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WHAT MAKES A “GOOD” STATISTICS STUDENT AND A “GOOD” STATISTICS TEACHER IN SERVICE COURSES?

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Abstract: Statistics is taught within a diverse array of disciplines and degree programs at university. In recent research we investigated international educators' ideas about teaching and learning 'service' statistics. This paper investigates what these educators think are important attributes, knowledge and skills for learners and teachers of statistics. Results show that educators are in agreement about qualities of 'good' statistics students, such as curiosity and critical thinking. An emerging issue was the role mathematics plays in learning statistics as a service subject with some academics postulating mathematics as the basis of statistical learning, others proposing it has limited or little importance in learning service statistics or even that it presents obstacles, detrimental to students' statistical thinking. The features of statistics teachers that were highlighted in the data were knowledge of statistics and its applications, empathy with students and knowledge about teaching and enthusiasm for it. Respondents had practical suggestions on how to help students become competent learners of statistics. We extend a theoretical framework for synthesizing the findings.

Keywords: teaching statistics at university, service courses, statistics in mathematics

1 Introduction

What are educators' experiences of teaching statistics as a service subject at university? This question was the topic of a recent investigation conducted through email interviews with statistics educators in many countries. In this paper we report findings from this qualitative research project that focus on what the participating educators think are the important attributes, knowledge and skills for students and teachers in their courses and how educators address the challenges of teaching students who lack the motivation or skills to be 'good' learners of

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statistics.

Statistics education has been transformed by the availability and widespread use of technology—especially software and the internet, the changing needs of society and the diversity of the contemporary student cohort. Historically, statistics as a tertiary subject was based on mathematics, and was taught as a topic in mathematics to students training to be professional statisticians. Today, the study of statistics and its applications to data analysis is part of the curriculum for students in many, diverse disciplines and these students have differing knowledge bases, a range of professional interests and goals and variable mathematical skills. There are resulting tensions between teaching statistics as a discipline in its own right, as a branch of mathematics, or as “methodology serving some other field” (Moore, 2005, p. 206). Issues that affect teaching and learning statistics at the tertiary level include training statistics students and teachers to work with other disciplines, encouraging students to solve problems collaboratively—in a team—and to communicate well with others both in writing and verbally (Nicholls, 2001). Statistics students are not homogeneous in ability, educational background or discipline specialisation. Indeed statistics students may be regarded as a microcosm of the diversity found in contemporary universities. Hence, as Latterell (2007) highlights for mathematics educators, statistics teachers need to understand their students, including being aware of how students’ cultures and mathematics backgrounds differ from their own experiences (summarised, perhaps, as less algebra, more EBay). This is similar to the first recommendation of the Mathematical Association of America’s (2004) *Committee on the Undergraduate Program in Mathematics Guide* (which includes Statistics). That is, to understand students and the world in which they live.

Teaching is arguably the most important factor that affects the quality of students’ learning (Kember & Gow, 1994; Ramsden, 2003; Prosser, Ramsden, Trigwell & Martin, 2003). Further, as Watson et al. (2007) observe, it cannot be assumed that content knowledge in a specialised subject is sufficient for effective teaching. As an extension of this idea, Hodgkinson (2005) asks to what extent it makes sense to think of learning as specific to a particular discipline such as mathematics?

Lindblom-Ylänne et al. (2006) show that approaches to teaching are relational—affected by both discipline and teaching context. These researchers found differences in whether approaches were student focused or teacher focused, in the self-efficacy beliefs of teachers in different disciplines and the contextual effects on their teaching. Studying teaching in service statistics provides a singular array of contexts to investigate learning and teaching. Statistics is unusual as a discipline as it is taught in a range of environments and in the context of a host of other disciplines—as disparate as business management, engineering, psychology and biology.

Teaching statistics as a service subject has special challenges: students studying statistics as part of their degree program do not necessarily have an interest in the subject and may not wish to engage with any study perceived as mathematical (Gordon, 2004). Further, studying subjects in statistics or quantitative methods can generate anxiety for some student groups (Onwuegbuzie & Wilson, 2003). There is no one method of teaching or learning that fits all statistics courses. Further, according to Northedge (2003), increasing levels of student diversity in higher education mean that educators cannot persist with transmission models of teaching nor replace these with

unfocused, student-centred approaches that do not offer students genuine opportunities in the realities of the classroom. This observation is particularly relevant to statistics pedagogy, as students will need statistical knowledge for their professional work as well as for their informed citizenship within a knowledge economy. Hence a study of statistics educators' insights about their students and their teaching approaches, including investigating the challenges presented by unmotivated or 'stats-phobic' students and ways of tackling these challenges, has the potential to stimulate reflection and debate in this important area of pedagogy.

2 Method

The investigation consisted of a three-phase series of e-mail interviews with statistics educators. Participation was invited through an electronic request to the membership list of the IASE (International Association for Statistics Education) and Faculty bulletin boards of Australian universities. Thirty-six IASE participants took part in the first email interview, with 32 completing the full series of three interviews, an indication of the engagement of respondents with the project. The remaining four carried out partial interviews before our cut-off date for data collection. The IASE statistics educators were from many countries: Argentina, Australia, Belgium, Brazil, Israel, Italy, Netherlands, New Zealand, Slovenia, Spain, Uganda and the USA. Most interviews were conducted in English (one was bilingual with English questions and Spanish responses). An additional nine interviews (seven completed, two partial) were conducted with Australian educators who responded to requests through departmental bulletin boards. The resulting interview transcripts of over 70 000 words formed the raw material of our study.

The interview protocol consisted of an initial series of six questions, reflecting our research focus on educators' ideas about teaching and learning statistics as a service subject. After studying the initial reply, we sent a second interview with questions following up and probing each participant's responses. Finally, a third interview was sent with further questions to elicit clarification and in-depth explanations of the responses given as well as a request to evaluate the e-mail interview method.

The initial questions included one on the specifics of the educators' backgrounds: *What country do you work in? What type of institution do you teach in? What level of students do you teach statistics? What discipline areas do you teach statistics in?* Responses to this question showed that participants taught service statistics at universities in a range of contexts. The respondents taught at the full range of levels, from pre-degree and first year to postgraduate, using various teaching methods including traditional, large-group lecturing, tutorials and small research groups, problem-based learning and distance education; in some universities, statistics teachers pooled their strategies and resources to work as a team. Many participants reported teaching service statistics to student groups in several disciplines, within programs ranging from the traditional areas of physical, health and social sciences, business, economics and management, engineering, psychology and education, through to less common areas such as theology and liberal arts.

All other questions were posed in a deliberately open way to enable the participants to explore their own ideas rather than we, the researchers, eliciting responses in a specified direction. Two of these questions, below, are the focus of this paper.

What do you think makes a good statistics student?

What are the attributes of a good statistics teacher at university?

The follow-up questions explored the thread of thought that was prompted by the original question and so depended on the individual response, for example: *Are there qualities specific to a good student in statistics? What do you feel you can do with a student or a group of students who don't display these qualities? Can you explain how mathematical ability can help students but can also blinker them? How do you go about teaching students to communicate statistics?* The follow up questions also generated discussion on how to encourage those students who were not 'good' to achieve the desired qualities.

The interview process was a written version of the usual face-to-face interview, with the modification that at each point in the process the respondent had a record of all previous communication including their own responses, and both interviewers and respondents could continue the dialogue in their own time. This iterative e-mail interview provided the participants with an opportunity to reflect on and expand their initial responses to questions. We found that the responses were well considered, and, at times, participants clarified and refined previous statements.

We have critically reviewed this method of e-interviewing (*Authors*, in press). This review includes data from the participants evaluating the methodology, thus positioning respondents as co-researchers. We have also previously written about other aspects of participants' experiences from the data: including educators' views of the importance of communication skills for their statistics students, educators' conceptions of teaching service statistics (*Authors*, 2005, 2007a), recognising and developing professional expertise in statistics pedagogy (*Authors*, 2006) and the range of tools, teaching strategies and approaches utilised by the respondents (*Authors*, 2007b).

In this paper we focus on participants' responses to the two initial questions concerning 'good' statistics students and teachers, and the follow-up discussion in the interviews. Pseudonyms were chosen by the participants themselves and included unusual choices such as 'Henry VIII' and 'QMmale' or the names of famous statisticians. Excerpts from interviews in this paper are reported under these self-chosen pseudonyms.

3 Results: What makes a good statistics student?

Many participants interpreted the notion of a 'good' student in terms of personal qualities. The attributes of good students commonly mentioned included critical thinking, curiosity or an active mind, a preparedness to work hard and try to understand and a willingness to overcome maths phobia. There were also more individualistic ideas such as a sense of humour, willingness to take responsibility or to play with abstraction.

Table 1 summarises the qualities that respondents reported were important with illustrative extracts from the interview transcripts.

Table 1: Qualities of Good Statistics Students

Quality	Illustrative excerpt
Critical thinking	Samuel: <i>A student who asks why, what is the connection to the context, have I met a problem like this before //A student who is systematic, who begins in an orderly way, asks the right questions and applies the appropriate techniques. A person who is self critical, always questioning themselves and checking their conclusions.</i>
Curiosity	Henry VIII: <i>The good student is the one who is curious to see what statistics has to offer, and how it relates to their careers (whatever their backgrounds, and their knowledge of maths). The bad student (by far, the majority) is the one who wonders how he can pass the examinations with the least effort and the least pain.</i>
Motivation	QMmale: <i>So there are two, opposite directed, mechanisms in play: level of prior education, and motivation. In the long run, the last one is dominating; in the short, the first one.</i>
Numeracy/literacy skills	John: <i>Just as enthusiasm alone will not do it for the teacher, motivation alone will not be the making of a good student. A good statistics student needs to have reasonable levels of numeracy literacy/skills, comprehension, interpretation and writing skills.</i>
Maturity	Maria: <i>The application of statistical techniques and interpretation of results require more maturity than the one we encounter in students in the first years at the university. Thus, I think that statistics should not be taught in the first years of a degree.</i>
Interest and diligence	Alice: <i>Students who attempt questions themselves as well as attending lectures and tutorials, students who read the learning guide, students who practice using exercises and students who continually ask why are we doing this!</i> Leigh: <i>One who wants to know! One who takes responsibility for his/her own learning.</i>
Same as a good student anywhere	Rose: <i>Same as a good student anywhere I guess //good sense of humour, open, sense of wonder about the world, appreciation of the beauty, of the inter-connectedness of things in general (and ideas specifically), grounded in the world but also willing to 'play' in the world of abstractions.</i>

The ability to see statistics as a tool that could be applied to their home discipline—to see the connections—was considered important by many educators. Natalie proposed that a good student: *is able to think about situations rather than just doing calculations and analyses*. At a more advanced level of study Sjeſke considered that: *a good statistics student knows how to formulate research questions. He/she knows how to get from constructs to variables and can take*

the measuring level of the variable in mind and the conditions when deciding which statistical technique to use to process the data.

Communication skills—the ability to write coherently as well as verbal skills—were addressed by surprisingly few (less than one third) of the respondents. Those that did write about this stressed various aspects including the importance of a good command of language, the ability to communicate statistical terms in plain, everyday language, to use language to teach their fellow students and to write reports (discussed further in *Authors*, 2005).

As with communication skills, we did not specifically ask respondents about the importance of mathematics for statistics students. However, many of the educators expressed views on how mathematics affected students' learning. We outline these in the next section.

4 Results: The role of mathematics in learning statistics

Responses showed mathematics in statistics to be a controversial topic with some educators of the opinion that mathematics is the basis of statistical knowledge, others that mathematical knowledge was not necessary for a 'good' statistics student in service subjects, or even detrimental to statistical thinking. Many educators were concerned about math-phobia and its effect on students' attitudes to learning statistics.

For those endorsing the role of mathematics in learning statistics, the abstraction, rigour and power of mathematics to solve problems were seen as fundamental to gaining skills in statistics. Daria maintained that: *Every "scientist" should have a minimum knowledge of calculus. The mathematical background helps in developing the ability to solve problems and in the process of generalization. [Do students without a maths background have a different approach to problem solving, or are they just less successful at it?] My impression is that they are less successful at it.*

Margaret qualified the idea of mathematics as fundamental to statistics, differentiating between students studying statistics as a major subject and statistics as a service subject. *(A good statistics student needs) a strong mathematical background and a methodical way of thinking. I am answering this in terms of a student who will go on to be a statistician. //For students in other disciplines who must take one or more statistics courses for their degree program, a good student is one who understands the theory in their own field of study enough so that they can ask appropriate questions and apply the statistical techniques in meaningful ways.*

Maria agreed, saying that for some introductory subjects the emphasis on mathematics was different. *Students' previous knowledge is one of the most important factors to influence learning. Therefore I consider that a 'good statistics student' should have a mathematical background and computer skills. [Is there a minimum amount or level of mathematics that students need in order to be "good" students?] It depends on the statistics course. In the course I teach ... students that have a stronger background in calculus and linear algebra have less difficulties in following the introduction of statistical techniques and their application. They also have less difficulties in abstract reasoning and computing. But if the statistics course is introductory with an emphasis on exploratory analysis applications, a student with a weak mathematics background (basic mathematical concepts and computation) may be a 'good' statistics student.*

Sjefke was more direct in stating an opposite view that: *in our competence based approach mathematics will play no role in teaching statistics to our (psychology) students. //Now we rather concentrate on interpretation and content than on mathematics.*

Cara spoke for many in reporting that: *statistics is much hated and feared by students. //I'd say there are two major reasons: hatred of maths dating back to the primary and secondary school + the way statistics is taught at most European universities: 'ex katedra' lectures in huge groups (sometimes as many as 300 students), lack of personal contact with the lecturer; it's fairly easy to lose track of what is going on up front + study materials are usually rather dull + the propaganda of senior classes (if you pass stats you've practically made it into the next year of studies).* Natalie observed that people who have a fear of mathematics would bring this fear into their learning of statistics: *Most people don't see statistics as any different from mathematics.* And Kay added: *A sizable minority of the students I meet have had someone in their background-either in K-12 (school) or as an undergraduate, who told them they were poor in math. Students are fearful mostly of what they see as the mathematics involved in statistics.*

Vivian felt that a lack of interest in mathematics was compounded by anxiety. *My experience is that most psychology students choose psychology because they want to help people who have psychological problems and not because they want to find answers for research questions. They want to work with people, and not sit in a room and do sums. //Because they already had low grades (at school) they don't see statistics as something they are good at and therefore they are anxious.*

However, Horace explained that one should take care with the assumption that many students have negative attitudes to mathematics in statistics. *An important issue I need to watch out for is that some students, maybe doing maths or even maths stats concurrently, do want to talk about formulas and assumptions and formalisms. So I need to be careful not to put down them or their formal approach, indeed to encourage them to see how that body of theory is essential for the software and all I'm doing, and that they therefore have a privileged insight, even though my main aim is to present in ways accessible to as wide a range of students as possible.*

Some educators put forward the idea that the philosophy underpinning statistical thinking is quite different to the thinking for mathematics. Leigh reported that: *It is a mistake to call the subject mathematics, at least the way we teach at this level. //In this class we are addressing questions about the real world through collecting and looking at data.* Ford Prefect felt that mathematical ability could even 'blinker' the students as: *Students will be looking for (right answers). //When students are taught maths at school and at university, there is a lot of the old theoretical QED type stuff. Students are graded for the correct answer and method. //In stats there is no guarantee that they get the right answer even if they do the right calculations and use the best method. That is a super tough concept to overcome. Part of the problem with teaching statistics in a traditional form is we sometimes don't get that concept across.*

Horace insisted that appropriate assessment was essential to avoid such deterministic thinking: *Don't just give marks for correct calculations otherwise we are encouraging them to think in exactly this way. Instead, always hold marks aside for interpretations and understanding of*

alternative approaches and the extent to which we might be wrong. //You will never overcome it for all students. Let's face it, stats is hard.

Andrew expanded on the differences in mathematical and statistical thinking explaining that each had its own beauty. *Some students just love the logical way in which mathematics develops and also enjoy the great generality which it develops. I suspect at the beginning calculus is quite exciting and also the problems that can be solved. But in reality these are quite simple problems that do not reflect real life without a lot more work. //Statistics on the other hand is a bit "dirty" at the beginning in comparison when it deals with numbers, graphs, variability etc.*

I feel the real beauty of statistics does not come from the beauty of mathematics. It comes from the fact that you are actually able to solve problems and answer questions for researchers. And you can see clearly the fruits of your work.

Given the diversity of the student cohort studying service statistics and the range of teaching contexts of our respondents, we would expect considerable variation in perceptions of good teaching. We next report participants' views on the knowledge, skills and qualities considered essential for teaching service statistics.

5 Results: What makes a good teacher of service statistics?

The most commonly mentioned requirement for 'good' teachers was solid knowledge of statistical theory and practice. Anette wrote: *I am absolutely sure that good statistics teacher should have at least some practical experience – I mean she has to be involved in real research projects as a data analysis expert.* Maria believed that: *Her/his background should be related to the statistics subjects she/he teaches. She/he should be involved in research about this subject.* And Samuel put it this way: *Sound background, the teacher needs to see the material being taught in the context of the wider picture of statistical theory and practice.* Ford Prefect gave more justification of this view: *Statistics has its own issues in that it is a subject that is taught in a variety of contexts and disciplines, each of which has its own complexity. This forms part of our problem, because approaches we take in business are different to psychology and are different to mathematics. We need to have a good understanding of our own discipline area. This is one of the dangers (I believe) of trying to centralise statistics teaching in maths / science departments at some universities.*

Some respondents noted that knowledge of applications was needed to "motivate students" and that teachers needed the ability "to show the basic statistics ideas and concepts without resorting to complicated maths". Natalie explained. *They need to realise that statistics is a really practical and useful interdisciplinary subject that will most likely be invaluable for them in the future. By broadening their concept of statistics from "doing exercises in the book" to seeing a wide range of applied statistics examples, they will hopefully be more motivated and inspired to learn statistics and not be plagued by the question: "why are we doing this?"*

Sjefke stated that: *Statistics is a way of describing psychology in another language; it is not performing calculations at all!* He went on to issue a warning: *against another 'possible failure' or pitfall: mathematics teachers constitute the overwhelming majority of teachers in the field of statistics education. But I fear that most mathematics teachers are not interested in the*

(psychological) content, that they can't really bridge the gap between theory and empirical reality, because empirical data are not ideal data for teaching sums and models.

Henry VIII summed up these ideas: *I think the good teacher is the one who is able to show the students that statistics is the science that provides the researchers with tools for dealing with the uncertainties of the real world, and not just a set of boring formulas and procedures that the students have to fit somehow in their research papers in order to have them accepted*

The next theme was the importance of a range of personal attributes. We summarise these in Table 2.

Table 2: Qualities of good statistics teachers

Quality	Illustrative excerpt
Curiosity	RON FISHER: <i>Curiosity about the world around them. //Some teachers view their field (whatever it may be) as “finished” in a real sense, and their role as just reporting on what was done. //I am constantly updating my examples, and looking for new applications that will interest my students. Not only do I do this for the students’ sake, it also makes the class much more interesting for me, since I am interested in the world around me.</i>
Enthusiasm	John: <i>Enthusiasm, enthusiasm, enthusiasm!!!</i> Janet Cole: <i>I looked at experts in the field of statistics education and identified a kind of ‘magic’ that each of them had in the classroom. I am not sure how to qualify this ‘magic’ in any other word. Passion and enthusiasm are a must. A good statistics teacher is not someone who is teaching only so that s/he can do research or just as a job – a good statistics teacher wants her/his students to learn and be excited about learning.</i>
Empathy with students	Cesar talked of: <i>Capacidad para comprender los códigos culturales de los jóvenes que ingresan a la universidad. Es decir, la habilidad de relacionarse positivamente con los estudiantes. [Capacity to understand the cultural codes of the young people who enter university. That is, the ability to relate well to students.]</i>
Confidence	Leigh: <i>Very confident about the subject matter. Use real data and make it interesting and relevant.</i>
Willingness to learn	Rose: <i>Willingness to learn (imperative!!!), ability to listen, excellent communication skills, capacity to respond with rather than react to, flexibility, sense of humour, healthy sense of self.</i>
Patience	Lizzie: <i>Patience!!!! //These are very nervous students who need a lot of encouragement and I need to be patient enough to say the same thing in as many different ways as I can think of until the student indicates their understanding.</i>
“All the usual things”	Leigh: <i>All the usual things: patience, availability, etc etc.</i>

There was consensus among the respondents that verbal and written communication skills were essential for teachers in service statistics courses: “such that the lecturer can communicate new concepts at an appropriate level”. Joanna amplified this. *Often lecturers can lose sight of the fact that they are teaching students who are new to statistical concepts and they unnecessarily complicate their presentations thereby alienating the students.* Anette described this skill as being a “vivid story-teller”. *I think that to keep students interested and motivated to learn and to give them the knowledge and skills they can apply, the teacher has to tell the “stories” (imaginary or real) about what has happened or could happen in real research projects //(including) what can go wrong and how to learn from the errors the other people have made.* Alice explained the necessity of being able to promote discussion. *Discussion is helpful in that students can see how others understand something (or don’t—which can be helpful in not feeling alone if they are confused!). It also helps clarify misconceptions.*

Heintje summarized her student-centred approach: *A good statistics teacher will stimulate students to take their own initiative, to become confident about themselves in doing statistics, exploring data, discussing subjects with other students or teachers. A good statistics teacher will help students to overcome their statistics anxiety and will take care for the process that they get familiar with the discipline step-by-step, embedded in a psychological context. A good teacher will also be a good listener and will seriously consider student evaluations as a means to improve the educational design.*

The above reports show that many of our respondents were passionate about their subject and desired to imbue students with curiosity about statistics and interest in its applications. However, as is well documented, not all students are motivated to study service statistics. Hence our interview conversations, in many cases, led to discussions about ways of engaging students with their study of statistics.

6 Results: Can you teach a student to be a good statistics student?

Some educators felt there was “not a lot” they could do with students who were unmotivated to study statistics. However, others were more positive and proactive in their approach.

Andrew felt the key was to access examples from recent consultation projects and not just to use textbook case studies. *I would like to think I can help turn them into a good student. //I believe it helps by being able to reference recent consulting examples by discussing them with the students and also getting them to work on project data, possibly in small groups.*

Kay stated that her first job, if there were stats-phobics in her class, was to reduce anxiety: *I address it directly by talking about anxiety; telling the class that people have actually survived the course before; that stats started with law and business and NOT mathematics; that stats has an underserved bad rep; by using humour or what passes for it with me.* She offered a practical approach to helping students who were struggling: *They get paired up with a group of other students, so they have peers to talk to about statistics who can help them. These students also get direction to plan on spending more time on the course than their friends might—and to spend some time each week with the instructor or the graduate teaching assistant. These students get extra worksheets with examples, they get extra help.*

Heintje acknowledged that a student who was *perhaps less talented and less motivated might be an excellent student in other domains. //It might be the case that such a student knows a lot of psychological treatments or practices, is a good writer or has excellent social or communicative skills. All these (different) skills and talents might be of great importance for the group assignment or group task. The accents of this student's contribution will be different, he or she will play a different role in the discourse, but his or her social, creative or writing contribution has its own value in the social construction of knowledge.* Like Kay, Heintje observed that often these students needed more active support and encouragement in statistics and methods. *In most cases the group itself takes this student by the hand in order to survive the struggle with statistics and methods.* Heintje pointed out that: *no academic institute is able to provide one recipe for one approach, to involve those students. But, supported by their peers, these students often are able to complete the program with a satisfying result.*

Respect for students' diverse abilities was also the basis for Janet Cole's approach to helping students learn statistics. *Any student has the potential to be a good statistics student—it is our job to motivate a desire to learn and to provide an environment that is conducive to learning and that is an environment where safety and respect for all are cherished. //Since I believe in students constructing their own knowledge, I tailor my questions and explanations to their needs. For those students who have not tried or have given up, I give them some direction, send them away with an assignment, and ask them to return to talk again.*

A key factor in helping students become motivated learners of statistics was to help them see the relevance of the discipline to their future professional work. Henry VIII explained his approach for medical students. *What I try to show medical students is that, even if they don't ever intend to do any research, they still need some basic knowledge of stats in order to be able to fully understand the concepts of "statistical patterns" and "typical values", and the probabilistic nature of the decisions they have to make every moment during their practice. I try to do this by highlighting, through examples, the probabilistic nature of the patterns and decisions, and by trying to steer them away from the sort of deterministic thinking they are exposed to during most of the other courses they attend at college.*

Moore (2005) describes views of statistics that emphasise different dimensions of the discipline—as mathematics, data analysis or a tool in the service of other disciplines. In resonance with this conceptualisation, Margaret reflected that there are three different sets of students: *(1) theoretical, mathematical statisticians, (2) applied statisticians, and (3) students in other fields who take some statistics courses.* Each group needed different skills and so different teaching. In the case of the first group, their needs were for: *a strong mathematical background and a methodical way of thinking. For #2, such students need to be able to learn how to manage not only the statistical techniques, but to appreciate what is and is not doable from practical perspective in the fields where they are applying their stats. They need to learn consulting skills so that they can appropriately interact with experts in other fields and work together to get a satisfactory solution to a given problem. They need to develop good teaching skills, too, because at least some of their interactions with clients will require subtle teaching. And, they need to be able to know how to learn from their clients, so that they can better assist them. For #3, I think*

our goal should be to give them enough information to appreciate the intricacies of good statistical work so that they can more successfully interact with type #2 above.

7 Discussion

The participants in this study found themselves in different sorts of contexts: disciplinary, undergraduate, postgraduate, servicing, mode of delivery and many other variations impacting on their teaching. These contexts provided a means for our respondents to interpret and reflect upon their experiences. Our data show that educators of service statistics have a range of ideas about what makes a good statistics student in service courses, including qualities such as critical thinking and curiosity, a diligent approach to learning and numeracy and literacy skills. Many of these attributes could be transferred to describing competent learners of many disciplines at tertiary level. In contrast, respondents' views about the role and even value of mathematical knowledge to learners of statistics diverged. Some participants acknowledged the historical embedding of statistics in mathematics and the necessity for learners to understand and appreciate mathematics as the basis of scientific thinking. Others contested the "deterministic thinking" students may learn from studying mathematics, describing it as antithetical to the uncertainty and complex interaction of context and content surrounding statistical problems, which students need to understand to appreciate the discipline.

Not surprisingly, discipline knowledge and experience in applying statistics to their research or professional work were prominent in our respondents' reports about what makes a good statistics teacher. Many of these educators appeared to concur with Moore (2005, p. 206) that a relevant introduction to statistics must include all the areas of project design, exploration of data and statistical reasoning "in the context of work with real data in real problem settings". Respondents collectively expressed qualities needed to teach service statistics. In general, these effectively matched the qualities they reported about good learners. Many educators offered practical suggestions on how to overcome 'stats-phobia' and to assist students who were struggling.

We have used the voices of the teachers themselves to illuminate their experiences of teaching and learning service statistics and focussed on responses to questions on what makes a good learner of service statistics, on the one hand, and a good teacher on the other hand. However, underpinning these questions is a more fundamental and broader issue: what is the basis of effective learning and teaching in service statistics? In expressing their responses to the interview questions our respondents were directly or indirectly articulating their positions and "embodied" theories (Hodkinson, 2005, p. 116) on this more complex issue.

It is tempting to suggest that there could be a match between espoused theories of good teaching and espoused theories of good learning. The educators' ideas about the qualities of 'good' teachers and 'good' students, summarised above, provide examples of familiar practices that are seen as successful (such as: *seeing a wide range of applied statistics examples*), and by comparison, or omission, practices that may be less conducive to learning (*doing exercises in the book*). Remarkably, the notion of 'good' was usually tied to some emotive personal quality, such as enthusiasm (in the teacher), motivation (in the student). The implication here is that enthusiastic teachers perhaps generate and support motivated learners. Yet, experienced teachers know that the broader contexts of learning impact hugely on the outcomes of learning. In this research project, we have shown that the role of mathematics for statistics provided a

spontaneous outpouring of tension. Other broader contexts included students' backgrounds and preparedness for their statistical study.

In a previous paper (*Authors, 2007a*) we explicated a model for the phenomenon of teaching statistics as a service subject that serves as a lens for the positions revealed in this paper. There we found evidence for three conceptions—qualitatively different ways of looking at service statistics teaching. The first of these conceptions was labelled 'Teacher' and focused on the qualities, expertise, resources and strategies brought to the classroom by the teacher. Students were 'acted upon' and the teacher used his/her expertise to decide on the important aspects of statistics to teach. A broader conception was labelled 'Subject' and represented a change of focus to the course content or subject matter itself. The role of the teacher changed to illuminating the material and helping students to understand it. The broadest conception was called 'Student', and highlighted the voices, perspectives and concerns of the students: the teacher was certainly part of the overall learning context, but not the sole part, nor even the most privileged part.

The characteristics of 'good' students of statistics and 'good' teachers of statistics, reported in this paper, could be viewed as positions along this theoretical continuum of Teacher – Subject – Student. We emphasise that we are not attempting to categorise any individual view. However, if we review participants' collective responses, we can locate views about aspects of the findings, outlined in sections 3, 5 and 6, along the continuum. Firstly, what makes a good statistics student? Focus on Teacher – personal attributes such as willing to listen and work hard; focus on Subject – personal attributes such as curiosity about the subject, ability to think through the issues rather than just do the technical bits; focus on Student – personal attributes such as willingness to see what role statistics has in their own discipline and how it can be useful.

Next, what makes a good teacher of service statistics? Teacher – the discipline knowledge and experience to motivate students; Subject – show students that statistics can illuminate their own discipline areas, ability to show that statistics is practical and useful; Student – willingness to engage with students' lives, contexts and problems, to put themselves into the background.

Finally, can you teach a student to be a good statistics student? Teacher – no, nothing much can be done; Subject – yes, if you can show them the interest in statistics and give them the right examples of its application; Student – even those who don't appear to be good students initially are likely to have other strengths and be able to contribute these strengths to a group approach to learning.

The theoretical lens we developed in *Authors (2007a)*, and expanded above, also provides a means of placing the collective (and divergent) conversations about the role of mathematics in statistics into a framework. A Teacher focus could fit with a view that students should work hard on developing their abilities in order to get an entrée into the world of statistics (as their teacher already has). Hence mathematics would emerge as very important, maybe even essential, along with an emphasis on other aspects of training or experience undertaken by statistics educators. This is illustrated by Daria's assertion that: *every "scientist" should have a minimum knowledge of calculus*. With the Subject conception, mathematics could be viewed as part of the development of the statistical theory and hence an important aspect of the learning. An example is given by Horace's comment showing that he encourages mathematics students (in his statistics

class) to see how mathematical theory is essential, *and that they therefore have a privileged insight*. With the Student conception, the view could be that mathematics is not particularly important unless the student wants to move towards studying mathematical statistics—a small minority, particularly in service subjects. For most statistics students the role of mathematics is essentially optional: one can discuss the meaning of statistical ideas and approaches without the intermediary of mathematics. This idea is encapsulated in Sjefke's assertion that for psychology students, mathematics plays no role—*we rather concentrate on interpretation and content than on mathematics*.

8 Conclusion

The empirical findings of this study provide an opportunity for statistics educators to become aware of and evaluate a range of ideas about learners and teachers, and to locate their own positions in the theoretical framework discussed above. More generally, the study alerts us to the complexity and diversity of educators' views about successful teachers and students and, by inference, about effective teaching and learning practices in service statistics.

Lindblom-Ylänne et al. (2006) showed that both discipline and teaching context impact relationally on approaches to teaching. In accord, Hodkinson (2005, pp. 117-118) answers his own question about whether learning is general or discipline specific by summing up that although "our broad conceptualizations of learning can be fairly general, understanding how these conceptualizations can be applied in practice requires attention to the specifics of each location". By presenting data on 'good' teachers and learners within a specific discipline area and applying the findings to expand our theoretical model on experiences of teaching service statistics, we hope to add to scholarly conversations about teaching and learning.

Qualities, knowledge and skills of good learners and teachers—however important—cannot in themselves promote effective learning in statistics. It is in the interactions-in-practice of teachers, students and their environments that the many dimensional and dynamic 'life' of teaching and learning plays out. We offer a provocation to statistics educators to acknowledge, reflect on and build upon these complex interactions to inform pedagogy and practice in service statistics.

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