User Perceptions of Using an Open Learner Model Visualisation Tool for Facilitating Self-regulated Learning

Check-Yee Law
Faculty of Information Science and Technology
Multimedia University,
Melaka Campus, Malaysia
+61 3 9214 8793
cylaw@mmu.edu.my

John Grundy, Rajesh Vasa
School of Information Technology
Deakin University
Melbourne, Australia
+61 3 924 {46227, 68060}
{j.grundy,rajesh.vasa}@deakin.edu.au

Andrew Cain, Alex Cummaudo
School of Software and Electrical Engineering
Swinburne University of Technology
Melbourne, Australia
+61 3 9214 5324
{acain, acummaudo}@swin.edu.au

ABSTRACT

Ways to encourage self-regulated learning have become a hot topic in higher education. In this research study we explored users' perceptions regarding the uptake and effective use of an open learner model visualisation prototype tool – Doubtfire++, in facilitating student self-regulated learning supporting task-oriented portfolio teaching and learning. We investigated student perceptions of setting appropriate goals, monitoring performance and reflecting on learning through the use of the visualisation tool to support students in becoming self-regulated learners. Data was collected from 134 users using an online survey questionnaire. Results show that Doubtfire++ positively impacted users' perception of setting appropriate goals, monitoring performance and reflecting on learning. User role, experience using Doubtfire++, frequency of using Doubtfire++ and different teaching units significantly impacted respondent perceptions whereas gender and familiarity with information visualisation techniques had no impact on respondents' perceptions. The results indicate that the approach can facilitate student self-regulated learning, especially for those new to Task Oriented Portfolio teaching and learning of programming units.

Categories and Subject Descriptors

• **Education – Computing education, Computer-managed instruction, Interactive learning environments.**

Keywords

Education; outcome-based learning; constructive alignment; open learner model; information visualisation; self-regulated learning.

1. INTRODUCTION

Many higher education institutions have reformed their academic programs to be more outcome-based by incorporating intended learning outcomes in their courses to reflect students' fundamental content knowledge, skills as well as graduate attributes. Teaching, learning and assessment approaches have been being transformed to support such an outcome-based paradigm. Educators are challenged to create an optimal learning environment that can facilitate students taking greater ownership of their learning. That is, to teach them to be self-regulated. Undergraduates today are also increasingly required to retain their learning artefacts to demonstrate their achievements in preparing themselves for the competitive workplace.

In pursuing Computer Science and Software Engineering related degrees, programming is a critical skill. Therefore, students are taught programming at the beginning of their degree courses in many universities. However, learning to program is recognised by students as being challenging [6, 22]. McGettrick, Boyle, Ibbett, Lloyd, Lovegrove and Mander [13] declare providing simpler models of computing as a discipline to be one of the seven grand challenges in computing education. Furthermore, computing education is rapidly evolving and expanding field that has been widely integrated with other disciplines [1]. In view of the problems and challenges in this area, many strategies and practices have been proposed to improve the way programming is taught and learnt. To this end, Constructive Alignment (CA) [2] has been applied in computing education as a means of improving student learning outcomes for teaching programming [6, 8, 22].

Cain has proposed an approach to implementing CA for introductory programming using Task Oriented Portfolio assessment [5]. Central to this approach is use for frequent formative feedback to help each student develop a portfolio of work to demonstrate they have achieved unit learning outcomes. This approach aims to provide greater opportunities for students to be more goal-oriented and self-regulated. To support this teaching approach, a number of resources and tools have been developed. One of the tools, known as Doubtfire, has been used by both staff and students as a platform to support such frequent formative feedback in assisting students to construct their knowledge.

Doubtfire aims to help support students set learning goals and work toward achieving these, thereby helping support the development of self-regulation. To better support these features, we have enhanced Doubtfire with open learner model visualisations to provide better support for indicating the links among these tasks and the unit's learning outcomes as well as expected outcomes. This new tool is named Doubtfire++ for the purpose of this paper.

The study we describe here explored user perceptions of the uptake and effective use of visualisations added to Doubtfire that aimed to facilitate self-regulated learning. This paper reports on users' perceptions regarding the use of Doubtfire++ in facilitating self-regulation and factors that influence their perceptions. Section 2 reviews key related work that provides the theoretical framework to this study. Section 3 illustrates Doubtfire++ interface design to facilitate student self-regulated learning. This is followed by research design that includes background study, purpose and research method in Section 4. We report and discuss the results obtained in Section 5 and threats to validity in Section

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6. We then conclude with a summary and highlight key future research directions in Section 7.

2. THEORETICAL FRAMEWORK

2.1 Constructive Alignment Approach

Constructive Alignment (CA) as proposed by Biggs is a teaching strategy for supporting a student-centred learning environment. Constructive refers to constructivism, and means learners learn through doing or interacting with activities to gain and construct their knowledge, whereas alignment refers to both teaching activities and assessment being aligned to intended learning outcomes (ILOs) [3]. Biggs promoted the use of teaching and learning activities to support active student engagement and recommended the use of portfolio-based assessment. 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. Biggs suggested the use of portfolio assessment whereby students demonstrate they have achieved the learning outcomes by justifying and evidencing their learning with learning artefacts related to unit objectives. That is, student self-regulation is an important factor to the success of CA model.

2.2 Technological Tools in Supporting Student Learning

Various technologies have been applied to facilitate the shift towards outcome-based paradigm to support various aspects of the teaching and learning process. For example, learning management systems (LMSs) have been used to link learning activities with program goals, and visualisation tools have been used to facilitate student learning through multiple analyses and visualisations. E-portfolios have also been used to ease the process of showcasing and evidencing achievements with learning artefacts in various electronic forms.

A learning management system (LMS) refers to a software program that is used for delivering, documenting, tracking and managing training programs or education courses [12]. LMSs have also been used to link learning activities with institutional missions and program goals for outcomes assessment purposes [21]. However, the linking of learning activities to program goals is mainly to fulfil the reporting purposes as requested by the professional accreditation agency [21] and it has limited support for student self-regulated learning.

An e-portfolio is a software product that supports the collection of learning artefacts by documenting student projects and reflections on learning produced in a unit or over the student's academic life [23]. E-portfolios have become more popular as accreditation agencies have begun to set institutional requirements for evidencing learning and are now widely used in higher education. E-portfolios take advantage of the expected gains and benefits to support a variety of student learning activities and achievements both as showcases of student work, for peer interaction and self-reflection, as well as to provide a more authentic forms of assessment [16, 20]. Some LMSs have integrated e-portfolio with LMS to better support course administration and evidence student learning such as the integration of the Mahara e-portfolio tool into the Moodle learning management system. However, such integration still lacks support to provide students with opportunities to become self-regulated learners. One of the major problems reported was that students struggled to create a suitable e-portfolio to evidence their learning. They did not have a distinct goal in their studies and were not aware of how they could achieve the unit learning outcomes with it [4]. As a consequence, they were unable to adequately build their competencies through e-portfolio. To this end, Wetzel and Strudler [24] recommended linking the purpose of using e-portfolio to the course learning outcomes.

2.3 Learning Tasks and Learning Outcomes

A "learning outcome" represents knowledge, skill or experience acquisition that is demonstrated and assessed during an individual course or degree programme. Learning outcomes play an essential role in defining what a learner knows, understands and is able to do on completion of a learning process [7]. Linking learning tasks to learning outcomes has become popular in unit and programme design.

To support an outcome-based learning environment, in most practices, teaching staff perform the alignment of assessment tasks with intended learning outcomes for each task. The alignment is, however, still vague from students' perspective. Students may benefit from visualisations aimed at communicating the relationships between outcomes and tasks, as well as visualisations depicting current achievement of learning outcomes during the teaching period.

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 student awareness of, and self-reflect on, their achievement of learning outcomes. Such a tool would allow staff and student to explore the links between tasks and learning outcomes, enabling staff to monitor student progress toward achievement of learning outcomes, and supporting students in better manage their learning progress. This is to say, in embracing outcome-based learning, students have to be supported with optimal learning environments that provide them with great opportunities to become self-regulated learners.

2.4 Self-regulation

Definitions of self-regulated learning vary according to researchers' theoretical orientation with a common conceptualisation about self-regulated learners emerging as metocognitively, motivationally and behaviorally actively engage in their learning [26]. In this study, we conceptualise self-regulated learners as active participants in engaging with their own learning. This means learners plan, set goals, organize, self-monitor and self-evaluate their learning process that leads them to be self-aware, knowledgeable, skilful, determined and decisive in their learning.

Self-regulated learners were found to be high achievers and were more confident than their peers [17, 27, 28]. Self-regulation is a cyclical process that consists of three distinct phases including forethought phase, performance monitoring phase and self-reflection phase [27] as shown in Figure 1.

The forethought phase is a task analysis phase that includes goal setting and task planning 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, the performance monitoring phase. This phase is a task implementation phase that involves the control of strategies and monitoring techniques that a learner used to engage in learning. The outcomes of the implementation phase are experienced and are evaluated in the following phase through self-reflection. Learners self-reflect to judge their learning outcomes and react to consider revisions or adjustments that may be needed. This is a cyclical process in which the result of self-reflection will impact learners' future task analysis and implementation to reengage with the subsequent forethought phase and so on. Self-regulation is an important skill for students to achieve. Teaching approaches and strategies should therefore promote learners' abilities to be self-regulated. We believe appropriate use of a tool integrating information visualisation techniques, such as open learner model visualisation, can help to better support student learning in such environments.

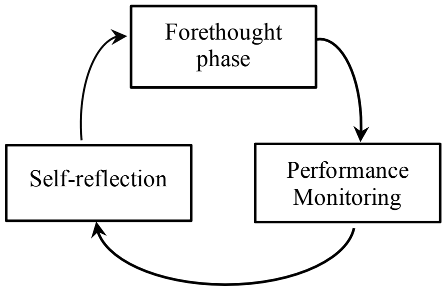

Figure 1. Self-regulation learning cyclical phase

2.5 Open Learner Model Visualisation Tool

The open learner modelling concept originated from intelligent tutoring systems in which the system stores students' learner models in order for it to provide individualised instruction to students. Traditionally, these models are not accessible to the students. Realising the great educational values and benefits, Self [18] proposed to expose the learner models to students. Since then, various information visualisation techniques have been extensively adopted and adapted to externalise various learning data through OLM tools that visualise concepts known, knowledge levels, difficulties, misconceptions and others.

Information visualisation (InfoVis) research explores the representation and interaction techniques in order to transform abstract data into appropriate mental models of information for users to understand and analyse through continuous visual exploration [11, 19]. Visual representations can amplify user cognition through the formation of mental models of information [11] and are believed to prompt users for further adjustment, planning and improvement, thus motivate them in taking greater ownership of their own learning. OLM tools have been exploited in various tools to model and present learning progress and achievement in various computer-based representation formats. OLM tools have been shown to improve learners' meta-cognitive activities, including self-assessment, self-monitoring, self-reflection [14]. With advancement in computer technology, OLM tools not only support users for viewing their learning data, but can support their interaction with the tool to negotiate, reflect and influence the system in modelling their own learner models [9]. This means students are provided with greater autonomy to manage and control their own learning. 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.

2.6 Doubtfire in Supporting Teaching of Programming Units

A range of programming units have adopted the principles of constructive alignment as the teaching strategy, with an additional focus on frequent formative feedback supported by Doubtfire as presented by Cain [5]. The teaching approach, known as Task Oriented Portfolio assessment, has been evaluated and refined through several iterations of action research and has now stabilised. This approach involves teaching staff setting up the teaching context by: 1) defining learning outcomes, 2) setting assessment criteria, and 3) designing teaching and learning tasks. As with other approaches to constructive alignment, the learning outcomes guide all 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, so these outcomes need to be clearly expressed in a language that students can engage with. 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.

Within this teaching system [5], the method of unit delivery is changed to be student-centered, where students can 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 with flexible deadlines to help students achieve the tasks to the required standard. In this model, staff assess student work to provide formative feedback aimed at helping the student improve their work and address any misconceptions. Where the task is of a good standard it is signed off by staff as being Complete, otherwise students are asked to fix and resubmit the work. This helps 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 they have completed though 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 results. This process can then be informed by the status of each student's tasks, with the assessor knowing that those that are marked as complete and have been assessed by staff as 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 has also helped change the student-teacher dynamic, with students being more receptive to constructive criticism as this feedback aims help them achieve their desired grade. We postulate that the flexibility within this model provides students with great opportunities to develop toward becoming self-regulated learners.

While teaching staff have endeavoured to create an optimal teaching and learning process to support outcome-based student-centred learning environment, there is a need to model student learning and gain better understanding on how students learn in this learning environment. To this end, Doubtfire++ has been deployed to more effectively support student self-regulated learning whereas staff can use it to monitor student learning.

We have enhanced Doubtfire with various new visualisations. These visualisations, inspired by the application of information visualisation in Open Learner Model (OLM) research, aim to guide students to be more goal-oriented and self-regulated, and enable users to visualise their desired grades, progress toward achieving unit learning outcomes, links between tasks and unit learning outcomes, and student self-reflection on task alignment as well as retaining their learning artefacts.

3. USER INTERFACE DESIGN FOR SUPPORTING SELF-REGULATION

Doubtfire++ incorporates various OLM visualisations to support the Task Oriented Portfolio teaching and learning approach and encourage student self-regulated learning. It supports staff with comprehensive learning analytic data about students in general, and will provide insightful data about possible staff and student perceptions on the links between tasks and learning outcomes. These analysis and visualisations aim to support staff reflection on teaching by identifying how teaching and learning strategies are working for students. The interface designs include pages to support students setting their target grade, managing their learning tasks, tracking their progress and achievement, facilitating self-reflection and evidencing their learning as shown in Figure 2 to Figure 8.

Figure 2 is the interface used by students to set their target grade. Each grade is linked to the amount of work needed to be completed in order to obtain the desired grade. It provides flexibility to students to adjust the target grade and see the workload required for different grades. This helps them to plan for their workload and learning schedule, and to set a realistic target. The task list and focus list, as shown in Figure 3 and Figure 4 respectively, support students engagement with frequent formative feedback on their tasks. The Task list exploits different colours to keep students informed about their task statuses, whereas the focus list suggests tasks to be focused on in order to stay on track to achieve the desired grade. A burndown chart, as in Figure 5, enables students to track their progress, showing target and projected completion time, percent of tasks submitted and completed. This keeps students aware of the number of tasks remaining at a certain point of time for students to estimate effort required to complete their tasks in meeting the minimum requirement of their desired grade. This tool helps students to assess their progress, and to estimate if they need to increase their effort and time exploiting support resources available in order to attain the required rate of progress. Figure 6 shows a bullet chart for students to visualise their learning outcome achievement. This chart resembles Stephen Few's bullet graph, and exploits 4 different colours that represent the qualitative range for different level of achievements, indicating staff expectation for Pass, Credit, Distinction and High Distinction. The cut-off line that shows the class average achievement and the grey shaded area that shows class range as well as the small triangle that denotes individual achievement on the bullet chart enable users 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 bullet chart is linked to all tasks that contribute to each learning outcome as in Figure 7. Students can easily click to view the tasks that contribute to a specific learning outcome to identify tasks to be focused on in order to improve a specific learning outcome. Figure 8 shows an example of the student reflection interface through which students align unit tasks with intended learning outcomes to demonstrate 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 then can upload their work to showcase or evidence their achievements. The reflection data provide insight about student learning and help 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.

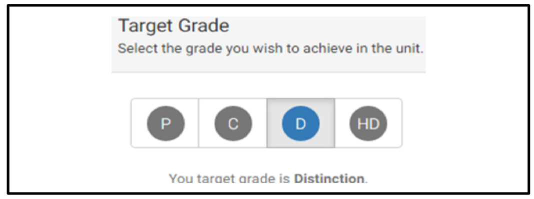

Figure 2. Interface for setting target grade.

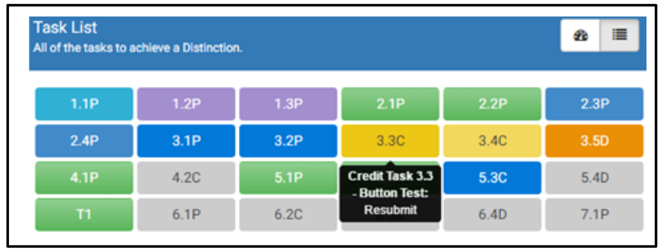

Figure 3. Task list exploits colours to keep students informed about their task statuses.

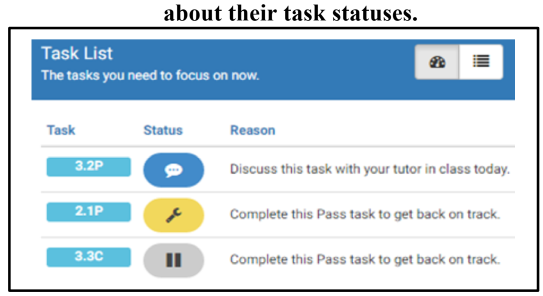

Figure 4. Focus list suggests tasks to keep students on track.

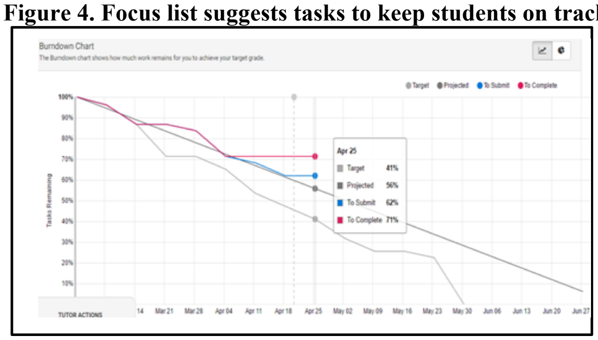

Figure 5. Burn down chart helps students to self-assess.

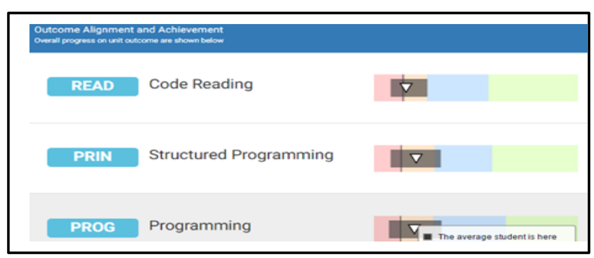

Figure 6. Bullet chart gives information about individual and class LO achievements.

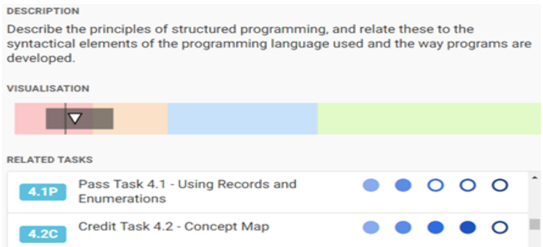

Figure 7. Interface for a student to inspect the tasks that contribute to a specific learning outcome.

Figure 8. Clickable rating scales for a student to reflect their LO achievements based on the tasks completed.

4. RESEARCH DESIGN

4.1 Background

Initially, Doubtfire was used by teaching staff to outline assessment tasks and provide feedback to students [25] in supporting the model for teaching introductory programming units based on Constructive Alignment (CA). After several iterations of action research to refine the approach and to evaluate Doubtfire usage, the application of CA model in teaching programming units has been stabilised and Doubtfire has been recognised as a useful tool in assisting students in managing their assessment task and learning time [25]. To further encourage student self-regulation in taking greater ownership of setting learning goals, tracking, monitoring and reflecting on their learning, Doubtfire has been enhanced with various open learner model visualisations showing the links between tasks, progress toward learning outcome achievement, and student reflection on task alignment. Its use has now been extended to various units in Faculty of Science, Engineering and Technology at Swinburne University of Technology in supporting student self-regulated learning. In March 2016, Doubtfire++ was deployed in 12 teaching units.

We postulated that the use of Doubtfire++ could help students to: (1) set appropriate and realistic learning goals; (2) monitor their progress and achievement, and (3) assist them to reflect on their learning. Depending on the adoption of teaching and assessment approach, the unit deliveries were different in terms of how frequent the formative feedback was appropriate and if the unit fully or partly adopted portfolio assessment. Thus, we also postulated that users from different units would have used Doubtfire++ in different ways at different usage rate in supporting student self-regulated learning.

4.2 Purpose

Doubtfire++ is an enhanced version of Doubtfire to better support student self-regulated learning in terms of setting appropriate learning goals by allowing user inspection of the links between tasks and learning outcomes, helping users to monitor their performance by keeping them aware of their progress and achievement as well as supporting their reflections on task assessment. It is important to investigate users' perceptions, both teaching staff and students, in terms of how Doubtfire++ can assist students in taking greater ownership of their learning. The aim of this study was to examine teaching staff and undergraduate student perceptions regarding the use of Doubtfire++ in supporting self-regulated learning. We also endeavored to find out factors that could have affected their perceptions. Five research questions are as the following:

RQ1 - How do Doubtfire++ OLM visualisations impact users' perceptions of setting their learning goals?

RQ2 - How do Doubtfire++ OLM visualisations impact users' perceptions of monitoring student performance?

RQ3 - How do Doubtfire++ OLM visualisations impact users' perceptions of facilitating student self-reflection?

RQ4 - Do user role, gender, user familiarity with information visualization, prior experience of using Doubtfire, frequency of use, and different teaching units impact user perceptions?

RQ5 - How do Doubtfire++ OLM visualisations impact users' perceptions of facilitating student learning as compared to the previous version of the tool?

4.3 Research Method

This research (SUHREC Project 2015/309) was conducted in accordance with Swinburne's Human Research Ethics policies and procedures. Doubtfire++ was deployed in Semester 1, 2016. Students interacted with Doubtfire++ to view unit tasks, submit their work for feedback, track their progress, visualise their learning outcome achievement 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 achievement. At the end of the semester, when users had had a chance to fully interact with Doubtfire++, they were invited to participate in an online survey questionnaire through an online announcement with the survey link included in the announcement to collect the quantitative data. A 15-item questionnaire was developed to assess the following aspects: Setting learning goals, monitoring performance, and facilitating self-reflection on learning. All items used a five-point Likert scale ranging from 1 – strongly disagree to 5 – strongly agree. Remaining items were open-ended questions about participants' demographics and comment columns soliciting user input about how a specific visualisation could have facilitated student learning and problems they encountered. Items were derived from the literature.

As suggested by Bolliger and Shepherd [4] and Wetzel and Strudler [24], keeping students inform and aware of course learning outcomes can assist them in setting their learning goals. 2 items were used to examine student perceptions regarding how Doubtfire++ can assist them to set their learning goals as follows:

1) Doubtfire++ helped me see the links between tasks and learning outcomes.
2) Doubtfire++ helped me engage with the leaning outcomes.

In monitoring performance, 7 items were used to investigate user perceptions on how Doubtfire++ helped them to monitor their performance through the way they managed their learning tasks and how they acted upon the feedback received through frequent formative feedback [6]. The items were: "Doubtfire++ helped…"

3) motivate me to complete tasks.

4) me to engage with learning.
5) me to manage my learning.
6) me keep on track.
7) make it easy for me to access tasks.
8) make it easy for me to submit work for feedback.
9) me to act upon feedback I received.

Within the CA teaching approach as described in Section 2.6, students were asked to use the work they have completed through the unit's tasks to create a portfolio at the end of the teaching period. Reflection is one of the purposes for portfolio or e-portfolio development [4]. 6 items were used to examine user perceptions on how Doubtfire++ can facilitate them to reflect upon their learning in terms of constructing knowledge, showcase their learning with learning artefacts, their progress as compared to their peers and preparation for summative assessment. As such, they were able to self-evaluate their progress and achievement to determine if any action can be taken to improve their learning in preparation of summative assessment and for future planning. The items included: "Doubtfire++ helped …"

10) motivate me to construct my knowledge.
11) me retain my learning artefacts.
12) guide me in preparing my portfolios.
13) me compare my progress with peers.
14) me to prepare for final assessment.
15) me to attain greater achievement.

Three faculty members – an instructor with several years of teaching experience adopting constructive alignment approach with considerable experience using Doubtfire and two instructors with more than 10 years of teaching experience reviewed the questionnaire prior to its administration.

Statistical Package for the Social Sciences (SPSS) software was used to generate the descriptive statistics, to determine the internal consistency of the scales and to investigate the differences between the independent groups based on their demographics. Cronbach's alpha coefficient was calculated using SPSS to determine the internal consistency of the questionnaire (α = .915). The reliability for each of the scales: Goal setting, performance monitoring and self-reflection of the questionnaire was also computed to examine the internal consistency for the scales as shown in Table 1. The Cronbach's alpha values ranged from 0.834 to 0.852. This indicates that each construct exhibited strong internal reliability. Nunnally and Bernstein [15] 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.

Table 1. Internal consistency reliability coefficients

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

Frequencies and descriptive statistics were generated. A series of independent samples t-tests was conducted to measure differences in means based on user demographics that include user role, gender, experience using Doubtfire++ and frequency of using Doubtfire++ with all measurement scales (goal setting, performance monitoring and self-reflection) whereas a one-way ANOVA analysis was used to determine the differences between respondents' familiarity with information visualisation techniques and different teaching units with all the measurement scales.

5. RESULTS AND DISCUSSION

5.1 Demographics

12 units in Faculty of Science, Engineering and Technology that deployed Doubtfire in the unit teaching were invited to participate in this research study. The teaching staff modified these 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.

171 teaching staff and students from 11 units voluntarily accepted the invitation to participate in this study yielding 134 valid samples. 15 of them were teaching staff while 119 were students spreading across 7 programming units, 3 software engineering units and 2 information technology units. All of the programming unis fully adopted portfolio assessment with other units either fully or partly adopting portfolio assessment. There was an imbalance of gender proportion, that is, 110 were male with only 20 females. 4 did not disclose their gender. The majority (94) were familiar with visualisation techniques, i.e. 21 were very familiar and 73 were somewhat familiar, 32 had heard about them, and 8 were not familiar. 113 of them were Doubtfire++ frequent users (used it every day or at least twice in a week) whereas 21 of them occasionally or rarely used it (less than 2 times in a week). While 85 used it in programming unit only, 19 users were from software engineering unit only with 28 users used it in programming unit and at least 1 other unit. 2 did not disclose this.

5.2 Descriptive Statistics

In general, participants responded favourably to all questions. All items in the scales yielded a mean score above 3.00 ranging from μ=3.33 for the item "Doubtfire helped me compare my progress with peers" to as high as μ=4.51 for the item "Doubtfire helped make it easy for me to submit work for feedback".

5.2.1 RQ 1: User perceptions of setting their learning goals

56.7% of the respondents agreed or strongly agreed that Doubtfire++ helped them to see the links between tasks and learning outcomes (μ=3.54) whereas 46.2% of them felt that it helped them to engage with the leaning outcomes (μ=3.38). 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.

5.2.2 RQ 2: User perceptions of monitoring performance

90.3% highly valued that Doubtfire++ had made it easy for them to access learning tasks (μ=4.49) and submit their work for feedback (μ=4.51) respectively. 82.8% agreed that it helped them to keep their learning on track (μ=4.13) and assisted them to manage their learning (μ=4.17) respectively. While 76.1% found that Doubtfire++ helped them act upon feedback they received (μ=4.07), 70.2% said that it motivated them to complete their learning tasks (μ=3.84) with 60.4% strongly agreed or agreed that Doubtfire++ engaged them with learning (μ=3.70). Only less than 10% of respondents strongly disagreed or disagreed with all items.

5.2.3 RQ 3: User perceptions of facilitating their self-reflection

80.6% of the respondents felt that Doubtfire helped to guide them in preparing their portfolios (μ=4.10) and 71.6% said that it helped them to prepare for final assessment (μ=3.85). In addition, more than half agreed that Doubtfire helped them to attain greater achievement (67.1%, μ=3.82), assisted them to retain their learning artefacts (66.4%, μ=3.74) and motivated them to construct their knowledge (53.8%, μ=3.56). However, fewer than half of the respondents felt that Doubtfire++ helped them to compare their progress with their peers (47.8%, μ=3.33). While this item also recorded the highest percentage of disagreement (24.6%), followed by 13.4% who disagreed with "Doubtfire motivate me to construct my knowledge." And 10.4% who hold negative opinions on "Doubtfire++ helped me retain my learning artefacts.", only a small percentage of the respondents (less than 10%) strongly disagreed or disagreed with the rest of the items. The highest percentage disagreement for "Doubtfire++ helped me to compare my progress with peers" could be due to the reason that some students only care for their own achievement and thus did not really value the comparison feature [10].

5.2.4 RQ 4: Difference in means between user demographics and all measurement scales

5.2.4.1 User Role

An independent samples t-test was conducted to compare all the measurement scales (goal setting, performance monitoring and self-reflection) for teaching staff and students. The general assumptions associated with this parametric technique were verified to ensure no violation. Our data was collected using voluntary response sampling. Thus we assumed random sampling from the population. The 5-point Likert scale used means the dependent variables were measured at the interval level. Each of the users interacted with Doubtfire++ to inspect their own learning data, thus we can assume independence of observations. The valid sample size of 134 denoted that scores on the dependent variable were normally distributed. To ensure homogeneity of variance, appropriate set of results was used based on Levene's test for equality of variances.

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 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 student 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:

"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."

"Selecting a Target Grade helped me see if the amount of work required to do well was manageable with my schedule."

"It was good to be able to flick between the different levels and see your progress on each. This was reassuring in case I didn't have enough time to achieve as high as I hoped."

"I often changed this to see where I was at the time, at a Pass or Distinction level, it helps to narrow down what to focus on in the face of overwhelming tasks"

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

It can be seen from student comments that the use of visualisations have formed a mental model that guides them in setting a realistic goal by adjusting their time and effort to meet their desired grade and vice versa.

5.2.4.2 Gender

An independent samples t-test was conducted to compare all the measurement scales (goal setting, performance monitoring and self-reflection) for males and females. Although generally females rated each scale higher than males, gender had no effect on all the measurement scales. Table 2 shows the mean and standard deviation by gender. The mean scores for all scales for both males and females were more than 3.00, ranging from 3.44 to 4.33. This means that, in general, both males and females were receptive to the use of Doubtfire++ in their learning.

Table 2. Mean and standard deviation scores by gender

Scale		*M*	*SD*
Goal setting	Male	3.44	0.91
	Female	3.60	0.94
Performance monitoring	Male	4.11	0.63
	Female	4.33	0.60
Self-reflection	Male	3.74	0.77
	Female	3.80	0.63

5.2.4.3 Familiarity with Information Visualisation

A one-way ANOVA test was used to compare measurement scales (goal setting, performance monitoring and self-reflection) for 4 groups of users with different levels of experience in information visualisation (Group 1: Not familiar at all; Group 2: have heard about it; Group 3: somewhat familiar; Group 4: very familiar). We found that experience in information visualisation also had no effect on all the measurement scales. The mean scores for goal setting, performance monitoring and self-reflection were at least 3.40, 4.00 and 3.60 respectively across all the groups. Table 3 shows the mean scores and standard deviations of all the scales. This can be attributed to the simple and easy to understand visualisations and user friendly interfaces in Doubtfire++ that it does not require users to have considerable experience and knowledge in information visualisation techniques.

Table 3. Familiarity with information visualisation techniques

Group	N	Goal setting		Performance monitoring		Self-reflection	
		M	*SD*	*M*	*SD*	*M*	*SD*
1	8	3.44	0.94	4.16	0.43	3.60	0.68
2	32	3.55	0.79	4.13	0.55	3.84	0.64
3	73	3.42	0.92	4.16	0.66	3.68	0.81
4	21	3.45	1.10	4.01	0.72	3.78	0.72

5.2.4.4 Experience of Using Doubtfire++

The result of independent-samples t-test indicated significant difference for performance monitoring between experienced

Doubtfire++ users and new users. However, there was no significant difference for goal setting and self-reflection.

A significant difference in scores was 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 –0.62) was small (η^2=0.047). Interestingly, new users were more favourable in using Doubtfire++ to monitor their performance.

5.2.4.5 *Frequency of Using Doubtfire++*

An independent-samples t-test was conducted to compare all the measurement scales (goal setting, performance monitoring and self-reflection) for frequent users and users who rarely used Doubtfire++. Frequency of using Doubtfire++ had no effect on goal setting and self-reflection. However, 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. This implies that frequent users valued Doubtfire++ more than users who rarely used it in monitoring their performance.

5.2.4.6 *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 unit only; Group 2: Used in software engineering units only; Group 3: Used in programming unit and at least 1 other unit). There was a statistically significant different at the p<0.05 level for performance monitoring scale for the 3 groups: $F(2, 129)$=3.5, p=0.03. Despite the statistical significance, the effect size that showed the difference in mean scores between the groups was small (η^2=0.05). 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. However, different teaching units had no effect on goal setting and self-reflection scales.

Doubtfire++ has become an essential tool in supporting the teaching of programming units that engaged students with small, frequent tasks. Users in programming units valued it more than other users for helping them to monitor their performance mainly due to it helped them to access numerous small tasks and submit their tasks easily in supporting fully portfolio assessment. Various visualisations as in Figure 2 to Figure 8 supported student effective use of Doubtfire++ to monitor their progress and performance in achieving the intended unit learning outcomes and the preparation for portfolio assessment. The simple and easy to understand visualisations kept them aware of their learning pace that led them to quickly act on feedback and helped them to track their learning. In other words, while helping them to manage learning, it also motivated them to complete their tasks and engaged them in learning to construct their knowledge and evidence their learning in portfolio.

5.2.5 *RQ5 – Users' perceptions of Doubtfire++ as compared to previous version (Doubtfire)*

43 out of 134 respondents had had experience using both versions, Doubtfire and Doubtfire++. Figure 9 shows their opinions.

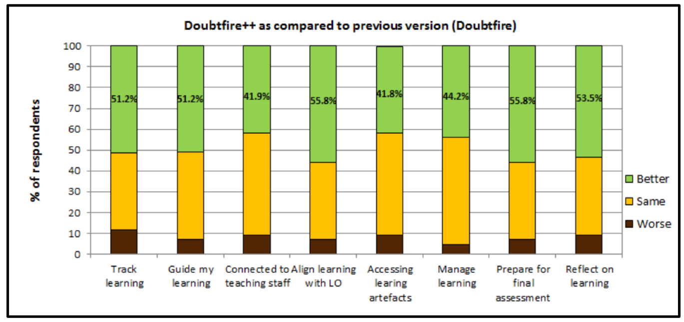

Figure 9. User perceptions of Doubtfire++ as compared to previous version (Doubtfire).

Respondents were quite receptive to the enhanced features in Doubtfire++. 55.8% of them felt that Doubtfire++ had better support to help them align learning with learning outcomes and better helped them prepare for final assessment respectively, followed by 53.5% that agreed it better helped them to reflect on learning. 51.2% said that Doubtfire++ had better support for them to track and guide their learning respectively. More than 40% of them, i.e., 44.2%, 41.9% and 41.8% agreed it better helped them manage their learning, better connected them to teaching staff and had better access to learning artefacts respectively. Only a small number of the respondents (less than 12.0%) held a negative view of Doubtfire++ in supporting their learning.

Respondents also expressed the problems they encountered when using Doubtfire++. The major issue highlighted was about the uploading problem. As Doubtfire++ only accepted certain file formats, they expressed the need for Doubtfire++ to support various file types so that they would be able to upload their learning artefacts that were in various file formats as certain formats would better demonstrate their learning. Also, they wanted Doubtfire++ to accept single file upload whenever re-submission is needed. The other major issue was about the burn down chart (Figure 5). Some had problems interpreted the data represented by each of the line graphs in the chart. A few of them felt that the clickable ILO rating (Figure 8) was redundant as the teaching staff had done the alignment. A small number of them claimed that the integration of LO visualisations (Figure 6 & 7) had increased the complexity of Doubtfire++ and suggested having options for users to toggle it. Tutor support was also pointed out as an important factor for effective use of the tool.

5.3 Discussion

The various visualisations in Doubtfire++ have helped students to form appropriate mental models of information for them to understand and analyse the learning data through continuous exploration in helping students to set their learning goals, monitor their performance and self-reflect on their learning. From the favourable results in Section 5.2.1, it can be deduced that the interface as shown in Figure 2 that linked target grades to the amount of work needed to be completed in order to obtain the desired grade as well as the links between assessment tasks and the intended learning outcomes can assist students in setting appropriate goals. It had provided students with flexibility to adjust the target grade and see the workload required for different grades for them to allocate time needed for achieving a realistic learning goal. While staff were doubtful that Doubtfire++ can facilitate students in setting appropriate learning goals, students generally agreed that it did.

The results obtained in Section 5.2.2 indicate that the user interfaces as shown in Figure 3 to Figure 7 played an essential role in assisting students to keep track of their progress and achievement, that is, to help them monitor their performance. Students especially valued task list (Figure 3) that they can click to easily access to the learning tasks and submit their work for feedback as well as to track their task statuses. The focus list (Figure 4) directed student focus to stay on tracks in achieving the desired grade. Burn down chart (Figure 5) enabled students to track their progress in relation with the remaining time to complete the tasks, thus helped them to estimate time and effort needed to complete their tasks in achieving their desired grade. The bullet chart (Figure 6) allowed students to inspect and self-assess their learning outcome achievements. A click on the bullet chart enabled students drilling down to see a list of tasks that contributed to a specific learning outcome. This feature supported students to improve their work and hence the learning outcome.

Through these visualisations, students not only can easily access learning tasks and submit their work for feedback, they can also obtain a quick view on their task status and LO achievements that can direct 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. These visualisations helped them to monitor their performance. As experienced users had had ideas about some of the Doubtfire++ features, new users were more impressed the way it can helped them to monitor their performance. This aspect was also influenced by the frequency of use and its deployment in different teaching units, with frequent users and programming unit users felt that it was of great value to them in monitoring their performance. Doubtfire++ indeed has built student confidence, both experienced and new users in managing their learning tasks and motivated them to strive for excellence, especially to those frequent users and programming unit users.

The results in Section 5.2.3 are encouraging. While the visualisation in Figure 6 displayed high staff expectation and students' achievement level, visualisation in Figure 8 helped students to reflect on their LO achievement and evidence their learning by uploading their learning artefacts. These visualisations encouraged students to reflect on their learning, thus helped them to prepare for their portfolio, final assessment and for future planning. They had positively impacted most users' perceptions in the way Doubtfire++ facilitated student self-reflection.

Overall, respondents valued the use of Doubtfire++. Our evaluation has shown that it helped students to: (1) set appropriate and realistic learning goals; (2) monitor their progress and achievement, and (3) assist them to reflect on their learning. From the results presented in Section 5.2.1 to 5.2.3, more users perceived that the tool helped students in performance monitoring than goal setting and self-reflection, implying room for improvement in these 2 aspects to better support self-regulation learning. User role, experience using Doubtfire++, frequency of using Doubtfire++ and different teaching units significantly impacted respondent perceptions of how it can facilitate student self-regulation in setting appropriate goals, monitoring performance, and reflecting on their learning.

While user role was found to be influential for helping students in setting their goals, frequency of use, programming unit users and new users were among the factors significantly impacted users perceptions on how it can facilitate students in monitoring their performance. Familiarity in information visualisation techniques and gender had no impact on respondents' perceptions. This can be attributed to simple and easy to understand visualisations and the user friendly interfaces that both males and females were receptive in using it. Users with prior experience using Doubtfire felt that Doubtfire++ is better than the previous version.

Doubtfire++ is a prototype system we designed and developed to help students in taking greater ownership of their learning in encouraging student self-regulated learning. Although generally Doubtfire++ has positively impacted user perceptions in supporting self-regulated learning, there are a few major problems to be rectified including the uploading and burn down chart issues. Other concerns to be addressed are to keep the interface design simple and easy to understand, importance of tutor support and the need to communicate the ideas of having clickable ILO rating scales clearly to students.

6. THREATS TO VALIDITY

Our data was collected using voluntary response sampling. Thus we can assume random sampling from the population. So far we have had 134 valid responses to our online survey questionnaire. Most teaching staff and students were from the same faculty with more than 60% of them used it in programming units. It is also important to note that there is an obvious gender imbalance in this faculty in which more than 80% are males. Thus further feedback from more diverse end users from other faculties with various units and female respondents are needed for generalising these results. Besides that, this research is mainly descriptive, and the content is subjective. The results were solely based on data collected from the online survey questionnaire. More data will be collected from other sources such as interviews and focus group discussions to triangulate, cross-validate and further explain the initial quantitative results obtained in this study in more depth.

7. SUMMARY

We have extended a tool to support self-regulated learning via open leader model visualisations. We deployed this tool with 12 units during Semester 1, 2016 at Swinburne University of Technology. Our evaluation of the tool's effectiveness using feedback from 15 teaching staff and 119 students indicates that the tool makes a significant difference for students to set their learning goals, monitor their performance especially those new users and facilitate student self-reflection.

Different staff teaching approaches that involved partly or full use of portfolio-based assessment could have impacted the use of Doubtfire++ in facilitating self-regulated learning and is an area that worth further exploration. We plan to separate the results from the staff and students to investigate the use of open learner model visualisations in supporting different functional roles including convenor, tutor and students. We conclude that Doubtfire++ can support student self-regulated learning in Task oriented portfolio teaching.

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