee (SUHREC) in line with the *National Statement on Ethical Conduct in Human Research*. If you have any concerns or complaints about the conduct of this project, you can contact:

Research Ethics Officer, Swinburne Research (H68),
Swinburne University of Technology, P O Box 218, HAWTHORN VIC 3122.
Tel (03) 9214 5218 or +61 3 9214 5218 or resethics@swin.edu.au

Online Consent Form

Should you agree to participate, you need to click on the "Start" button indicating your agreement to participate at the bottom of this page. This will take you to the survey page. Once you have completed the survey, you need to click on the "Submit" button. By clicking the submit button, you are implying your consent for the researchers to use the data for research purposes and that you understand that the submitted data cannot be withdrawn after this.

> Start

> Cancel

PART 2: DEMOGRAPHIC INFORMATION

1.   How familiar are you with data visualisation?
        ○ Not familiar at all
        ○ I have heard about it
        ○ Somewhat familiar
        ○ Very familiar

2.   Are you:
        ○ Male
        ○ Female

3.   Have you ever used Doubtfire++ in any of your units?
        ○ Yes
        ○ No

4.   In which years have you used Doubtfire++?
        ○ 2016 only
        ○ 2016 and earlier

5.   How frequent did you access Doubtfire++?
        ○ Always (Almost everyday)
        ○ Often (A few times in a week)
        ○ Sometimes (at least 2 times in a week)
        ○ Occasionally (less than 2 times in a week)
        ○ Rarely (1-2 times throughout the semester)

6.   In which of the following units did you use Doubtfire++ in this semester? Select all
        that apply.
        ○ Concurrent Programming (COS40003)
        ○ Creating Data Driven Mobile Applications (COS80020)
        ○ Database Implementation (INF30011)
        ○ Database Implementation (INF80033)
        ○ Development Project 1: Tools and Practices (SWE20001)
        ○ Development Project 2: Design, Planning and
        ○ Management(SWE30010)
        ○ Enterprise Development (SWE80005)
        ○ Enterprise Development (UG) (SWE40003)
        ○ Interface Design and Development (COS30043)
        ○ Introduction to Programming (COS10009-COS60006)
        ○ Object Oriented Programming (COS20007)
        ○ Object Oriented Programming (COS70006)
        ○ Problem Solving With ICT (ICT10001)
        ○ User-Centred Design (COS20001-COS70004)

○ I prefer not to disclose

7. Which of the following assessment types can best describe your unit?
   ○ Fully portfolio assessment.
   ○ Partial portfolio assessment.
   ○ No portfolio assessment.

PART 3: VISUALISATIONS: RATE BY PERCEIVED USEFULNESS

8. Doubtfire++ exploits various visualisations to communicate student progress and achievement. Please rate each of the following visualisations to the extent that it would be useful to you. Briefly explain how you used this visualisation, and why it was useful / not useful.
   [1-Not useful, 2-Slightly useful , 3-Moderately useful, 4-Useful, 5-Very useful, 6-Did not use]

   1   2   3   4   5   6
   Not useful   Very useful   Did not use

Items	Rating	Briefly explain how you used this visualisation, and why it was useful / not useful.
Target Grade Setting	1 2 3 4 5 6	
Task List	1 2 3 4 5 6	
Focus List	1 2 3 4 5 6	

Burndown Chart	1 2 3 4 5 6 o—o—o—o—o—o	
Task Summary Chart	1 2 3 4 5 6 o—o—o—o—o—o	
Outcome Alignment and Achievement	1 2 3 4 5 6 o—o—o—o—o—o	
Outcome Alignment and Achievement Task View	1 2 3 4 5 6 o—o—o—o—o—o	
Task Alignment Rating	1 2 3 4 5 6 o—o—o—o—o—o	

PART 4: ADDRESSING OLM SUPPORT TO STUDENT

9. Please indicate to what extent you agree or disagree with the following statements about your usage of Doubtfire++ for supporting your learning.
    [1-strongly disagree, 2-disagree, 3-neutral, 4-agree, 5-strongly agree]

    Doubtfire++ helped me…

#	Items	Strongly disagree				Strongly agree
1	…see the links between tasks and learning outcomes.	1	2	3	4	5
2	…engage with learning outcomes.	1	2	3	4	5
3	…to easily submit work for feedback.	1	2	3	4	5
4	…to easily access tasks.	1	2	3	4	5
5	…manage my learning.	1	2	3	4	5
6	…keep on track.	1	2	3	4	5
7	…act upon feedback I received.	1	2	3	4	5
8	…to be motivated to complete tasks.	1	2	3	4	5
9	…engage with learning	1	2	3	4	5
10	…self-evaluate to showcase achievements in portfolios.	1	2	3	4	5
11	…self-evaluate to prepare for final assessment.	1	2	3	4	5
12	…make self-judgement to attain greater achievement.	1	2	3	4	5
13	…make self-judgement to retain learning artefacts.	1	2	3	4	5
14	…gain self-satisfaction to construct knowledge.	1	2	3	4	5
15	…self-evaluate my own progress.	1	2	3	4	5

PART 5: USER EXPERIENCE INTERACTING WITH DOUBTFIRE++

10. Please indicate the extent to which you agree or disagree with the statement about your experience interacting with Doubtfire++ on a scale of 1 to 5.
    [1-Strongly disagree, 2-Disagree, 3-Neutral, 4-Agree, 5-Strongly agree]

#	Items	Strongly disagree				Strongly agree
1	Having Doubtfire++ is a good idea.	1	2	3	4	5
2	It is a pleasant experience using Doubtfire++.	1	2	3	4	5
3	I am satisfied with Doubtfire++.	1	2	3	4	5
4	I will recommend Doubtfire++ to others.	1	2	3	4	5

11. In comparison to previously, please rate the effect of the additional features in Doubtfire++ on the following aspects to your learning:
    [1-Worse, 2-Same, 3-Better]

#	Items	1 Worse	2 Same	3 Better
1	Manage learning.	1	2	3
2	Track learning.	1	2	3
3	Guide my learning.	1	2	3
4	Connected to teaching staff.	1	2	3
5	Align learning with LOs.	1	2	3
6	Reflect on learning.	1	2	3
7	Access learning artefacts.	1	2	3
8	Prepare for final assessment.	1	2	3

PART 6: OPEN ENDED QUESTIONS

12.   Describe your experience in using Doubtfire++.

_____

_____

13.   List out the major problems that you encounter when using this tool, if any.

_____

_____

14.   Please suggest improvements to Doubtfire++ that you think would help you.

_____

_____

15.   Other comments.

_____

_____

THANK YOU

Reminder

This is the end of the questionnaire. Please be reminded that by clicking on the "Submit" button, you are implying your consent for the researchers to use the data for research purposes and understand that the data cannot be withdrawn after submission.

```
Submit
```

```
Cancel
```

Appendix A.6

Contact for interview

We would like to interview some respondents to find out more detail about their experience using Doubtfire, their recommendations and their acceptance of this tool in the teaching and learning process.

1. Please fill up your contact information if you are willing to be interviewed or join the focus group discussion. Otherwise, leave the columns blank and click "Finish" if you opt out to be interviewed.

Name:	Email:	Contact number:

Finish

Appendix A.7

Consent Form (Study 1)-Interview

Project Title : A study of convenor and student opinions on open learner model visualisations

Principal Investigator : Professor John Grundy
Dean, School of Software and Electrical Engineering
Faculty of Science, Engineering and Technology (FSET)
Swinburne University of Technology
PO Box 218, Hawthorn VIC 3122
Australia
Ph +61 3 9214 8731
Email: jgrundy@swin.edu.au

I consent to participate in the project named above. I have been provided with a copy of the Project Information Consent Statements to which this consent form relates and any questions I have asked have been answered to my satisfaction.

In relation to this project, please circle your response to the following:

- I agree to be interviewed by the researcher   Yes   No

- I agree to allow the interview to be recorded on an electronic device   Yes   No

- I agree to make myself available for further information if required   Yes   No

I acknowledge that:

(a) my participation is voluntary and that I am free to withdraw from the project at any time without explanation;

(b) the Swinburne project is for the purpose of research and not for profit;

(c) my anonymity is preserved and I will not be identified in publications or otherwise without my express written consent.

By signing this document I agree to participate in this project.

Name of Participant:

………………………………………………………………

Signature & Date: ………………………………………………………………

Appendix A.8

Consent Form (Study 2)-Interview

Project Title   **:** Evaluation of Doubtfire++ Open Learner Model

                                     (OLM) Prototype Tool

Principal Investigator   **:** Dr Andrew Cain
Senior lecturer, School of Software and Electrical
Engineering, Faculty of Science, Engineering and
Technology (FSET),
Swinburne University of Technology
PO Box 218, Hawthorn VIC 3122 Australia
Ph +61 3 9214 5324
Email: acain@swin.edu.au

I consent to participate in the project named above. I have been provided with a copy of the Project Information Consent Statements to which this consent form relates and any questions I have asked have been answered to my satisfaction.

In relation to this project, please circle your response to the following:

- I agree to be interviewed or to join the focus group discussion.   Yes   No
- I agree to allow the interview or discussion to be recorded on an electronic device.   Yes   No
- I agree to make myself available for further information if required.   Yes   No

I acknowledge that:

(a) my participation is voluntary and that I am free to withdraw from the project at any time without explanation;

(b) the Swinburne project is for the purpose of research and not for profit;

(c) my anonymity is preserved and I will not be identified in publications or otherwise without my express written consent.

By signing this document I agree to participate in this project.

Name of Participant:

……………………………………………………………

Signature & Date: ……………………………………………………………

Appendix A.9

Staff Interview Plan (Study 1)

Interviewee Code: **C0X**

PART 1: DEMOGRAPHIC QUESTIONS

1. User roles
2. Teaching field
3. Gender
4. Familiarity with information visualisation

PART 2: OLM VISUALITIONS FROM USER PERSPECTIVES

5. Among the proposed visualisation, which one do you think can best represent a student's: Learning task status? Task statistics? An individual student's learning outcome achievements? Group learning outcome achievements? Comparison of learning outcomes? Why or why not?
6. Do you find this visualisation tool is useful for you/students to see their achievement in terms of: Learning task status? Learning outcome achievements? Why or why not?
7. What are your preferred visualisations? Why?
8. Using this visualisation tool to view student progress and achievements in terms of learning outcomes, how will this affect your teaching? How will this affect students in their learning?

PART 3: QUESTIONS FOR ADDRESSING QUANTITATIVE RESULTS

9. Do you think it is important for students to know the achievements of their peers or class achievement? Why or why not?
10. How do you perceive Task List/Task Summary Pie Chart/Bar Graph/Boxplot and Compare Group Average visualisations?
11. Do you find comparison feature is useful to you? Why or why not?
12. Do you find comparison feature is useful to students? Why or why not?
13. Do you think the Compare Group Average is important to you? Why or why not?
14. Do you think the Compare Group Average is important to your students? Why or why not?

PART 4: IMPROVEMENTS AND BARRIERS

15. Are there any other information visualisation approaches that you think could assist you to better understand student progress and achievements?
16. Do you have any suggestions on improving the proposed visualisations?
17. What other features would you like to see in the proposed visualisations?
18. Do you see any barriers in using these visualisations?

Appendix A.10

Student Interview Plan (Study 1)

Interviewee Code   **C0X**

PART 1: DEMOGRAPHIC QUESTIONS

1. User roles
2. Field of study
3. Gender
4. Familiarity with information visualisation

PART 2: OLM VISUALITIONS FROM USER PERSPECTIVES

5. Among the proposed visualisation, which one do you think can best represent your: Learning task status? Task statistics? An individual student's learning outcome achievements? Group learning outcome achievements? Comparison of learning outcomes? Why or why not?
6. Do you find this visualisation tool is useful for you to see your achievement in terms of: Learning task status? Learning outcome achievements? Why or why not?
7. What are your preferred visualisations? Why?
8. Using this visualisation tool to view your progress and achievements in terms of learning outcomes, how will this affect your learning?

PART 3: QUESTIONS FOR ADDRESSING QUANTITATIVE RESULTS

9. Do you think it is important for you to know the achievements of your peers or class achievement? Why or why not?
10. How do you perceive Task List/Task Summary Pie Chart/Bar Graph/Boxplot and Compare Group Average visualisations?
11. Do you find comparison feature is useful to you? Why or why not?
12. Do you think the Compare Group Average is important to you? Why or why not?

PART 4: IMPROVEMENTS AND BARRIERS

13. Are there any other information visualisation approaches that you think could assist you to better understand your progress and achievements?
14. Do you have any suggestions on improving the proposed visualisations?
15. What other features would you like to see in the proposed visualisations?
16. Do you see any barriers in using these visualisations?

Appendix A.11

Staff Interview Plan (Study 2)

Interviewee Code   **C0X**
Focus Group Discussion Session Code   **D0X**

PART 1: DEMOGRAPHIC QUESTIONS

1. Teaching field
2. Assessment type
3. Gender
4. Doubtfire++ usage
5. Experience using Doubtfire++
6. Experience with information visualisation

PART 2: THE USE OF OLM VISUALITIONS

7. How did Doubtfire++ support your role as a convenor/teaching staff?
8. Did you find Doubtfire++ useful to you/ your students? Why or why not?
9. Describe your interaction with each of the visualisations.
10. Which features/visualisaions of Doubtfire++ did you find most beneficial to you/ your students? Why?
11. (Refer the visualisations in the survey questionnaire.) Which of these visualisations did you use the most/the least/have never used? Why?
12. How did it affect your teaching?
13. How did it affect your student's learning?

PART 3: QUESTIONS FOR ADDRESSING QUANTITATIVE RESULTS

14. How did you use the Target Grade Setting visualisation?
15. How often did you use the Target Grade Setting visualisation?
16. How many of your units used Doubtfire++?
17. Is there any difference the way Doubtfire++ was used in different teaching units?
18. How Doubtfire++ was used in unit A as compared to unit B?

PART 4: ADDITIONAL DOUBTFIRE++ FEATURES

(For those staff who have experience using the previous version of Doubtfire++)

19. Did you see any difference between previous Doubtfire++ and current Doubtfire++ tool?
20. In comparison to previous version, is the enhanced version, Doubtfire++, better? Why or why not?
21. What aspects are better/worse? Why?

PART 5: EXPERIENCE USING DOUBTFIRE++

22.   Do you like Doubtfire++? Why or why not?
23.   Will you use it again? Why or why not?
24.   Will you recommend it to other staff or students? Why or why not?
25.   Please describe any problem/s you encountered with Doubtfire++?.
26.   What other features/visualisaions would you like to see in Doubtfire++?
27.   Do you have any suggestions on improving Doubtfire++?
28.   Describe your overall experience using Doubtfire++.

Appendix A.12

Student Interview Plan (Study 2)

Interviewee Code   **C0X**
Focus Group Discussion Session Code   **D0X**

PART 1: DEMOGRAPHIC QUESTIONS
1. Area of study
2. Assessment type
3. Gender
4. Doubtfire++ usage
5. Experience using Doubtfire++
6. Experience with information visualisation

PART 2: THE USE OF OLM VISUALITIONS
7. How did Doubtfire++ support your role as a student ?
8. Did you find Doubtfire++ useful to you? Why or why not?
9. Which features/visualisations of Doubtfire++ did you find most beneficial to you? Why?
10. Describe your interaction with each of the visualisations.
11. (Refer the visualisations in the survey questionnaire.) Which of these visualisations did you use the most/ the least/have never used? Why?
12. How did it affect your learning?
13. How did it affect the way you manage your learning?

PART 3: QUESTIONS FOR ADDRESSING QUANTITATIVE RESULTS
14. How did you use the Target Grade Setting visualisation?
15. How often did you use the Target Grade Setting visualisation?
16. How many of your units used Doubtfire++?
17. Is there any difference the way Doubtfire++ was used in different teaching units?
18. How Doubtfire++ was used in unit A as compared to unit B?

PART 4: ADDITIONAL DOUBTFIRE++ FEATURES
(For those students who have experience using the previous version of Doubtfire++)
19. Did you see any difference between previous Doubtfire and current Doubtfire++ tool?
20. In comparison to previous version, is the enhanced version, Doubtfire++, better? Why or why not?
21. What aspects are better/worse? Why?

PART 5: EXPERIENCE USING DOUBTFIRE++

22. Do you like Doubtfire++? Why or why not?
23. Will you use it again? Why or why not?
24. Will you recommend it to other staff or students? Why or why not?
25. Please describe any problem/s you encountered with Doubtfire++.
26. What other features/visualisations would you like to see in Doubtfire++?
27. Do you have any suggestions on improving Doubtfire++?
28. Describe your overall experience using Doubtfire++.

Appendix A.13

The Coded Data and Raw Data Used for Word Cloud Analysis

1.   Task List

Actionable info	Tells you sequentially what to do, know what to do next, this is necessary to see what's done and what's not, each task is separated and can be easily ignored or focused on as needed, can see what need to improve.
Better visualisation	It is better than other 2 displays, better than the other.
Clear	Can see clearly, looks clear, it is clear, clear information.
Detailed	Most readable with the most information, provide the level of detail needed, gives most info for me, the details are more obvious than other methods, it is itemized, compartmentalized.
Discernable by colour	Easy to see the color task, can differentiate the status with different color, colour coding makes the data easy to read.
Easy to track status	Easy to trace status, it is easy to track the tasks, easy to read the status, can identify different task status.
Easy to understand	Understandable, easy to understand.
Efficient	Efficient.
Effective	Effective.
Good	Good.
Neat	Neat.
Simple	Simple.
Specific	Shows specific task, specific.
Visually appealing	Visually appealing.

2.	Task Summary Pie Chart

Actionable info	Shows where more resources should be allocated.
Attractive	Attractive view, more interesting to view.
Clear	Not confuse, clear, can see clearly, obvious, data is presented clearly.
Direct	Direct.
Easy to compare	Easy to compare, visually compares results better than others, easy to compare how many total tasks are remaining.
Easy to see	Easy to view, easy to view the results, visually significant.
Easy to understand	Easy to understand, easy way to read, easy to interpret, can know the details by one glance, can know the details by one glance.
Familiar	Familiar, familiarity with pie charts, looks familiar.
Like	I like pie chart.
Motivating	Motivating.
Simple	Simple.
Task break down and whole	Show percentage precisely, easy to understand by the percentage, view according to percentage, can see my task status as a whole, can know the percentage, easy to know the number, proportions seem to fit pie charts well, appropriate representation for percentages of the whole, easy to obtain statistics of tasks completion, can immediately see the proportion of students who have or have not completed a task, and if there are any who have failed, data encompass a whole, better overall feel to where the majority of students are, easier to see all results in a single pie.
User friendly	User friendly.
Wonderful	Wonderful.

3.   Bar Graph

Actionable info	Can know any points of struggle.
Clear	Immediately clear, it is very clear to show our current achievement, can see result clearly, the message is clearly shown, this display method is clear enough, clear view, clear when compare with others.
Comfortable to use	Comfortable to use it, comfortable with it.
Common	Widely used, common, most common.
Definite	Can see accurately the value, accurate, very quantitative way of visualising my learning.
Detailed	More detail in feedback.
Direct	Direct.
Easy	Easy.
Easy to compare	Easily compare, could compare easily, easy to differentiate, easy to compare each task, vertical axis gives a point of reference so results have more meaning, can see difference between each LO.
Easy to see	Easy to see, easy to view, easy to visualise.
Easy to understand	Easy to understand, easy to determine, I understand better, easily understood, easier to understand, understandable, direct interpretation with sufficient data, easy to read, only takes a quick glance, able to gauge achievement, glancable information.
Familiar	More familiar, used it since I was 13, I'm familiar with reading bar graphs, recognisable.
Like	I love bar graph.
Motivating	Boosts confidence if doing well, helps me to work harder if not.
Neat	Neat.

4.   Boxplot

Better	Better than other.
Clear	Clear, unambiguous, clearer illustration for comparison, clearly see the level of comparison for individual and group achievement, clear to view, conveys data in the clearest form, clearly show your achievement in relation to the group and also clearly shows if you are performing very well, clearer placement, clearly demonstrates targets and current achievement, it's clearer to read.
Common	Most widely used, widely used.
Concise	It visualises the necessary areas, no more no less.
Definite	Accurate measurements.
Detailed	Provides the most information, allows me to know where I stand amongst the group, conveys the most info.
Direct	Straight forward, straight to the point.
Easy to see	Easy to see, can easily see what your personal level, easy way to see achievement.
Easy to understand	Easy to understand, faster information can get, most understandable, easy to interpret, easy to read.
Familiar	Familiar, well known, I'm familiar with this type of visualisation, I am used to this, most familiar with this representation, I recognise it from statistics.
Less clutter	Clean, less cluttered than other charts, clutter free, doesn't feel overcrowded.
Simple	Not as complicating as others, not so complex, the simplest, simplicity.
Unique	Unique.
Vertical ranking	Higher shows good wtih lower shows no good, vertical higher is better.
Visually appealing	Eye appealing.

5.   Compare Group Average

Actionable info	Can give an indication that a student needs help, it's a good way to have the individual evaluate their abilities compared to the group and possibly learn from them.
Attractive	Attractive
Better	Better than other, best among all.
Clear comparison	The comparison is clearly visible with one bar on top of another, can directly see how one bar is different as compared to another, clearer to compare, clear comparison between individual and group, clearer illustration for comparison, clearly see individual performance and achievement of all LOs for group and individual, clearly known about achievement, shows the comparison message clearly, clear and useful comparison, easier to see comparison, easy for me to distinguish immediately and with specificity, personal vs. group is easy to distinguish, instantly compare.
Creative	Creative.
Detailed	Shows more info, shows more information which makes it easy to compare achieved scores to other students.
Discernable by colour	Bar with colour which makes us easily to see the result, colourful makes a difference.
Easy to see	Easy to see, easy to view.
Easy to understand	Self-explained, easy to understand, easy to read.
Effective	Effective.
Efficient	Efficient.
Familiar	Used to this.
Helpful	Helpful to visualise.
Like	I like it, just personal preference.
Nice	Nice graphic.
Relevant	I find that this is more relevant to me
Simple	Simple, less messy.

List of Publications

1. Law, C. Y., Grundy, J., Cain, A., & Vasa, R. (2015). A preliminary study of open learner model representation formats to support formative assessment, in Proceedings of the IEEE 39th Annual International Computers, Software & Applications Conference (COMPSAC), pp. 887– 892.

2. Law, C. Y., Grundy, J., Cain, A., & Vasa, R. (2016). An empirical study of user perceived usefulness and preference of open learner model visualisations, in Proceedings of the IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC 2016), pp. 49-53.

3. Law, C. Y., Grundy, J., Cain, A., Vasa, R., & Cummaudo, A. (2017). User perceptions of using an open learner model visualisation tool for facilitating self-regulated learning, in Proceedings of the Nineteenth Australasian Computing Education Conference, pp. 55-64.