Chapter 7
Scaffolding Statistical Inquiries for Young Children

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Abstract Statistics in the early years is often limited to the construction and 'reading' of simple data representations as distinct from employing statistical inquiries that engage students with data in more authentic and meaningful contexts. One of the challenges of engaging with data inquiries is the extent to which students struggle with the lack of structure and direction, thus requiring additional support, or scaffolding. This chapter details the framework used for introducing statistical inquiry to young students and then provides insights that emerged from observation and analysis of a class of 5–6 year olds engaged in their own data investigation to illustrate. The findings suggest that considerable teacher scaffolding is required to progress students through inquiries and this was largely achieved through questioning employed to focus students on both the inquiry process and the statistical content to be addressed.

7.1 Introduction

Statistics is most commonly taught at the early childhood level in a surface and procedural fashion. A characteristic example is the teacher asking the students what their favourite fruit is. Students are provided with fruit cutouts to place on a pre-prepared picture graph as modelled by the teacher. If the students are slightly older, there may be some modelling of tallying first as each child selects their favourite fruit from a pre-populated, limited list of common fruits. In both examples, any questions asked of students will be simple, literal comprehension questions about the graph: *What is the most popular fruit*? *How many more people like oranges than apples?*

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This commentary is not intended to diminish the requirement for children to learn to construct and read data representations, but to do so in this way removes the reality of statistics from the classroom: gone is decision making about problems, consideration of the data that is needed, planning for obtaining data and so on. Activities of this nature also remove the inherent messiness of data by artificially restricting the data to be ‘workable’.

In real life, problems requiring the application of statistics are not neatly packaged in this way. Students need, from an early age, to develop an appreciation of the dynamics of statistical inquiry—such as the formulation of problems and appreciation of issues associated with planning and measurement—rather than a focus only on the collection, organization and conclusions that could be drawn from data sets (Wild & Pfannkuch, 1999).

To provide a contrast to the example, consider what might have happened had the students been asked to engage with an inquiry, ‘*What are the best fruits for a class fruit platter?*’. Left to their own planning, students may not have pre-defined potential responses (apple, banana and so on) and then had to deal with the potential for 20 different fruits to be named as ‘favourite’. Such messiness would have led to many opportunities to enhance statistical thinking and decision-making, as well as providing a valuable lesson in the planning of data collection/surveys. Another potential benefit of an investigation is in considering the role that context plays. Students may have further considered the authentic purpose of such an investigation: ‘*We will have to narrow the choices to fruits that are readily available and in season now*’.

While an inquiry approach clearly supports more authentic engagement with statistical understandings, the ill-structured nature of inquiry problems means that students do not immediately or intuitively see how to address them. As inquiry is not widespread in classrooms, it isn’t surprising that students struggle with the unaccustomed lack of structure and direction, and require additional structured support, or *scaffolding* to engage with them. So, what supports work?

The aim of the research described in this chapter was to provide insight into the ways in which a statistical inquiry could be facilitated with very young children. These insights emerged from observation and analysis of teacher-student interactions as an experienced inquiry teacher immersed a class of 5–6-year-old students in their first data inquiry. Sufficient detail of the classroom context has been provided to enable the reader to envisage the learning. Implications and suggestions for educators have been addressed.

7.2 Statistical Inquiries and Investigations

Simplistically, statistical investigations can be considered activities in which students engage with a genuine, contextualized problem they can apply statistical methods to, in order to lead to a data-based solution. As distinct from approaches often seen in schools—in which students are given neat, organized, *convenient* problems—investigations address the complexities and difficulties inherent in more genuine problems; thus, apprenticing students into the discipline of statistics.

Statistical inquiries and statistical investigations can be viewed along a continua of problem structure from well-defined to ambiguous, with inquiry problems lying further towards the ill-structured end of the continua. Ill-structured problems are those which have multiple potential solutions and solution paths: they 'contain uncertainty about which concepts, rules and principles are necessary for the solution' (Chin & Chia, 2006, p. 47). One of the essential components of addressing ill-structured problems is that students must engage in discussion to establish the elements of the problem; that is, they must first interpret the problem in its context and consider how data could address it (Allmond & Makar, 2010). Thus, investigative and inquiry problems develop a need for additional stages of statistical investigation to be addressed—refining of problems and planning of approaches (Shaughnessy, 2007; Wild and Pfannkuch, 1999)—in turn providing genuine opportunities for addressing these complexities and engaging in authentic statistical decision-making and reasoning. Shaughnessy argues:

> If students are given only pre-packaged statistics problems, in which the tough decisions of problem formulation, design and data production have already been made for them, they will encounter an impoverished, three-phase investigative cycle and will be ill-equipped to deal with statistics problems in their early formulation stages. (Shaughnessy, 2007, p. 963).

One commonly used model for statistical investigation is the investigative cycle, or 'PPDAC' due to the model acronym, as adapted by Wild and Pfannkuch (1999):

Problem	The deconstruction, negotiation and refining of the problem in conjunction with *context familiarization*
Plan	The identification of the data needed to address the problem and consideration of effective collection, recording and analysis of that data
Data	Data collection, recording and cleaning
Analysis	Organizing, manipulating, representing, and interpreting data to identify trends or patterns and provide evidence with which to address the problem; and
Conclusion	Reflecting upon the evidence identified in the analysis stage and linking it back to the initial problem to provide a response to that problem

This cycle is useful in identifying and describing the stages of investigation, in enabling teachers to plan investigations, and in providing students with structure by displaying this cycle for them.

Existing research supports the capacity of young children to engage in statistical inquiries (Fielding-Wells, 2010; Fielding-Wells & Makar, 2013; McPhee & Makar, 2014), but little research has been undertaken into *how* teachers scaffold young students in their initial inquiries. Fielding-Wells (2016) suggests there are three domains of knowledge that are drawn upon in inquiry: knowledge of the context; knowledge of [mathematical and statistical] content; and, knowledge of [statistical] inquiry.

The shift from a view of early childhood statistics practice from data collection, display and literal interpretation, to a rich inquiry approach is complex and requires a significant shift in teaching and learning practices from one which is teacher-led, to one in which the children are following a complex, 'messy' practice. Previous research has demonstrated that many teachers struggle with such a shift (Makar & Fielding-Wells, 2011).

7.3 Scaffolding

Scaffolding was first introduced by Wood et al. (1976) as a building metaphor to describe the expert support that could enable learners to reach goals considered beyond their reach (1976, p. 90). Scaffolding extends from Vygotsky's Zone of Proximal Development (ZPD),

> the distance between the actual developmental level as determined by independent problem-solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers. (1978, p. 86)

The scaffolds used to support the learner are then gradually withdrawn until the goals can be achieved unaided. To be considered scaffolding, supports are required to meet the criteria of contingency (the type, timing and strength of supports must be responsively adapted to the student's current level of performance), fading (supports should be gradually withdrawn, or faded, as the student develops increased confidence and competence), and transfer of responsibility (accountability for performance should be progressively shifted to the learner) (van de Pol, Volman, & Beishuizen, 2010). This definition of scaffolding has been adopted in this chapter, as distinct from the informal notion of general 'support'.

Research into scaffolding has predominantly focussed on one-to-one or small group scaffolding due to the ZPD underpinning, as whole class scaffolding can be complex due to the nature of the numerous student ZPD's involved (van de Pol, et al., 2010). However, the practicalities of classrooms require whole class instruction; therefore, in practice, a teacher must work with group ZPD as well as consider individual learner's ZPD (Smit, van Eerde, & Bakker, 2013).

7.3.1 Scaffolding Framework

Wood et al. (1976, p. 98) identified six *functions* or *intentions* of the expert scaffolder from observation of young children being taught to perform a repetitive, mechanical task. These categories are provided below, but it is worth noting that modelling is often regarded in the literature as a means, rather than function, of scaffolding (van de Pol, et al., 2010):

1. Recruiting the learner: engaging the problem solver's interest in the task requirements.
2. Reducing the degrees of freedom: reducing the number of component processes or performances required to achieve a solution.
3. Maintaining student direction: maintaining the learner's focus and motivation.
4. Marking critical features: noting and drawing attention to the specific and relevant features of the task to identify discrepancies in production.
5. Frustration control: dealing with the affective state of the learner.
6. Demonstration: modelling a solution to a task for imitation.

The mechanistic task was chosen to enhance opportunities for the researchers to identify mastery but potentially reduces the applicability of the framework to tasks requiring higher cognitive and metacognitive regulation—tasks such as the solving of ill-structured problems (Shin, Jonassen, & McGee, 2003).

While Wood et al. (1976) focused on the functions or intentions of scaffolding, Tharp and Gallimore (1988) focused their attention on 'how' the expert assists the performance of the learner. They identified six ways that learners were supported in one-to-one interactions between an expert and the learner: modelling, contingent rewards and punishments, feeding back, instructing, questioning, and cognitive structuring. Again, this framework has reduced applicability for whole-class research as children in a classroom setting are less likely to work on an individual basis with a teacher and more likely to engage in group or whole class activities. To address the need to work with entire classes, van de Pol et al. (2010) built upon the work of these two seminal studies to tackle the issue of analysing scaffolding intentions and means in a natural classroom setting, deriving categories of feedback, hints, instructing, modelling, questioning, explaining and miscellaneous. These categories were used as a starting point for the research reported in this chapter.

7.3.2 Research Question

The question specifically addressed by this exploratory research was: What insight can be gleaned into scaffolding of statistical inquiry through observing a teacher as she worked to support young learners new to addressing ill-structured problems?

7.4 Method

The aim of the research described in this chapter was to ascertain how an experienced teacher of inquiry supported young learners to engage with an ill-structured problem. The classroom and lesson sequence, that is the focus of this chapter, was a single iteration of a larger design-based research (DBR) study. DBR was adopted as a methodology as DBR suits the intent of this research: to develop theory [about the process and scaffolding of learning during the teaching of statistical inquiry], to undertake highly interventionist research [teacher and researcher seeking together to implement and study classroom interactions during inquiry], and to have a practical focus and application [the support of young students engaging in statistical inquiry]. These principles underpin design-based research (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003).

The class participating in this research was a Year 1 class (5–6 years old) from a large suburban, mid-range socio-economic school in Australia. The teacher, Miss O, was an early career teacher with two years of experience in using inquiry pedagogies to teach mathematics. The unit was implemented in the third quarter of the school year, with a focus on data gathering, representation and analysis based on informal measurement of area. This was the students' first experience with statistical inquiry.

The ill-structured question that drove this inquiry was, '*How big are most Year 1 feet*?'. This problem lacked structure in that both 'big' and 'most' are ambiguous words. The former may refer to length, height, volume, area, mass and so on, whereas the latter might mean the most in our class, school, state, country or world. The teacher deliberately chose a context that would be familiar to all students in the class (their feet), and the measurement concepts included had been addressed previously with these students. Thus, the use of measurement for data collection served to reinforce previous work these children had undertaken.

Each lesson was videotaped and transcribed in full. All non-relevant speech was removed prior to coding (e.g. requests for bathroom breaks). The remaining teacher discourse was then coded using the thematic framework described below. Coding was undertaken concurrently with the viewing of the videotape to ensure alterations to meaning, for example because of an interrogative inflection, were not overlooked as may have been the case if relying on transcript alone.

Thematic codes were taken from van de Pol et al. (2010) as described in the scaffolding framework section above. These originally included *feedback, hints, instructing, modelling, questioning, explaining* and *miscellaneous*. After an initial pass, the need for additional codes became apparent to distinguish purpose or intent of questioning as most teacher interactions were of that nature. To address this, the categories were re-coded to reflect both the scaffolding means/purpose and the linguistic sentence type. The sentence types identified were as follows: interrogative [Q]—those which aim to elicit information; declarative [D]—those that provide information; or imperative [I]—those that convey a command or request (Brinton & Brinton, 2010). The codes are provided in Table 7.1 with the added categories marked with *. To illustrate, a code of Q-AMS is an interrogative [question] that serves to draw attention to a mathematical or statistical concept: similar to the marking of critical features as identified by Wood et al. (1976), with the difference that there was no intent to highlight discrepancies in performance, but rather, to highlight important concepts or understandings. Two category codes drawn from van de Pol et al. (2010) were not noted during the period of the inquiry: explaining and modelling. By the definitions of these category codes, these means of scaffolding address more explicit interactions—explicit showing or explicit telling. Explaining might include an explanation of the purpose of a column graph, whereas modelling might include step-by-step demonstration of how to create one.

Table 7.1 Code guide for analysing classroom discourse

Means	Code	Description	Example
Feedback	F	Direct evaluation of the work of the student	Yes, we could definitely use something to measure it
Hints	H	Provision of a hint but without providing whole solution	… we have been learning a little bit about the space in between things, haven't we?
Instructing	I	Provision of information so the student knows what to do/how to do it	So, here's an idea, why don't you go back over and have as little gaps as you can and for the space where it doesn't fit
Explaining	E	Provision of information on why to do something or content information	No instance
Modelling	M	Demonstration of behaviour for imitation	No instance
Extending	EX*	Prompting of student to think of/provide greater depth of reaction/response	Does anybody have another idea why tracing our feet is a good idea?
Clarifying	C*	Prompting students to explain their thinking or ideas more coherently.	Why do you think that is a good idea?
Revisit	R*	Reiterating/revisiting a question that did not elicit an adequate response after additional input (rewording, hint, etc.)	Alright so now I have got to think about how am I going to represent that? (Q) How am I going to put that on the board so we can see it and work out how big most year one feet are? (QR)
Attending inquiry	AI*	Drawing students' attention to important aspects of the inquiry process—explicitly or implicitly	So, what we're going to do today, how are we going to find this out? How big are year one feet?
Attending mathematical or statistical knowledge	AMS*	Drawing students' attention to important aspects of the mathematical of statistical content—explicitly or implicitly	There's a little space here, though isn't it? And that's not quite enough for one is it and a bit would be overhanging
Attending to the context	AC*	Drawing students' attention to important aspects of the context—explicitly or implicitly	What are we going to have to do in order to show so we know Katie's foot is probably one of the smallest in the class?
Miscellaneous	O	Other	OK hands on heads. Hands in laps

7.5 Illustrations from the Classroom

The final pass coding count from the entire unit is provided in Table 7.2 (interrogative interactions), Table 7.3 (declarative interactions) and Table 7.4 (imperative interactions). These have been included for demonstrating the highly disproportionate profile of the interactions: over two-thirds of all teacher dialogue being questioning and an almost complete absence of directives (imperatives).

There was also a significant distribution of questions towards the latter end of the cycle. This was only of interest in that the students engaged in less overall discussion during the early parts of the inquiry. This was likely because the problem was posed by the teacher as she was aware of the difficulties novice students have in question posing (Allmond & Makar, 2010).

More generally, there is a consistent pattern of interaction in this classroom. The teacher, Miss O, spent time with the children, talking through what students had done

Table 7.2 Total number of interrogative [question] interactions from teacher by stage of inquiry

Code	Stage of statistical cycle					Total
	P	P	D	A	C	
QAC			2			2
QAI	2	1	3	8	3	17
QAMS	2	1	9	7	8	27
QC		1		2		3
QEX			3		1	4
QH				1		1
QR				2		2
Total Q	4	3	17	20	12	56

Table 7.3 Total number of declarative interactions from teacher by stage of inquiry

Code	Stage of statistical cycle					Total
	P	P	D	A	C	
DAI					1	1
DE	1		1	1		3
DF	3	6	2	3	1	15
DI					1	1
DM					1	1
Total D	4	6	3	4	4	21

Table 7.4 Total number of imperative interactions from teacher by stage of inquiry

Code	Stage of statistical cycle					Total
	P	P	D	A	C	
II		1	1		1	3
IO	1					1
Total I	1	1	1		1	4

and then discussing ways to move forward. The children carried out the next stage of the inquiry in their group or pairs before the teacher drew them back to the whole group for discussion. While the students were working in groups, the teacher spent time circulating and working with students as needed: challenging, providing hints, clarifying and so forth.

The following section will guide the reader through the inquiry from start to finish. While the PPDAC cycle has been used as the organizer, and the unit thus presented chronologically, only sample excerpts have been included to illustrate the activities and interactions. Whole class discussions are prominent to highlight scaffolding means. The sequential numbering is provided only to enable discussion, with dialogue missing between sections but not within a section. Elipses (…) represent short pauses with long pauses indicated as [pause].

7.5.1 Problem

The teacher commenced by posing the question, drawing the students into a discussion that quickly engaged them. The excerpt below shows the initial whole-class conversation, demonstrating the students becoming excited about the topic in a relatively brief time. The teacher involved the students in narrowing the focus of the inquiry to aspects of measurement and data, both making the inquiry manageable and directing the students towards desired curriculum foci of measurement and area.

In this first interaction with the students, the teacher can be seen to be *marking* those features which are critical to statistical inquiry by focusing attention on important aspects: the problem posed [1] and the need for evidence [3]. Once these ideas were planted, she quickly moved to the planning phase.

1.	Miss O:	OK. How big are most Year 1 feet? How big do you think they are?	Q-AI
2.	Katie:	About this big? [holding hands close together]	
3.	Miss O:	Seems about right	D-F
		but we've got to prove that right?	Q-AI
4.	Kylie:	I think this big. [holding hands an extended distance apart]	
5.	Miss O:	You think this big? I think Miss O's feet aren't as big as that! [smiling]	D-F
6.	Students:	[calling out] This big, this big	
7.	Miss O:	OK hands on heads. Hands in laps. Still waiting….	I-O

7.5.2 Planning

The teacher intentionally limited the student involvement in the posing of the question; however, she wanted students to become more involved in the planning phase to begin to envisage the data collection process. By using predominantly questioning and extensive feedback, the teacher guided the conversation and language use and thus the planning.

8.	Miss O:	So, what we're going to do today, how are we going to find this out? How big are year one feet?	Q-AI
		How are we going to find out what the space of the bottom of our feet are?	Q-AMS
9.	Students:	Draw around them.	
10.	Miss O:	Draw around our feet? Yep, we definitely could do that.	D-F
		Why do you think that's a good idea?	Q-EX
11.	George:	Because it's the shape of our feet.	
12.	Miss O:	Yes, because it gets the whole shape of our feet, that's pretty good. Good explanation!	D-F
		Does anybody have another idea why tracing our feet is a good idea? James what do you reckon?	Q-AMS
13.	James:	Because then we can get some stuff to move around our feet.	
14.	Miss O:	Yes, we definitely could use something to measure our feet. Yep?	D-F
15.	Harry:	Tells us how big our feet are?	
16.	Miss O:	Yes, it could tell us about how big our foot is if we trace it. Yes, that's another good reason.	D-F
17.	Tanya:	We can use something to measure it.	
18.	Miss O:	Yes, we could definitely use something to measure it. Yes Jessica?	D-F
19.	Jessica:	You could write the number inside if you draw around it like the number inside it.	
20.	Miss O:	Do you mean once you've traced the foot you could actually write the measurement is that what you mean?	Q-C
		Alright well let's find out a little more about it. We're going to get on with it because that's the fun part.	D-I

The students could now see a way forward and required little assistance to envision data collection. They proceeded to collect materials and trace around their feet before measuring using whatever informal unit of measure they wished (these included dominoes, unifix cubes, tangram pieces and so on). The teacher did not lead the students to consider uniform units as she wished this to arise naturally through observation.

7.5.3 Data Collection

During data collection, the teacher initially focused on accuracy [as is valued by the discipline] before discussing other aspects of 'fair' data collection more broadly. This was a precursor to understanding sources of variability as due to either natural variation or error. The teacher worked individually with students to discuss their approaches at a level appropriate for the child. In the excerpt below, the teacher has the students consider the spaces on the foot outline (the 'yellow' in [21]) that are not covered by the unit of measurement, that is, 'gaps':

21.	Miss O	I'm looking and I'm thinking that's pretty good [the student's tiling] but I am also looking and I can see a lot of your yellow.	D-F
		What do you think that might mean for your measurement?	Q-AMS
22.	Alex	There's gaps	
23.	Miss O	Yes, there's gaps, so if there's gaps on your foot is that going to give you a correct measurement?	Q-AMS
24.	Alex	No	

The second opportunity the teacher orchestrated was to establish a need for accurate measurement to enable fair comparison. By allowing students to choose their own unit of measure, the students were led to see that this did not enable the data to be meaningfully compared. In the excerpt below, the students had measured their foot outline, recorded their data on the outline and were then discussing the results. One student, Peter, tried two different units, and the teacher took the opportunity to draw out the issue of 'fairness' to address variation that would be caused by measurement discrepancy (error), using the context of the inquiry to develop appreciation of the need for similar units [33].

25.	Miss O:	You used dominoes and unifix did you? Which one did you use first Peter?	Q-EX
26.	Peter:	Dominoes.	
27.	Miss O:	And how did you find that? Did it work? And what was the measurement of your dominoes?	Q-EX
28.	Peter:	10	
29.	Miss O:	It was 10 dominoes and what was the measurement with your unifix cubes?	Q-EX
30.	Peter:	24	
31.	Miss O:	24. Um, why was the unifix cubes a bigger number?	Q-AMS
32.	Peter:	Because they [unifix] are smaller.	

33.	Miss O:	So, while Seth has a bigger foot, his measurement shows if we looked at that, that his foot is actually smaller but what I am saying, yeah, but the units told us differently didn't it? What are we going to do then?	Q-AC Q-AMS
		Let's go back to our question, 'How big are year one feet?'. What do we need to make it a fair test? What are we going to have to do in order to show so we know Katie's foot is probably one of the smallest in the class? *Probably* [stressed]. And Seth probably has one of the bigger feet?	Q-AI
			Q-AC
		What are we going to do? Amanda? What could we do?	Q-AMS
34.	Amanda:	Use um the same units.	

The students elected to use unifix cubes as a comparative unit. These data were collected, and results are recorded by students, along with their name, on the outline of their feet. Giving students opportunities to plan and collect the data established connections between context and data: students could see the natural variation that was inherent as they made connections between what they observed in each other's foot sizes and the data as they were recorded. The questioning by the teacher [33] suggested the familiarity of context enabled her to facilitate appreciation of variation resulting from erroneous data collection while the students were recognizing that natural variation in data also occurs.

7.5.4 Analysis of Data

During data analysis, the teacher's purpose was to have students focus on the type and range of the data to organize them meaningfully. The teacher was supporting the students to experience the decision making inherent in dealing with raw data. Harry suggested focusing on the value of the tens in the measurements taken [35–39], and the teacher effectively privileged that suggestion. Binning the data, as Harry suggested, may somewhat mask the shape of the data; however, it was a valid and, for his age, sophisticated means of organization. From [39] on, the teacher tried persistently to establish, through questioning, how Harry's idea could be represented. It would have been far easier to create a bar graph of 'bins' at this point for the students; however, this would not have given them the experience of grappling with the issue themselves and resolving it. Throughout this discussion, the teacher preferenced responses of order and organization: characteristics of effective graphing.

35.	Miss O:	What are we all looking for to answer this question 'How big are most Year one feet?'.	Q-AI
		Now we know that we had to collect all our information that we have right now.	Q-AI
		What's the information I am looking for?	Q-AMS
36.	Harry:	The first number of the two numbers. [Harry is referring to the digit in the tens place on the measured feet, that is, if the foot was 24 blocks in area then the first of the two numbers is a 2—representing two tens].	
37.	Miss O:	What do you mean by that Harry?	Q-C
38.	Harry:	Like if the person had two and a number or if they had something different… if most have 2 and something then … then 20's is the most …more than 30 …	
39.	Miss O:	So, let me just clarify what you're saying. Are you saying that we need to collect the numbers and we're finding out if it's a teens number, something in the 20s, something in the 30s, something in the 40s, is that what you're saying? So, collecting the measurements? [Henry indicates assent]	Q-C
		Alright so now I have got to think about how am I going to represent that?	Q-AI
		How am I going to put that on the board so we can see it and work out how big most year one feet are? [waits]	Q-R
		So, we need some ideas now and you're going to help me to display the data and find out what we are going to do with all that information we have collected over the last couple of days. How are we going to figure this out? [waits]	Q-R
		If you just call numbers out at me we're probably not going to get a good idea, are we?	Q-H
		Because they're just numbers going all over the place inside our brains, outside our brains and we're going to lose all of that information so we need to figure out a way to display it on our whiteboard.	D-E
		So, does anyone have an idea?	Q-AMS, Q-AI
40.	Matt:	We could [stick] um this onto the whiteboard so we know what the number is and who it is.	
41.	Miss O:	OK we could do that ok that's not a bad idea.	D-F
		Well what will I do though will I just get all of these feet and just [stick] them wherever?	Q-AMS, Q-AI
42.	Students:	No.	
43.	Miss O:	Why isn't that going to work?	Q-AMS
44.	Peter:	Because they wouldn't be in order.	

45.	Miss O:	OK you're saying then that we need some kind of order to put the…	Q-AMS, Q-AI
46.	Peter:	[interrupting] Columns.	
47.	Miss O:	Columns? That's an interesting word. Alright so you're thinking, 'how about we put them in columns'.	D-F
		What am I going to do? Put all the blue ones in a column, all the green ones in a column, the orange ones in a column, the yellow ones in a column.	Q-AMS
48.	Jenny:	All the ones that are 20 in columns	
49.	Miss O:	All the ones that are 20 in a column. Ok is everybody agreeing with that? Does everybody think that might be a good idea to display our ideas?	Q-AMS, Q-AI
50.	Students:	Yes.	

The teacher proceeded to work with the students, through questioning, to determine what each column should represent and how these columns could be labelled. There were several instances [as in 47] where she provided the students with an incorrect process to ascertain understanding. This setting up of 'adversary' statements was a popular approach with this teacher. If the students argued, and corrected her, she would move on. This dialogic movement served (and this was confirmed by the teacher) to assess student knowledge 'on the fly' to monitor understanding and enabled her to adapt contingently.

7.5.5 Conclusions

The final stage of the statistical investigation was to provide a conclusion derived from data. The students were seated on the floor in front of the whiteboard looking at the image seen in Fig. 7.1. In the exchange below, the teacher supported and guided student appreciation of the investigative cycle by drawing attention to the need for a conclusion [51] and for that conclusion to be linked to evidence and drawn from such [53, 55]. In doing so, the teacher privileged the key features of the students' data representation [66] to enhance their interpretation. Finally, the teacher used questioning heavily to draw the students to a conclusion.

Fig. 7.1 'Binned' representation of the students' feet

51.	Miss O:	Can we answer our question from the data we've collected and represented on the board? Can we answer it?	Q-AI
		How big are most year one feet or at least in this classroom?	
		How can we answer it? Who can tell me?	
52.	Bethany:	The 20s, the most biggest because lots of people have… [tails off]	
53.	Miss O:	Well, how do you know? [pause]	Q-AI
		Have you checked? [drawing focus to data]	Q-AI
54.	Students:	Yeah	
55.	Miss O:	How am I going to tell exactly? Because you are telling me there's lots of feet in there but there's lots of feet in the 30s too. But how are you going to tell me? How do I know, how do you know that there is the most in the 20s?	Q-AMS
56.	Bethany:	There's lots of space there and there's not much space in the 20s. [meaning absence of data]	
57.	Miss O	Well that's true but I could make less space by doing this. [Moving all the feet together]. But that's not answering it really because now I've got lots of space in here too. How do you know for sure?	D-F Q-EX
		It's not about space in those columns, [waits]	D-H
		but how do you know for sure? That the answer is the 20s James?	Q-AMS
58.	James:	The 20s have 14 because I counted and the 30s have 8. [the students continue to count all items in each column]	

59.	Miss O:	So, can I answer my question? Who can answer my question? Who can answer my question that we have been trying to answer for the past two days?	Q-AI
		I'm hoping everybody has their hands up? How big are year one feet? William?	Q-AMS
60.	William:	20's	
61.	Miss O:	Ah in the 20s's. So when I say How big are most year one feet? We could all say because the data shows us, all the measurements we took over the last couple of days and all the information we collected tells that—Year one feet are mostly in the 20s.	D-M D-AI

7.6 Discussion and Conclusion

The aim of this research was to develop insight into how a teacher familiar with inquiry scaffolded her students to engage with the complexities of addressing ill-structured statistical problems. To begin, the first question was whether the teacher was in fact providing scaffolded support. Returning to van de Pol et al.'s (2010) requirement that scaffolding meet the requirements of contingency, fading and transfer of responsibility offers a structure to explore this.

Contingency addresses the need for the type, timing and strength of the supports to be responsive to the learner. The strength of the response is important as the teacher must have knowledge of the students' current level of understanding to respond. A teacher needs to assess and consider both class and individual ZPD in order to make contingent responses, and this is quite complex and difficult a requirement. Here, we saw the teacher exploring the degree of support required: in exchanges with students [eg. 39], she provided a question prompt, and then worked to reformulate the question, and eventually provided a minor hint to establish what the students needed in order to continue. The teacher neither 'told' students nor 'rescued' them but rather provided the minimum of progressive assistance. The practice of offering minimal support and building on it served to address class ZPD but may be problematic in terms of building up future capability. The teacher was experienced at inquiry and had some experience in teaching early childhood: this poses the question of how we can 'bottle' this approach to assist novice teachers. The contrasting argument is that should the teacher have chosen to provide stronger scaffolds, or more direction, earlier, the task challenge may have been overly reduced and the benefits of the statistical inquiry lost. Obtaining a balance is a challenge.

The second requirement of scaffolding is the fading of supports (van de Pol et al., 2010). Unfortunately, the examination of a single unit of work to develop a complex understanding of the statistical inquiry process does not provide a realistic measure of fading as students have only had the opportunity to cycle through the process once. It is thus impossible to demonstrate fading sufficiently without a longitudinal study.

Finally, transfer of responsibility deemed a necessary component of scaffolding (van de Pol et al., 2010). Again, a longitudinal study would be of more benefit in ascertaining the effectiveness of transfer. The purpose of implementing statistical investigation is to develop students capable of engaging as apprentice statisticians, and therefore, the aim of the process is to use the PPDAC cycle (Wild & Pfannkuch, 1999) as a scaffold via a learnt process. With this goal in mind, increased adoption of responsibility and decreased support would be target outcomes, at least in terms of students developing the *process* of statistical inquiry. It is likely that support for the content being developed would alter and deepen as students progressed through schooling, and therefore, the scaffolding specific to the content may be of an ongoing, changing nature.

A second aim of this study was to ascertain the means of support or scaffolding. In observing the overall pattern of class interaction, there were several strategies or means of scaffolding that were employed by this teacher for specific and clear purposes. The predominant means of scaffolding was the use of questioning, so much so that multiple sub-categories were needed to assist with the classification of interrogative interactions. The purpose of these questions was largely to draw students' attention to one of three identified knowledge categories: knowledge of the statistical inquiry process; knowledge of the mathematics and statistics content areas; and knowledge of context (Fielding-Wells, 2016). While the latter was familiar to students, the teacher's specific linking of results to context served to allow the context to support statistical ideas.

In supporting the statistical inquiry process, the teacher focused on the broader objectives: the need to address a question; the need to plan, gather and organize the data; and the need to provide a data-based conclusion which addressed the initial question. By leading the students through this cycle, she explicitly and implicitly demonstrated the valuing of the process to the students. Simultaneously, she guided students through the 'discovery' of statistical understandings essential to students' appreciation of the 'big ideas' of statistics (e.g. Watson, 2006): variation (error and natural, within group), distribution and centre (implicitly).

7.7 Implications for Teaching and Research

The results of this study have implications for both teaching practice and future research studies. In terms of classroom teaching practice, the findings suggest that considerable teacher scaffolding is required to guide young students with little experience in engaging in statistical inquiries. To enact a shift from more traditional data activities that utilize neat, organized data sets to learning that involves the 'messiness' of more realistic data investigations is complex. Such a shift requires that teachers have a solid grounding in the process of statistical inquiry, have the conceptual knowledge of statistics to guide and draw out key statistical concepts and be willing to relinquish the control they might have otherwise had of the learning process. Beyond this, a shift to statistical inquiry also requires facility with scaffolding students through the process. This research suggests that the predominant supports that were beneficial to young children came in the form of questioning and feedback.

Questioning supports that draw students' attention to both the process of statistical inquiry and the underpinning knowledge of statistics/mathematics was required, and this reinforces the importance of teachers having underpinning understanding of these statistical and inquiry knowledge domains.

In consideration of future research, further studies that provide insight into the scaffolding of statistical inquiry are needed; in particular, studies that address engaging children of varied ages and levels of experience with statistical inquiry and also longitudinal studies that focus on the extent to which the crucial scaffolding requirements of *fading* and *transfer of responsibility* can be more adequately addressed. A second area of future focus needs to be the identification of mechanisms for assisting teachers to identify class ZPD accurately so as to provide the least amount of support necessary to progress students. In this way, students can be engaged as authentically as possible with the inquiries, while not exceeding the class ZPD and therefore requiring explicit instruction or direction which may undermine their ability or interest in making their own judgements.

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References

Allmond, S., & Makar, K. (2010). Developing primary students' ability to pose questions in statistical investigations. In C. Reading (Ed.), *Proceedings of the 8th international conference on teaching statistics*. Voorburg, The Netherlands: International Statistical Institute.

Brinton, L. J., & Brinton, D. M. (2010). *The linguistic structure of Modern English* (2nd ed.). Amsterdam, The Netherlands: John Benjamins.

Chin, C., & Chia, L. (2006). Problem-based learning: Using ill-structured problems in biology project work. *Science Education, 90*(1), 44–67.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9–13.

Fielding-Wells, J. (2010). Linking problems, conclusions and evidence: Primary students' early experiences of planning statistical investigations. In C. Reading (Ed.), *Proceedings of the 8th international conference on teaching statistics*. Voorburg, The Netherlands: International Statistical Institute.

Fielding-Wells, J. (2016). "Mathematics is just 1 + 1 = 2, what is there to argue about?": Developing a framework for Argument-Based Mathematical Inquiry. In B. White, M. Chinnappan, & S. Trenholm (Eds.), *Opening up mathematics education research (Proceedings of the 39th annual conference of the Mathematics Education Research Group of Australasia*) (pp. 214–221). Adelaide: MERGA.

Fielding-Wells, J., & Makar, K. (2013). *Inferring to a model: Using inquiry-based argumentation to challenge young children's expectations of equally likely outcomes*. Paper presented at The Ninth International Conference on Statistical Reasoning, Thinking and Literacy Superior Shores, Minnesota.

Makar, K., & Fielding-Wells, J. (2011). Teaching teachers to teach statistical investigations. In C. Batanero, G. Burrill, & C. Reading (Eds.), *Teaching statistics in school mathematics-challenges* *for teaching and teacher education: A joint ICMI/IASE study* (pp. 347–358). Voorburg, The Netherlands: Springer.

McPhee, D., & Makar, K. (2014). Exposing young children to activities that develop emergent inferential practices in statistics. In K. Makar, R. Gould, & B. daSousa (Eds.), *Sustainability in statistics education: Proceedings of the ninth international conference on teaching statistics.* Voorburg, The Netherlands: International Statistical Institute.

Shaughnessy, J. M. (2007). Research on statistics learning and reasoning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 957–1009). Charlotte, NC: NCTM.

Shin, N., Jonassen, D. H., & McGee, S. (2003). Predictors of well-structured and ill-structured problem solving in an astronomy simulation. *Journal of Research in Science Teaching, 40*(1), 6–33. https://doi.org/10.1002/tea.10058.

Smit, J., van Eerde, H. A. A., & Bakker, A. (2013). A conceptualisation of whole-class scaffolding. *British Educational Research Journal, 39,* 817–834.

Tharp, R. G., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning, and schooling in social context*. New York: Cambridge University Press.

van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher–student interaction: A decade of research. *Educational Psychology Review, 22*(3), 271–296. https://doi.org/10.1007/s10648-010-9127-6.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Watson, J. (2006). *Statistical literacy at school*. Mahwah, NJ: Lawrence Erlbaum Associates.

Wild, C. J., & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry. *International Statistical Review/Revue Internationale de Statistique, 67*(3), 223–248. https://doi.org/10.2307/1403699.

Wood, D., Bruner, J. S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*(2), 89–100. https://doi.org/10.1111/j.1469-7610.1976.tb00381.x.