Enhancing self efficacy in experimental design and statistics using e-learning technologies: an interactive approach.

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Abstract

A core area in any psychology degree is the practical course that runs along side the lecture course and provides students with training in running experiments and analysing data. However, the challenge is to deliver this training in large classes, where many students express anxiety about the statistics element of their course. This article describes the design and evaluation of a web based interactive tutorial that introduced students to the concepts behind basic experimental design and statistics. The interactive component of the tutorial focussed on understanding of experimental design, step by step feedback on calculation of statistics and how to interpret and report results.

Students' self efficacy in a number of statistical tasks was measured before and after completing the online tutorial and results showed a significant increase in self efficacy after the tutorial. Students reported the tutorial as particularly useful for understanding inferential statistics and for their assessed laboratory reports. Future developments of an online tutorial based on these findings are discussed.

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Introduction

One of the key sources of educational "friction" in an undergraduate Psychology is the learning of statistics.   Students come to Psychology with a wide range of numeracy skills (Mulhern & Wylie, 2004, 2006) and are often unaware of the importance of statistics in psychology. As many psychology undergraduates have not encountered statistical analysis of any form before, it is unsurprising that statistics is a significant source of anxiety in psychology students (Baloglu & Zelhart, 2003), and up to two thirds of students report high levels of statistics anxiety in courses where statistics is a component (Onwuegbuzie & Wilson, 2003).

Two factors exacerbate this situation: the key role statistics has in a psychology degree and the size of classes.   For a psychology degree to be accredited by the British Psychological Society the course must provide training in quantitative methods, research design, and a practical component (British Psychological Society, 2008). A key part of this is the collection and analysis of data; from early on in their course psychology students have to learn to use descriptive and inferential statistics both within the practical classroom and for course work. Added to this problem is at the lower levels of the degree the classes in Psychology are large as it remains a very popular subject (431 in the 2006-07 level 1 class at the University of Glasgow). Efficiency is a priority, which means that the practical course at level 1 is often delivered using a self paced computer based programme of experiments, with little or no staff contact. Thus, any form of instruction to assist with the statistics encountered in the level 1 practical course, needs to be implemented effectively in large classes.

Although most departments provide an element of formal lecture based statistics teaching, this is an aspect of the undergraduate course at the lower levels that could be targeted for additional support. One method of approaching this problem, given the large class sizes, is to use online interactive tutorials that introduce the students to the concepts behind basic experimental design and data analysis. In fact, use of Internet

based interactive tutorials to support the teaching of introductory statistics in Psychology and in other subjects is a widespread practice (Aberson, Berger, Healy, Kyle, & Romero 2000, Aberson, Berger, Healy, & Romero 2003; Bartz & Sabolik 2001; Richardson & Segal, 1998). When evaluated, these online tutorials had a positive effect on learning equal to more traditional lectures and laboratory classes (Aberson et. al., 2000, 2003), especially when included in a blended approach to teaching (Utts, Sommer, Acredolo, Mahler, & Matthews, 2003). However, it is less clear whether the positive effect of online tutorials extends to improving students' self confidence in statistics.   To address this question, the present study will evaluate the effectiveness of an online statistics tutorial developed at the University of Glasgow in improving psychology students' self efficacy (self confidence) in statistics.

Development of the online resource

The aim of the online learning approach was to enhance level 1 students understanding of statistics in psychology, and develop their skills in data analysis as preparation for assessed coursework. An interactive, online tutorial using example data from a psychology experiment was developed to cover experimental design, calculation of the mean, t-tests, and interpretation of results.

Consistent and helpful feedback on students' answers has been shown to be an effective teaching method in statistics (Garfield, 1995), thus, development of an interactive component in the tutorial was crucial. However, many statistics websites, which include interactivity (e.g., Lane, 2008, West, 1996), often assume prior basic statistical and mathematical knowledge. When developing the resource, it was important to tailor the feedback to introductory psychology students and the skills required for their coursework. With this in mind, the interactive aspects of the tutorial focused not only on calculation of statistics, but understanding of experimental design and how to interpret and report results. For elementary descriptive and inferential statistics (e.g., calculating the mean, standard deviation, t-test), formulae were explained and feedback was provided at each stage of the calculation process. Students were provided with extra 'pop ups' if they needed a clue, and to help them understand why their answer was incorrect. The tutorial was introduced as a link (Swingler, 2006) on the psychology department virtual learning environment

(http://portal.psy.gla.ac.uk/) in early 2006. The website is freely available as a stand-alone web page, accessible on and off campus, and can be incorporated into learning management systems (e.g. Moodle).

An initial survey in April 2006 highlighted that although many level 1 psychology students said they would find an online statistics tutorial beneficial, they were not aware of the online tutorial on the student portal (McCotter & Bishop, 2006). To increase awareness and encourage use of the website, level 1 psychology students were asked to complete a section of the online tutorial as a preparation exercise for a face to face tutorial in statistics. Students recorded their answers to the online exercises and these were discussed and incorporated into the face to face tutorial.

Evaluation approach

Evaluation of the resource focussed on whether use of the online tutorial improved students' self-efficacy in statistics. Self-efficacy is defined as the confidence a student has in completing a specific task, and has been shown to be a good predictor of performance in a variety of contexts (Bandura, 1997). Current self-efficacy in performing statistical tasks is positively related to statistics performance and negatively related to statistics anxiety (Finney & Schraw, 2003). Given that psychology students express anxiety and lack of confidence regarding statistics in psychology (Boluglu & Zelhart, 2003) it seemed relevant to evaluate the online resource with a measure that included an affective component (e.g., Ashcraft & Kirk, 2001; Piotrowski, Bagui & Hemasin, 2002; Schutz, Drogosz, White & Distefano, 1998; Trembley, Gardner & Heipel, 2000). The present evaluation used self-efficacy statements similar to those used by Finney and Schraw (2003) but adapted the tasks to the learning outcomes of the online tutorial. Students merely have to indicate their confidence in their "current ability" to complete statistical tasks.

The self-efficacy measure has advantages over traditional measures of comprehension or knowledge in evaluating the tutorial. Firstly, it measures the important element of students' affective response to statistics, something that comprehension tests can only measure indirectly, if at all. Also implementing an additional test on students' statistical

knowledge when they have already expressed anxiety about statistics may only serve to increase anxiety levels and reduce confidence. In addition, psychology undergraduates vary widely in their level of mathematical qualifications and numeracy (Mulhern & Wylie, 2004, 2006). A test of statistical knowledge at this early stage in their psychology course may reflect students' initial mathematical ability rather than the effect of a single teaching approach. Using self-efficacy as an evaluation measure avoids these pitfalls and provides a direct measure of confidence and to some extent an indirect measure of ability.

Evaluation Method

Participants

118 level 1 psychology undergraduates participated as part of their psychology tutorial programme. All gave consent for their data to be used anonymously.

Design.

A within subjects design was used. Self-efficacy ratings on a number of statistical tasks were measured before and after students completed the online tutorial. Students' feedback on the usefulness of the online tutorial, and problems encountered were also recorded.

Measures

The evaluation measure was implemented online, before and after the tutorial and responses recorded on a database. The pre tutorial questionnaire consisted of 8 self-efficacy statements on current ability to complete a number of statistical tasks directly related to the content of the tutorial. Participants rated each statement (e.g., "Interpret the result of a t-test") using a Likert scale from 1 (no confidence at all) to 6 (complete confidence). The post tutorial questionnaire asked participants to rate their current ability on the same 8 self-efficacy statements. Participants completed a further set of questions on how useful the tutorial was for understanding experimental design and statistics (1=Not useful at all, 5=Greatly improved understanding), how helpful the tutorial was, and any technical problems encountered. At the end participants were

asked to enter comments they had about the tutorial. The self-efficacy questionnaire is in appendix 1, and post tutorial questionnaire in appendix 2.

Procedure

Students were asked to complete the online tutorial in their own time in the week before their face to face statistics tutorial. Participants were asked for consent for their data to be used and informed their data would remain anonymous. Participants completed the pre tutorial questionnaire, and went on to complete the 'Design', 'Plot Averages', 'Paired t-test', 'significance' and 'Report' sections of the t-test tutorial, which took approximately 20 minutes, followed by the post tutorial questionnaire. At the face to face tutorial the following week (approximately 10 students per tutorial group), students worked in pairs on calculations of descriptive statistics using a similar data set.

Results

Although data was from Likert scales and therefore could be considered ordinal, it was analysed as interval data. This is a reasonably accepted practice (Nunnally & Bernstein 1994). All analysis was conducted using SPSS package, the analysis of variance was performed using the General Linear Model.

Table 1.   Mean and median self-efficacy ratings before and after participation in the online tutorial (N=118).

Current ability to successfully Complete the following tasks.	Mean		Median	
	Before	After	Before	After
1. Distinguish between different types of experimental design	3.8	4.7	4	5
2. Calculate a mean	5.5	5.7	6	6
3. Calculate a standard deviation	2.8	4.0	3	4
4. Select the correct t-test based on an experiments' design	2.8	4.3	3	4
5. Explain how to calculate degrees of freedom	3.1	4.8	3	5
6. Explain the calculations of the t-test.	2.5	3.7	2	4
7. Interpret the result of a t-test	3.3	4.0	3	4
8. Explain what a p value is	2.7	3.8	3	4

(1) no confidence at all, (2) a little confidence, (3) a fair amount of confidence, (4) much confidence, (5) very much confidence, (6) complete confidence.

A 2 way repeated measures ANOVA with factors of time administered (before or after tutorial) and self-efficacy task (8 levels) found significant main effects of time ($F_{(1,117)}=240.1$, $p<.0001$), task ($F_{(7,819)}=136.9$, $p<.0001$), and a significant interaction between time and task ($F_{(7,819)}= 24.8$, $p<.0001$). The pre and post test efficacy scores for each task were compared using 8 paired t-tests (the α was set at 0.001 following a Bonferroni adjustment for family-wise error). All tasks showed significant improvement apart from Task 2 (calculating a mean), explaining the significant interaction (all ps<.001). To investigate the main effect of task, 8 paired t-tests (one per task) compared self-efficacy ratings on each task in the before condition and found mean ratings were highest for task 2, followed by task 1 and lowest for task 6 (all ps<.001). Self-efficacy ratings in the after condition were highest for task 2, followed by tasks 1 and 5 (all ps<.001).

Table 2.   Perceived usefulness of online tutorial. Percentage of participants who responded to each value of the Likert scale on each item (N=118).

How useful was the online tutorial for understanding?	1	2	3	4	5	Median	Mean
1. How hypotheses are used to make predictions.	0.8	21.0	27.7	33.6	16.8	4	3.5
2. Identifying within subjects and between subjects experimental designs.	0.8	10.1	22.7	43.7	22.7	4	3.8
3. Identifying the dependent and independent variables in the experiment.	0.8	18.5	25.2	34.5	21.0	4	3.6
4. Calculating the group means from the data.	3.4	30.3	19.3	15.1	31.9	3	3.4
5. Creating bar graphs, including titles and labels.	4.2	22.7	26.1	19.3	27.7	3	3.4
6. Choosing the correct T-test based on the experimental design and hypothesis.	1.7	4.2	19.3	52.1	22.7	4	3.9
7. How to calculate a paired T-test.	3.4	4.2	16.0	52.9	23.5	4	3.9
8. How to calculate an independent samples T-test.	4.2	5.9	23.5	49.6	16.8	4	3.7
9. Checking the significance of T-values.	4.2	9.2	29.4	42.0	15.1	4	3.6
10.Reporting results of T-test in the correct format	2.5	10.1	26.9	42.0	18.5	4	3.6
11.Summarising the results.	3.4	11.8	32.8	32.8	19.3	4	3.5

1=Not useful at all, 2=Did not add to my existing knowledge, 3=Added to my existing knowledge, 4=Helped me to understand it better, 5=Greatly improved my understanding.   Mean and median statistics for each item are reported.

A frequency analysis found the distributions of scores for some items of the questionnaire to be skewed (skewness<-1), thus non-parametric tests were used. After the α was set at 0.001 for multiple comparison using a Bonferroni adjustment, sign tests (one sampled) found responses to questions, 2, 6, 7,and 8 to be significantly higher than the middle response ("added to my existing knowledge") value of 3 (all ps<.001).

Table 3.   Percentage Yes responses to post tutorial evaluation questions (N=121).

Question	Percentage Yes responses
1. Did you enjoy the t-test tutorial?	70
2. Improve understanding of statistics lectures?	90
3. (a) Helpful when completing lab report?	91
3. (b) Which section of the lab report was the tutorial most helpful for?	Hypothesis 26 Design 29 Means and Graphs 34 Calculating the t-test 83 Checking significance 72 Reporting t-test result 78
4. Online feedback useful?	86
5. (a) Any problems experienced?	29
5. (b) Types of problem experienced	Navigating 7 Entering answers 9 Calculating answers 13 Confusing layout 5 Instructions unclear 9

Chi Square tests (one variable) were conducted for each question. For questions 1, 2, 3 (a) and 4, significantly more yes responses were observed than the 50% expected (all ps<.0001, α set at 0.005 after Bonferroni adjustment) For question 5 (a), significantly fewer yes responses were observed than expected (p<.0001). Chi Square analysis of responses to question 3 (b) showed that the online tutorial was rated most frequently as helpful in lab reports for calculating the test, checking significance, and reporting the t-test (p<.0001). Chi square analysis of question 5 (b) (types of problems experienced) showed no one problem was experienced more than any other (p<.0001).

Discussion

Self efficacy

The results of the evaluation suggest that the online tutorial improved students' self-efficacy in their ability to complete statistical tasks. It is worth noting that while all self-

efficacy ratings in all tasks improved before and after the tutorial, ratings between tasks were variable (see Table 1). In particular, ratings were already high for tasks 1 and 2 (experimental design, calculating a mean) in the before condition, and there was little room for improvement after the tutorial. This suggests that students were already confident in these areas. Indeed, these are concepts that have been covered in depth prior to testing, both in lectures and tutorials. Self-efficacy ratings for the more advanced tasks (calculating and interpreting a t-test, explaining a p value, and calculating the standard deviation) did increase after the tutorial. Overall, it appears that the tutorial had a positive impact in terms of student confidence in key tasks related to the level 1 practical course. This is encouraging as it shows that the self efficacy gains that have been found with face to face teaching (Finney & Schraw, 2003) can be replicated with carefully designed online resources.

Was the tutorial perceived as useful?

Students indicated that the tutorial was most useful for experimental design, choosing and calculating results of the t-test (see Table 2). However, ratings were lower for developing hypotheses, calculating descriptive statistics and creating graphs. This pattern is echoed by students' feedback that the tutorial was most useful for the sections of the lab report involving calculating and interpreting a t-test (see Table 3). Combined with the results in self-efficacy, these findings suggest that students perceived elements of the tutorial where they were most confident (descriptive statistics) as least useful, and elements where they were least confident (inferential statistics) as most useful. The interactive element of the tutorial focused primarily on explanation of formulae and step by step calculation of t-tests, which may explain the lower ratings for the sections on hypotheses and descriptive statistics. In addition, psychology students are known to struggle with use of formulae and symbols (e.g., Mulhern & Wylie, 2004), thus, students may have benefitted more from this component of the tutorial than others.

Interactive component

The interactive element of the tutorial provided immediate feedback, and students reported this as useful. Examples of students' comments include "Easy to use, and very useful, especially when it says you have got the right answer". Relatively few problems

were reported; although some reported problems in calculation of the answers (see Table 3). The tutorial asked students to calculate answers step by step, and provide feedback, but this inevitably included some use of formulas. Inclusion of formulas could be problematic for those students with a limited mathematical background (Mulhern & Wylie, 2004, 2006). Indeed, this issue may have been reflected by the lower self-efficacy ratings found with tasks involving calculations (see Table 1). Future developments of the online resource could focus on providing challenges to students that require them to go beyond the calculation of statistical values (Ben Zvi, 2000, Mayer & Anderson, 1992; Park & Hannafin, 1993). For example, by providing a version of the tutorial where results of statistics are pre-calculated and the focus is on interpretation of the results and conceptual understanding.

Use of tutorial

Overall, combining the on line tutorial with traditional face-to-face teaching approach increased the numbers of students using the resource, and was workable in a large undergraduate class. Of a possible number of approximately 431 level 1 students, over a quarter (118) completed all the online tutorial and questionnaires voluntarily. This compares with 15 students from a sample of 98 in our previous evaluation (McCotter & Bishop, 2006). Actual participation was in fact higher than 118 students, as an additional 154 students completed the initial online questionnaire, but did not complete the post tutorial questionnaire. Thus, a substantial number of students attempted to use the tutorial, and either did not complete it, or did complete it, but did not fill in the post tutorial questionnaire. While there is no data on reasons why these students did not finish the tutorial, it is possible that some students found the content of the tutorial either too simplistic or too complex. Future versions of the tutorial could address this by providing versions of the tutorial aimed at different levels of mathematical ability. It is also possible that students were not motivated to complete the online tutorial because participation was voluntary and students were not rewarded with a grade or credit for participating. If students adopt a strategic or surface approach to learning (Entwistle, 1997, Mann, 2001), it can be difficult for tutors to motivate students to engage in additional preparation for classes with no clear payoff (Reader, 2007). Perhaps if an incentive was introduced to motivate students to take part, uptake would increase.

Conclusions

Overall, the interactive approach to online learning of statistics seemed an effective one for level 1 psychology students. Student feedback suggests that future development of an online resource that focuses on inferential statistics and underlying statistical concepts would be beneficial. Furthermore, it may be more effective for this resource to cover statistics at different levels of learning, to suit the varying mathematical backgrounds of psychology students.

Although statistics self-efficacy is positively related to performance (Finney & Schraw, 2003), performance per se was not measured in the present evaluation. Previous research on web based approaches to teaching of statistics has often included pre and post measures of comprehension (Aberson et al., 2000, 2003; Utts et al., 2003). Evaluation of resources in future could correlate measures of comprehension, initial statistics anxiety and self-efficacy to build a clearer picture of the benefits of online resources from both affective and performance related perspectives.

Acknowledgements

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Appendix 1: Self-efficacy

Please rate your confidence in your current ability to successfully complete the following tasks. The item scale has six possible responses: (1) no confidence at all, (2) a little confidence, (3) a fair amount of confidence, (4) much confidence, (5) very much confidence, (6) complete confidence. For each task, please mark the one response that represents your confidence in your current ability to successfully complete the task**.**

	No confidence at all				Complete confidence

Distinguish between different types
of experimental design   **1 2   3   4   5   6**

Calculate a standard deviation   **1 2   3   4   5   6**

Explain what a p-value is   **1 2   3   4   5   6**

Explain the calculations of the t-test.   **1 2   3   4   5   6**

Select the correct t-test based on an experiment's design   **1 2   3   4   5   6**

Calculate a mean   **1 2   3   4   5   6**

Explain how to calculate degrees of freedom   **1 2   3   4   5   6**

Interpret the result of a t-test   **1 2   3   4   5   6**

Appendix 2: *Post tutorial Questionnaire*

How useful were the on-line exercises for understanding Experimental Design and Statistics?   Rate each of the statements below from 1 to 5.

1=Not useful at all

2=Did not add to my existing knowledge.

3=Added to my existing knowledge.

4=Helped me to understand it better.

5=Greatly improved my understanding

	Rating (1-5)
How hypotheses are used to make predictions.	
Identifying within subjects and between subjects experimental designs.	
Identifying the dependent and independent variables in the experiment.	
Calculating the group means from the data.	
Creating bar graphs, including titles and labels.	
Choosing the correct T-test based on the experimental design and hypothesis.	
How to calculate a paired T-test.	
How to calculate an independent samples T-test.	
Checking the significance of T-values.	
Reporting results of T-test in the correct format	
Summarising the results.	

Was it helpful?

1. Did you enjoy the T-test tutorial ?   Yes/No

2. Did the T-test tutorial improve your understanding
   of the 1A lectures on Statistics and Experimental Design?   Yes/No

3. Do you think that the T-test tutorial will help with completing
   Level 1B lab report (Social psychology)?   Yes/No

   If Yes, circle which parts of the lab report it will help with.
   Hypothesis/Design/Means and Graphs/Calculating the T-test/Checking significance/Reporting T-test results.

4.   Was the feedback in the tutorial useful?   Yes/No

5.   Did you experience any problems when using the tutorial?   Yes/No

If yes, circle the type of problem(s) you encountered from the options below.

Navigating to each web page/entering answers/calculating answers/confusing layout/instructions unclear/other.