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A Preliminary Study of Open Learner Model Representation Formats to Support Formative Assessment

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***Abstract*—Open learner models provide a way of showing teachers and students the learning progress of a student against expectations. Creating an effective interface to present a learner model is an important part in open learner modeling. Usefulness of the learner model relies on using a clear and effective representation format to facilitate users' understanding of the information presented. In this paper, we propose a range of open learner model presentation formats to display students' learning task status and achievement in terms of learning outcomes. We investigate different types of presentation formats and data useful for users to inspect the learner model. An interface design prototype has been built to provide potential users with an evaluation platform that enables investigation of these aspects. The results obtained will allow us to develop a more effective new open learner model visualization tool.**

Keywords-formative assessment; open learner model; learning task; learning outcome; visualisation

I. INTRODUCTION

Using purely *summative* assessment - which tries to represent a learner's performance using a single numerical value or a grade - is claimed to be ineffective as the learning aspects of students, such as their knowledge, skills, ability, strength, weaknesses, misconceptions, needs and goals, are extremely rich and diverse [1]. Mislevy, Steinberg and Almond [2] argue to that this only suffices to provide a basic decision to determine pass or fail status but it inherently cannot express what learners really know or are able to do. Therefore over the past several years there has been an increasing shift from summative to formative assessment practices. Many higher educational institutions have transformed their assessment approaches to gauge student learning with learning outcomes that reflect students' knowledge, skills as well as graduate attributes. As a result of this conceptual change, various educational tools have been developed to facilitate such *formative* assessment. Some tools have been developed based on open learner modeling in order to facilitate the learning process through formative assessment.

Open learner modeling offers students a perspective about their level of understanding that is not usually accessible to them. This modeling concept originated from intelligent tutoring systems where students' learning models are maintained in order to provide individualised instruction to students. Traditionally, these models are invisible to the students. Recent study and research work in this area has shown that there is great potential educational value and supporting benefits in exposing students to their own learning models. Open learner model (OLM) tools support both the teaching staff and students with valuable learning data in the form of multiple analyses and visualisations. OLM is used to show students' knowledge level and misconception [3], [4]. It allows students to inspect their model thereby facilitating self-reflection [5], [6], improving students' involvement in their own learning process [7]–[9] and hence helping students to acquire meta-cognitive skills [6], [10].

Creating an effective interface to present the learner model and to support user interaction is believed to be key challenges in opening learner models to students [11]. There are many forms of model presentations or interface design that have been proposed, or might be tried, in order to present the intended learning data. These include but are not limited to skill meters, achievement badges, smiley faces, concept maps, tree structures, bar graph, pie chart, table, matrix and many more. The presentation format of the learner model is an important part in open learner modeling as OLM systems rely on clear and effective representation of the user model to facilitate users understanding on the display of the intended data [10], [12]. It is therefore important that the representation formats can provide an easy-to-read visual data for users to view, analyse and compare their learning progress and achievements data.

In this paper, we explore a range of existing and new presentation formats that can be used in open learner models to display students' learning task status and achievement in terms of learning outcomes. We propose a tool to present the learner model using multiple views to support formative assessment. This tool enables every piece of a students' work to be linked to the intended learning outcomes for a course. This enables teaching staff to provide feedback and assess the learning task based on the intended learning outcomes. Our tool then displays students' learning task

status and learning outcome achievement to support them for self-reflection and provide them with graphical data as learning evidence. Through this tool, students can track if their work has achieved the expected level of learning outcomes. It aims to provide both the teaching staff and students with valuable information about student' progress towards achieving the intended learning outcomes and provide an avenue for students to view and compare their achievement.

In Section II we survey key related work on various open learner presentation formats used in other research and some findings about the effect of presentation formats on OLM use. This is followed by a description of the presentation formats of our OLM visualisation tool and we provide an overview of its use in Section III. The paper then discusses our prototype tool and our ongoing research activities in Section IV. Conclusions and key future research work considerations are discussed in Section V.

II. Related Work

There are many visual representation formats 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 [8]. Skill meters are used to present a student's progress on domain concepts as in [13] and to show students' knowledge level and misconception on a topic as in [9] and [14]. Smiley faces are used to present students' knowledge level [15], to display the development of learning for a specific concept which is known as pedagogical target [16] and to show students' competencies [17]. Concept maps are used to show the domain concepts learnt and their relationships as in [18]–[20] and to display students' conceptual models as in [21]. Mabbott and Bull [18] and Conejo, Trella, Cruces and Garcia [22] use tree structures to describe a learner's understanding of a subject learnt based on a color scale whereas Albert, Nussbaumer and Steiner [23] use bar graphs and matrix to present students' knowledge level for the concepts learnt from a lesson and to show activities performed for a class respectively. Pie charts are used to show relative weight in the total knowledge achieved in the course [24], whereas tables are used to display competences achieved [25]. Some research uses a combination of graphical and textual representations to reveal the open learner models [24].

Some researchers have found that users incline towards certain representations to view their learner models. For example, Duan, Mitrovic and Churcher [26] reported that users prefer skill meters to more complex visualisations. In addition the types of visual representation are also affected by the types 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 according to Maries and Kumar [19]. Tabular formats have been found to be incomprehensible with a poor logical organisation and difficult to support instructor to track student data [27]. In addition, multiple representations have been found useful to accommodate users' 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 [28]. Reference [29] recommends the provision of text feedback in addition to multiple graphical forms of OLM views as this may help students to 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 which is used to support a variety of stakeholders include students, teachers, parents, peers, school administrators, policy-makers and researchers, 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 [29].

III. Representation Formats and Pilot Study Results

Our OLM tool aims to capture students' learning task progress and achievement in terms of learning outcomes. It enables the teaching staff to link learning tasks to intended learning outcomes. This enables feedback and assessment of learning tasks firmly link to learning outcomes. Several visualisation techniques are used to display the status of the learning tasks, the number of learning tasks remaining or completed by week, student's learning outcome achievement as well as the learning outcome achievement statistics of a class. Students can also compare their achievement against their class achievement through various visualisations.

A pilot study gaining feedback on the tool from lecturers and students has been conducted with eight respondents. While these results are not be meaningful statistically, they provide some initial insight into which visualisations seem to be popular and more useful. In this section, we present two aspects of OLM visualisations, the representation formats and types of data for inspection which also include initial results from our pilot study. The tool has multiple representation formats to present learning data for the following purposes.

A. Inspecting the status of learning tasks, the number of task remaining or completed

There are three representation formats, adopted from [30], to inspect the status of a student's learning task which are known as task list, task backlog tracking tool and task completion tracking tool as shown in Fig. 1. The task list shows the total tasks of a unit for a student. Different colours are used to show the status of the task such as black

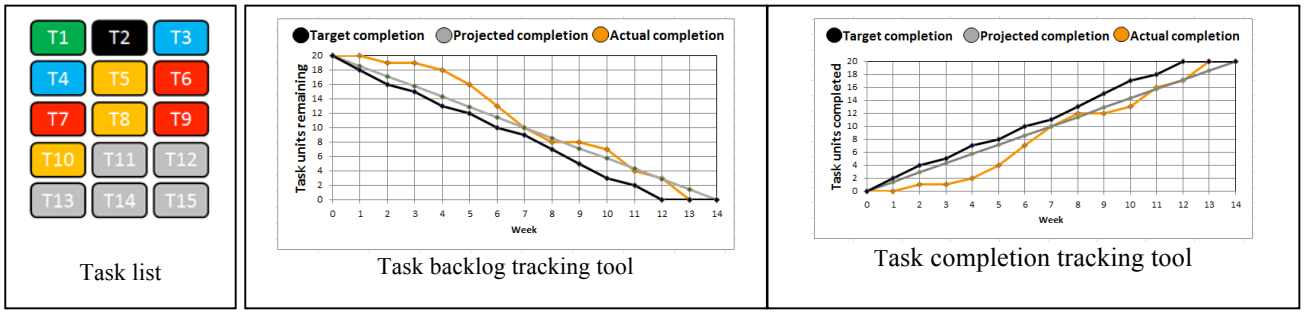

Fig. 1. Visualisations showing the status of learning tasks, the number of task remaining or completed

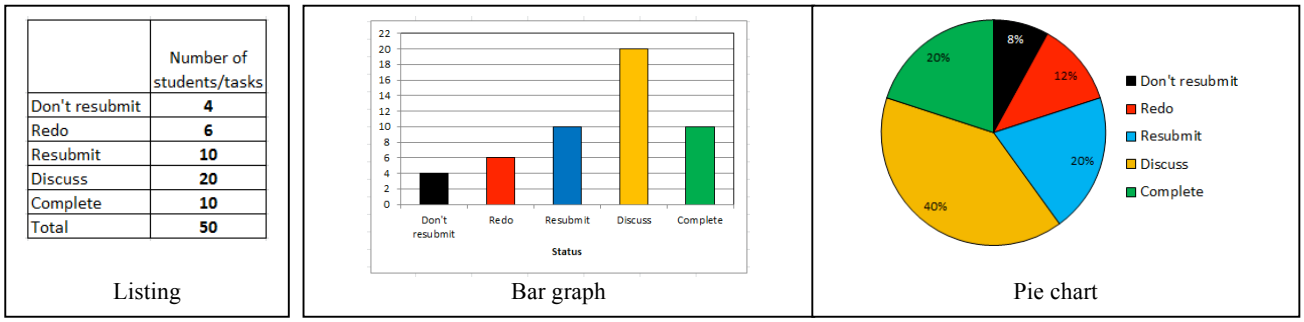

Fig. 2. Visualisations showing the status of learning task statistics

for "Don't Resubmit" if a student has submitted the work too many times without making any progress, red for "Redo" if the work requires significant changes, blue for "Resubmit" if the work requires small changes, yellow for "Discuss" if student needs to discuss their work with their tutor, green for "Complete" if the task is complete and grey shows a student has not started working on this task yet. A task backlog tracking tool shows the backlog of tasks remaining by week whereas the task completion tracking tool shows the number of tasks completed by week. The x-axis of these graphs shows the number of week. The y-axis of task backlog tracking tool shows the number of task remaining whereas the y-axis of the task completion tracking tool shows the number of task completed by week. 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. The result of the pilot study suggests both the task list and task completion tracking tool are the more popular visualisations.

B. An overview of learning task status statistics

We have three types of graphical representations to show the overview of students' learning task status as shown in Fig. 2. The representation formats include listing, bar graph and pie chart. These formats are popular graphical representation used in Statistics. Students are able to check the number of learning tasks for various statuses. They are able to visualize the number of tasks, especially those need their further action such as redo or resubmit. Teaching staff are able to inspect the status of learning task for their class to monitor progress. The result of the pilot study shows that bar graph is the most popular visualisation for both lecturers and students.

C. Visualize individual learning outcome achievements through various charts

There is no general agreed set of OLM visualisations as yet [29]. We have proposed ten different possible representation formats to visualize a student's learning outcome achievement. Six of them were adopted from [17], one from [23], and the rest are adopted from graphical representations used in the study of Statistics and we have adapted them to be used in our study. These include the bar graph, skill meter, target plot, grid plot, spider plot, tree map, smiley face, word cloud, table and pictogram. Examples are as shown in Fig. 3.

As each representation format has its own expressive power in presenting data to a user, we need to find out users' preference and visualisations that are useful in displaying the learning outcome achievements. A student's achievement is denoted by the height and length of the bar in bar graph and skill meter respectively. Colors are used to denote if a student is making good progress for grasping that particular learning outcome such as green indicates good progression and red for at risk. Positions of dots are used in grid plot and target plot to display a student's achievement whereas this information is indicated by area in spider plot and tree map. While smiley face uses face expression, word cloud uses the size of text to represent the achievement. As for table, the representation uses combination of text and graphic whereas in pictogram, achievement is indicated by the number of stars. Bar graph, skill meter and table were

found to be the more preferred visualisations in our pilot study.

D. Visualize class learning outcome achievement statistics through various charts

There are four types of representation formats in our OLM tool to display the learning outcome achievement of a class. They are the boxplot, ladder scale, fan scale and line scale as shown in Fig. 4. 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 [31]. Based on how a boxplot can graphically depict a summary of the data distribution, we propose another three types of representation formats, namely the ladder scale, fan scale and line scale. An exhaustive literature review related to OLM shows that most of the researchers in this field are focusing on representation of individual data instead of data statistics of a class. We enrich the current OLM for users to inspect data statistics of a class in terms of learning outcome achievement which includes the class average, the median score, maximum score, minimum score and the range score of fifty percent of the students in the class. We propose these representation formats in OLM as we postulate that these formats can reveal comprehensive and insightful learning data to users. We expect that users might be interested to know how their class performs in achieving a particular learning outcome and hence be motivated in improving their learning outcome achievement. The boxplot was found to be the most popular visualisation in our pilot study.

E. Comparison of learning outcome achievements

Most existing OLMs focus on presenting the learning data of an individual student. In this research, we enrich current OLMs for users to compare their achievements with the average achievement of their class and class statistics as well as comparison between sub-groups as shown in Fig. 5.

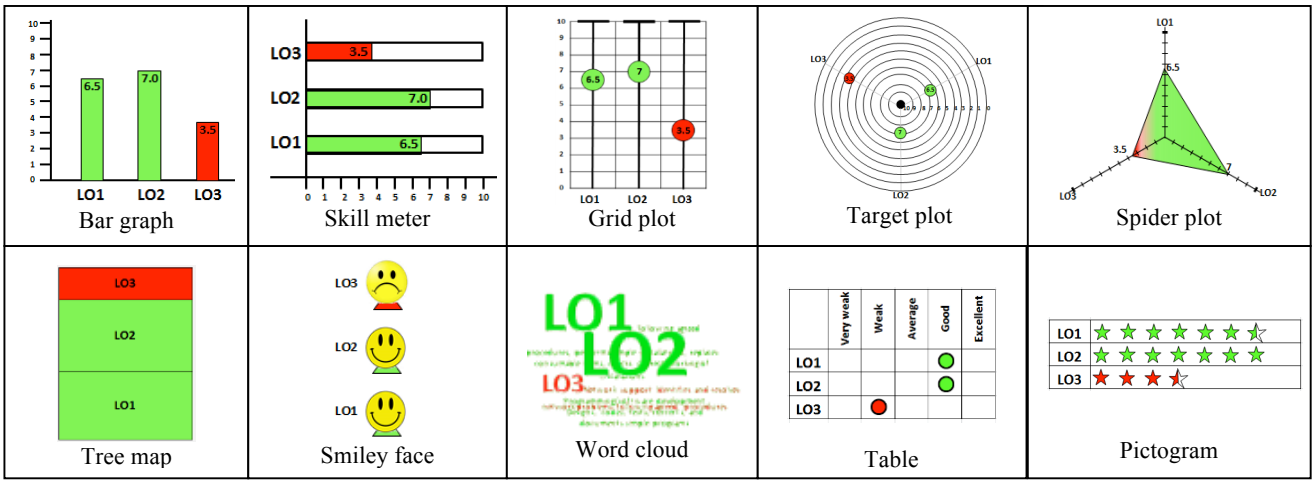

Fig. 3. Visualisations showing individual student's learning outcome achievements

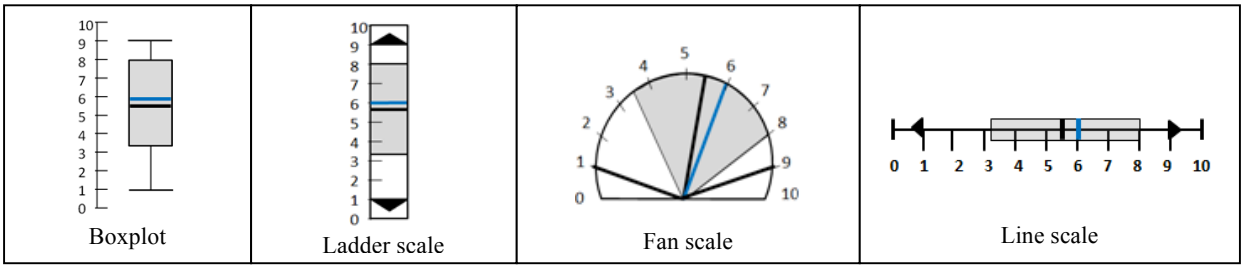

Fig. 4. Visualisations showing learning outcome achievement of a class

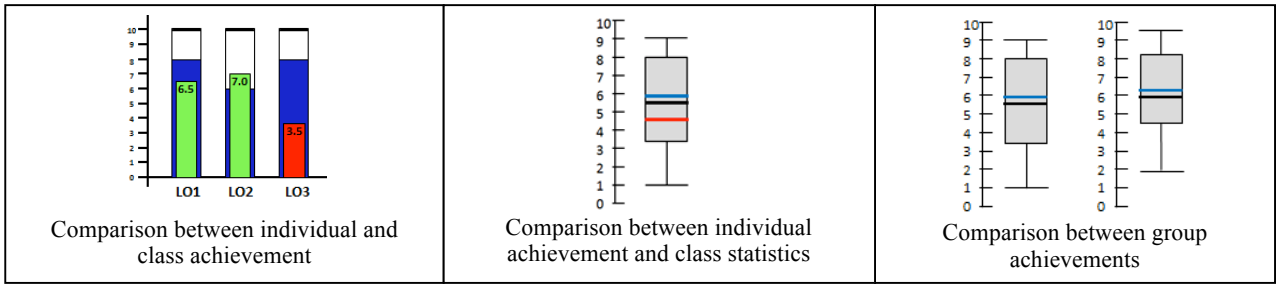

Fig. 5. Visualisations showing comparison of learning outcome achievements

Based on the representation formats as discussed in *C* and *D*, different colours will be used to display the comparison of the data, i.e. blue color represents class achievement and a green or red denotes individual achievements. The comparison can be seen from the height of the bars. For the comparison between individual achievement and class statistics, individual achievement is denoted by the red line in the example given in Fig. 5. A comparison between group achievements can be seen when the boxplots are placed side by side. Through these open learner visualisations, students are able to know if their achievement for a particular learning outcome is ahead or falling behind the class average and how their class is performing as compared to other class. Our proposed tool will enrich existing OLMs with class-wide and course-wide statistical data and comparison features. We expect that students will monitor their progress toward improving their learning outcome achievement relative to the progress made by their class or other classes. We posit that this can better fulfill users' information needs for inspecting their OLMs. Teaching staff can benefit from information about an individual student's achievement and also from information about the achievement of the class they are teaching. The result of our pilot study shows that respondents like to compare individual achievement with class statistics.

IV. PROTOTYPE DESIGN, DEVELOPMENT AND PLANNING OF EVALUATION STRATEGY

Our prototype design of the visualisations tool has been built through the video simulation using Macromedia Captivate. We developed a prototype of each of the visualisations shown above for example scenarios of use. We then had a set of target end users, teaching staff and students, use the simulation and give feedback on its support for visualisation of different courses, tasks, performance, individuals, groups and classes. After validation of our design with a number of students and teaching staff we plan to implement a full prototype for integration into our Blackboard Learning Management System and e-portfolio system. Blackboard LMS will provide information about course tasks and student progress. The e-portfolio will provide evidence of student task achievement. We will provide a detailed Course Learning Outcome and Unit Learning Outcome breakdown to support extraction and visualisation of student and class progress.

The key target end users for this tool are teaching staff and students from Swinburne University of Technology in Australia. We have recruited eight teaching staff and students for an initial pilot study of our tool. They were briefed about the features of the tool and how to use it via a tutorial and video. Further respondents will be recruited from interested teaching staff and students and introduced to this tool through our video simulation. A qualitative and quantitative analysis will be conducted through interviews with respondents as well as online survey questionnaires in order to solicit respondents' input to gain some insights on the following research questions:

1) *Which presentation formats are useful to present a student's learning task status?*
2) *Which presentation formats are useful to present a student's learning outcome achievement?*
3) *Which are users' preferred presentation formats?*
4) *Does the information given to users reflect their information needs to inspect the learner model?*
5) *Does the information given to users reflect their information needs to compare the learner models?*
6) *How important this tool in addressing some of the teaching and learning related needs and issues?*
7) *To what extent users will adopt this tool?*
8) *What are the factors affecting the adoption of this tool?*
9) *How to improve this tool to reflect users' information needs?*
10) *What are the barriers in using this tool?*

Both the teaching staff and students opinions on these aspects are useful for developing the OLM visualisation tool as they are the main users. The results of this study will give useful insights to the software development team to develop the tool. Thus, the contributions of this study are three-fold. First, the proposed visualisations will enrich current OLMs with more data for OLM inspection. Second, the results will serve as a guideline for the software development team to develop the OLM visualisation tool. Third, the potential users will benefit from the user-friendly interface to inspect the OLM which will then increase buy-in of this tool in the future.

V. CONCLUSIONS AND FUTURE RESEARCH

The new open learner model supporting tool proposed in this paper is concerned with improving the interface design of educational tools that can display useful learner model information regarding students' learning task progress and learning outcome to both the teaching staff and students. It is very important that OLMs have representation formats that are appropriate for users' information needs. Users' perceptions on how useful a representation format in viewing the intended data and their preference to inspect the learner model are important and yet interesting aspects to be studied.

Our OLM interface design prototype provides potential users with an evaluation platform that enable investigation of these aspects. We aim to investigate the feasibility of the proposed tool by identifying any significant issues relating to its use and by tackling any barriers an early stage of its development in order to improve it. The development of this tool and conducting field studies to analyse its use are important parts of our ongoing research work to improve it. In the future, we aim to offer guidance about the opportunities of incorporating its use in e-portfolio systems

as we posit that the graphical form of achievement representation can be a useful learning evidence to be documented as learning artefact in e-portfolio.

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