FACILITATING LANGUAGE-FOCUSED COOPERATIVE LEARNING IN INTRODUCTORY STATISTICS CLASSROOMS: A CASE STUDY

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ABSTRACT

With the GAISE emphasis on prioritising concept development over mathematical calculation in statistics education, statistical language has increasingly become the focus of research. Yet, there is a dearth of research investigating techniques to teach statistical language. To redress this gap, we introduced a group of statistics tutors to some cooperative learning techniques commonly used to teach language and concepts in other disciplines (Jigsaw and Think-Pair-Share). The twofold aim was to explore the tutors' uptake of the techniques and how to improve their proficiency in implementing the techniques. The techniques were delivered experientially with tutors through a professional development session followed by implementation of the techniques in their tutorials. A semester-long exploratory case study was conducted using surveys, focus group sessions and shared self-reflection on a digital discussion board. From the tutors' reported experience and feedback, areas for improvement in the implementation of the techniques were identified, pertaining to the effectiveness of the techniques, expectations of teacher and student roles in learning, and classroom management. Plans for addressing these areas for improvement in future studies are presented, which include enhancing the professional development and adding in-class mentor ing of tutors.

Keywords: *Statistics education research; Active learning; Language learning; Statistical literacy; Classroom management; Teacher roles*

1. INTRODUCTION

The learning and understanding of statistics terminology and the associated concepts are components of *statistical literacy*. The American Statistical Association's recently revised *Guidelines for Assessment and Instruction in Statistics Education College Report* (GAISE, 2016) highlights the importance of statistical thinking and literacy in the teaching of statistics. GAISE describes the need for teachers to focus on "helping students become better educated consumers of statistical information by introducing them to the basic *language* and the *fundamental ideas* of statistics, and by emphasizing the use and interpretation of statistics in everyday life" (GAISE, 2016, p. 12).

GAISE recommendations offer details about *what* should be taught to enhance statistical thinking and literacy, but the scope of the document affords little detailed guidance for *how* statistical literacy should be learned and taught in the classroom. The fourth GAISE recommendation explicitly suggests teaching statistics using an active learning approach. This recommendation is supported by a meta-analysis of 225 studies (Freeman et al., 2014) which concluded that active learning increases student performance in quantitative disciplines.

The current study was motivated by a small action research pilot study that briefly trialed some techniques addressing *how* to teach the statistical language and concept development component of

statistical literacy. We used the cooperative learning approach and language-focused techniques with one experienced first-year statistics tutor (i.e., teaching assistant) and his students. The tutor was positive towards the techniques, and commented that "I'm ten minutes into the first (cooperative learning task) and absolutely love it! I have small productive groups focused on their work and it's amazing…" One outcome of the pilot study was that existing paper and pen-based tutorial activities could be easily adapted to the cooperative learning approach. Encouraged by this positive feedback, we designed a study to provide nine introductory statistics tutors with professional development on cooperative language-focused techniques through experiential learning. We then explored their experiences of implementing the techniques over the following semester.

To this end our research questions were the following:

1. How, and to what extent, are the techniques adopted?
2. How can the tutors' implementation of the techniques be improved in the future?

To answer these questions, we conducted an explorative case study at a small, regional university in Australia (10,447 students in 2015). We monitored the implementation of the techniques with surveys, focus groups, and shared personal reflection via an online discussion board to learn how the tutors' implementation of the techniques can be improved in the future. As our initial focus is on ensuring tutors are proficient in implementing the techniques, measures of student learning were not included in the design of this explorative study.

2. BACKGROUND

2.1. LANGUAGE, CONCEPT FORMATION, AND STATISTICAL CONCEPTS

Students being introduced to unfamiliar academic disciplines undergo a process of concept construction through exposure to, and acquisition of, the language of that discipline. In learning the language of a new discipline, a certain amount of ambiguity in discipline language is experienced, and statistics is an example of this (Dunn, Carey, Richardson, & McDonald, 2016; Kaplan & Rogness, 2018; Richardson, Dunn, & Hutchins, 2013; Richardson, Dunn, Carey, & McDonald, 2016). For this reason, teaching statistical concepts and language is incredibly challenging (Garfield & Ben-Zvi, 2007, 2008; MacGillivray, 2009) and requires specialised skills to teach statistical concepts through the language used in the discipline (Dunn et al., 2016; Richardson et al., 2016). As an example of the linguistic challenges, ordinary language appears in statistical discourse but has technical (not ordinary) meanings (Dunn et al., 2016; Richardson et al., 2016), which is called lexical ambiguity (Kaplan, Fisher, & Rogness, 2009, 2010; Kaplan & Rogness, 2018; Richardson et al., 2013). For example, the words *significant*, *independent*, and *error* are all ordinary English words with technical meanings in statistics, all of which cause substantial difficulties for students (Dunn et al., 2016; Richardson et al., 2016). Despite this, and the many other linguistic challenges, very little research is available to inform the teaching of statistics which addresses these lexical issues (Dunn et al., 2016; Kaplan & Rogness, 2018; Richardson et al., 2016).

Linguists who study the *use* and *function* of language (functional linguists) argue that ambiguity in language has an important and useful (rather than a deficit) function in learning (Chater & Christiansen, 2010) which might be embraced in order for the ambiguous terminology, such as that used in statistics, to be understood (Kaplan & Rogness, 2018). Ambiguous terms can be explicitly taught by drawing attention to them, comparing and contrasting words that have polysemous general and statistical meanings, and directly dealing with the reasons for their ambiguity. In doing so they become a resource exploited by the teacher to teach statistical vocabulary and associated statistical concepts (Dunn et al., 2016; Richardson et al., 2016). Also see, for example, the explicit vocabulary comparison activities developed by Kaplan and Rogness (2018).

2.2. ACTIVE LEARNING, COOPERATIVE LEARNING, AND STATISTICS INSTRUCTION

The fourth GAISE recommendation argues for statistics teachers to *foster active learning* to contextualise statistical concepts (GAISE, 2016). The active learning approach typically involves students cooperating on meaningful tasks, such as projects, lab exercises, and group problem-solving and discussion activities (Aliaga, 2010). The difference between active learning and the focus of this

paper (cooperative learning) is outlined with examples from the statistics education context by Roseth, Garfield, and Ben-Zvi (2008); they contrast the two approaches as follows:

> Cooperative learning and active learning are often used interchangeably to describe instructional methods that allow students to solve problems, participate in activities, and discuss content with students. Importantly, cooperative learning is a form of active learning, but active learning is not necessarily cooperative. An important distinction is that cooperative learning methods capitalize on the motivational and epistemic processes occurring between students rather than within any one. This means that cooperative learning methods derive engagement and interest from the way students' individual goals are linked to each other, rather than rely on individual curiosity, work ethic, or the provocative nature of the curriculum, activity, or lesson plan. (p. 2)

When cooperative learning tasks are structured explicitly to enhance communication and the use of discipline-specific language, a cooperative, language-focused approach to learning is being used. Cooperative learning is not just an effective teaching approach; it also develops communication skills that are transferable to, and valued in, the workplace. A survey of employers of statistically-educated employees found that communicating in cooperative teams is rarely covered well enough (Utts, 2015) in the education of graduates, so should be mandatory in the teaching of statistics. This attribute of cooperating in teams may be developed in students of statistics who learn to communicate about statistics in the cooperative classroom.

2.3. COOPERATIVE LEARNING APPROACH, METHOD, AND TECHNIQUES

Every teacher in the classroom is implementing a theory of learning regardless of whether that teacher is conscious of the underlying theory or not (Thomson, 2009). In order to articulate clearly the relationship between theory and practice that informs this case study, we illustrate our model of learning and teaching and the educational terminology used in this paper in Figure 1.

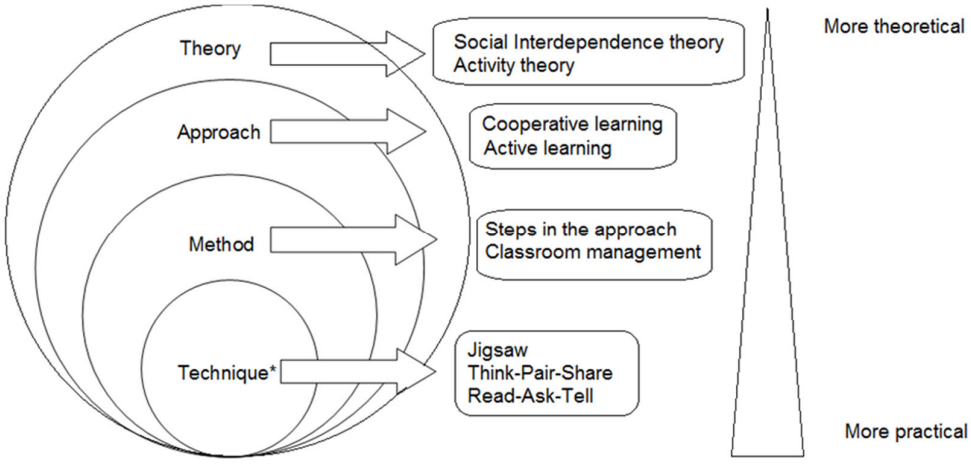

Figure 1. A model illustrating the theories, approaches, method, and techniques associated with this case study. Note: The sequence of steps in a technique is called a procedure.

Working from education theory to education practicalities, our andragogy is fundamentally informed by Activity Theory (Engeström, Miettinen, & Punamäki, 1999). Activity Theory developed from the social constructivist epistemology of learning and teaching most notably advocated by Vygotsky (1978). It is also informed by Social Interdependence Theory (Deutsch, 1962; Johnson & Johnson, 2005), a theory that uses cooperation, rather than competition, between students in learning to create a shared purpose and personal investment in achieving learning task goals. These *theories* in turn inform the *approach* of cooperative learning, which is implemented by a *method* that involves a systematic series of steps and classroom management practices in order to teach statistical language

and concepts. In this paper we discuss the use of three *techniques* chosen to deliver language-focused cooperative statistics lessons: Jigsaw, Think-Pair-Share, and Read-Ask-Tell.

Roseth et al. (2008) outlined the importance of using the cooperative learning approach, in addition to an active learning approach, in the teaching of statistics. They also suggested various learning and teaching techniques and some practical "tips" for the cooperative classroom. The tips they provide are suggestions for classroom management microskills. Others have trialled techniques such as the Jigsaw and reported limited success (Perkins & Saris, 2001). The gap in these studies appears to be in the articulation of the *method* connecting the *approach* and the *technique*. To this end, our case study sought to conduct professional development with statistics tutors by introducing them to the *method* used in the classroom teaching of languages. The method consists of steps used in facilitating learning in the cooperative classroom, accompanied by explicit modeling of classroom management microskills associated with the cooperative learning approach.

2.4. TEACHING STATISTICS WITH LANGUAGE-FOCUSED TECHNIQUES

Historically, the traditional approach to teaching statistics generally uses transmission-style teaching and involves computation (Cobb, 1992). To teach statistical literacy, the contemporary teaching of statistics may benefit from a shift to a cooperative approach emphasising language-teaching techniques. This shift away from computation has been made possible because computations and constructing plots by hand are now generally relegated to computers (GAISE, 2016; MacGillivray, 2009). To make this shift, statistics educators must be provided with strategies to place language at the centre of cooperative learning approaches (Roseth et al., 2008).

Statistics educators at university level, at least in Australia, generally have training in statistics and mathematics, but few have formal training in teaching; some may have studied a discipline in which statistics is used; rarely do they have language-teaching skills. Despite this, language is at the heart of teaching statistics (Dunn et al., 2016; Richardson et al., 2016). This disconnection can lead to statistics educators, even those who appreciate the importance of language in teaching statistics, lacking the skills or knowledge to provide the required focus on language in statistics classes.

Without knowledge of the cooperative approach to learning and teaching, statistics tutors tend to emulate the traditional teacher-centred, transmission-teaching approach through which they learned statistics or mathematics via "apprenticeship of observation" (Lortie, 1975). This passive teaching approach is no longer considered effective and is increasingly being replaced in STEM disciplines by more active and cooperative learning (for example, see Barr, Readman, & Dunn, 2014) which subverts teaching to learning (Young & Messum, 2011).

In previous research, statistics educators have trialled unstructured small-group activities that encourage students to talk with each other (Garfield, 1993). Other attempts to engage students in talking about statistics in class offer ideas for how such activities can be included, for example, giving groups a data set to analyze and to discuss, followed by a written report of what they have learned about the data (Garfield, 1993), but these earlier attempts did not offer any structure or focused strategies or give guidance to the teachers about how to manage these activities in class. The issue is that there needs to be a method to take advantage of this cooperative learning approach and to implement the relevant techniques (Figure 1). Only talking about statistics does not necessarily help students to understand what terms mean and does not necessarily help with the language issues in statistics because there is not an explicit focus on language.

2.5. LANGUAGE-FOCUSED TECHNIQUES

Various language-focused techniques, following a cooperative learning approach, are reported in the current higher education scholarship of learning and teaching literature (Arends, 2012; Johnson, Johnson, & Smith, 2014; Macpherson, 2015). One technique, the Jigsaw technique (Dat-Tran & Lewis, 2012; Gömleksi˙z, 2007; Perkins & Saris, 2001) (Figure 2), involves students working in one of two small groups. Members of Group A work cooperatively to understand part of the text (such as an Abstract) and then paraphrase the content, explain concepts, and teach the meaning of terms in the text to students in Group B. Members of Group B, who have read a different but related component of the

text (such as the Results section). orally paraphrase the content of that section and explain the concepts and teach the vocabulary to members of Group A.

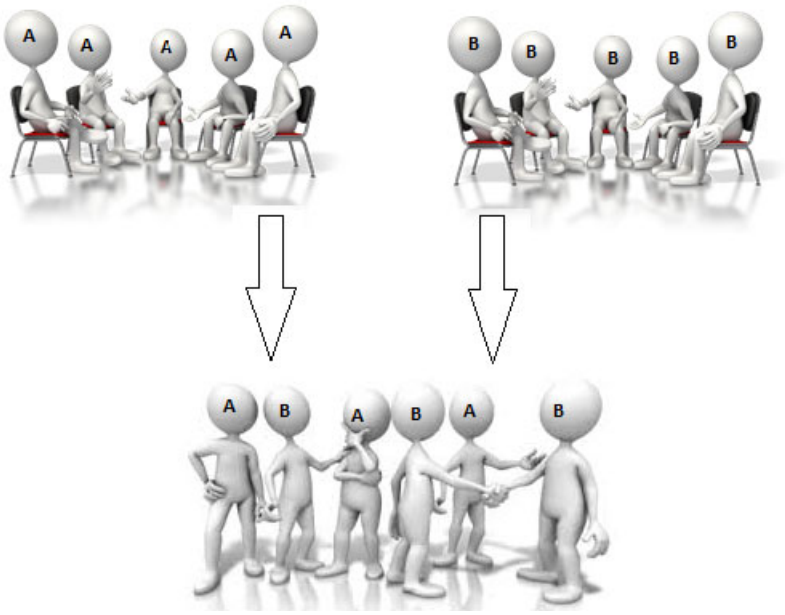

Figure 2. The Jigsaw technique

The value of techniques, such as the Jigsaw, within first and second language acquisition, have been understood by education researchers and applied linguists for many years. The Jigsaw technique activates comprehension and concept development through social interaction and a dialectic produced between learners, made to be meaningful and engaging because it is situated in an authentic context of communication (Brown, Collins, & Duguid, 1989; Miller & Gildea, 1987; Nation, 2001). The technique is particularly suitable for large statistics tutorials and for learning contexts with variation in ability (Perkins & Saris, 2001) and cultural diversity. Studies in the English language teaching context suggest that the Jigsaw technique is effective in large and small classes and increases learner motivation in various international cultural contexts (Dat-Tran & Lewis, 2012; Gömleksi˙z, 2007). Thus, this project's outcomes could also assist international students in using the language of statistics in English.

The Think-Pair-Share technique (Bataineh, 2015; GAISE, 2016; McTighe & Lyman, 1988), Figure 3, involves students individually thinking of answers (Think) to questions in any question format: multiple choice, open response, or binary response, such as agree/disagree, or yes/no. Then students discuss their answers with their peers in pairs (Pair). Finally, students might revise their answers as they share them with their other peers in the class (Share).

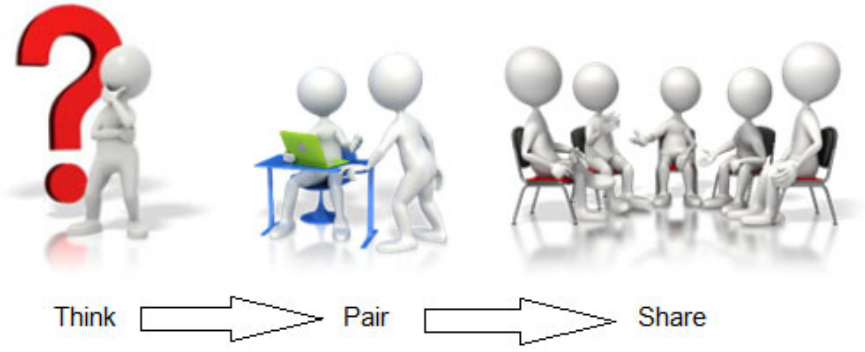

Figure 3. The Think-Pair-Share technique

A variant of the above techniques that can be used in teaching statistics classes is the Read-Ask-Tell (RAT) technique (Remsburg, Harris, & Batzli, 2014). One way to conduct a RAT is to divide the class into Group A and Group B (sitting in sub-groups of 3 or 4 students). Students in Group A answer some questions; Students in Group B answer different questions related to the same text. When the groups have answered their own respective questions, the tutor distributes the respective answers to the questions to each group. The groups then work together discussing the answers and trying to establish the reason for any errors in their answers. The tutor monitors and helps as required. Then a member of Group A is paired with a member of Group B (assuming equal numbers); A asks B each of the questions s/he answered and A assists B to find the correct answer and then B asks A each of the questions and B assists A to understand the answers. The role of the tutor is to monitor and assist any students who had the wrong answer or could not understand the correct answer.

These techniques are commonly used by language teachers, but as statistics teaching has moved from preferencing computation to preferencing language, teachers of statistics have not been suitably prepared to teach in this new paradigm (Justice, Zieffler, & Garfield, 2017; Kaplan & Rogness, 2018). As a consequence of unfamiliarity with language-focused techniques, statistics tutors may not feel confident and may be reluctant to implement such initiatives (Lesser et al., 2013) unless they receive experiential instruction and have access to resources.

2.6. PROFESSIONAL DEVELOPMENT OF STATISTICS INSTRUCTORS AND EXPERIENTIAL LEARNING

Professional development (PD) of statistics instructors in tertiary institutions has been identified in the United States as an area in need of improvement for graduate teaching assistants (GTA). A recent survey-based study (Justice et al., 2017) of 213 GTAs' beliefs about how to teach statistics, and the PD experiences they had to prepare them for teaching introductory statistics, found their teaching practices were generally not aligned with professionally-endorsed recommendations for teaching and learning statistics. One of the recommendations of the study was to provide GTAs with mentoring from faculty and experienced peers in statistics learning through active and cooperative teaching approaches.

The current PD was conducted 'with' participants through the process of experiential learning (Kolb, 1984), rather than being delivered 'to' them. Experiential learning is the process of learning through experience, or more specifically, learning through reflection on doing. Experiential learning theory defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (Kolb, 1984, p. 41).

3. STUDY CONTEXT AND PROCEDURE

3.1. THE LEARNING AND TEACHING CONTEXT

The course examined in this case study (*Science Research Methods*) is an introductory statistics and research design course taken by students in science, engineering, and allied health, usually in their first year of study. The course is taught over 13 teaching weeks, in which students participate in one 2-hour lecture and one 2-hour tutorial (both non-compulsory) each week. The assessment includes five online quizzes, and a final open-book examination. The major piece of assessment is a free-choice project where students plan a small project, then collect data, analyse the data, and produce a report (Forster & MacGillivray, 2010).

In semester one, 2015, over 650 students completed the course. Apart from the lecturer (who tutored and was the course coordinator), nine sessional tutors and one permanent tutor were originally assigned to teach the course: five females and five males, six experienced in tutoring the course and four inexperienced (having taught the course once before, or never before). Apart from two former school mathematics teachers, none of the other tutors had any formal training in teaching. However, the tutors had been recruited via an informal interview that sought to determine, amongst other attributes, that the candidate was open to the idea of taking a non-traditional, non-passive approach to teaching statistics. None had formal training in statistics apart from the permanent tutor, but all had experience in using statistics in research or were current PhD students in quantitative disciplines. The tutors facilitated

between one and six tutorials per week, each week of the semester. The permanent tutor originally assigned to teach this course, who participated in the early stages of this project, was reassigned to other teaching commitments before the semester began. The lecturer was part of the research team and no data were collected from the lecturer. Consequently, results from the initial stages of this project are for 10 tutors, but results that emerge from the teaching are based on nine tutors.

The course has evolved over many years and an established tutorial workbook is available for students, with a version of this workbook available for tutors with all answers and some notes on teaching activities. The GAISE recommendations (GAISE, 2016) for introductory statistics are implicit in the original design of the course and the course workbook:

1. *Teach statistical thinking*. Students are encouraged to think about the data and what the data mean. For example, exercises may ask students to place their statistical answers in the application context and to write answers for a lay audience, to make visual rather than numerical comparisons, to identify which conclusions are consistent with given output, to critique the presentation of data or conclusions.
2. *Focus on conceptual understanding*. Concepts are taught by having students discuss answers and explain their answers to other groups, to select appropriate graphs or techniques without needing to complete the analyses or draw the graphs, matching symbols to meanings, matching conclusions to test summaries.
3. *Integrate real data with a context and a purpose*. More than 80 real research studies are cited and used. For example, short extracts, graphs, and tables from articles are provided for critique; data from papers are analysed; article abstracts are deconstructed; results are interpreted; etc. These studies are drawn from journal articles and aligned with the disciplines of students who undertake the course, and from other sources that may appeal to students more generally (such as Dunn, 2012, 2013; Luo, Wood, & Jones, 2004; Wagner, Larson, & Wengreen, 2010), and data collected on the price of used cars (Smith, 1998).
4. *Foster active learning*. Students are given activities that involve research design, data collection, and student discussion. Research design and data collection activities include reaction time measurement comparing dominant and non-dominant hand;,testing the accuracy of students' estimates of the width of a room, determining relationships between two qualitative variables, comparing students' own heights to Australian norms (ABS, 1995).
5. *Use technology to explore concepts and analyze data*. SPSS is used for data analysis. Non-laboratory exercises include analysis of data using SPSS and interpretation of SPSS output. Technology-based investigations are used when appropriate.
6. *Use assessments to improve and evaluate student learning*. Assessment tasks in the course are designed to be effective for learning, which is an approach to assessment design commonly referred to as *assessment for learning* (Earl, 2003). For example, implicit in the tasks are opportunities to maximise learning actively by providing students with opportunities to discuss their research projects with other groups. Also implicit in the course workbook design is *assessment as learning* (Barr et al., 2014; Earl, 2003;): for example, students work through an online quiz with their tutor.

Previously, the tutors had been provided with limited instructions on how to teach and manage the classroom (due to financial and time constraints). In most classes, depending on the tutor, students would work through activities (previously described) in the tutorial workbook, and tutors would discuss answers at various points during class. In 2015, the teaching team decided to change the teaching approach to intentionally include more cooperative learning in tutorials. In preparation for this change, a presemester tutors' professional development workshop was held for all tutors on cooperative learning techniques. The workshop was facilitated by an experienced educator with a background in applied linguistics and language teaching (the first author).

3.2. PROFESSIONAL DEVELOPMENT PROCEDURE

The PD facilitator conducted an experiential PD session with the initial ten tutors to integrate cooperative language-focused learning activities into the tasks within the tutorial workbooks. When experiential learning is applied to the PD of tutors to enable the teaching and learning of specific

techniques for the tutorial context, the tutors play the role of the learner (introductory statistics students) and the PD facilitator (or mentor) plays the role of the statistics tutor. This is done so that the teaching techniques are modeled by the PD facilitator and the tutors can reflect on the experience of their learners and to reflect on the teaching techniques being modeled by an expert facilitator. All the interactions that accompany this learning (classroom management microskills such as placing students into groups or pairs, verbalising clear teacher directives and questions, monitoring students' learning, opening and wrapping up the session) are modeled by the PD facilitator. An additional variation on this practice is for the PD facilitator to relinquish some of these roles to a tutor that they feel can take on these roles.

All but one tutor adopted the role of students experiencing the technique; the other tutor, who was the tutor in the previous trial (see Section 1), and was the most experienced of the tutors, adopted the role of a classroom tutor, to monitor and eavesdrop, occasionally providing guidance when necessary. The facilitator modeled how to manage a cooperative learning session, drawing the tutors' attention to the directives given to students at the various stages of the lesson. The facilitator demonstrated the first opening stage of the lesson and asked probing questions after the final round up stage by eliciting from tutors what they had activated cognitively when they performed a certain behaviour (such as paraphrasing their understanding of a text, verbally recalling information to consolidate/memorise, pronouncing and contextualising statistics vocabulary and concepts).

The presemester PD session was conducted in a standard tutorial room for two hours. Although we intended to adopt three techniques for this study, an unscheduled fire alarm during the session restricted the facilitator to discussing and modelling only two techniques: Think-Pair-Share and Jigsaw. Consequently, RAT was explained, but not modelled in the session. The structure and roles of the PD session was as follows.

The first activity was a Think-Pair-Share (TPS). The TPS technique was applied to a task in which students (role-played by the tutors) were asked a series of questions that guided them to formulate a research study on a topic of their own choosing (Appendix 3). The students individually read a research study scenario, read the questions, and thought about their answer; then pairs discussed their individual answers to the questions together to arrive at an answer through a dialectic; then the pairs combined into groups of four to share their responses and consolidate their understandings.

The second activity was a slightly-modified form of the Jigsaw (JS) technique. The tutors were placed into groups of three (Groups A, B, C). All groups were instructed to read a journal paper abstract (Appendix 4), paraphrase it verbally together and discuss the meanings of the terms used. The Jigsaw component was a division of the eight questions accompanying the abstract text. Group A was instructed to discuss and answer Questions 1 to 3; Group B to discuss Questions 4 to 6; Group C to discuss Questions 7 to 8.

Supplementary documentation was supplied to tutors in the form of PowerPoint presentations on the Cooperative Learning Approach and teaching notes on the language-based techniques.

3.3. PD WORKSHOP SURVEYS

A pre-PD workshop survey was conducted to obtain a baseline for the tutors' approach to teaching. The survey was repeated at the end of the PD workshop to determine whether a shift had taken place following the PD session. Before the PD workshop, the ten tutors were provided with a preworkshop survey (Appendix 1) with seven, seven-point ordinal scale items to assess the tutors' initial theoretical perspective on teaching statistics and whether their extant teaching approach was traditional (transmission teaching) or contemporary (student-centred, cooperative learning) (Marshman, Clark, & Carey, 2015).

Following the PD activities, the ten tutors were asked to complete a postworkshop survey (Appendix 1). The postworkshop survey included the same seven questions from the preworkshop survey, plus two additional questions asking whether the tutors would use each of the two cooperative learning techniques.

The pre- and post-PD survey data were analysed using only descriptive and graphical methods, given the small sample size. The data from items 3, 5 and 6 on the survey were reverse coded, so that larger numbers represent the use of constructivist learning, as opposed to transmission teaching techniques, for all items.

3.4. DISCUSSION FORUM: WEEKLY THOUGHTS ON IMPLEMENTATION

We adopted a Narrative Inquiry approach to investigate the nine tutors' thoughts on the implementation of the techniques. Narrative Inquiry is a way of inquiring into and understanding experience through "collaboration between researcher and participants, over time, in a place or series of places, and in social interaction with milieus" (Clandinin & Connelly, 2000, p. 20). The tutors were asked to integrate the techniques into their teaching, and to discuss and share their thoughts on implementing the techniques: to think about how they teach, and to document barriers to implementing the techniques discussed. As a framework, tutors were asked to respond weekly to six statements on an online tutor-only discussion forum following their tutorials for the week:

1. Overall comment;
2. What went well;
3. What did not go well (with suggestions for improvement);
4. Any specific area where students were confused;
5. Comment on how you might deliver the session differently next time, pedagogically (including your teaching role and classroom management).

These comments were later collated and analysed by looking for themes in a content analysis. Content Analysis is a research method for studying communication artifacts, such as online forum postings, via coding and thematic analysis (Vaismoradi, Turunen, & Bondas, 2013). The analysis may include discussion of the frequency of different categories and themes, but due to the small sample size, we did not include frequency. Two researchers independently performed a cross-case analysis on the participants' forum submissions to identify themes, similarities, and differences across cases of individual responses (Creswell, 2007), and then cross-checked for consistency in theme identification before constructing a descriptive narrative to present and discuss the findings.

3.5. FOCUS GROUP: OVERALL PERSPECTIVE

To obtain an overview of the tutors' whole-semester experience of using the new techniques, a two-hour tutor focus group was held, with five of the nine tutors in attendance, in the intra-semester break (after Teaching Week 5). The focus group was conducted using the frame in Appendix 2. The focus group discussion was recorded and professionally transcribed. The two researchers independently analysed the focus group transcription using a coding and theming method known as "cut and paste" to identify the themes (Stewart & Shamdasani, 1990), and then cross-checked for consistency in theme identification before constructing a descriptive narrative to present and discuss the findings.

4. RESULTS

4.1. PRE- AND POSTSURVEY

The results of the survey showed that the tutors' attitudes before the PD towards teaching cooperatively were generally positive, with only one tutor (P3) showing a more "Traditional" attitude towards teaching (Table 1; Figure 4). This is due partly to the selection process for the tutors: the lecturer used an informal selection process for employing tutors in which tutors employed were open to using a non-passive approach to teaching. For most items, the changes were small; the largest changes were for "Discussing" and "Defining," both of which moved towards a more language-focused collaborative approach (that is, more discussion, and less explicit defining of terms). The fact that the mean for both Defining and Discussing—skills highly utilized in the new techniques—increased substantially (and all other items barely changed) suggests that a shift in attitude has occurred. The IQR for these two items was also large, suggesting that some tutors were perhaps still reluctant adopters.

Table 1. The mean and median responses and the IQR of the responses from the tutors in the pre- and postworkshop surveys, and the changes in the responses (n = 9)

	Mean			Median			IQR
	Pre	Post	Change	Pre	Post	Change	Change
Q1: Thinking	6.2	6.1	-0.1	6.0	6.0	0.0	0.75
Q2: Understanding	5.7	5.9	0.2	6.0	6.0	0.0	0.75
*Q3: Explaining	5.2	5.1	-0.1	5.5	5.0	-0.5	1.00
Q4: Facilitating	6.4	6.2	-0.2	7.0	6.0	-1.0	0.75
*Q5: Discussing	3.4	4.3	0.9	3.0	4.5	1.5	3.00
*Q6: Defining	3.8	4.5	0.7	3.5	4.5	1.0	2.00
Q7: Talking	5.6	4.5	-0.1	5.5	6.0	0.5	0.75

Note: Items with an asterisk have been reverse coded so that positive changes for all items correspond to moves towards a more contemporary teaching style. The original data were measured on a seven-point ordinal scale.

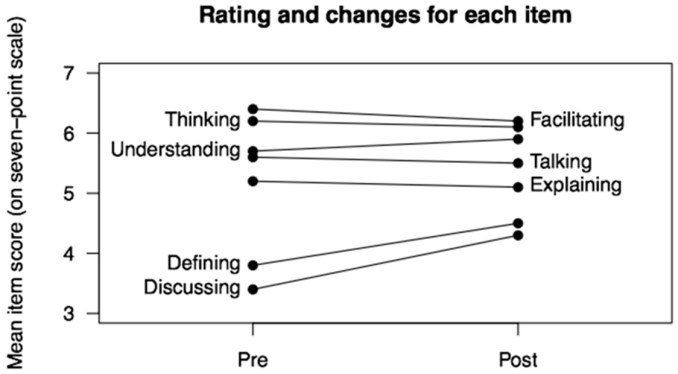

Figure 4. The pre- and postworkshop ratings and changes in rating for each survey item. All items are coded so that larger scores represent more contemporary constructivist learning practices.

4.2. TECHNIQUES SURVEY

After the PD session, tutors were asked how likely they would be to use the two teaching techniques presented at the workshop using a seven-point scale. The results (Figure 5) show that both techniques were rated highly in general, and that each tutor rated each method somewhat similarly, apart from one tutor who rated TPS highly (rating: 7) but the Jigsaw technique much lower (rating: 4).

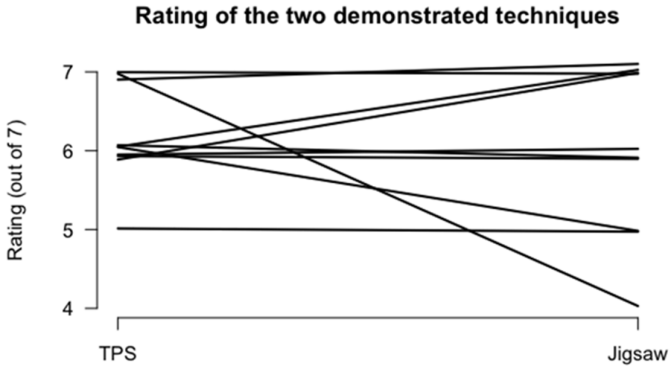

Figure 5. Tutors' opinions of whether they would use the two teaching techniques (Jigsaw (JS) and Think-Pair-Share (TPS)) using an ordinal seven-point scale, where 1 represents "Strongly against using" and 7 represents "Strongly for using" to the statement "I would use [technique]." Each line represents a tutor's responses.

4.3. FOCUS GROUP

The thematic analysis of the focus group transcriptions revealed the following three broad themes: Effectiveness of the techniques, expectations of teacher and student roles in learning, and classroom management.

Theme 1: Effectiveness of the techniques This theme related to tutor comments about the techniques contributing to engagement with learning, demonstrations of understanding, enjoyment of learning, or increased social interaction. The tutors generally embraced the techniques (except for one—P3), finding the student collaboration to have an impact on the students' learning:

P1: I did use the Jigsaw technique and I used it quite a bit […] it was good in that it enabled you to break the task down to several sub-tasks and to get students to take responsibility for doing a good job on some of the subtasks and then reporting to the rest of the group […] and then some general discussion came out of that. I found that and I'm still finding that technique quite useful.

P2: I did Jigsaw but I think I did the RAT one more… and it worked really well... I think the students really did like it because I asked them. I said, "did you like it" and at first they were apprehensive but then I think they said it was very helpful.

However, the techniques were perceived to be less applicable when the tutorial topics began to involve more complex statistical concepts (such as hypothesis testing) and basic computations (such as odds and odds ratios). These topics began in teaching week 5 (the previous materials covered topics such as asking research questions, research design, and producing graphs), when some tutors decided to resort to a more teacher-centred, individual student work approach.

P2: I used these techniques more intensively for the first few weeks and I think it's just this week, being (teaching) week 5, where I might have stopped because we're going into more calculations which it's a bit harder to use the technique. [...] I definitely did it for three or four weeks.

P1: I was the same because I know from past experience this week is where you get the basics and often because of that I reverted to techniques that I'm familiar with and comfortable with. I can't say whether that will continue or not.

P4 provided an indication of why the tutors reverted back to a teacher-centred approach. They believed the students needed more didactic guidance from them for fear of them developing incorrect understandings if left on their own to develop conceptual understanding:

P4: It might say something about me being a control freak but I wouldn't trust the students to actually come up with satisfactory answers for some things, because I know from past experience they get pretty wonky ideas about some of these things and I feel as though I need to have some control over that.

Theme 2: Expectations of teacher and student roles in learning The tutors made a number of statements relating to their own, and their students', expectations of teacher and student roles. The tutors generally believed the younger students were more reluctant to take responsibility for their own learning compared to the more autonomous mature age students.

P5: I had one class which many of them are straight from high school so they're always expecting me to give. They just sit there going "what's next," "tell me what to do."

P4: I definitely find in my classes there's more mature aged students who are willing to discuss what their answers are and explain it to the other group members about how they got there.

One tutor perceived that the passivity of some of their students and reluctance to engage in collaborative activities with their peers was due to their introverted personalities and a preoccupation with their mobile devices interrupting the cooperative learning process.

P5: Some students are really very introverted. They don't wish to engage with other students so when you had a very quiet bunch of people together it's just a nightmare, they don't even talk or they're just playing with their iPhones and they don't even engage, and if you go "how you going?" they go "I don't even know which question I'm doing."

Tutors also reported a student perception that teacher-centred learning was expected by students and that they had to explain to students that they would need to be more active in class if they expected to learn.

P1: They (the students) would have preferred to sit on their bums and have me work. Not all of them but a lot of students believe, "we're paying to be here, you do the work and we'll just absorb it all."

P2: I still occasionally remind the students... that the tutorial is not a place where students come to watch the tutor work; it's a place where the tutor comes to watch the students work and I occasionally have to remind them of that. There are some students who want to pressure me into doing it all on the board. That's not going to work. I'm not the one who needs to learn this, you need to learn it and you only learn it by doing it.

One tutor (who was inexperienced) expressed great difficulty in establishing teacher and student roles that would facilitate student-directed cooperative learning. She believed that this was due to her inability to exercise an authoritative teaching role in the tutorial:

P3: I think I'm just not strict enough with them. I don't have as much confidence getting up in front of everyone. Even when I tell them what they've got to do they always just either revert back to going through it themselves or just chatting.

Theme 3: Classroom management The tutors had to come up with their own method to manage the new cooperative language-focused techniques and some managed it better than others. One tutor developed a strategy of applying time pressure on the students to motivate them to get the work done before they had to move on to another group with the risk of losing face if they had not completed the work in the time allocated.

P2: I'd say to the students "you're doing this part and you're doing this part" and then you'd share answers in 15 or 20 minutes. The first times I did it, ... I noticed that they would just go back to "let's all do every question," even though I had instructed them "you guys do the first one" or "you're odds and evens" ... So, I'd let them do that for a while and then ... we'd try it again and this time if they didn't do it I put a time pressure. … "In 10 minutes I'm going to take two people from this group and put them over in that group" and so there was this time pressure ... because we had this agreement that they were in these groups so then they had to go somewhere else and that's when it really became effective. So, in moving people away from that table and putting them into another table and it requires a bit of management but that was great.

It also seemed as though clear directives were not being provided to students about the activities by some tutors, some of the time, and the tutors expressed surprise that the students were not following the instructions they provided.

P4: I also found that when I tried to use the (RAT) technique, … that I would split the questions up and get different group members to work on that and then to share their answers but they just went back to working one on one with themselves and so I would walk around and say, "how are you going" with this particular question and they'd say, "well we've done question one." Everyone had done question one but no one else, they weren't sharing.

The same tutor explained that it was a problem for him to organise the classroom furniture in the facilities provided by the university, which made it difficult to set up for the Jigsaw activity.

P4: One of the things I would say about some of my attempts at the Jigsaw was the moving of students in some rooms is really difficult. I spend a lot of time setting a classroom up before it starts and/or just moving people around and physically it's a bit difficult and depending on which rooms. Some rooms it's really easy, some rooms you walk in there and there's tables everywhere and you can't even get two tables together to put a group together. So, some days I wish the tables were bolted to the floor.

One tutor expressed a difficulty with managing his time to stage the rotations of the groups, which resulted in him becoming flustered and giving unclear directives to students.

P2: You pick your minutes and if it's close to a break you sort of swap them but you know it's going to be a break so you say, "swap over but don't take all your stuff because you'll be going back there in a minute" and then maybe if there's opposite chairs you just go "you two swap with you two."

Many tutors reported that the techniques were getting tiresome. It did not occur to them to stagger the techniques with other styles of teaching to add variety, perhaps because this was not presented as an option in their PD.

P2: It just gets a bit tiring, if you're doing it every week. I actually felt the students were getting a little bit annoyed of having to move around: "oh come on." They'd do it but I kind of felt like it was under duress.

Some tutors seemed unaccustomed to a classroom environment filled with student conversation and did not have the microskills at their disposal to attract the students' attention when they wanted to address their students.

P2: I find sometimes that... you start talking and you talk really loud and everyone's talking over the top of you and then you just stop and you wait until they stop and eventually they're all like "shut up." It worked, silence, don't try and talk over the top of them because you're just adding to the chaos.

4.4. ONLINE DISCUSSION FORUM

The online discussion forum was a weekly review of the previous week's classes, and so provided insight into the week-to-week experiences of the tutors. The three themes that emerged from the focus group session informed the design of a discussion forum created on Blackboard through which the tutors interacted on their teaching practice during the following semester. In what follows, the discussion forum comments are discussed within these same three broad themes.

Theme 1: Effectiveness of techniques These techniques were new to all of the tutors. At the beginning of semester many comments in the discussion forum showed that the tutors were using the techniques and they mentioned the successes of the collaborative learning techniques, and no negative comments were noted. Example comments include:

P8 (Week 1): What a fun interactive workshop this was… so much more talkative.

P9 (Week 2): All was good, lots of interesting discussions… no one has been shy about giving answers...

However, some tutors found the techniques harder to use later in the semester, opting to teach the content through transmission and computation instead of cooperation:

P8 (Week 8): I want to deliver it like a maths class... it's all I know.

P2 (Week 7): Still trying to incorporate more teach-and-tell stuff (RAT) but it is really hard when they all need to be able to do the steps for a calculation.

At the start of semester some tutors were reflecting on how to adapt the techniques to their teaching context; later in the semester their reflections showed that they had been somewhat successful and they, and their students, had embraced the new techniques:

P7 (Week 2): Mixing the students is good but I'd like to think about how to get students to articulate the answers in smaller groups rather than a class discussion while still being able to monitor their discussions.

P7 (Week 7): I think I'd teach this way again—reinforcing the group approach worked really well and most of the students embraced it—we had nice noisy productive tutes.

Theme 2: Expectation of teacher and student roles Some tutors found adapting to their new teaching roles and introducing students to their roles worked well:

P7 (Week 3): Handing over control to students by picking several volunteers… helped identify leaders in the class… they worked really well together.

P1 (Week 8): I tried… pushing students to explain to each other in their own words what a "standard error" is. I think that worked well—much better than having them listen to what I have to say about it.

The above P1 statement mirrors the finding in Table 1 of increased time on student discussion and less time spent on tutors defining statistical terms.

An emerging issue was that the tutors sometimes struggled with the cooperative- learning facilitator role and encouraging students in their peer-teaching role. Some examples are

P7 (Week 7): One student did not see the value in teaching others, and resented having to work with others who were slower than her, but I think I dealt with this OK by trying to explain the benefits that she would gain from the activity.

P5 (Week 3): I might let students lead the class a little bit more.

P4 (Week 5): In two of my tutorials the students were quite engaged, but in the last tutorial I really struggled to engage them and get them to participate.

Theme 3: Classroom management Some tutors commented on their classroom management; some comments were positive:

P7 (Week 7): I split the tutorials into four groups and encouraged everyone to work together on everything rather than working at their own pace. That meant people who

already had a good grasp of the material spent time explaining concepts to others in the group while I supervised discussions.

However, some comments consisted of tutors querying how to adopt these techniques successfully:

P4 (Week 2): I am not really sure how to go about mixing groups up in one of my classes because I have a student who has told me she has really bad social anxiety. She refused to work in a group... I had plans to mix the groups up halfway through discussions, but discussions were going so well that I didn't want to interrupt them… (but) I will definitely try it next time.

P8 (Week 9): This class wasn't as interactive as it could have been. Next time I might try to get some small group work happening.

Towards the end of the semester, tutors struggled to keep their students engaged as students were becoming noticeably overwhelmed with their study load which impacted on their engagement:

P8 (Week 8): My students are tired and overworked… I've been racing through a bit more content than I'd normally like.

P7 (Week 8): Classes were a bit quiet—didn't manage to get as much discussion in this class—many students were a bit distracted getting feedback on assessment.

5. DISCUSSION

This discussion frames the issues raised under the three main themes identified in the Results (effectiveness, teacher and student roles, classroom management). However, only some of these can be addressed within the scope of this paper, others have been raised but cannot be dealt with in detail.

To begin, all but one of the tutors believed that the new techniques were effective, and embraced and used the new teaching techniques, which were new to all of the tutors. The results from this study showed that existing teaching resources can be adapted to use the new techniques (such as the Jigsaw), and that the benefits in the classroom were clear to tutors. However, tutors were reluctant to adopt the techniques when the tutorial topics began to involve more complex statistical concepts (such as hypothesis testing) and basic computations (such as odds and odds ratios). Part of the reason was that the tutors "wouldn't trust the students to actually come up with satisfactory answers" (P1). That is, the perceived effectiveness was dependent upon the content, at least partially.

A barrier to using the techniques was that the tutors' effectiveness was sometimes compromised by a lack of understanding of what learning content is best suited to the techniques. For example, some tutors believed that it was always good to use the new cooperative techniques, and always bad to use traditional techniques such as individual learning, and did not realize that mixing different techniques was sometimes appropriate. As a result, doing the same type of activity for many weeks may have become a type of drudgery, so it is also important to vary the types of tasks and include some individual and pair work tasks amongst the more collaborative group work. In general, the cooperative learning techniques were more useful for social cohesion and systematizing discussion of language and concepts at the start of semester. Later in the semester, the techniques became less necessary as groups had established themselves, and the students knew who they were comfortable with and worked well with.

The finding that establishing teacher and student roles is important for ensuring the effectiveness of the techniques led us to the decision that future PD needs to include explicit instruction on teacher and student roles in the language-focused cooperative learning classroom. For example, the model of the enabling teacher style could be used to assist tutors to understand the importance of establishing more active roles for themselves and their students when using cooperative learning. This model defines three broad teaching roles (Scrivener, 2005): *The explainer*, who focuses on the subject matter; *the involver*, who focuses on the subject matter plus methodology; and *the enabler*, who focuses on the subject matter, methodology, and social interaction. The more adaptable, experienced teacher is described as

an *enabler*. The enabler has a variety of roles that they assume flexibly at different times: planner, informer, manager, monitor, involver, pastoral carer, diagnostician, or resource.

Another barrier was that the tutors' effectiveness was sometimes compromised by a lack of classroom management skills, particularly around the forming of groups and the transition to form new groups; specific issues included

1) Small class sizes, especially in the last few teaching weeks, made the use of the new techniques difficult for some tutors. For example, in the discussion forum some tutors reported class sizes of two, five, and six in later weeks. (As stated previously, class attendance was not compulsory.)
2) Anxious or reluctant students who did not want to participate in groups.
3) Allocation of students to groups, particularly in the transition to form new groups.
4) Fatigue of students, when students became comfortable in their own groups which they perceived as working well (apparent from Teaching Week 4) and resented having to move.
5) The time consumed in the classroom through the need to allocate students to groups and transition between groups.
6) The physical environment often made group work and transitions hard to manage: the classrooms were often crowded (with classroom furniture and bags, as well as students) and the classroom acoustics amplified background noise that competed with student discussions.

These issues were not always independent.

Some of these issues are easier to address than others. For example, tutors need to provide clear, brief directives for transitions so that students do not get confused. An example of a poor directive would be

> Jack… and what was your name? Phoebe… can you come over here and join this group, but Sue, I'll need you to go over and join the group over there with James. Don't take your bags with you; just leave your stuff…

In contrast, the PD session modelled an efficient technique for re-arranging groups that involved giving each student in each group a number (1, 2, 3; 1, 2, 3; 1, 2, 3; …) then asking all the 1s to move to one table, and all the 2s to another table. In addition, some tutors reported that it was difficult to have to come into a room and change the seating from (say) a horseshoe configuration, or rows of seats to groups of four tables and chairs. It did not occur to tutors that they could ask the students to do it.

One combined result of these barriers is that the new techniques were used less frequently as the semester progressed, partly in response to the part of the content requiring computation with finite answers and involving complex statistical concepts, partly due to the fatigue and reluctance of the students, partly due to the classroom management issues, and partly due to falling numbers of students in class. Note that the decline in tutorial attendance is a known university-wide phenomenon, and has been experienced in previous offerings of this course and in other courses.

The focus group and the online discussion were not designed to elicit tutor observations of student improvement in language and concept understanding as a result of using the techniques. Evaluation of student improvement and student attitudes towards the language-focused cooperative learning techniques was not the focus of this initial study, but will be a focus of future studies once we have observed improvements in the tutors' proficiency and confidence in managing language-focused cooperative learning. Future research will also explore the tutors' social, emotional, and cognitive behaviours through the online teaching discussion forum in which they share their reflections on working with students in cooperative learning activities.

As identified in previous cooperative learning literature in the statistics learning context (Roseth et al., 2008) statistics tutors tend not to have experience in facilitating cooperative learning, so some tutors had difficulty establishing their teaching role and explaining to students what their role was in the language-focused cooperative learning classroom. In future PD, we will provide a more explicit focus on assisting tutors to develop their cooperative learning and teaching method, in particular managing the physical classroom space, phrasing directives to students, monitoring the students' conversations, interacting with students, providing feedback, and introducing and rounding up activities. To do this, mentors will be paired with tutors in the classroom to assist in developing the tutors' classroom management microskills.

The tutors identified some specific situations where they struggled, so future PD will address strategies to deal with the following:

1) *How to conduct language-focused cooperative learning with small class numbers.* It is possible to conduct such activities with as few as four students, but any fewer than this number and the social dynamic is not conducive to stimulate conversations around language.
2) *How to assist students with learning disabilities, including social anxiety, to engage in group work.* Although some students may have learning disabilities, much of the time the reluctance to participate in group work may be what Roseth et al. (2008) refer to as the social norm of "academic disinterest," which educators can address by encouraging and developing trust and social cohesion. This is a skill that is mastered with experience, but the skill is teachable, and is best introduced on the first day of class when the social tone for future classes is set.
3) *How to identify tutorial content that is amenable to language-focused cooperative learning and content that is better learned by students individually*. The tutors initially thought the cooperative techniques had to be applied all the time. Future professional development will focus on developing skills to determine why, how, and when to vary the activity types between individual and group learning.

6. CONCLUSION

This explorative case study trialled some language-focused cooperative learning teaching techniques with a group of Introductory Statistics tutors with a range of teaching experiences at a regional Australian university. Preparation for the trial consisted of a mentorship-based professional development session facilitated by a Faculty member with extensive English language teaching experience. The professional development provided experiential training in the method and teaching techniques, and modelled classroom management microskills.

In relation to our first research question (How, and to what extent, are the techniques adopted?), the techniques were well-received by all but one of the tutors and when put into practice the techniques generated student discussion that caused the students to engage with the language and concepts of statistics. However, the techniques were not applicable to sections of the course when the workshops involved computation tasks or more complex statistical concepts, for which tutors stated that the students required more teacher-centred learning.

In relation to the second research question (How can the tutors' implementation of the techniques be improved in the future?), the tutors would benefit from further development of their *teaching method*, particularly in establishing their expectations of teacher and student roles in learning, and their classroom management. Plans for addressing these areas for improvement in future studies include enhancing the PD and adding in-class mentoring of tutors.

REFERENCES

Aliaga, M., Cobb, G., Cuff, C., Garfield, J., Gould, R., Lock, R., ... & Witmer, J. (2010). *Guidelines for assessment and instruction in statistics education: College report*. Alexandria, VA: American Statistical Association.
[Online: http://www.amstat.org/education/gaise/GAISECollege.htm]

Arends, R. I. (2012). *Learning to teach*. New York: McGraw-Hill Higher Education.

Australian Bureau of Statistics (ABS). (1995). *How Australians measure up. Technical Report 4359.0.*

Barr, N., Readman, K., & Dunn, P. (2014). Simulation-based clinical assessment: Redesigning a signature assessment into a teaching strategy. *Australasian Journal of Paramedicine*, *11*(6), 1–9. [Online: https://ajp.paramedics.org/index.php/ajp/article/view/133]

Bataineh, M. Z. (2015). Think-pair-share, co-op and traditional learning strategies on undergraduate academic performance. *Journal of Educational and Social Research*, *5*(1), 217.

Bech, B. H., Obel, C., Henriksen, T. B., & Olsen, J. (2007). Effect of reducing caffeine intake on birth weight and length of gestation: Randomised controlled trial. *British Medical Journal*, *334*(7590), 409.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, *18*(1), 32–42.

Chater, N., & Christiansen, M. H. (2010). Language acquisition meets language evolution. *Cognitive Science*, *34*(7), 1131–1157.

Clandinin, D. J., & Connelly, F. M. (2000). *Narrative inquiry: Experience and story in qualitative research*. San Francisco, CA: Jossey-Bass.

Cobb, G. (1992). Teaching Statistics. In L. Steen (Ed.). *Heeding the call for change: Suggestions for curricular action.* Notes, No. 22. Washington, DC: Mathematical Association of America.

Creswell, J. W. (2007). *Qualitative enquiry and research design: Choosing among five approaches*. London: SAGE Publications.

Dat-Tran, V., & Lewis, R. (2012). Effects of cooperative learning on students at An Giang University in Vietnam. *International Education Studies*, *5*(1), 86–99.

Deutsch, M. (1962). Cooperation and trust: Some theoretical notes. In M. Jones (Ed.), *Nebraska symposium on motivation*. Lincoln, NB: University of Nebraska Press.

Dunn, P.K. (2012). Assessing claims made by a pizza chain. *Journal of Statistical Education*, *20*(1), 1–19.
[Online: https://doi.org/10.1080/10691898.2012.11889637]

Dunn, P.K. (2013). Comparing the lifetimes of two brands of batteries. *Journal of Statistical Education*, *21*(1), 1–19.
[Online: https://doi.org/10.1080/10691898.2013.11889666]

Dunn, P. K., Marshman, M., McDougall, R., & Wiegand, A. (2015). Teachers and textbooks: On statistical definitions in senior secondary mathematics, *Journal of Statistics Education*, *23*(3), 1–26.
[Online: http://www.amstat.org/publications/jse/v23n3/dunn.pdf]

Dunn, P. K., Carey. M. D., Farrar, M. B., Richardson, A. M., & McDonald, C. (2016), Introductory statistics textbooks and the GAISE recommendations. *The American Statistician*, *71*(4). 326–335.
[Online: http://dx.doi.org/10.1080/00031305.2016.1251972]

Dunn, P. K., Carey, M. D., Richardson, A. M., & McDonald, C. (2016), Learning the language of statistics: Challenges and teaching approaches, *Statistics Education Research Journal*, *15*(1), 8–27.
[Online: https://iase-web.org/documents/SERJ/SERJ15(1)_Dunn.pdf]

Earl, L.M. (2003). *Assessment as learning: Using classroom assessment to maximise student learning*. Thousand Oaks CA: Corwin Press Inc.

Engeström, Y., Miettinen, R., & Punamäki, R. L. (1999). *Perspectives on activity theory*. Cambridge, UK: Cambridge University Press.

Forster, M., & MacGillivray, H. (2010). Student discovery projects in data analysis. In C. Reading, (Ed.), *Data and context in statistics education: Towards an evidence-based society*. *Proceedings of the Eighth International Conference on Teaching Statistics*, Ljublijana, Slovenia. Voorburg, The Netherlands: International Statistical Institute.

Fredholm, B. B., Bättig, K., Holmén, J., Nehlig, A., & Zvartau. E. E. (1999). Actions of caffeine in the brain with special reference to factors that contribute to its widespread use. *Pharmacological Reviews*, *51*(1), 83–133.

Freeman, S., Eddy, S. L., McDonough, M. K., Smith, N. O., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, June, 2014, 111*(23), 8410–8415.
[Online: http://www.pnas.org/content/111/23/8410.full]

GAISE College Report ASA Revision Committee. (2016). *Guidelines for Assessment and Instruction in Statistics Education College Report 2016.*
[Online: http://www.amstat.org/education/gaise]

Garfield, J. (1993). Teaching statistics using small-group cooperative learning. *Journal of Statistics Education*, *1*(1).
[Online: https://www.tandfonline.com/doi/full/10.1080/10691898.1993.11910455]

Garfield, J. B., & Ben-Zvi, D. (2007). How students learn statistics revisited: A current review of research on teaching and learning statistics. *International Statistical Review, 75*(3), 372–396.

Garfield, J. B. & Ben-Zvi, D. (2008). *Developing students' statistical reasoning: Connecting research and teaching practice*. New York: Springer.

Gömleksi˙z, M. N. (2007). Effectiveness of cooperative learning (jigsaw II) method in teaching English as a foreign language to engineering students (Case of Firat University, Turkey). *European Journal of Engineering Education, 32*(5), 613–625.

Johnson, D. W., & Johnson, R. T. (2005). New developments in social interdependence theory. *Genetic, Social, and General Psychology Monographs*, *131*, 285–358.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (2014). Cooperative learning: Improving university instruction by basing practice on validated theory. *Journal of Excellence in University Teaching*, *25*(4), 1–26.

Justice, N., Zieffler, A., & Garfield, J. (2017). Statistics graduate teaching assistants' beliefs, practices and preparation for teaching introductory statistics. *Statistical Education Research Journal, 16*(1), 294–319.
[Online: https://iase-web.org/documents/SERJ/SERJ16(1)_Justice.pdf]

Kaplan, J. J., & Rogness, N. (2018). Increasing statistical literacy by exploiting lexical ambiguity of technical terms. *Numeracy, 11*(1), 1–14.
[Online: http://scholarcommons.usf.edu/numeracy/vol11/iss1/art3/]

Kolb, D. (1984). *Experiential learning as the science of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

Lesser, L. M., Wall, A. A., Carver, R. H., Pearl, D. K., Martin, N., Kuiper, S., Posner, M. A., Erickson, P., Liao, S.-M., Albert, J., & Weber, J. J. (2013). Using fun in the statistics classroom: An exploratory study of college instructors' hesitations and motivations. *Journal of Statistics Education*, *21*(1), 1–33.
[Online: https://www.tandfonline.com/doi/abs/10.1080/10691898.2013.11889659]

Lortie, D. C. (1975). *Schoolteacher: A sociological study*. Chicago: University of Chicago Press.

Luo, D., Wood, G. R., & Jones, G. (2004). Visualising contingency table data. *The Australian Mathematical Society Gazette, 31*(4), 258–262.

MacGillivray, H. (2009). *The teaching and assessment of statistical thinking within and across disciplines.* ALTC Senior Fellowship Report. Canberra: Australian Learning and Teaching Council.

Macpherson, A. (2015). *Cooperative Learning Group Activities for College Courses.* Surrey, BC Canada: Kwantlen Polytechnic University.

McTighe, J., & Lyman, F. T. (1988). Cueing thinking in the classroom: The promise of theory-embedded tools. *Educational Leadership*, *45*(7), 18–24.

Marshman, M., Clark, D., & Carey, M.D. (2015). The use of mathematical investigations in a Queensland primary school and implications for professional development. *International Journal of Mathematics Teaching and Learning.*
[Online: http://www.cimt.plymouth.ac.uk/journal/marshman.pdf]

Miller, G. A., & Gildea, P. M. (1987). How children learn words. *Scientific American*, *257*(3), 94–99.

Nation, I. S. (2001). *Learning vocabulary in another language*. Cambridge, UK: Cambridge University Press.

Perkins, D. V., & Saris, R. N. (2001). A "jigsaw classroom" technique for undergraduate statistics courses. *Teaching of Psychology, 28,* 111–113.

Remsburg, A. J., Harris, M. A., & Batzli, J. M. (2014). Statistics across the curriculum using an iterative, interactive approach in an inquiry-based lab sequence. *Journal of College Science Teaching*, *44*(2), 72–81.

Richardson, A. M., Dunn, P. K., & Hutchins, R. (2013). Identification and definition of lexically ambiguous words in statistics by tutors and students. *International Journal of Mathematical Education in Science and Technology, 44*(7), 1007–1019.

Richardson, A. M., Dunn, P. K., Carey, M. D., & McDonald, C. (2016). Ten simple rules for learning the language of statistics. In H. MacGillivray, M. Martin, & B. Phillips (Eds.), *Proceedings of the 9th Australian Conference on Teaching Statistics (OZCOTS) December, 2016, Canberra, Australia* (pp. 32–37).
[Online: http://iase-web.org/documents/anzcots/OZCOTS_2016_Proceedings.pdf]

Roseth, C. J., Garfield, J. B., & Ben-Zvi, D. (2008). Collaboration in learning and teaching statistics. *Journal of Statistics Education*, *16*(1), 1–15.
[Online: http://jse.amstat.org/v16n1/roseth.pdf]

Scrivener, J. (2005). *Learning teaching: A guidebook for English language teachers*. London: Macmillan.

Smith, G. (1998). Learning statistics by doing statistics. *Journal of Statistics Education, 6*(3), 1–12.
[Online: https://doi.org/10.1080/10691898.1998.11910623]

Stewart, D. W., & Shamdasani, P. N. (1990). *Focus groups: Theory and practice*. London: Sage.
Thomson, J. (2009). Post-Dartmouth developments in English teaching in Australia. In Gannon, S., Howie, M., & Sawyer, W. (Eds). *Charged with Meaning. Reviewing English in the 21st century* (3rd Edition), (pp. 5–17). Putney, Australia: Phoenix Education.
Utts, J. (2015). *Seeing through statistics* (4th edition). Stamford, CT: Cengage Learning.
Vaismoradi, M., Turunen, H., Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & Health Sciences, 15*(3), 398–405.
Vygotsky, L. (1978). Interaction between learning and development. *Readings on the Development of Children*, *23*(3), 34–41.
Wagner, D. R., Larson, J. N., & H. Wengreen, H. (2010). Weight and body composition change over a six-week holiday period. *Eating and Weight Disorders*, *17*(1), e54–e56.
Young, R., & Messum, P. (2011). *How we learn and how we should be taught: An introduction to the work of Caleb Gattegno*. London: Duo Flumina.

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APPENDIX 1: PRE- AND POSTWORKSHOP BELIEF SURVEY

The preworkshop survey did not include Items 8 and 9. Items 3, 5, and 6 were reverse coded, so that larger numbers on the 7-point ordinal disagreement-agreement scale (where 1 represents "strongly disagree," 4 represents "neither," and 7 represents "strongly agree") represent the use of more effective, contemporary learning techniques for all items. Items in square brackets are the abbreviated terms used in the results. Tutors were asked to state their current attitude regarding the following statements:

1) It is more important to develop students' statistical thinking and literacy than their mathematical competencies. [Thinking]
2) It is more important to develop students' conceptual rather than procedural understanding of statistics. [Understanding]
3) My role as a tutor is primarily to explain the content of lectures. [Explaining]
4) My role as a tutor is to facilitate an activity-based learning approach to learning statistics. [Facilitating]
5) I should spend a lot of time eliciting and discussing students' answers to the set questions in the tutor workbook. [Discussing]
6) I should spend a lot of time on defining statistical terms. [Defining]
7) In my tutes the students should do most of the talking. [Talking]
8) I would use the T-P-S activity.
9) I would use the Jigsaw technique for students to answer questions in the workbook.

APPENDIX 2: TUTOR FOCUS GROUP FRAME

1) During the PD session with you, I demonstrated two activity-based techniques for teaching statistics:
   a. Think-Pair-Share.
   b. Jigsaw technique.
2) (Tutors were reminded of the techniques with examples from the tutorial workbook.)
3) Did any of you use these techniques? (Ask each tutor in turn)
   a. What did you do?
   b. What worked? Why?
   c. What didn't work? Why?
4) Are there any particular behaviours the students demonstrated when participating in the activities?

5) Are there any particular behaviours of your own in the role of tutor during these activities that you want to comment on?
6) Did the students comment on the activities at all? If so, what did they say about them?
7) Which of the following statements would you agree with and why?
    a. I *reject* these techniques and wouldn't use them in future tutorials.
    b. I would *adapt* these techniques in future tutorials.
    c. I would just *adopt* these techniques as they have been presented to me.
8) If you think that the activities need to be further adapted, how would you adapt the activities next time you attempt them?

APPENDIX 3: THINK-PAIR-SHARE ACTIVITY

Consider the following scenario:

> While at cafe one day enjoying a small, organic, almond-milk, half-strength decaffeinated latte, Nim mindlessly observed, "Exams start next week. I suppose we'll all start feeling stressed soon." After a slight pause, Jane said, "I had better buy more teabags then."
> "Why?" asked Nim, not unreasonably.
> "Everyone knows that Earl Grey tea relaxes students. . . " replied Jane, looking upwards then closing her eyes dreamily.
> "How do you know that?" Nim retorted, unintentionally aggressive.
> "It *does*," snapped Jane. "Earl Grey relaxes people."

Nim wants to study Jane's assertion using a formal research study.

1) Nim decides to use 'All university students' as the *population (P)*. Do you agree or disagree? Why? Discuss with your group.
2) Identify an *outcome (O)* that Nim can measure.
3) Nim thinks that the best *comparison (C)* to make is with those who drink coffee. Do you agree or disagree? Why?
4) Construct a precise, well-worded *interventional (I)* research question that Nim can ask to assess Jane's assertion, clearly identifying *P, O, C* and *I*.

APPENDIX 4: JIGSAW ACTIVITY

Coffee is one of the "most consumed beverages in the world" (http://www.statisticbrain.com/coffee-drinking-statistics/, accessed 19 June 2014), and has been studied comprehensively (see, for example, Fredholm et al., 1999). An issue not well understood is the impact of caffeine consumption during pregnancy, so health advice given to pregnant women may sometimes lack an evidence base.

In your small groups, read the 'Abstract' of Bech et al. (2007), then answer the questions that follow, and discuss your findings with another group.

1) Construct a research question that the study appears to be answering, by first identifying *POCI*, where possible.
2) Define the variables measured (including units of measurement if possible), and identify the explanatory and response variables.
3) Identify any terms that need defining.
4) Explain whether the study is observational or experimental (true or quasi).
5) Identify the units of analysis, and the units of observation.
6) Would the presence of twins affect the study? If so, how?
7) From the Abstract, determine the answer to the research question.
8) What did you learn about the effects of caffeine consumption during pregnancy?