Abstract

Modern introductory statistics courses continue to evolve in order to reflect the progress of statistics education and the needs of modern students. Many of these developments relate to an increase in the use of technology and innovative teaching and assessment practices. However, while many of these changes have been informed by learning theories and extensive teacher experience, their efficacy has not been thoroughly evaluated. This thesis reports the findings of three major projects that have evaluated theory-based interventions aimed at improving the key learning outcomes of introductory statistics courses, namely statistical literacy, reasoning and thinking.

In Part I, the important topic of technological skills in statistics education is examined. As technology has become an inseparable part of modern statistical practice (Gould, 2010), so too has it become an integral part of modern notions of statistical literacy. From this perspective, understanding the development of technological skills in statistics education becomes a priority. Unfortunately, very little is known about the development of these skills (Chapter 3). Part I compares the effect of two different training methods, Error-management Training (EMT)and Guided Training (GT) on the development of students' ability to operate statistical packages. EMT is based on active-exploratory training principles where students develop skills through actively exploring a task domain (Dormann & Frese, 1994). Active-exploration is prompted by the use of minimal instruction. GT, on the other hand, is a passive form of training where students' proficiency is developed through comprehensive guided step-by-step instructions (Chapter 3, Keith & Frese, 2008). Previous studies in general software training (e.g. training to use word processors, spreadsheets and presentation software) suggested that EMT is superior to GT in promoting students' ability to adaptively transfer their skills outside of the training environment (Keith & Frese, 2008). A pilot

study was conducted to initially evaluate the feasibility of delivering statistical package training using minimal instructions required by EMT (Chapter 4). The pilot was conducted using a sample of 13 science and business university students who had previously completed an introductory statistics course.

Following the success of the pilot, Trial I compared EMT to GT using an explanatory mixed methods approach in a sample of 100 university psychology students enrolled in an introductory statistics course (Chapter 5). The quantitative phase of Trial I used a randomised experiment embedded in the course to compare measures of training transfer between students assigned to fortnightly EMT or GT for learning to operate the statistical package *SPSS*. The second qualitative phase used 15 in-depth interviews to help explain the quantitative results and explore the overall student experience of the statistical package training sessions (Chapter 6). While the quantitative results of Trial I were inconclusive, a thorough evaluation of Trial I laid the foundation for a second trial in the same course the following year. Trial II addressed the major limitations of Trial I using a quasi-experimental design in a sample of 115 psychology students (Chapter 7). EMT and GT were compared between two campuses of the same introductory statistics course. After controlling for important covariates, no difference in students' development of statistical package skills was found between the two training strategies. The outcomes of this series of studies suggested that other factors appeared to be playing a more important role than training strategies in the development of technology skills in statistics education.

In Part II of the dissertation, cognitive conflict strategies were evaluated for improving students' statistical reasoning by confronting students' misconceptions. Cognitive conflict strategies are designed to promote conceptual change by presenting contradictory information and replacing students' faulty conceptualisations with more scientifically valid understandings (Chapter 9, Limón, 2001). Cognitive conflict interventions had been identified by previous studies in statistics education as a promising method for reducing misconceptions related to a wide range of misunderstandings (e.g. Kalinowski, Fidler, & Cumming, 2008; Jazayeri, Lai, Fidler, & Cumming, 2010; Liu, Lin, & Kinshuk, 2010). Part II evaluated the use of brief conceptual change-based activities embedded in lectures for confronting a wide variety of misconceptions across the semester of an introductory statistics course for medical science students (Chapter 10). The study was conducted over two years on two separate student cohorts with a total sample size of 328. In the control cohort, baseline measures of statistical reasoning and misconceptions were included in an end of semester multiple choice exam. In the following year, the intervention cohort received eight brief cognitive conflict-based activities embedded in lectures and also completed the same select multiple-choice questions in the exam. The results of the study found two of the eight activities were associated with a statistically significant improvement in students' statistical reasoning. The results also suggested that the complexity of the misconception being targeted is likely to moderate the effect of a "brief" intervention format. More pervasive and difficult to change misconceptions related to statistical inference require longer and more intensive interventions.

Part III of the dissertation evaluated the impact of project-based learning on the development of statistical thinking. Project-based learning (PBL) is a form of experiential learning which is based on the concept of learning by doing (Blumenfeld et al., 1991). PBL has been used to help develop statistical thinking by engaging students in the entire data investigative cycle of statistical enquiry (MacGillivray, 2010; MacGillivray & Pereira-Mendoza, 2011; Snee, 1993). As a consequence of the difficulty of defining and assessing statistical thinking, empirical evidence of this proposed link is lacking (Chapter 12). In Study I an online virtual environment called the *Island* was first validated as a tool for delivering PBL in an online masters level introductory biostatistics course (Chapter 13). The quantitative and qualitative results of 42 student surveys and 5 in-depth interviews confirmed the validity of using the *Island* for PBL and provided qualitative evidence of the theoretical link between PBL and statistical thinking. In Study II this proposed link was initially tested using an experimental design. Participants from a large introductory statistics course for science students were randomly allocated as individuals or in small groups to complete two different types of research designs, observational or experimental, for an *Island*-based course project (Chapter 14). Study II hypothesised that a student's ability to think statistically about different research designs would depend on the project type they were allocated. Towards the end of the semester, 356 students completed a test of statistical thinking about experimental and observational studies. The results of Study II found that performance on the test of statistical thinking did not depend on students' allocated project type. While this study found inconclusive evidence of the proposed link between PBL and the development of statistical thinking, the outcomes of this study highlighted a number of major challenges facing this area of research.

The outcomes of these major parts provide valuable insight into the importance of evaluation research in statistics education and the challenges it presents to researchers. The findings discussed build upon statistics education research and suggest promising directions for future research.