

OPENING REAL SCIENCE: EVALUATION OF AN ONLINE MODULE ON STATISTICAL LITERACY FOR PRE-SERVICE PRIMARY TEACHERS

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ABSTRACT

Opening Real Science (ORS) is a three-year government initiative developed as part of the Mathematics and Science Teachers program. It is a collaboration across universities involving teacher educators, scientists, mathematicians, statisticians and educational designers aimed at improving primary and secondary pre-service teachers' competence and confidence in mathematics and science. The ORS project has developed 25 online learning modules for pre-service teacher programs. Statistical literacy is prioritised. The Statistical Literacy Module for Primary Teachers (SL-P) adopts an inquiry-based approach and uses resources and contexts relevant to their practice. This paper documents the development and evaluation process of SL-P from its conception to implementation, and reviews the initial trials .

Keywords: *Statistics education research; Pre-service primary teachers' education; Opening Real Science (ORS); Statistical literacy; Inquiry-based learning*

1. INTRODUCTION

The demands of the 21st century require that individuals be statistically literate in order to make the informed decisions and judgments necessary for participatory citizenship. Thus, an active citizenry requires the ability to interpret data, as it is represented in a range of formats and for different purposes. Internationally, however, the teaching of mathematics and statistics has tended to focus on mechanical skills and procedures with less emphasis placed on solving real-world problems (Tishkovskaya & Lancaster, 2012). While there have been numerous attempts at reform, it is widely acknowledged that there is still more work needed to improve statistics education in schools (Garfield & Ben-Zvi, 2007). The challenges associated with introducing a stronger focus on statistical understanding and skills into school curriculum are well documented internationally. For example, in Brazil, teachers' statistical knowledge has been identified as limited and many teachers lack confidence to teach even basic statistical concepts (de Souza, Lopes, & de Oliveira, 2014). A similar scenario exists in South Africa that has led to significant disparities between the intended and enacted curriculum (North, Gal, & Zewotir, 2014).

Challenges associated with students' statistical literacy development are not simply restricted to teacher knowledge but can also be related to curriculum design. A recent review (Watson & Neal, 2012) of the Australian curriculum in mathematics (ACARA, 2011) analysed the links between 'Statistics and Probability' and 'Number and Algebra' in relation to the mathematical proficiencies of understanding, fluency, problem-solving and reasoning, and with other curriculum areas, general proficiencies and cross-curriculum priorities. Watson and Neal concluded that this curriculum exhibits inconsistent connections between statistical literacy and other areas related to content and mathematical skills and that these represent 'curriculum gaps'; in order to fill these gaps there is need within initial teacher preparation to heighten the focus on the embedding of data representation, statistical reasoning and inference and make explicit connections of statistics to other curriculum areas.

Thus, in the Opening Real Science (ORS) program statistical literacy was prioritised in the mathematics suite of modules with two of eight modules focused on statistical reasoning; these were developed for both primary and secondary pre-service teachers. The modules addressed the broader aims of ORS by embedding inquiry-based tasks and contexts involving the pre-service teachers in collecting and analysing their own data and interpreting relevant data sets.

The purpose of this paper is to document the development and evaluation process of the module *Statistical Literacy – Primary* (SL-P) from its conception to trialling, and to report on initial trials with two samples of primary pre-service teachers.

2. STATISTICAL LITERACY: A RATIONALE

Statistical literacy as a goal of education was highlighted as early as the 1980s in the influential Cockcroft Report (1982) where it was argued that:

... the need in the modern world to think quantitatively, to realise how far our problems are problems of degree even when they appear to be problems of kind. Statistical ignorance and statistical fallacies are quite as widespread and quite as dangerous as the logical fallacies that come under the heading of illiteracy. (p. 11)

Consistent with this view, Gal (2002) defines statistical literacy as "people's ability to interpret and critically evaluate statistical information, data-related arguments, or stochastic phenomena" and "their ability to discuss or communicate their reactions to

such statistical information” (pp. 2-3). Further, Gal argues that becoming statistically literate is achieved through developing two capabilities: (1) an ability to interpret and critically evaluate statistical information within diverse contexts; and (2) the capacity to discuss and communicate the interpretation and evaluation of statistical information. These capabilities empower an individual to make judgments and decisions based on evidence and to support or challenge opinion from an evidence base.

Gal (2002) also positions statistical literacy as something to be activated rather than learned or developed. In doing so, he proposes a model of statistical literacy that combines knowledge and dispositional elements (literacy skills, statistical knowledge, mathematical knowledge, context knowledge and critical questions for the former; beliefs and attitudes, and a critical stance for the latter).

The need to educate about the use of statistical information to support or challenge stated positions (often in a political context) means it is vital that topics such as average, sampling, variation, inference, probability and data handling are explored and brought into relief against application in the real world (Watson & Callingham 2003). Steen, (2007) points out the danger of failing to address the critical aspect of statistical reasoning:

As information becomes even more quantitative and as society relies increasingly on computers and the data they produce, an innumerate citizen today is as vulnerable as an illiterate peasant of Gutenberg’s time. (p. xv)

Watson (2006) has also reported that task motivation is an important factor to achieve statistical literacy and needs to be developed as early in the education process as possible (e.g., during primary school years).

Despite the demonstrable importance of developing the capacity in individuals to reason statistically, there remain challenges for promoting statistical literacy within the Australian context and internationally. Garfield and Ben-Zvi (2004) have noted that these challenges include: the complex nature and counter intuitiveness of some aspects of statistical reasoning and thinking; the reliance on a learner’s knowledge of other forms of mathematics; the misleading nature of some contexts in statistical situations; the messiness associated with data drawn from authentic contexts; and the open-endedness of interpretation based on initial assumptions.

From another perspective, Groth (2007) asserts that statistics is a discipline in itself rather than a branch of mathematics. However, he highlights the relations between mathematics and statistics where the content knowledge developed for mathematics differs to some extent from the knowledge developed to teach statistics. Understanding statistical concepts centres around activities that are not exclusive to mathematics; for example, interpreting and constructing meaning from data and being able to reason about the reasonableness of results represented by the data in a variety of contexts. He presents a balanced view that mathematics and statistics do share some commonalities, such as mathematical language and graphical representation, but there are distinct disciplinary differences between the two fields.

These challenges, however, provide background for opportunity to innovate about how statistical literacy and, specifically, statistical reasoning is promoted in the pre-service and in-service teaching space. The following sections of this article address this opportunity by outlining and describing an approach utilised to develop an online teaching and learning module aimed at promoting pre-service teachers’ statistical reasoning capabilities.

3. OPENING REAL SCIENCE (ORS) PROJECT

3.1. FOCUS AND GOALS OF ORS

The Australian-Government-funded *Enhancing the Training of Mathematics and Science Teachers* (ETMST) program aims to drive a major improvement in the quality of mathematics and science teachers by supporting new pre-service programs in which faculties, schools or departments of science, mathematics and education collaborate on course design and delivery, combining content and pedagogy. The overarching goal is to promote mathematics and science teaching as dynamic, forward-looking and collaborative human endeavours (Office of the Chief Scientist, 2013). As one of five consortia across Australian universities, the ORS project, focused on developing a new pre-service teacher education program in mathematics and science (Mulligan, Hedberg, Parker, Coady, & Cavanagh, 2014). An interdisciplinary approach was adopted, and included the engagement and perspectives of both mathematicians and statisticians.

The ORS project aims to improve the quality of mathematics and science education by engaging pre-service teachers, particularly those in primary programs, in authentic concepts of science (Braund & Reiss, 2006; Ziman, 2000). One of its goals is to embed an understanding of the role of mathematics within scientific processes (Matthews, Belward, Coady, Rylands, & Simbag, 2012). The project's approach focuses on student-centred learning, employing problems in which students are genuinely interested, utilising investigative approaches, coupled with scaffolded applications of digital technologies (Bower, Hedberg, & Kuswara, 2010).

ORS developed 25 online learning modules, eight of which focused on mathematics. In particular, there is a focus on numeracy in applied contexts, statistical and financial literacy to prioritise those aspects for which pre-service students have not had sufficient experience. Another key focus was on the development of 'authentic' statistical reasoning experiences utilising an inquiry-based model adopted from science education.

3.2. INQUIRY-BASED, AUTHENTIC PEDAGOGIES: THE 5Es APPROACH

An inquiry-based approach to science education, formalised by Bybee (2009), structures learning into five phases: engage, explore, explain, elaborate and evaluate. Nunes-Bufford, Burton and Eick (2013) demonstrated for pre-service teachers, and Stinson, Harkness, Meyer, and Stallworth (2009) for in-service teachers, that they can recognise commonalities in inquiry-based teaching approaches of science and mathematics, even if their pre-conceived ideas were contrary to this (Phoshoko, 2013), after learning specifically about teaching styles for integrated curricula. Similarly, research by Lyons (2011) provided evidence that, through authentic and integrated inquiry-based learning in astronomy, non-science university students were able to identify the relationship between data and evidence. Alternatively, inquiry-based learning and concept representation were successfully used as a constructivist lesson-sequencing strategy for science teacher professional development (Nakedi, 2014) and in a small primary school to "mediate the kind of authentic practices that scientists apply but also make learning more holistic" (Liljeström, Enkenber, & Pöllänen, 2013).

ORS uses an authentic inquiry-based pedagogical approach, an extension of the 5Es model incorporating a sixth E, 'elucidate', in which mathematics is embedded in authentic or 'real science' settings. The inquiry-based 6Es model supports the design of learning activities with appropriate resources to support individual and peer learning. This is discussed further in the following sections.

4. MODULE DEVELOPMENT

An interdisciplinary team comprising six academics who are mathematicians and/or statisticians, mathematics and/or statistics educators, as well as one educational developer, from three Australian universities contributed to the development of the SL-P module. A ‘storyboard’ of the module was organised around the *engage, explore, explain, elaborate* and *evaluate* phases of the 5E inquiry-based framework. The module learning experiences utilised authentic settings in which statistics may be used by primary-school teachers. Core concepts were embedded, as a basis to developing statistical literacy such as making inferences and critiquing statistical claims. Core questions were based on empirical research of students’ conceptions of statistics, learning statistics, and its role in their personal and professional lives (Petocz & Reid, 2010; Reid, Abrandt Dahlgren, Dahlgren, & Petocz, 2011). This research showed that students have qualitatively different ways of thinking about such questions, and highlighted the pedagogical benefit of being exposed in a group situation to a wider range of views than one’s own, particularly to views that are broader and more holistic.

It was also intended that settings provide opportunity for a sixth ‘E’, ‘*elucidate*’, to be incorporated in the model. Module team members generated contexts for statistical learning based on their expertise. They discussed ideas and resources for activities and assessment tasks that could be delivered in an online format, as group and individual activities, and to develop a succinct set of learning outcomes. The SL-P module was equivalent to 30-40 hours of study at the undergraduate level, or approximately one-third of a semester unit applicable to a teacher education program.

The module was then constructed as a narrative by the educational developer, using a ‘backward-faded’ scaffolding approach (Slater, Slater, & Shaner, 2008). Backward-faded scaffolding requires the initial exploration of an inquiry to be extensively supported with assistance in conducting all stages. As students develop and demonstrate their sophistication for conducting inquiries, support is gradually withdrawn. Finally, the narrative was transferred to a learning management system site (Moodle) by an educational designer. The resulting online module comprised five topics, *Using Statistics in the Real World, Key Concepts in Statistical Literacy, Critiquing Statistical Claims, Using Statistical Reasoning, and Presenting and Evaluating Evidence*.

The following sections describe the outcomes, learning activities and assessment tasks developed as a sequence of topics.

4.1. ENGAGE PHASE: USING STATISTICS IN THE REAL WORLD

The learning outcome for the initial topic was to explore how statistics is used in the real world. The students were given a set of questions to provoke them to consider their views of statistics and the use of statistics in their lives. They were asked to post their answers to a discussion forum to create a common ground for their future collaborative work. The stimulus questions were:

- What do you think statistics is?
- Why do you want to learn about statistics?
- How do you think you would best learn about statistics?
- Which role do you think that statistics can play in your professional work as a teacher?
- Which role do you think statistics can play in everyday life?

Three videos were used to engage students’ interest in the presence of statistics in people’s lives. They viewed (online) a video produced by the UN Economic Commission

for Europe entitled, “What is Statistics?” (UNECE, 2013), and two videos presented by Professor Hans Rosling entitled, “200 Countries, 200 Years, 4 Minutes” and “Don’t Panic – The Facts about Population” (Gapminder, n.d.). Students were then asked to discuss in another forum:

- Which aspects of statistics are mentioned in the videos?
- Do you think that videos such as these would help you to learn more about statistics? Please give reasons for your answer.
- Which aspects of statistics could be interesting for your students and why?
- Which role do you think statistics can play in the development of a sustainable future for the world?

The aim of the first discussion forum was to gauge the background range of students’ statistical literacy. The videos then identified examples of professional uses of statistics in education and other careers, and included some rich graphical visualisations of the data discussed. The second discussion forum prompted the students to make interpretations of the data presented and discussed in the videos and then to think about their relevance in a classroom setting.

4.2. EXPLORE PHASE: KEY CONCEPTS IN STATISTICAL LITERACY

The learning outcome for the second topic was to identify, calculate and interpret key statistical concepts needed in analysing a dataset. By using demonstration datasets from Australia’s national numeracy testing (NAPLAN: National Assessment Program – Literacy and Numeracy, NAP, n.d.) for Years 3 and 5 (ages 8-9 and 10-11 years), the module focused the pre-service teachers in a context of immediate interest for their future profession. This latter module allowed to explore and become familiar with various categories of numeracy data and their visual representation. Students were then required to select 30 Year 3 students’ results from the demonstration dataset, to calculate descriptive or summary statistics, and to post in a discussion forum answers to four questions, including their evidence as calculated from and visualised by their sample data set:

- Which areas of numeracy are examined?
- Which areas does the Year 3 class appear strong/weak in?
- How can you tell?
- Which conclusions can you make about the numeracy results of this class?

This activity was complemented by a resource window at the beginning of the topic, which linked to videos and websites on how to calculate descriptive statistics and create graphs in Excel, and how to interpret them. There was also a broad range of optional resources that extended these explorations of statistical concepts. The assessment for this topic was to explore a dataset from the Year 5 demonstration set in a similar manner and to submit results, both numerical and graphical representations, online in a brief 1-2 page report. The purpose of this assessment was to gauge how well students had grasped these procedures and understood their meaning by replicating the activity with a different dataset. An example is provided in Appendix A.1.

4.3. EXPLAIN PHASE: CRITIQUING STATISTICAL CLAIMS

The learning outcome for the third topic was to critique statistical claims as made in the media by investigators (see Appendix A.2). In this topic, students were provided with links to international data on mathematics and science performance of Year 10 students (ages 15-16 years) through the Program for International Student Assessment (PISA) and

Year 4 and 8 students (ages 9-10 and 13-14 years) through the Trends in International Mathematics and Science Study (TIMSS, n.d.). They were asked to examine newspapers' claims about PISA data and to explain in a discussion forum post why they are accurate (or not) using the following questions:

- What do these data represent?
- Describe the trend(s) for Australian students over the period 2003 to 2012 for PISA data.
- Are the conclusions made by the authors of the articles accurate? Why or why not?

For the assessment, they were directed to an official report of TIMSS data on the Gapminder (n.d.) website and asked to choose one finding for Year 4 or 8, comparing results from 1995, 2003 and 2007, and to demonstrate how the authors of the report arrived at their conclusions, using summary statistics and graphical representations of the data in a report of 1-2 pages. They were provided with a rubric (see Appendix A.3) to guide the quality of their report.

Students could refer to previous sections for assistance with calculating descriptive statistics and graphical representations, and their answers were scaffolded by the rubric.

4.4. ELABORATE PHASE: USING STATISTICAL REASONING

The learning outcome for the fourth topic was to formulate a question that could be answered quantitatively and to answer the question and argue the claim (i.e., their answer) using statistical evidence and reasoning. Students were asked to undertake an investigation in a small group (of two or three students), choosing an education- or science-related topic on the Gapminder website, to find a media report that investigated the same issue, and to examine the accuracy of the media report via statistical analysis. Students were asked to:

- Formulate a scientific (testable) question;
- Identify the variables involved and the data sampling strategy required;
- Download appropriate data from the Gapminder website;
- Calculate descriptive statistics;
- Present results graphically in a PowerPoint or Prezi web-based software or using a multimedia presentation (video);
- Make a judgement on the accuracy of the media report and support their claims with analysis they performed.

This complex activity was scaffolded by three examples of media reports that explained other people's reports and demonstrated how they have misinterpreted data and/or analyses, and then provided the correct interpretations.

4.5. EVALUATE PHASE: PRESENTING AND EVALUATING EVIDENCE

The learning outcome for the final topic was to evaluate the use of relevant evidence such as data, analysis, statistics and interpretations. Students were asked to upload their group's presentation, to view fellow-students' group presentations, and to comment in a discussion forum on at least two presentations regarding their effectiveness in using evidence and statistical reasoning to evaluate an education or science issue reported in the media. A rubric (see Appendix A.3, for a shortened version) was provided to guide the formulation of a scientific (testable) question, identification of variables involved and sampling strategy required, selection of appropriate data from the Gapminder website, calculation of descriptive statistics, graphical presentation of results, and making

judgements about the accuracy of media reporting of similar data. Students were then asked in their groups to assess two of their fellow students' group presentations, provide reasons for their grades, and then reflect on how well the presentation addressed each part of the rubric. These reports were uploaded to an assessment Dropbox.

Finally, students were asked to reflect individually (and submit to an assessment Dropbox) on how they would use statistics, evidence and the evaluation of evidence differently in their personal and professional lives after completing the module, by answering these stimulus questions:

- What do you think the role of statistics is in everyday life?
- What did you do in this module that has influenced your thinking?
- In which way (if any) have your ideas about statistics changed after completing this module?
- Has your attitude to the use of statistics changed? Explain how it has changed in relation to the future impacts on your teaching.

The inquiry-based activity in the previous topic, the critical evaluation of others' reports in this final topic, and the reflection on their changed understanding of statistics provide in-depth opportunities for students to develop skills in inquiry-based investigation (Bybee, 2009).

4.6. ELUCIDATE PHASE: AUTHENTIC MATHEMATICS AND SCIENCE

Elucidating key statistical concepts was attempted through the semi-authentic setting of manipulating and interpreting demonstrations from the NAPLAN data. Critiquing statistical claims was elucidated (a) through comparison of media interpretation of PISA versus professional statisticians' interpretations of TIMSS data, and (b) by using statistical reasoning to present and evaluate evidence used in authentic inquiry into scientific and educational problems, using data available on Gapminder. The contexts for using statistics were not explicitly mentioned within the learning strategy and instructions; but, as will be revealed in the results, prompted attention and comments from students and tutors.

5. MODULE TRIALLING

An initial review was carried out by members of the project team comprising three expert academics and a primary pre-service teacher. This was followed by the revised SL-P module being trialled at two participating universities during 2015, a pilot during the first semester at one university, and a larger trial during the second semester at the other. The sample was drawn from primary teacher education programs with Bachelor of Education (Primary) degree programs. These programs focused on Education (and Pedagogy). In the first trial, 16 pre-service primary teacher education students completed the module as an optional addition to the regular program requirement. The data collection included a survey of the pre-service teachers' views of a range of key aspects including confidence, content and statistical reasoning. The evaluations were completed by 9 of the 16 students (56%). The module was offered fully online, with the tutor responsible for providing prompt and timely feedback.

5.1. THE EVALUATION QUESTIONS

The evaluation questions are shown in Table 1 and comprised three modes: a survey using a Likert scale indicating the range of agreement; binary responses to aspects of

functionality and usefulness, and some open-ended questions designed to gain deeper responses. The university tutor also provided in-depth evaluation of the module via open-ended questions (shown in Table 2) designed to describe the context of module delivery and questions about module effectiveness for student learning

Table 1. Pre-service teacher evaluation questions

Questions (Likert scale)	
Q1	I felt engaged as soon as we started the module.
Q2	The module included a variety of activities which allowed me to explore the topic.
Q3	I can now offer an accurate explanation of the mathematical concepts covered.
Q4	The assessment tasks allowed me to demonstrate my understandings of the topics.
Q5	I have a better understanding of the mathematical thinking process ('working mathematically').
Q6	I feel more confident designing learning experiences about mathematical/statistical concepts.
Q7	Completing this module was relevant to my studies.
Q8	I would recommend completing this on-line module to a fellow student.
Binary Response Questions	
Q1	Was it easy to navigate the module?
Q2	Was it clear what you were supposed to do?
Q3	Do you think your understanding of the module topics has changed?
Open Ended Questions	
Q1	What were your first impressions of this module?
Q2	List two features of the module you found enjoyable.
Q3	How would you improve the module?
Q4	Do you have any other comments or feedback about the module?

The survey began with a request for an overall rating for the module (Figure 1).

Table 2. Tutor evaluation questions

Q1	How effective do you think the module was in encouraging pre-service primary education students to employ an inquiry-based approach (engage, explore, explain, elaborate, evaluate and elucidate) to the module topic?
Q2	How successful was the module in improving pre-service primary education students understanding of the scientific/mathematical concepts embedded in the module?
Q3	How do you think the module will enable pre-service primary education students to undertake a scientific 'working mathematically' approach to their own teaching and learning?
Q4	Which aspects of the module did you find most interesting?
Q5	Which aspects detracted from the module?
Q6	Which elements of the module need to be changed for the next version and why?

5.2. DISCUSSION OF FINDINGS

Pre-service teacher evaluations The small-scale initial trial is reported first as it provided pilot data that informed the evaluation process for the second trial. The responses were almost uniformly scattered between the lowest and the highest rating, indicating the wide range of responses to the module.

Question: Thinking about the online module you completed, how would you rate it overall?
(Please note, you need to move the slider tool to register a response.)



1/7



2/7



2/7



1/7



1/7

Using a scale of 1 to 5, Mean 2.9, SD 1.3, N = 7

Figure 1. First trial pre-service teachers' overall satisfaction level

A second trial was carried out with a larger group at a second site: 100 pre-service teachers, 93 of these completed the module, indicated by their submission of the final assignment, and 34 of these (37%) completed the evaluation. These pre-service teachers completed the module as a formal part of their studies (rather than as an optional extra). They worked in their regular class on the online tasks, with support from their tutor. Thus, they experienced the module in a mixed mode of delivery.

The slider function used in the previous trial was replaced by a six-point Likert scale, from 1 = strongly disliked to 6 = strongly liked. These responses are shown in Table 3.

Table 3. Trial 2 pre-service teachers' evaluation

Rating	1	2	3	4	5	6
Frequency	0	2	3	13	13	3
Mean, SD	(4.4, 1.0)					

The first question was followed by eight Likert-scale statements (see Table 1) on a six-point scale, three questions with Yes/No answers, and four open-ended questions (Figure 3). Since these questions were the same for both trial groups, the responses (N = 43) have been combined for analysis.

The variability of pre-service teachers' responses is clearly indicated (Figure 2). Most students reported that the variety of activities in the module allowed them to explore the topic (79%), that they understood the mathematical concepts involved (76%), had developed a better understanding of 'working mathematically' (68%), and that the assessments allowed them to demonstrate their understanding (81%). However, others reported that they did not feel engaged by the module (43%) and would not recommend it to fellow students (41%). The most obvious feature of the responses is the dichotomy between a group with cautiously positive responses (4s and 5s) and a smaller group with stronger negative reactions (1s and some 2s).

Mostly, students found the module easy to navigate (88%, 38 out of 43), and they were aware of what they were supposed to do (79%, 34 out of 43). A smaller number of

students (69%, 30 out of 43) thought that their understanding of the topics had changed after completing the SL-P module.

In response to the open-ended questions (Table 1), comments made by the pre-service teachers indicated the wide range of responses. The word clouds shown in Figure 3 were created by Wordle, a free, web-based software (see, Wordle, n.d.), where the size of the font in the clouds is indicative of how often the words are used. The word cloud of the pre-service teachers' first impressions of the module (Figure 3A) shows that 'hard' and 'difficult' were common responses, but so also was 'interesting'. One participant wondered "*Why did I agree to do this?*", while another reported that it looked "*interactive, interesting, hands-on.*" The pre-service teachers commented on the enjoyable and positive aspects of the module and mentioned the authentic nature of the work (the 'elucidate' aspects), the engaging introductory videos, the use of NAPLAN, PISA, TIMSS and Gapminder data, learning to use spreadsheets and making videos and/or presentations for assessments (Figure 3B).

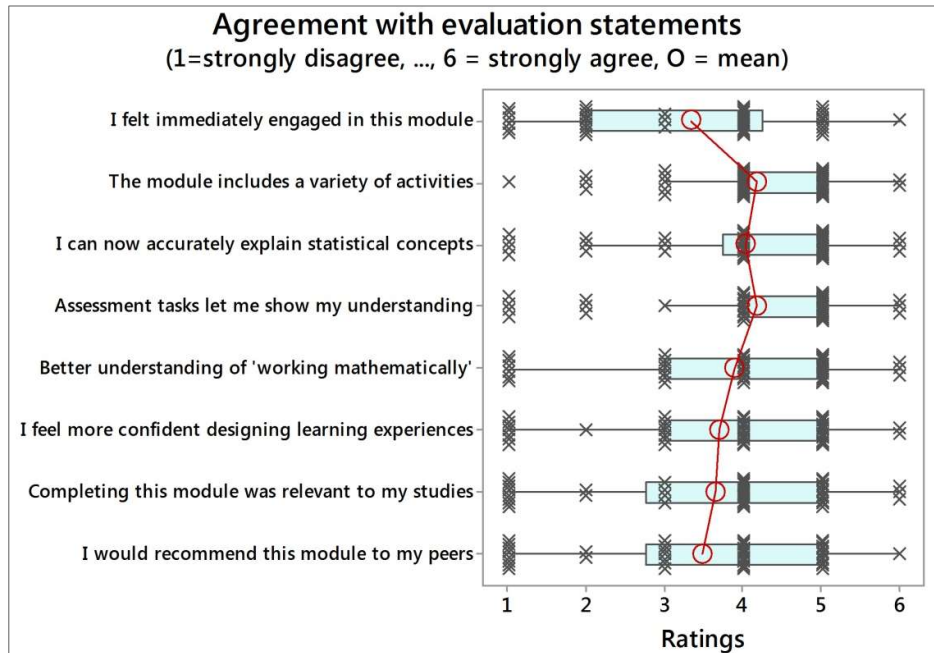


Figure 2. Pre-service teachers' agreement level with different aspects of SL-P module

Suggestions for possible improvements included more practice in tutorials, more guidance with Gapminder and NAPLAN, and more video support (Figure 3C). They wrote that it would be good to "*make the assessments less ambiguous and less difficult to understand and develop,*" and asked for more "*examples of what we can implement into our teaching*" and even "*explicit instructions on how to use an Excel spreadsheet to analyse data.*" These comments might explain why some pre-service teachers found the module less engaging, especially towards the end when they needed to complete their assessments. On the other hand, many gave positive feedback that their understanding of statistics had increased (Figure 3D). Their comments included: "*Overall, I found myself to have improved in my knowledge of statistical literacy*" and "*I now have a greater understanding of standard deviation and how to design activities incorporating statistics with primary aged students.*"

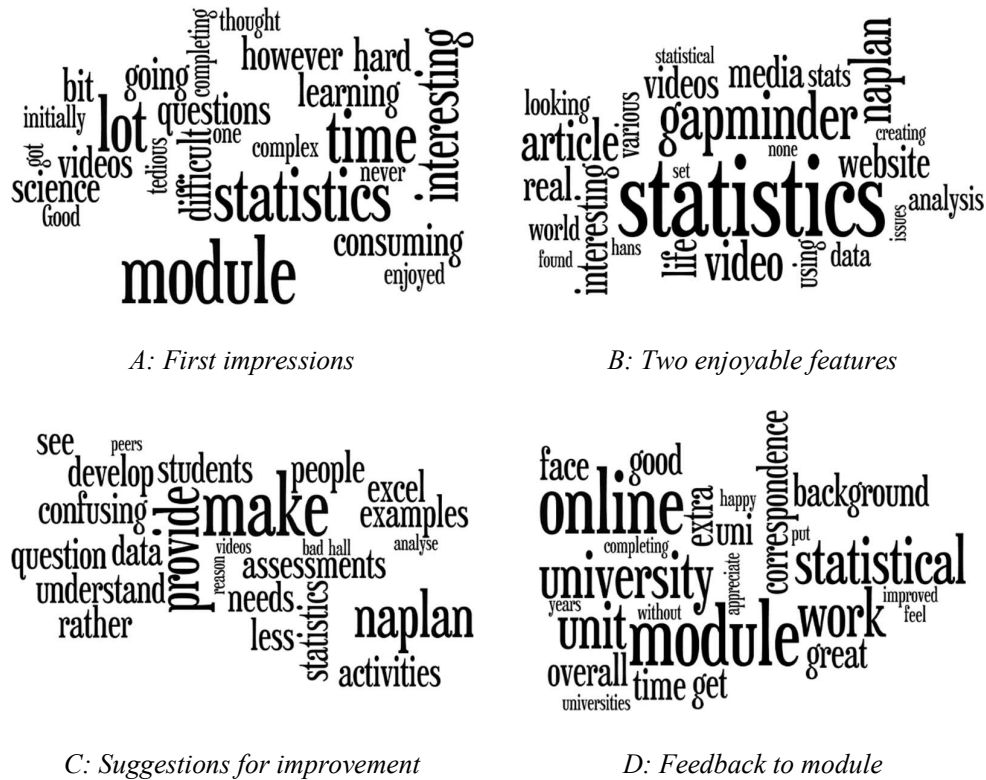


Figure 3. Students' responses to open-ended questions as word clouds

Tutor Evaluations The tutor employed in the first trial (T1) was a trained secondary school teacher with several years of experience teaching mathematics and science. The tutor employed for the second trial (T2) was an experienced primary-school teacher. The analysis of responses indicated that the tutors indicated that the module required more time for facilitation, including face-to-face tutorials as well as the online mode. Thus a mixed mode approach was considered a major recommendation.

Both tutors agreed that the pre-service teachers who had completed the module improved their statistical knowledge and skills in working mathematically in a scientific context, and would now be able to apply the 6Es inquiry-based approach in their teaching: “[students] developed confidence in skills and concepts in both Maths (and Science) that encouraged students to use inquiry-based approach in planning. I think that the students that applied themselves well to complete the module will use the approach in teaching.” T1 also suggested that the 6Es could have a higher profile in the module. He acknowledged the range of skill levels brought to the module by the students. For those students demonstrating lower skill levels he was more active in facilitating their participation with the module by producing and uploading short videos on how to carry out some of the tasks. Similarly, T2 commented that: “Some really enjoyed the application of critical thinking and had a lot of fun with it. Others really struggled with the independence of it and needed a lot of support (they were always looking for the ‘right’ answer).” T2 also identified that the module demonstrated the ‘flipped’ approach to teaching, encouraged collaborative learning and required students to research and find various methods to answer questions. The word cloud of tutors’ responses to the open-ended questions (in Table 2) is presented in Figure 4, showing that ‘students’,

5.3. LIMITATIONS AND IMPLICATIONS

The trialling of the SL-P module was undertaken with small samples of pre-service teachers from two university programs and thus the results cannot be generalised. What these evaluations show is that the relevant inquiry-based contexts engaged participants even though some lacked numeracy and data analysis skills. The real improvement in statistical literacy skills cannot be ascertained until the ORS data have been analysed on the impact of this learning on pre-service students' classroom teaching of statistical literacy and the applications in their professional work. This is essential for a longitudinal evaluation of the effectiveness of this training. Future research with larger cohorts will incorporate evidence from pre-service teachers' problem solving and how their statistical literacy is developed by studying the module. Evaluation of the module's impact on learning through the addition of pre-testing of statistical competency to compare with summative assessment will be used to test the 6Es inquiry-based curriculum framework of the Opening Real Science project and to compare it with similar approaches (e.g., Lyons, 2011; Nakedi, 2014). Further and larger-scale evaluation is in progress. The authors expect that it will provide evidence for overall suitability of the authentic, inquiry-based approach exemplified in the SL-P module as well as more direction on how to improve it, and particularly, on how to develop different learning pathways for students with differing backgrounds.

The experiences of pre-service teachers may vary enormously and this is a challenge for the academic development and tailoring of programs. Some participants were unaware of the important role of the statistics module while others commented on the positive outcomes for their learning: *"I believe that I now completely comprehend the concept of statistical literacy and am able to apply my new found knowledge and skills to my future students"*. An authentic inquiry-based approach to statistics learning can be very effective, but it needs to be pitched at an appropriate level for the intended audience – in this case, pre-service primary teachers. Evaluation of the impact of other mathematics modules developed using the same (ORS) framework will enlarge the evidence base illuminating the effectiveness of this approach for developing mathematical competence, including statistical literacy, among pre-service teachers.

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APPENDIX

Examples are given from the online module for Explore (A.1), Explain (A.2) and Evaluate (A.3) Phases.

A.1. ACTIVITIES AND FORMATIVE ASSESSMENTS – PRIMARY: TOPIC 2 – KEY CONCEPTS IN STATISTICAL LITERACY

Information about NAPLAN results & interpretation

Read the materials available on NAPLAN's school support [webpage](#) and refer to the resources below to help you answer Activity 2.1

Access the [SMART website](#) using the following guest login details:

Username:

Password:



Once you have logged in, click the OK button, then click the SMART button to take you to the NAPLAN website. You can then explore the website as it demonstrates the powerful NAPLAN database and its data analysis tools.

Data Resources: [NAPLAN](#)

This folder contains MSExcel files of demonstration numeracy results for years 3 and 5 to be used in Discussion 2.1 and Assessment 2.2.

Resources: [Stats and MS Excel help](#)

Refer to these resources to help you with understanding and calculating key statistics for the module activities and assessments.

[2.1 Discussion: NAPLAN Data](#)

[2.2 Assessment: NAPLAN data](#)

Please download the excel file (from the Data Resources above), which documents numeracy results for a year 5 class in NAPLAN. Select a class sized subset of the data and calculate descriptive statistics (means and standard deviations) for selected numeracy capabilities of the 'class'. Provide a summary of your main findings and conclusions. Make use of summary statistics and graphical representation to support your findings/conclusions. Your report should follow the attached template below, approx. length 1-2 pages. Submit your report to the assignment dropdown.

Discussion: NAPLAN Data (to open this discussion, students click on the link above)

Please download the excel file from the resources above, which demonstrates results for a year 3 class in NAPLAN (you can also refer to [sample numeracy tests](#) and [sample student reports](#) on the SMART website). Hint: use the sample tests to determine which area of numeracy each question addresses. You can then partition the test into its numeracy areas and tally the number of correct answers for each section. Use a class-sized sample of results (eg., 30) to calculate means and standard deviations for each area of numeracy and numeracy overall. Present your results in one or more graphs.

Post your answers to each of the questions in the discussion forum and include your evidence as calculated from and visualised by the data (1-2 pages):

- What areas of numeracy are examined?
- What areas does the year 3 class appear strong/weak in?
- How can you tell?
- What conclusions can you make about the numeracy results of this class?

HANDY HINT: You can use MS Excel to calculate descriptive or summary statistics and to plot graphical representations of the data. MSExcel: is almost universally available. It has many benefits as a spreadsheet for storing and managing data. It can carry out basic statistical tasks without too much trouble but is limited for carrying out complex statistical and graphical procedures. There are some good video tutorials available on the Microsoft website on how to use MS Excel for analysing and graphing data. (see also 'Resource: Stats and MS Excel help' at the beginning of the module)

OPTIONAL RESOURCE: A good website for learning about statistics is the [Top Drawer Teacher](#)

A.2. PUTTING KNOWLEDGE INTO APPLICATION, STATISTICAL LITERACY – PRIMARY: TOPIC 3 – CRITIQUING STATISTICAL CLAIMS

Overview In this section, you will learn how to make judgements about the validity of others' claims, using analysis and visual representation of data to provide evidence for your critique.

Learning Outcomes Critique statistical 'claims' as made in the media / by other investigators.

Learning Activities Read the newspaper articles, "Maths results a concern in PISA schools study" and "Latest PISA results 'cause for concern'" and access the official PISA website using the links in the articles and on this page. Then respond to the stimulus questions in Discussion: PISA data (below) and submit your response to the discussion forum.

For Assessment: TIMSS Data, download the resource document, TIMSS Full Report 2007. Go to the Gapminder website via the links to "grade 4" and "grade 8" data and examine the graphical representations of the data in the TIMSS Full Report, then follow the instructions for completing the assessment, using the template and rubric as a guide.

Discussion: PISA Data

Australia's score in maths vs selected OECD nations

This interactive does not include all nations assessed by Programme for International Student Assessment. Link to larger version with all assessed countries in 2012: <http://cf.datawrapper.de/9KCoq/2/> Note: Data is unavailable for the UK in 2003.

Read the articles, "Maths results a concern in PISA schools study" and "Latest PISA results 'cause for concern'"

2012

Country	Score
South Korea	554
Japan	536
Canada	518
Poland	518
Germany	514
Australia	504
New Zealand	500
France	495
United Kingdom	494
OECD average	494
United States	481
Sweden	478
Mexico	413

and examine the graphical representation of PISA data for Australia's performance in maths by grade 10 (15 year old) students compared with other countries in 2012 and compared with previous years.

- What do these data represent?
- Describe the trend(s) for Australian students over the period 2003 to 2012 for PISA data
- Are the conclusions made by the authors of the articles accurate? Why or Why not?

Please post your answers to the questions in the discussion forum and include your evidence as calculated from and visualised by the data (1-2 pages).

A.3. RUBRIC FOR STATISTICAL INVESTIGATIONS WHERE STUDENTS EXAMINE THE ACCURACY OF THE REPORT VIA STATISTICAL ANALYSIS

Report criterion	A high-distinction-level report will include:	A pass-level report will include:
Formulate a scientific (testable) question	Interpreting the report, the claim being made and its main conclusion are accurately stated. Sources of data / statistics used to support the claim that are questionable or not clear are accurately identified and interpreted. The claim is accurately rephrased into a question that can be answered (tested).	Interpreting the report, the claim being made and its main conclusion are accurately stated. Some sources of data / statistics used to support the claim that are questionable or not clear are identified. The claim is rephrased into a question but it cannot be answered (tested).
Identify the variables involved and data sampling strategy required	Correctly identifies the phenomenon that the claim is being made about and interprets the differences or variation in its level of expression. Accurately describes the variable(s) used to measure the phenomenon and how and why is it measured.	Correctly identifies the phenomenon that the claim is being made about and attempts to describe differences or variation in its level of expression. Attempts to describe the variable(s) used to measure the phenomenon and how is it measured.
Download appropriate data from the Gapminder website	Locates an excellent dataset on Gapminder that measures a sample(s) for the chosen variable(s). Describes the sample(s), how the measures were made / data were collected and why the method is appropriate.	Locates an appropriate dataset on Gapminder that measures a sample(s) for the chosen variable(s). Describes the sample(s) and identifies the measures were made / data were collected.
Calculate descriptive statistics	Selects, calculates and interprets appropriately summary statistics and describes how and why they were calculated, e.g., to compare means of two or more samples or groups on a particular variable, which is being used to measure an attribute that the groups (may) differ on.	Selects and calculates some summary statistics and attempts to describe how and why they were calculated, e.g., to compare means of two or more samples or groups on a particular variable, which is being used to measure an attribute that the groups (may) differ on.
Present your results graphically	Presents results accurately in a graph and describes why the type of graph is suited to the data analysed / why the data are presented in this way.	Presents results in a graph and attempts to describe why the type of graph is suited to the data / why the data are presented in this way.
Make a judgement on the accuracy of the report and support your claims	Accurately interprets results in relation to the question (rephrased claim from media report). Elaborates on why it challenges or confirms the claim made by the report.	Attempts to interpret results in relation to the question (rephrased claim from media report). Does not explain clearly why it challenges or confirms the claim made by the report.
Present your results in a narrated (i.e., include audio) slide or video presentation	Presents results creatively and with a high degree of accuracy. The reason for challenging the report and the alternative interpretation are made clear and convincing.	Presents results creatively in a video or slides with audio. The reason for challenging the media report is not made clear and convincing.