

Does the introduction of non-traditional teaching techniques improve psychology undergraduates' performance in statistics?

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We report a study in which five non-traditional teaching techniques were applied to an introductory statistics course for psychology undergraduates: active and implicit learning, use of breaks, mastery learning, peer tutoring and problem-based learning. Collectively, these techniques improved students' scores in a statistics examination by ten percent compared with a matched control group and this improvement was statistically significant. Students' responses to the new course were positive.

INTRODUCTION

The traditional lecture format used in universities has changed little since mediæval times. Typically, lectures consist of a monologue by the lecturer, which is reproduced in note form by the students. Some have argued that, in the light of modern research and technology, this format is limited (Butler, Phillman and Smart, 2001). The educational and psychological literature does suggest a number of potential techniques that could improve this basic lecture format both in terms of learning outcomes and the efficiency with which these outcomes are achieved. In the current study we focus on five non-traditional techniques, which are summarised below.

1. Active learning

One approach that may improve learning in lectures is the use of active learning techniques. Instead of being the passive recipients of information, students are encouraged to be more proactive and actively engage with the material. For example, Butler *et al.* (2001) report some evidence that active learning via short, in-class writing exercises increased examination performance amongst psychology undergraduates.

One situation in which more active learning may benefit students is when the material to be learned can be viewed as a type of problem-solving skill. Some researchers (Lesgold, 2001) have argued that skills can often be learned more efficiently by doing them rather than by explicit instruction. This approach has been successfully implemented in sophisticated technical training in a number of real-life industry situations (Lesgold, 2001).

In addition, several studies in the implicit learning literature have shown that explicit instruction (the staple method of teaching in the traditional lecture) does very little to help the learning of some materials (Berry and Broadbent, 1984) and may even hinder it under some conditions (Reber, 1976). Such findings, if we assume that they will generalise to the classroom,

further suggest that active participation may be superior to explicit instruction alone.

2. Breaks

Another technique that may prove useful in aiding learning, particularly in longer lectures, is the use of breaks. Students' attention is known to decrease rapidly after twenty minutes in a lecture situation (Gibbs, 1992). The inclusion of breaks, such as experimental demonstrations or some other type of activity, at 20-minute intervals has been shown to be an effective way of maintaining students' concentration (Gibbs, 1992).

3. Mastery learning

Mastery learning (Bloom, 1976) proposes that all students should achieve 100% success at material being learned early in a given curriculum, before progression to later material in the curriculum. The assumption is that learning of material later in a curriculum is dependent upon successful learning of earlier material. Mastery techniques have been shown to lead to higher achievement in the classroom (Guskey and Gates, 1986; Kulik, Kulik and Bangert-Downs, 1986).

One practical problem with the technique is worth mentioning. According to Anderson (2000), many programs, despite their success, have been dropped from school curricula due to the extra teacher commitment and energy required to manage them. Therefore, given the well-publicised pressures on lecturers' time in higher education, the inclusion of mastery learning in undergraduate courses needs to be designed so as not to increase the workload of teaching staff.

4. Peer tutoring

Rooted in Vygotsky's ideas, peer tutoring is usually applied to teaching young children (see Eysenck, 2000). It assumes that the best teachers for young children are slightly older children, who will be able to focus their instruction at a level suitable for the younger child, not least because they remember the

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limitations they experienced when learning the material themselves. Peer tutoring has become increasingly popular in schools and has been shown to be effective (Barnier, 1989, cited in Eysenck, 2000).

Peer interaction at university level has been used, for example, to teach medical examination procedures (Goodfellow and Schofield, 2001) and was positively rated by students.

5. Problem-based learning

A recent change to the style of teaching medical students has been a move to more problem-based learning. Instead of passively memorising information, students are presented with problems based on real-world applications of the information (Mifflin, Campbell and Price, 2000). They then have to seek out information relevant to solving the particular problem. This maps much more closely onto the job a qualified medical practitioner has to do in the real world. In the past, the assumption has been that passive learning (for example, by listening and memorising information in a classroom) makes that knowledge readily accessible for use in real world applications; that is, there is a transfer of training between the classroom and the real world.

In the skill acquisition literature, transfer of training between different situations simply does not occur in many cases, even if the task is essentially the same. An interesting example is a study of Brazilian children (Carragher, Carragher and Schliemann, 1985) which found that children from deprived backgrounds had great difficulty performing mathematics in a classroom environment. However, when they were tested in the street market environment where they worked, it was found they could effortlessly carry out complex calculations involving buying and selling (even though the actual mathematics involved were the same). Transfer of skill between different situations was not trivial in this case.

Teaching students the mechanics of statistical analysis is expected to enable them to implement that knowledge in their own experiments. However, anecdotal evidence from our own course suggests that many students struggle to do this. By applying problem-based learning, in which students learn about statistics through dealing with examples, we might expect a better transfer between the teaching and the application of that teaching.

Some researchers have pointed out that problem-based learning should not be assumed to be superior to traditional methods in all situations (Norman, 2001) and our own view is that the advantage of any particular implementation needs to be determined by empirical test.

“HOW TO DO PSYCHOLOGICAL RESEARCH” – A COURSE IMPLEMENTING THE ABOVE PRINCIPLES

Our aim was to bring about an empirically demonstrable improvement in psychology undergraduates' understanding and implementation of basic research design and statistics. Understanding of

research design and statistics could be argued to be critical to studying psychology but, anecdotally, students often report this to be the least manageable aspect of psychology courses. In addition, we wanted to achieve this improvement in student performance without any substantial increase in lecturer workload, given increasing pressures on staff time.

The course itself was composed of a total of seven sessions (an introductory lecture plus six two-hour sessions) spread over the course of two ten-week terms. During the first 50-minute part of each of these sessions, students were given problem-based explanations of certain theories and techniques. In these talks, breaks were included at least every 20 minutes for demonstrations of experiments relevant to the principles being taught. These interactive demonstrations were designed to help students maintain concentration, while at the same time reinforcing the material by engaging some students in active participation. The second part of the session (lasting approximately one hour) was designed to encourage further active learning and to encompass the other techniques described above. Students were given a worksheet consisting of problems that could be solved using the material taught in the lecture part of the session, and were required to complete the worksheet with 100% accuracy by the end of the session, thus encouraging the principle of mastery learning. In order to help students achieve this, a large number (usually between eight and 12) of postgraduate students were recruited as tutors (typical class size was around 100 students). The postgraduates were available to help students when required and they also checked the completed worksheets before allowing students to leave. The use of postgraduates in this role was of twofold importance. First, it ensured that the peer tutoring principle was also included in the course (typically, the postgraduates would have just completed an undergraduate psychology course). Second, it enabled the principle of mastery learning to be included without imposing an additional workload on the lecturer responsible for teaching the course.

EMPIRICAL STUDY: DO THE TECHNIQUES APPLIED IMPROVE LEARNING OUTCOMES?

We carried out the empirical study in addition to, and separately from, accredited coursework for the students concerned. This was because it would not have been ethical to carry out any experimental manipulations that could have given some students an advantage over others within the same year, given the course contributed towards a degree. A sample of the students who had been taught the new course sat the end-of-course test from the previous year's course, under strict examination conditions. This examination had an open-book, short-answer format, which included identifying research designs, calculating the appropriate statistical test, and drawing conclusions on the basis of their findings. We then compared these scores with examination scores from a matched sample of students who had completed the same test the previous year (but who were taught without the

techniques under examination). Thus we maintained some degree of experimental control, while making sure that the learning outcome measure (examination score) was as ecologically valid as possible in the circumstances.

The control course, which was the research design and statistics course from the previous year, involved virtually the same syllabus. The second author taught the control course and the bulk of the experimental course. The first author taught two sessions in the experimental course. There were the same number of lectures in the same time slots, but the second hour involved a surgery in which the lecturer was available for consulting (though students were not compelled to stay and most did not). There were no demonstrations and no worksheets, though the content of the handouts was virtually the same. It should be noted that all the test papers were collected at the end of the examination and so were unavailable to students in the new course (including all those in the experimental group).

Method

Participants

Forty-six undergraduate students from the year 2000 entry of the Department of Psychology at the University of Reading were used as experimental group participants. Forty-six undergraduate students from the 1999 entry were used as matched control group participants. Each of the 46 experimental group participants was matched with a control group participant on: (1) A-level points, (2) average marks from term 1 and term 2 practical reports and (3) average marks from part 1 examinations. Experimental group participants were rewarded for their participation with £10 (if they had fulfilled their course credit requirements), or £5 plus course credit.

Design

We used an independent-samples design with group (experimental or control) as the single independent variable. The dependent variable was overall percentage examination score. For experimental participants, this was the score they achieved in the special sitting of the examination, separate from their own coursework. For control participants, this was the score they achieved when they completed the same examination as part of their course a year previously.

Materials

We used the examination script from the Spring term of the 1999-2000 'Understanding Data' course (Dept of Psychology, University of Reading) as a measure of learning for both groups. Students had 50 minutes to complete three questions which involved identifying design aspects of described studies and then applying an appropriate statistical test to the given data using hand calculation. They were allowed to use calculators but were asked to show all stages in working.

Procedure

After the experimental participants had been taught the 'How to do Psychological Research' course, they were recruited to sit the 1999 term 2 examination. The examination was taken before their own assessed term 2 examination (year 2000), at around the same stage of the term as the 1999 entry students would have taken the same examination one year previously (note that this particular exam paper was not made available to the students). This helped to ensure that both experimental and control group participants had the same experience prior to the examination, with the exception that the experimental group participants had experienced the new course while control participants had experienced the old course. All participants sat the test under strict examination conditions and those in the experimental group were instructed to treat it as if it were their actual course examination (for the control group, it was their actual course examination).

Results

Independent samples t-tests confirmed that experimental and control groups did not differ significantly on any of the matching variables: all p 's > 0.32 (see Table 1), despite a 91% chance of detecting a medium effect size (.5 standard deviations between the means: Cohen, 1992) for $\alpha = .32$. The matching variables used took into account both previous examination-based performance (A-levels and Part 1 examinations) and previous coursework-based achievement (term 1 and 2 practical report marks).

Table 1

Matching variables. Mean A-level points, term 1 and 2 practical report marks, and part 1 examination marks by group (standard deviations in parentheses).

	A-Level points	Practical marks	Part 1 Exam mark
Experimental	24.71 (4.96)	59.22 (5.4)	59.1 (11.56)
Control	24.56 (3.85)	57.87 (7.52)	60.65 (10.47)

Note: Groups did not differ significantly on any of the matching variables

Groups did significantly differ on test score: $t(81.487) = 2.499$; $p = 0.014$, corrected for unequal variances. The mean scores of the experimental and control groups are shown in Figure 1. In terms of their examination scores on the 1999 examination, students taught using the new course significantly outperformed students who were taught the old course.

Data from feedback forms distributed after the course revealed that students' opinions of the course were generally favourable. Specifically, data showed that a majority of students (90% for research methods content, 70% for statistics content) found the course content interesting at least some of the time. Furthermore, almost all students felt that completing

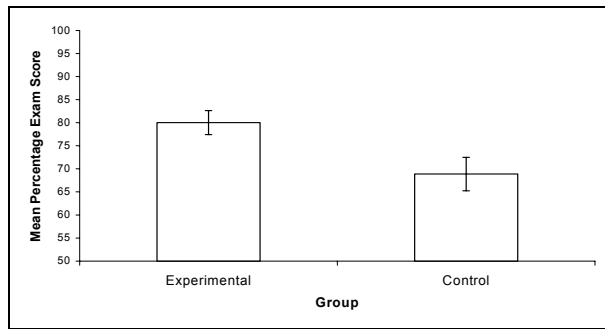


Figure 1

Mean percentage examination score by group (with standard error bars)

worksheets in the class (mastery learning) was a good idea (85%) and felt that the course had helped them write up their term 1 and 2 practical reports (95%).

DISCUSSION

The results demonstrate that undergraduate psychology students who completed our course on research design and statistics, which incorporated a number of non-traditional teaching techniques, outperformed a matched group of students who completed a previous course without these innovations. Their exam scores were 10.1% higher, indicating that the effect was not trivial. In addition, students' ratings of the course were favourable across a range of criteria.

However, this data should be treated as exploratory. Given the ecological nature of this study, there are a number of criticisms of the methodology that need to be addressed by further experiments.

First, it was not clear which of the different aspects of the new course had the greatest impact on the students' performance. Further research, which was not possible within the scale of the present study, would be needed to determine this.

Second, Kulik, Kulik and Cohen (1979) found a novelty confound, such that the difference in effectiveness between old and new teaching techniques decreased over time, possibly due to the extra enthusiasm teachers might have for new techniques. However, the course used as the control in the present study had also just been re-designed, so we would expect any novelty confounds to be minimal. Nonetheless, it would be useful to reassess the new course in subsequent years to see whether the performance benefits remained.

Third, the experimental group had already undergone an examination that included some of the material in the test because of changes to course content. We would need to examine this material separately in further studies (this was not possible in the present study).

Fourth, it was possible that the students in the experimental group had spent more time studying than

controls as a result of the compulsory worksheets. Future studies could take a measure of study time to control for this factor.

Despite these criticisms, it should also be borne in mind that there were confounds that favoured the performance of the control group. For example, the control group completed the test as an assessed examination, which had serious consequences for their degrees. For reasons already stated, the experimental group completed the test knowing that their results had no consequence and so it would be expected that they should be less motivated to revise.

While this study should only be regarded as exploratory, the results give us grounds for optimism regarding the application of these techniques to material of this kind. We have managed to obtain an increase in student performance without a substantial increase in lecturer workload (the lecturer remained available for the workshop), or a substantial increase in resources. While the postgraduates were paid as demonstrators, the hours of work involved were small (approximately 48 demonstrator hours spread over two terms) compared with, for example, postgraduate demonstrating for our first-year practical classes (which involve the detailed assessment of a significant number of practical reports).

We would hope that this could lead to significant changes in the philosophy of teaching certain topics at University level and that these changes would have measurable benefits in terms of learning efficiency for our students.

ACKNOWLEDGEMENTS

This work was supported by the Teaching and Learning Development Fund (University of Reading, UK) and we would like to thank Elizabeth Gaffan and Teresa Young for gathering the student feedback on the course. We are particularly grateful to Elizabeth Gaffan for her support as Head of Teaching (Department of Psychology, University of Reading) in implementing the course. We would also like to thank Andrea Waylen for tracking down some key references.

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Manuscript received on 14 March 2002

Revision accepted for publication on 23 May 2002.