AN ONLINE RESOURCE TO INSPIRE LEARNING AND REFLECTION ON TEACHING: THE POTENTIAL OF THE SER

Lynda Ball

Melbourne Graduate School of Education, The University of Melbourne; lball@unimelb.edu.au

This paper will outline a new STEM Education Resource (SER) which was initially targeted for use with year 9 and 10 students. The SER aims to 'inspire' learning by developing students' independence and their capacity to plan and conduct real life investigations. The challenge is to ensure that there is adequate focus on 'M' in a STEM investigation and this is going to be evidenced through students' analysis, interpretation and presentation of evidence to support conclusions. The design of the resource can prompt teachers to consider ways to develop the investigative skills of their students, thus there is the potential to 'inspire' teachers to reflect on their teaching through use of the resource.

Keywords: Mathematics education, STEM, secondary school

STEM IS A FOCUS IN AUSTRALIA

Australia has a national STEM education strategy, which is in place from 2016-2026 (Education Council, 2015). In Australia, education is state based so the existence of a national strategy which has the support of all states highlights the importance placed on improving STEM outcomes across the country. There are three areas of national action in the STEM education strategy:

- "Increasing student STEM ability, engagement, participation and aspiration" (p.8)
- "Increasing teacher capacity and STEM teaching quality" (p.8)
- "Building a strong evidence base" (p.9)

Thus, there is a national imperative to improve STEM outcomes, increase the number of students studying STEM in later years of secondary schooling and there is recognition of the importance of building teacher capacity in order to achieve these goals.

OVERVIEW OF THE SER (STEM EDUCATION RESOURCE)

The goal of the SER was to provide an online resource with the capacity to improve the investigative competence of year 9 & 10 students through supporting students in conceptualising and carrying out STEM-based investigations. The SER had the potential to inspire learning and teaching by:

- developing students' independence and their capacity to plan and conduct real life investigations.
- prompting teachers to reflect on their teaching through consideration of use of the SER to develop the investigative skills of their students.

It was necessary to consider design features which could promote and develop students' independence in planning and conducting real life investigations. Independence was fostered by requiring students to make decisions, implement their approach to solve a problem and then articulating their thinking. For example, the inbuilt functionality of the SER prompted practices such as consideration of how to unpack a given scenario (which was pre-populated into the system by the teacher), followed by student identification of a problem to solve based on the scenario. Appropriate data to answer the problem then needed to be identified, as well as strategies to find or collect the required data. The SER supported group collection of data, however, students within a group could choose which subset of data they would use in their analysis. Decisions needed to be made about how to display selected data to assist in finding an answer for the problem. Independence was also fostered through the ability for students to keep a record of their thinking, findings and interpretation through the online system. Requiring students to decide on evidence to support their solutions and the production of a report to substantiate a solution to the given problem encouraged students to consider what is necessary to appropriately communicate a solution.

OVERVIEW OF DESIGN AND TRIALLING OF SER

Figure 1 provides an overview of the design and classroom trials of the SER. The SER was developed in an iterative fashion, where features were modified or changed as the system was developed. It was trialled in two teacher workshops and during the classroom trials. In the first teacher workshop there were ten teachers from the three project schools. Three teachers volunteered to use the SER with one of their classes and these teachers were present in the second teacher workshop. In between trials with teachers and students there were multiple iterations in response to project team trials.

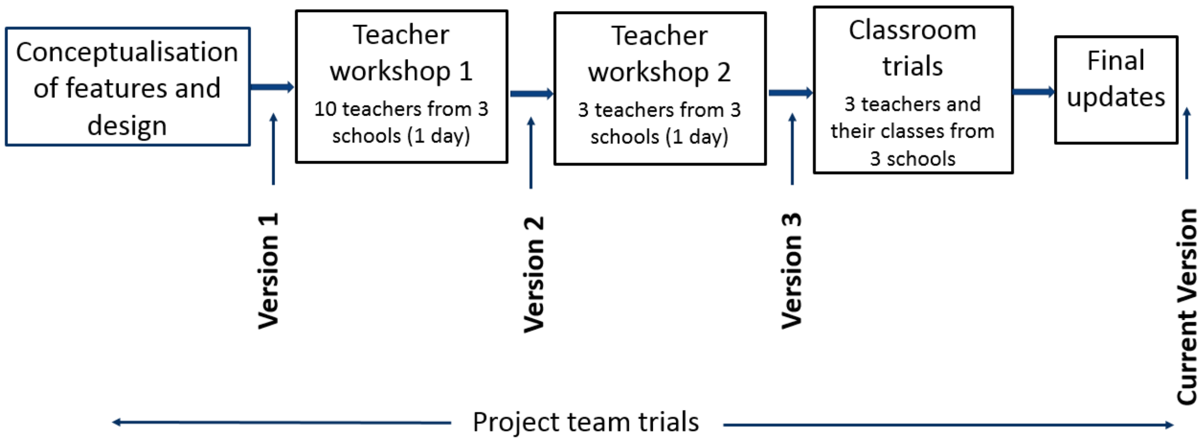

Figure 1. Overview of design and classroom trials

USER INTERFACE

There were design decisions in conceptualising both the content of the resource and the structure of the user interface. The user interface would impact engagement with the SER, so the system needed to be easy to navigate and use so that the educational goals could be realised. Decisions were made about which features would be fixed and unable to be adapted by the teacher and where there would be choice of features or the facility for the teacher to add tasks to focus students on particular aspects of the investigation.

Figure 2 shows part of the teacher interface, where teachers had the opportunity to create master versions of projects which could be shared with other teachers in the same school ("School projects"), access active projects being used with current classes ("My active projects"), set up sensors and Raspberry Pis for class use ("Admin") and organise student groups to work on projects. In order to support classroom implementation of the resource the team wanted to provide a resource for teachers where aspects could be customised to enable teachers to implement a range of investigations for students.

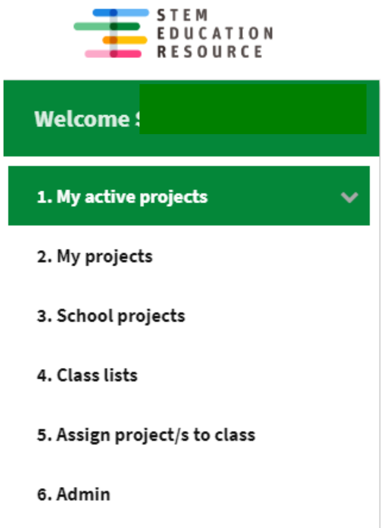

Figure 2. Overview of the teacher interface menu

To cater for a range of implementations of STEM the SER was designed with the functionality to be used by students in one subject (e.g. in their maths class) or across several subjects (e.g. where the data and work for a project could be accessed by students online in multiple classes). Enabling projects to be shared across classes supported interdisciplinary projects.

The student interface consists of five modules which support students in identifying a problem, collecting appropriate data, analysing and interpreting data, providing a solution supported by evidence and reflecting on the investigative process. Students can view their work for all modules and print a PDF of their written responses and any saved graphs, etc.

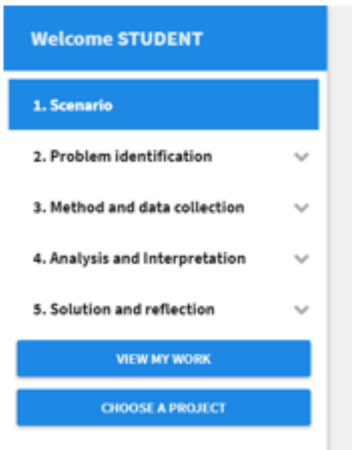

Figure 2. Overview of the student interface menu

Each module provides students with information to support them in their investigation. For example, in the "Problem identification" module students have to identify a problem to solve based on the scenario provided by the teacher. As part of this, students identify the explicit and implicit information to help them to understand the scenario. To support this, students are provided with an explanation about explicit and implicit information and they are then asked to identify and record this information for the scenario they are investigating. Students are expected to state a problem to solve, based on the scenario, and make a conjecture to predict what the answer might be.

In module three, students need to identify and collect data to assist in solving their problem; this data can be from a variety of sources including existing data sets, measurements from sensors or data collected via surveys, etc. When completing the modules students can collect data, produce graphs/tables/summary statistics and record their thinking and reflections on the investigation through the given prompts.

In the final module students produce a solution to their problem, supported by evidence from within the other modules. In this module students are asked to reflect on their solution, as well as the investigation as a whole. Students are asked to comment on 'things I know for next time' and advice they would give a friend who had to do the same investigation. This reflection is intended to promote metacognition about the investigative process.

SER SUPPORTING CLASS DISCUSSION

Technology displays have been identified as playing an important role in enabling discourse in the mathematics classroom (Ball & Barzel, 2018). The SER supports communication by enabling groups of students to access common datasets, so that they can compare and contrast representations and analysis of data with other members in their group. The ability to view technology displays can facilitate student discussion about selection of appropriate subsets of data to answer a given problem, choice of graphs, tables and statistics to provide evidence for a solution and reasoning to communicate thinking.

In addition to facilitating discussion in small groups, the SER can also enable teachers to promote discussion at a class level. Classroom display of student work using technology has been shown to support engagement with mathematics through consideration of cases which prompt mathematical discourse (Clark-Wilson, 2010). Using the teacher interface, it is possible for the teacher to access the data collected by all groups of students, as well as each individual student's responses to prompts requiring written reasoning. The ability for the teacher to show up to four displays at one time using a split screen (Refer to Figure 2) can provide prompts for class discussion through:

- multiple representations of one data set, to compare the appropriateness or usefulness of different graphical representations
- graphical representation of multiple data sets for comparison
- displays of tables of data or summary statistics
- display of student written responses for discussion (accessed through 'View prompts')
    - this can facilitate discussion of effective reasoning and use of mathematical terminology and ideas to support the investigation

Metacognition can be promoted through reflection on strategies (Baker, 2013); in this case the choice, representation and analysis of data can be used to promote student reflection about their strategies for finding a solution to their problem. Mathematical discourse can be promoted through consideration of choices when displaying data, as well as what the 'best' graph may be for answering a given problem and through comparison of students' reasoning for responses to prompts.

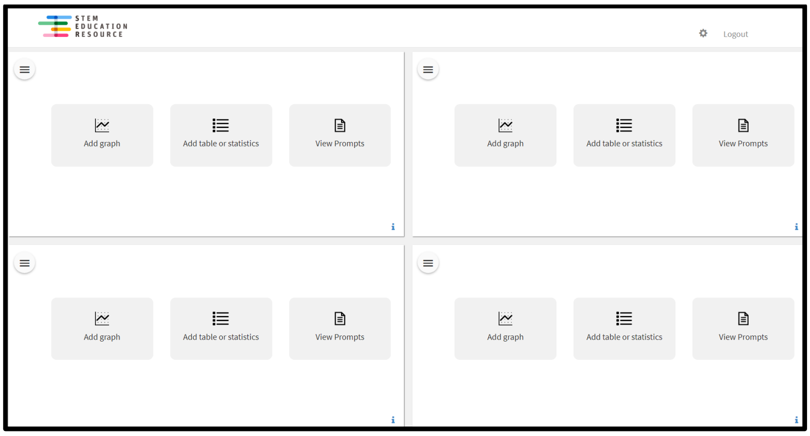

Figure 3. Four data displays - prompt class discussion

MATHEMATICAL FUNCTIONALITY

English (2015) highlighted the need to ensure that mathematics had appropriate importance in STEM. One challenge in developing the SER was to ensure that there was the potential to support a focus on 'M' in STEM investigations. The actual investigations were to be determined by the teacher, so the design features of the SER needed to support the use of mathematics in investigations. Major functionality identified as crucial to investigation was the ability to collect and tabulate data, produce graphs and find some summary statistics. This approach was supported by English (2016), in a commentary on STEM education, when she suggested that mathematics has a key role in enabling students to work with and critically interpret data in context. The SER was designed to support such data interpretation through the functionality within the system.

The SER does not contain a computer algebra system (CAS), or a calculator, so if students want to use these technologies to support their investigation they will need to be used independently of the resource. The ability to upload pdfs enables students to include screendumps, graphs or images from other technologies, as well as hand drawn graphs or pen-and-paper solutions to problems. This can assist in students' communication of the reasoning for their solutions to problems.

CLASSROOM IMPLEMENTATION OF THE SER

To prepare for classroom implementation of the SER it was necessary to introduce teachers to the features of the latest version of the SER during the second teacher workshop. The intention was to ensure that teachers were familiar with any updated functionality and the use of data collection tools, namely the sensors and Raspberry Pis. Teacher workshop two also had time for teachers to develop draft scenarios for use in their schools. This gave teachers an opportunity to discuss potential scenarios across the three schools and to work on descriptions to be used with their students.

The SER was trialled in three classes. The participants were three teachers from three different schools and the students in the classes where they used the SER. The three classes were: a year 8 class, a year 9 class and a group of students drawn from year 7 & 8 classes (in one school).

SNAPSHOT OF STUDENTS' USE OF SER FROM THE TRIAL

This section provides a snapshot of some initial findings from the trial of the SER. Sample student responses are presented to highlight some potential of the SER to foster investigation and promote communication about investigations. It is important to note that there were limitations in the data collected, as not all students had the opportunity to complete all aspects of the given tasks, due to timetabling constraints, but for the students who did manage to complete all tasks the sample responses show that there is potential for the SER to provide support for investigations involving data.

Graphs prompted classroom discussion of mathematics in context

The inbuilt functionality of the SER supported analysis of data and production of graphs. When students included graphs to support their investigation, the SER prompted them to explain what the graph shows, as well as explain how the graph contributes towards a solution to their problem (Figure 4). These two aspects ensured that students were considering any graphs produced in the context of the entire problem, not in isolation from the problem.

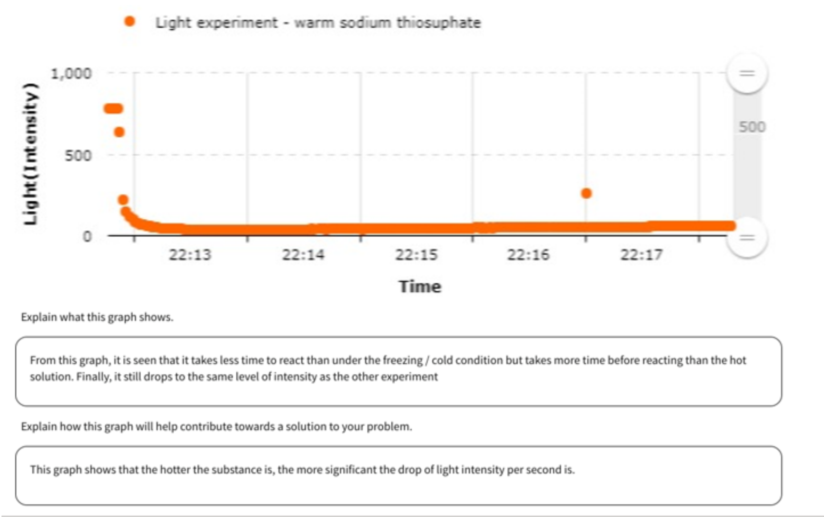

Figure 4. Sample student graph with responses to two prompts

Students identified further opportunities for analysis, including alternative displays and calculations. This implies that students engaged with the investigative process, considering how well the chosen displays helped with providing a solution to their problem.

Having students give written responses to prompts appeared to be positive and links to mathematical language were evident in some responses. One student used understanding of the shape of the graph of exponential functions to describe results, even though exponential functions had not been covered in mathematics yet.

> "…The results collected…seem to defy the normal and expected by going back up again after reach[ing] it's lowest point. This means it is most likely that there was an uncontrolled variable in there (sic) practical as most results took on the shape of an exponential. The main trend seen in the rest of the data is this steep slope from the moment the liquid is introduced. This slope looks steeper the hotter the liquid is."

This suggested that where problems afforded students the opportunity to use mathematics other than the current topic, the SER could have the potential to support this through the structure of the prompts presented to students.

Student reflection on the investigative process

One goal of the SER was to develop students' independence and their capacity to plan and conduct real life investigations. Achievement of this goal relies on students being able to reflect on both the current investigation and the investigative process, thus drawing on metacognitive knowledge. As students complete the modules there are points where they are asked to reflect on their work and on the investigation. In the small trial carried out to check the efficacy of the SER there were a range of reflections produced; some of which showed that students were being critical of their choice of data display, in the context of providing good displays to enable the problem to be answered effectively. For example, one student noted the need to consider choice of data sets, while another noted the need to collect multiple data sets to support the solution of a problem:

> "In order to improve the display of data, it would be better if my set(s) of data are combined together and compared at the same time, figuring out the difference of the reaction time of different experiments."

> "Try collecting multiple data sets of data so that you have enough data to work with and solve your problem".

The importance of accuracy in dealing with data and providing appropriate evidence to support solutions was emphasised:

> "Furthermore, during the data collection process, it is important to keep the consistency, accuracy and precision at all times. When answering the question, use graphs and tables to interpret the data and support your "argument" or "hypothesis"."

In reflecting on what students would need to know for the next time they used the SER, there were comments that focussed on aspects of a mathematical investigation, namely the need to understand a problem, collect appropriate data and use mathematics to support answers.

> "Firstly, it is highly essential to understand your aim and what you are going to investigate. This means you have to firstly identify and analyse your problem, trying to "problem-solve" it."

> "Make sure the evidence you provide an actually support your claims"

These comments suggest that the SER prompted consideration of more than technical issues, which might be expected when students are learning to use a new technology. A focus on evidence supporting the claims made could be capitalised on when students are working on other mathematical tasks where reasoning needs to be supplied for a solution to a problem.

CONCLUDING REMARKS

The SER was found to be useful, with positive feedback from teachers and students. The engagement by teachers and students was generally high, with teachers very keen to use the SER in subsequent years.

Based on the data we have we can't say that the SER improved investigative skills, as we have not collected longitudinal data at this stage. But, students' reflection on the investigative process points in a positive direction. One challenge for use of the SER is in developing scenarios at an appropriate level where students can have genuine choice of problem to solve.

The initial trials of the SER suggest that there is potential for capacity building with regards to students' ability to carry out investigations. Future investigations will consider types of scenarios to be used with the SER to focus on M in STEM; an important consideration if we are to include STEM investigations in secondary school.

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