Teaching Statistics through Data Investigations in Australian Secondary Schools: An Island-based Pilot Project

Minh Huynh[a] and James Baglin[b]

Corresponding author: mhuynh@swin.edu.au
[a]Department of Statistics, Data Science and Epidemiology, Swinburne University, Hawthorn VIC 3122, Australia
[b]School of Mathematical and Geospatial Sciences, RMIT University, Melbourne VIC 3001, Australia

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Abstract

Declines in secondary school students' attitudes towards, and participation in, mathematics and science are cause for concern. In 2012, a report from the Office of the Chief Scientist called for universities and schools to develop partnerships aimed at improving mathematics and science education in schools. Responding to this call, this pilot project used an online simulation of a human population, known as the *Island* (Bulmer & Haladyn, 2011), to develop innovative activities for teaching statistics through data investigations. The activities were aligned with the Statistics and Probability strand of the Australian Mathematics Curriculum. The *Island*-based activities aimed to engage students in meaningful and realistic statistical practice and thereby improve their attitudes towards statistics. The resources were piloted in four partnered secondary schools from the northern suburbs of Melbourne in years 8 to 11 mathematics classes. Questionnaire data from students' attitudes towards statistics before and after completing the project activities were collected from 237 students. The results found statistically significant increases in positive attitudes towards statistics, however, students' attitudes towards career prospects in statistics were resistant to change and competency significantly declined. The qualitative feedback indicated that most students found the *Island* to be novel and interesting, with very little difficulty in running the program. This paper discusses the limitations of these findings and the future directions for a national project.

Introduction

To remain economically competitive, Australia must increase the rates of science and mathematics graduates (Australian Industry Group, 2013; Office of the Chief Scientist, 2012). Unfortunately, Australia has been failing to the meet the demand for science and mathematics graduates required by government, education and industry (Australian Industry Group, 2013; Bourguignon, Dietrich, & Johnstone, 2006; Edwards & Smith, 2009). Graduates with mathematical and statistical backgrounds, in particular, have become increasingly important as our society relies more and more on the data-based decision making. Unfortunately, Australia ranked 23rd out of 26 countries within the Organisation for Economic Co-operation and Development (OECD, 2015), with only 0.46% of all Australian graduates having a mathematical or statistical background. The OECD average for mathematics and statistics graduates was 1.19%. Mathematical ability is not the cause, either as Australia was ranked significantly higher than the OECD average mathematical ability (OECD, 2014). This suggests other factors are at work in determining low graduate rates. Data from the Victorian Auditor General (2012) highlighted concerns regarding changes in students' attitudes towards mathematics and science between primary and secondary school. Based on a cross-sectional survey of eight primary and eight secondary schools in Victoria, the report found that student interest in science and mathematics subjects dropped from 93.3% and 74.8% in year six to 62.9% and 41.9% in year nine, respectively. Data reported by Kennedy, Lyons and Quinn (2014) also demonstrate that since 1992, participation rates in science and mathematics classes have shown concerning downward trends. Recent work by Wilson and Mack (2014) support these findings, with the authors additionally suggesting that the decline in participation rates has much to do with students' and teachers' attitudes and engagement in the classroom.

Attitudes are important and particularly so in statistics, which is a dedicated strand within the Australian Mathematics Curriculum F-10 (ACARA, 2015). A meta-analysis of 17 studies by Emmioğlu and Yesim (2012) found a consistent negative relationship between student attitudes towards statistics and achievement. Ramirez, Schau and Emmioğlu (2012) hypothesised that student attitudes drive engagement in learning and determine later use of these skills. This implies that if students are disengaging during secondary school statistics classes, they will be very unlikely to pursue statistics-related careers. Recognising this problem, the Office of the Chief Scientist released a report in 2012 entitled *Mathematics, engineering & science in the national interest* (Office of the Chief Scientist, 2012), in which many recommendations were made to improve the state of science, technology, engineering and mathematics (STEM) education in Australia.

The Office of the Chief Scientist raised concerns around the teaching of mathematics and science in schools, commenting that common practices were too didactic and disinteresting. The report urged schools and universities to develop innovative approaches to bring the 'practice' and relevancy of mathematics and science into the classroom to improve student interest. The Chief Scientist's report echoes what many statistics educators have long been advocating, that the teaching of statistics should be through data investigations as it aligns with real world statistical practice (Gordan & Nicholas, 2010; Holmes, 1997; MacGillivray & Pereira-Mendoza, 2011; Marriott, Davies, & Gibson, 2009; Wild & Pfannkuch, 1999). Students who complete statistical data investigations gain valuable experience working through the entire cycle of an investigation from initial problems, planning, data collection, analysis and drawing conclusions. Such investigations also draw close parallels with the Science Inquiry strand of the Australian Science Curriculum (ACARA, 2015), opening the doors to interdisciplinary teaching (Watson, 2014). However, schools and teachers face many barriers to teaching statistics through data investigations, including practical and ethical constraints and the necessary know-how.

This pilot project, briefly outlined in Baglin and Huynh (2015), aimed to develop and pilot an innovative technological approach to teaching statistics through data investigations in year 9 and 10 mathematics and science classes. The project utilised the *Island* (http://island.maths.uq.edu.au/) to overcome the challenges for implementing statistical data investigations in schools, while still engaging students in a realistic simulated context (Bulmer & Haladyn, 2011). (Please note that a newer version of the *Island*, titled: *The Islands*, http://islands.smp.uq.edu.au/login.php is now available and is recommended over the previous iteration.) The *Island* is a free, online, human population simulation that provides students with a virtual playground for practicing statistical data investigations. The *Island* is explored by clicking between the 36 villages that are home to approximately 9000 virtual residents. Simulation models govern the population's births, deaths, health, social lives and residency. Each resident has their own personal story and genetic code that are linked to their appearance and reactions to over 200 interacting tasks controlled by realistic statistical models. Task categories include surveys, blood tests, physiological measurements, mental tasks and exercise. Archival information can also be gathered relating to births, deaths, marriages, demographics, medical records and relationships. Many different types of statistical data investigations are made possible, including surveys, observational studies and experiments. The *Island* also educates students about the practicalities of investigations as Islanders have sleep/wake cycles and can refuse consent, drop out (withdraw consent or die), lie or become ill.

The *Island* has been utilised extensively in Australian universities to improve student engagement in statistical data investigations without the practical and ethical limitations imposed by real human research. University students using the *Island* have reported high levels of engagement and improved statistical thinking (Baglin, Bedford, & Bulmer, 2013; Baglin, Reece, Bulmer, & Di Benedetto, 2013; Bulmer, 2010; Linden, Baglin, & Bedford, 2011; Baglin, Reece, & Baker, 2015). Preliminary work in secondary schools with the *Island* has also suggested similar benefits (Huynh, Baglin, & Bedford, 2014), with the authors providing initial evidence that innovative technology, paired with sound pedagogical practice, may help assist in changing student attitudes at the secondary school level. This article reports data collected as part of a pilot project that was used to determine if students' attitudes towards statistics change after engaging in the project's activities.

Project Activities and Teacher Manual

The pilot project's main outcome was the development of a free teacher manual, *Island in Schools*: *Innovating the Teaching of Statistics and Data Analysis in Years 9 and 10*, that provided a series of classroom-ready *Island*-based activities (request a copy by emailing the authors). The activities were aligned to the Data Representation and Interpretation content area of the Statistics and Probability strand of the Year 9 and 10 Mathematics Curriculum, but also drew links to the Scientific Inquiry Skills strand of the Science Curriculum (ACARA, 2015). The following ten activities were developed along with an open-ended data investigation project: 1) Gathering samples from a population – an introduction to the *Island*; 2) The effects of temperature on exercise performance; 3) Balance as a repeated measures design; 4) Reaction time and adrenaline; 5) Gender and mental health survey; 6) Height and liver size; 7) Peak flow meter and age; 8) Ball bouncing and age; 9) *Island* climate longitudinal data; 10) Birth rates over time and 11) Student data investigation project.

Each worksheet contained a problem statement, a detailed description of the data collection process to be completed on the *Island*, space to report and process the data collected, and questions to assess the students' understanding of the activities and their ability to interpret data and draw conclusions in context. The activities were not intended to teach the statistics curriculum content, but were included to assist teachers with enriching the classroom experience. Most teachers used the activities to motivate and open opportunities to teach elements of the curriculum as the need arose. After reading the activity outline and research plan, students logged into the *Island* to collect their respective data using random sampling methods. Students completed their data collection on the *Island* using portable computing devices, typically iPads or laptops. Some classes used school computer laboratories. Once the data collection process was completed, students would answer the activity questions, which required students to reflect on data representation and interpretation covered in the curriculum and relate back to the context of the research problem.

The student data investigation project provided a teacher outline for how to have students conduct their own open-ended investigations using the *Island*. The *Island* contained in excess of 200 tasks and activities, so students were likely to find a topic of interest to them. The open-ended investigation was seen as a capstone experience for the Statistics and Probability strand of the Mathematics Curriculum as students would be required to manage their own investigations without much guidance. A number of partnered schools chose to complete the data investigation project, with students presenting their findings in poster formats.

Pilot and Evaluation

Approximately 20 mathematics coordinators from secondary schools in the northern suburbs of Melbourne, Victoria, were mailed an invitation letter to join the project. Four schools joined the project: two government schools and two private schools. Data pertaining to students' attitudes towards statistics before and after engaging in the *Island*-based activates are reported in this paper from a total of 237 questionnaires returned from the four partnered schools, representing nine year 9, one year 10 and two year 11 mathematics classes and one year 8 science class. However, reported sample sizes are typically less due to missing values. Almost all students in each class completed the questionnaires, but an exact response rate could not be determined as the study was not privy to class lists or attendance. The number of activities/projects completed by each class ranged from one to four, with the majority (8/13, 62%), implementing three *Island*-based activities.

Measures and Procedures

Prior to commencing the study, a baseline measurement of student attitudes was acquired via a 22-item pre-test questionnaire. These items were loosely adapted and modified from the Expectancy–Value Theory (EVT) of Achievement Motivation (Wigfield & Eccles, 2000) and were rated on a five point scale ranging from 1) Strongly disagree to 5) Strongly agree. Attitudes are affective responses that accompany a behaviour initiated by a motivational state (Guthrie & Knowles, 2001) and can be linked to understanding motivational processes. Fourteen items (Items 2–15) on the pre-test pertained specifically to attitudes towards statistics and have been listed in Table 1. Descriptive statistics and the percentage of students' agreement (those rating either "Agree" or "Strongly agree") to each item on the pre and post questionnaire are reported in Table 2. The administration of the questionnaire was approved by the authors' institutions and by the Victorian Department of Education and Training and relevant school principals. The questionnaire was used to evaluate the associated impact of the activities on students' attitudes towards statistics. A project member was on hand to deal with any technical difficulties and in some cases to assist the teacher in the delivery of the first *Island* activity. After the first class, the teachers were left to implement the remaining activities and *Island*-based project and a later time was arranged for the project team to administer the post questionnaire following the completion of the *Island*-based activities.

Results

Factor Analysis

Exploratory factor analysis (EFA), using *Factor* (Lorenzo-Seva & Ferrando, 2006), was performed on the 14 attitude items. The EFA analyzed the polychoric correlation matrix, which is advised when ordinal rating scale items have been used (Baglin, 2014; Timmerman & Lorenzo-Seva, 2011). Parallel analysis (PA) using minimum rank factor analysis (MRFA, Shapiro & ten Berge, 2002; ten Berge & Kiers, 1991; Timmerman & Lorenzo-Seva, 2011) was chosen for the retention and extraction technique. Three stable factors were identified after removing item 14 due to a poor loading. Table 1 provides the final rotated solution using the oblique Promin method (Lorenzo-Seva, 1999). The three factors identified included *Attitudes, Career Prospects* and *Competency*. The *Attitudes* factor referred to students' dispositions towards statistics and includes items such as *Statistics is enjoyable and stimulating for me*. The *Career Prospects* factor explores the perceived value that studying statistics has on students' future careers. An example item was *Statistics is an important subject for me because I need it for what I want to study after finishing school*. The final factor, *Competency*, related to how the students viewed their statistical ability, with an example item being *I learn statistics quickly*. Based on their contribution to the variance, three factors were identified (see Table 1). For each component, scores was computed as the mean scores of the items with the highest absolute loading.

Multilevel Modelling

To compare the pre and post factor scores derived from the questionnaire responses, multilevel modelling (MLM), using a Maximum Likelihood estimation method, was selected. MLM takes into consideration the 'nested' structure of the data (i.e. students nested within different classes). Nested data may violate the assumption of independence which is required by traditional statistical models. Independence would assume that each students' responses to the questions was independent from other students' responses. However, students share a common school and classroom environment, so the experience and responses from students within the each school might share a relationship. In other words, students' responses from the same school are dependent. For this study, there were eleven different classes that students were nested into that had to be taken into consideration. If this assumption is ignored it may result in an increased Type I Error rate and biased parameter estimates

(Peugh, 2010). Further, to avoid the problem of multiple hypothesis testing (which will be addressed in more detail when the multilevel analyses are discussed), the MLMs utilised the latent variables identified from the EFA, and their respective factor scores for the analyses.

Table 1: **Attitudes Towards Statistics Questionnaire - Rotated Factor Loadings, Reliability and Variance Explained**.

Item	Attitudes	Career Prospects	Competency
2. Statistics is enjoyable and stimulating for me	**.885**	-.061	.066
3. I enjoy learning and reading about statistics	**.908**	-.032	.015
4. I look forward to my statistics lessons	**.901**	-.015	-.023
5. I am interested in the topics I learn in statistics	**.800**	.064	.013
6. Making an effort in statistics is worth it because it will help me in the work that I want to do after finishing school	.027	**.852**	-.025
7. Learning statistics is worthwhile for me because it will improve my career prospects and chances in getting at job	.018	**.832**	.038
8. Statistics is an important subject for me because I need it for what I want to study after finishing school	.013	**.874**	-.099
9. I will learn many things in statistics that will help me get a job	-.023	**.803**	.094
10. I am just not good at statistics	-.119	.013	**-.464**
11. I learn statistics quickly	.197	-.043	**.570**
12. If I put in enough effort, I can succeed in statistics	-.025	.110	**.733**
13. Whether or not I do well in statistics is completely up to me	-.130	-.005	**.705**
14. If I had different teachers, I would try harder in learning about statistics	-	-	-
15. If I wanted to, I could do well in statistics	-.068	-.058	**.814**
Reliability[a]	.933	.911	.827
% Variance [b]	51.93	17.71	15.66

Note. Item 14 removed due to poor loading. Rotated factor loadings reported. Item factor loadings bolded belong to the respective column's factor. EFA Matrix: Polychoric correlations, Extraction: MRFA, Retention: PA, Rotation: Promin, [a] Mislevy and Bock (1990). [b] Percentage of common variance explained based on MRFA.

To measure the degree of dependency presented in the nested data and determine if MLM was appropriate, the intraclass correlation (ICC) and design effect (DE) were calculated for each of the factors. The ICC is a measure of the dependency between scores within the same group (Strijbos, Martens, Jochems and Broers, 2004) and the DE quantifies the effect of the dependency on the standard error estimates. Generally, MLMs are deemed appropriate for nested data when the calculated ICC is larger than 0.05 (Hayes, 2006) and the DE is larger than 2.00 (Peugh, 2010). The calculated ICCs and DEs for *Attitudes* (.051 and 2.18 respectively) and *Career Prospects* (.09 and 3.09 respectively) met these recommendations, and subsequently MLM was deemed appropriate. Only a naïve model for *Competency* was considered because the ICC (.014) and DE (1.32) were below the recommended values for MLM. The detailed results for the MLMs for each of the outcome variables are show in Table 3.

A naive model (with no random intercepts or slopes) was constructed to provide a baseline comparison for each of the MLMs. According to the naive model for Attitudes, the time effect, or change between pre and post, mean change of 0.34 points, 95% *CI* (.18, .51), was statistically significant, $F(1,486) = 16.34$, $p < .001$. The confidence intervals are based on a normal approximation. The pseudo-R^2 for the naïve model indicated that only 3% of the variability in factor one (attitudes) was explained by time. An overview of these parameters is provided in Table 3.

Table 2: Descriptive Statistics and Percentage Agreement to Statistics Questionnaire Items

			Pre			Post		
	Item	*n*	*M*	*SD*	% Agree	*M*	SD	% Agree
Attitudes	2.	236	2.64	1.08	24.6	2.77	1.09	23.7
	3.	234	2.67	1.13	27.4	2.75	1.18	27.4
	4.	235	2.57	1.14	23.4	2.69	1.18	24.7
	5.	230	2.84	1.11	31.3	2.87	1.14	30.9
Career Prospects	6.	235	3.13	1.25	40.0	2.93	1.18	29.8
	7.	236	3.30	1.19	44.9	3.08	1.15	37.7
	8.	236	2.69	1.10	19.5	2.68	1.11	20.8
	9.	237	2.93	1.09	27.0	2.95	1.09	30.0
Competency	10[a].	232	2.45	1.10	16.8	2.44	1.14	18.5
	11.	232	3.41	1.03	48.7	3.41	1.09	53.4
	12.	232	4.26	0.89	85.3	4.15	1.00	78.0
	13.	236	3.90	1.07	66.9	3.92	1.04	66.9
	14.[b]	231	2.70	1.41	31.6	2.79	1.46	33.3
	15.	233	4.13	0.99	80.3	3.91	1.07	70.0

Note. *n* = Sample size, *M* = mean, *SD* = standard deviation, % Agree = % of students rating item as “Strongly Agree” or “Agree”, [a] = item has been reversed coded, [b] = non-loading item based on EFA.

To take into consideration the dependency from the higher level (classes), random intercepts were added to the model. The difference between the naïve model and random intercepts model correcting for class was statistically significant according to a likelihood ratio test, χ^2 (1) = 8.63, $p = .003$. For this model, the time variable had an estimated slope of .34, 95% *CI* (.17, .50). When random intercepts are included at the school level, time was still statistically significant, $F(1,474.55) = 16.16$, $p < .001$ and the standard error had reduced slightly to .08. The pseudo-R^2 for the second model indicated that 9% of the variability in attitudes was explained by time. Finally, a model including both random intercepts and slopes was fitted. However, the difference between the random intercepts model and the random intercepts & slopes model correcting for class was not statistically significant according to the likelihood ratio test, χ^2 (2) = 1.461, $p = .481$ (see Table 3).

Table 3: Multilevel Linear Models Fitted to Test the Effect of Time on *Attitudes*, *Career Prospects* And *Competency* Towards Statistics After Correcting for Students Nested within Classes

	Attitudes			Career Prospects			Competency		
Parameters	1. Naive	2. Random Intercepts	3. Random Intercepts & Slopes	1. Naive	2. Random Intercepts	3. Random Intercepts & Slopes	1. Naive	2. Random Intercepts	3. Random Intercepts & Slopes
Fixed effects									
Intercept	2.67 (.06)*	2.67 (.09)*	2.67 (.07)*	2.82 (.04)*	2.82 (.05)*	2.83 (.07)*	3.84 (.04)*	3.85 (.05)*	3.85 (.05)*
Time	0.34 (.09)*	0.34 (.08)*	0.34 (.10)*	0.02 (.07)	0.02 (.06)	0.01 (.12)	-0.39 (.06)*	-0.39 (.06)*	-0.38 (.08)*
Variance of Random Effects									
Residual	0.88 (.06)	0.85 (.05)	0.84 (.06)	0.52 (.03)	0.52 (.03)	0.49 (.03)	0.45 (.03)	0.44 (.03)	0.43 (.03)
Intercepts		0.04 (.03)	0.03 (.03)		0.01 (.01)	0.02 (.02)		0.01 (.01)	0.02 (.02)
Slopes			0.03 (.06)			0.10 (.07)			0.03 (.03)
Covariance			0.02 (.03)			-0.04 (.03)			-0.02 (.02)
Model Summary									
-2LL	1318.4	1309.8[a]	1308.4[b]	1086.0	1085.1[c]	1075.6[d]	987.6	983.6[e]	981.5[f]
Parameters	3	4	6	3	4	6	3	4	6
Pseudo-R^2	.03	.09	.10	< .001	.03	.08	.08	.11	.23

Note: Values in parentheses refer to standard errors. * $p < .05$

[a] Likelihood ratio test of the difference to Model 1, $p = .003$, [b] Likelihood ratio test of the difference to Model 2, $p = .481$

[c] Likelihood ratio test of the difference to Model 1, $p = .336$, [d] Likelihood ratio test of the difference to Model 2, $p = .009$

[e] Likelihood ratio test of the difference to Model 1, $p = .003$, [f] Likelihood ratio test of the difference to Model 2, $p = .150$

Similar models were also fitted for *Career Prospects*, with an overview of these parameters provided in Table 3. According to the naïve model for Career Prospects, the time effect, or change between pre and post, mean change of 0.02 points, 95% *CI* (-.11, .15), not statistically significant, $F(1,492) = .095$, $p = .757$. Further, the difference between the naïve model and random intercepts model correcting for class was also not statistically significant, χ^2 (1) = .93, $p = .336$. However, the difference between the random intercepts model and the random intercepts & slopes model correcting for class was statistically significant, χ^2 (2) = 9.44, $p = .009$. The slope has reduced slightly to .01, *CI* (-.25, .27), and the standard error has increased to .12. The pseudo-R^2 for the third model was .08.

For the *Competency* factor, the time effect for the naive model, - 0.39, 95% *CI* (-.51, -.27), was statistically significant, $F(1,481) = 40.58$, $p < .001$. On average, the post test scores for *Competency* were 0.39 points lower compared to the pre-test. The standard error of the slope was found to be .06. The pseudo-R^2 for the naive model indicated that 8% of the variability in factor three (Competency) was explained by time.

Qualitative Analysis

In conjunction with completing the questionnaires, the student participants responded to three open ended qualitative items on the follow-up survey. These items included:

1. What did you enjoy about using the *Island*?
2. How difficult did you find using the *Island*? What factors impacted that difficulty?
3. If you could change or improve anything on the *Island* what would it be?

Qualitative data were analysed using a six-step inductive thematic analysis method described by Braun and Clarke (2006). The six steps included: 1) data familiarisation; 2) initial code generation; 3) theme searching; 4) theme revision; 5) theme definition and naming; and 6) reporting. A number of themes emerged from summarising the qualitative data from each of the three open-ended questions. Figure 1 includes a thematic map of these themes. Each theme will be discussed in the following sections, with direct quotes from student responses. Note the ID for these quotes represent a unique ID of the student participant.

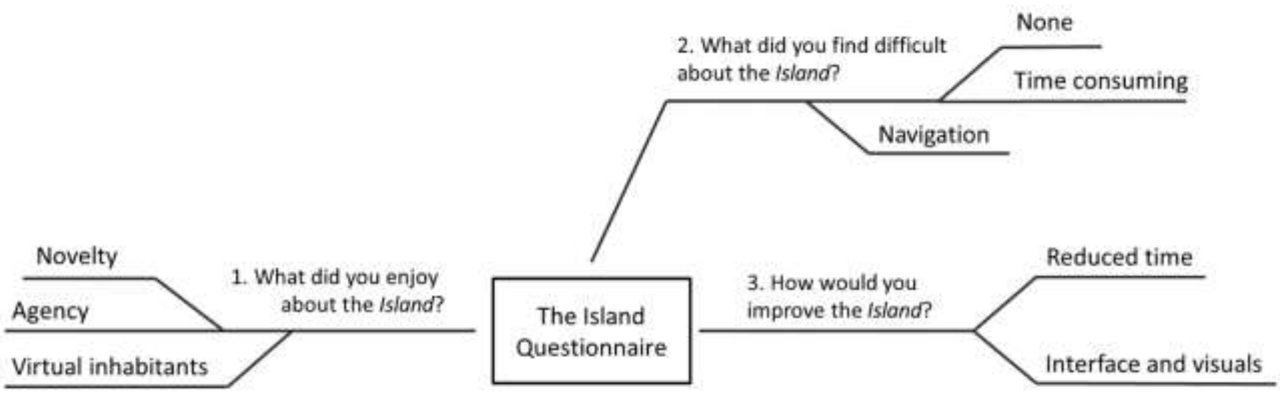

Figure 1: Map of Thematic Analysis

1. What did you enjoy about the *Island*?

Three major themes emerged from summarising the qualitative data for item 1 via the thematic analysis: (1) novelty, (2) agency, (3) virtual inhabitants.

Novelty

Students expressed that using the *Island* was different to completing their regular school work and that it provided a unique classroom experience. This was good news given it is quite difficult to engage students with statistics as many view the subject as *an obstacle standing in the way of attaining their desired degree* (Perney & Ravid, 1991, p.2). A number of sub themes were identified within this domain to explain how the *Island* was different to their traditional classes. For example, a number of students commented that they found the novelty of the *Island* to be interesting.

> *It was really unique and interesting to use, because there is nothing else even remotely like it …* [ID: 225]

Given the familiarity of the students with modern technology, a number of students commented on the *Island* approach being easier for them to learn.

> *I enjoyed using computers rather than a textbook. It was easy to find specific information.* [ID: 97]

Many students commented that they enjoyed the *Island* because it was more fun compared to their regular classes. This was good news for educators who might be looking for different ways engage their students with statistical activities.

> *It was more fun and was better/different compared to maths.* [ID: 240]

Another important sub theme that was identified was the concept of realism with the *Island*. Given the importance of making classroom activities more applicable to the real word, realistic tasks can aid students in seeing the value of learning statistics. Garfield and Ben-Zvi (2007) explain that teaching statistics through solving problems can improve students' skills as they interact with real data and conduct realistic statistical investigations.

> *It was stimulating. It seemed that I was a real statistician.* [ID:19]

Agency

This theme represented the action of "setting a task or activity" for the virtual Islanders to complete on the *Island* program. It was apparent that students seemed to thoroughly enjoy the notion of being in control of the virtual Islanders. This theme was the most frequently provided reason for student enjoyment.

> *I enjoy the different tasks available and the fact we have a lifelike scenario at our fingertips.* [ID: 81]

> *Using all the different tasks on the people and exploring the Island.* [ID: 198]

These comments provide further support for bringing practice and relevancy into the classroom, as suggested by the Office of the Chief Scientist (2012). More so than the in-class practice, it is the notion that the students are "in control" of their learning that may be the most appealing aspect of the *Island*. Unlike regular textbook activities, where students follow rigorous sets of instructions, the *Island* promotes *learning by doing* (Baglin, Bedford, & Bulmer, 2013). The data that the students are collecting are meaningful to them because it is only through their own actions (of setting tasks) that this data are possible.

> *I enjoyed experimenting with the Islanders and using different tasks to gather data.* [ID: 173]

> *I enjoyed the freedom of being able to test w[h]oever I wanted and to administer cool tests on them.* [ID: 117]

However, it is worth noting that not all students enjoyed setting tasks for the purposes of learning, with some finding the most pleasure in exploring the ability to assign unethical tasks without fear of real world implications.

I enjoyed enlisting tasks to the inhabitants, such as making a 4 month old baby smoking a cigarette. [ID: 183]

[I enjoyed] Drugging kids. [ID: 167]

Whilst their motivations are questionable, it is encouraging to see students experimenting in the virtual world, especially for a subject that is historically unpopular (Keely, Zayac and Correia, 2008). Students who are initially naturally uninterested in the subject may become engaged if allowed the freedom to explore the topics that interest them. With that said, it may not be topics that specially interest the students, but rather the fact that they are exploring something that appears taboo (i.e. drugs) that has piqued their interest. Understanding what it is about the nature of banned substances which interests students, and how it can be incorporated (legally and ethically) into classroom activities, should be an objective for future research. As a side note, it is worth mentioning that the teachers had full control of the tasks that the students were able to access, and that particularly sensitive tasks could be turned on and off based on the maturity of the students.

Virtual inhabitants

A large proportion of students had also commented that they enjoyed interacting with and learning about the virtual Islanders. Instead of recognising the data as individual data values in a dataset, there was a context (name and virtual face) behind each data point. The data had meaning which is crucial for students learning statistics who must experience data collection and the inherent variability of the (virtual and real) world.

Having people to work on instead of just numbers. [ID: 80]

It was different using the Island, [I] thought it was cool how people had their own personal difference [ID: 154]

Aligning with some of the previous themes, the students enjoyed the realism involved with interacting with the Islanders. Given the realistic nature of the Islanders, students would naturally be more aware of their choices (by setting the Islanders tasks) and the consequences these actions have.

I enjoyed how realistic the people were. Marriage, divorce, diseases, kids, death, smoking etc. [ID: 147]

I enjoyed the fact that people were just like real people. [ID: 158]

2. What did you find difficult about the *Island*?

For the second item (difficulty), three major themes emerged from summarising the qualitative data via the thematic analysis: (1) none, (2) time consuming, (3) navigation.

None

The majority of students commented that they found no real difficulty with using the *Island*, and represented the modal response (59.1%) for this item. Given that modern students find browsing and navigating the web a relatively simple task, it was expected that no major complications would arise from a program that was browser based.

It was not that difficult at all. It was very straightforward and was easy to understand. [ID: 11]

However, and not surprisingly, students without experience with computers will have a different experience.

The program was really slow. My lack of computer skills made this difficult. [ID: 252]

Perhaps more guidance, or extra assistance, from the teachers would benefit those who are not confident with their IT skills.

Time consuming

This theme reflects how the time taken for the Islanders to complete the tasks posed to be problematic for their *Island* experience. The tasks were designed to emulate real world experiences and reflect a realistic sense of time (although most tasks were severely shortened compared to the actual required time for a number of the tasks). Despite this, it would appear that some students prefer that they be able to collect their data immediately.

> *It was easy, waiting times were annoying though. [ID: 58]*
>
> *I wouldn't say it was difficult, just very time consuming and a bit boring. [ID: 69]*

The second quote demonstrates an issue that may plague many classrooms. Students who find an activity too time consuming may quickly lose interest in the task and their attitudes towards the subject becomes negative. This would be particular true if the students were only setting tasks one participant at a time. Students had the potential to set tasks for multiple Islanders simultaneously by opening up multiple tabs of their browser. This particular issue could have potentially been mitigated if students and instructors were encouraged to find efficient ways to collect their data.

Other students commented on the time taken to complete the sampling activity as part of the classroom tasks.

> *You should have been able to make the computer select a random sample because it was time consuming.* [ID: 51]
>
> *It was not difficult but however, it was frustrating to sample a large amount of people.* [ID: 229]

The first quote once again reflects the modern students' preference for immediacy and automation. This was unfortunate because one of the strengths of the *Island* was to allow students the ability to experience the very important and challenging process of sampling, and not to simply click a button and acquire a random sample. Students must think and work through the process.

Navigation

This theme relates to the user interface of the *Island* and how students go from one location on the *Island* to another (e.g. navigating from towns to houses to people). The difficulty students had was navigating between different Islanders who resided in different houses and towns, with the potential to lose track of their subjects.

> *Having to constantly go back through houses and towns when trying to choose another person* [ID: 134]
>
> *The difficult was clicking many times to go at someone's house. You keep on going back and forward* [ID: 145]

More training of teachers and clearer instructions are required for future activities so that the students are made aware of the 'contact list' feature on the *Island*. This is a tool that allows students to view all their recruited Islanders on one screen without having to navigate through the towns and houses to locate that individual. Regardless, real investigations face the same challenge of recruiting, coordinating and managing participants.

3. How would you improve the *Island*?
For the third item, students provided suggestions with how the *Island* could be improved. Responses varied from improving the visuals of the program to suggestions to update the interface.

Reduced Time
One of the most common suggestions for improvement was to update the tasks feature from the *Island*. Specifically, students wanted to reduce the time it took for tasks to be completed. One particular student commented that:

> *... Too long and boring! Make tasks QUICKER!* [ID: 133]

This aligns with similar themes from previous items. Many students commented on their dissatisfaction with the waiting time for tasks to be completed from the second item, so it was expected that a similar trend would be apparent for this item. Again this could be reflected by the nature of modern students and their preference for immediacy. Also as expected, many students suggested being able to test multiple Islanders simultaneously.

> *I would make everything quicker and make it so you can test more than one person at a time.* [ID: 216]

It was possible to test multiple Islanders at once, however, this student had not discovered how. This could be improved in future studies by having a better focus on working in groups to collect data quicker and highlighting approaches to testing multiple participants.

Interface and visuals
As discussed earlier, modern students are brought up and raised in an age surrounded by technology. Their familiarisation with mobile apps and computer software has developed high expectations. In particular, a lot of mobile apps and games now have an 'automatic' feature which permits actions to be completed by the software immediately, or at the very least, customisable by the user.

> *... improve user interface and make it easier and faster to sample.* [ID: 213]

With that said, the original design of the program was for explorative projects, and using it for students' time limited class activities might be stretching the design. Perhaps students would not feel pressured by the class period if the activity was to be done in the student's own time.

The visual aesthetics of the *Island* was another commonly suggested area of improvement among student participants. This was not surprising given the expectations of the modern students and how they responded on previous themes.

> *Maybe make it a bit more colourful and more fun to travel around the Island.* [ID: 164]

Given how advanced current programs and apps are, with stunning visuals and impressive animations, it is only natural that students' expectations in this domain were high. The ability to see the tasks being performed, or animated, would be more pleasing aesthetically, however more research is required to determine if it would also benefit the students' learning.

Discussion

This pilot project developed and piloted innovative, classroom-ready statistical data investigation activities based on the *Island* in order to enrich the teaching of statistics within the Australian Mathematics Curriculum. A teacher manual containing the activities can be obtained by emailing a request to the authors. The *Island*-based activities engaged students in meaningful and realistic virtual statistical practice and the entire process of a statistical data investigation. Students were required to understand the research problem, plan and implement data collection, process and analyse data and interpret data in context. Based on the pre and post questionnaire data from over 200 secondary students across four partnered schools, the activities were associated with statistically significant improvements in attitudes towards statistics, no change to career prospects and a statistically significant decline in competency (note that competency was a factor identified from the student's qualitative feedback and not based on actual assessment). Without a comparison group that did not complete the activities, it is impossible to solely attribute these associated changes to the activities. However, the associated improvement to students' attitudes towards statistics was promising. The significant decline in competency was difficult to interpret without a meaningful comparison. It is possible that students' initially overestimated their competency, which later declined on the post questionnaire as they had a better appreciation of the challenging nature of statistical practice. Despite this decrease, it was reassuring that attitudes still improved. The results also suggested that students' perceptions of career prospects in statistics may be resistant to short-term change, despite improved attitudes.

The low level of agreement to the attitude items in Table 2 highlight the relatively poor perceptions students hold towards statistics. For example, only 24.6% of students agreed that statistics is enjoyable and stimulating on the pre-test. Interestingly, this individual item slightly decreased to 23.7% on the post questionnaire, despite the overall attitude towards statistics factor (a composite score identified by the EFA) significantly improving. This suggests that improvements were being made to the disagreement side of the scale, by shifting responses from strong disagreement into slightly less disagreement or neutrality. Such a change was desirable, but was unlikely to be the required shift needed to inspire a new generation of statisticians. The results of this study suggest, assuming the associated changes in students' attitudes are attributable to classroom experiences, that change will likely be modest and will require continued efforts across year levels. Further research is also needed to refine the activities, better understand their impact across diverse schools, examine the variation between different *Island* activities, and learn under what circumstances the activities have their greatest impact on attitudes. Further research should also investigate the impact of these activities on student learning outcomes and compare the activities to other methods for more meaningful comparisons. Finally, future studies should also consider examining additional factors of the EVT model (such as effort) via interviews with respondents, as this study only focused on the effects of motivation on attitudes.

This pilot project laid the foundation for the *Island*-based activities and resources and provided the project team with an important experience working with secondary school partners. This experience and the feedback obtained from teachers highlighted a number of desirable improvements to be carried out in 2015. The project team was successful in gaining additional funding from the Australian Government Department of Education through the 2014 Australian Maths and Science Partnership Program (AMSPP). The 2015 project aimed to improve upon the pilot resources by creating a stronger curriculum alignment to the Statistics and Probability strand of the Mathematics Curriculum, cover years 7 to 10, and provide teachers with access to online professional development content to support their preparation for classroom implementation. The new resources align to the new version of the *Islands*, currently available at http://smp-island.smp.uq.edu.au. Those interested to learn more about the national project and access the project resources are encouraged to contact the authors and visit the project website at www.islandsinschools.com.au. This pilot project and the resulting national project both aimed to improve the teaching of statistics in Australian secondary schools by engaging students in the statistical data investigation process using innovative educational technology. Further research is needed to determine if and to what degree these improvements impact students' attitudes and interest in statistics and related career pathways.

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