

## Teacher's Scaffolding over the Year to Develop Norms of Mathematical Inquiry in a Primary Classroom

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Developing mathematical inquiry practices requires that teachers are explicit about classroom norms that support these practices. In this study, we asked: *How can a teacher scaffold the development of norms and practices in mathematical inquiry over time?* Analysis of classroom video over a year showed that the teacher constantly diagnosed classroom norms and responsively used strategies to improve them. By the end of the year, there was evidence of inquiry norms and practices independent of the teacher's presence.

In contrast to mathematics classrooms that focus on memorisation and reproduction of procedures, inquiry-based classrooms value building a climate of intellectual challenge (Goos, 2004). "Rather than rely on the teacher as an unquestioned authority, students in [inquiry-based] classrooms are expected to propose and defend mathematical ideas and conjectures and to respond thoughtfully to the mathematical arguments of their peers" (p. 259). In this study, mathematical inquiry is taken to be the process of addressing ill-structured tasks using mathematical evidence. Ill-structured tasks are those in which the problem statement and/or solution pathway contain ambiguities that need to be negotiated (Reitman, 1965). For example, children may address questions such as "What makes the best map?" (Fry, 2013) where the word "best" requires negotiation.

Although an inquiry approach has been promoted by the mathematics education community, it has been slow to take hold. A number of challenges exist for both teachers and students in addressing ill-structured questions. The challenge addressed in this paper is that of developing classroom norms for inquiry. The goal is to understand how a teacher experienced in teaching mathematical inquiry managed to use scaffolding to establish and develop classroom norms of mathematical inquiry with her students over a year. In order to gain insight into this scaffolding process, our research question was: *How can a teacher scaffold the development of norms and practices in mathematical inquiry over time?*

### Scaffolding Norms and Practices of Mathematical Inquiry

Scaffolding is traditionally described as a support provided by a teacher or more able peer to assist a student to solve a problem that they would not normally be able to solve on their own. Work by Smit, van Eerde, and Bakker (2013) goes beyond the conventional one-on-one teacher-student interaction to investigate scaffolding within a whole class context. A focus on scaffolding classroom talk becomes a key component for classroom-based inquiry because of its emphasis on collaboration (Quintana et al., 2004) and the need for making thinking visible (Linn, 2000). Researchers have cautioned against using the scaffolding metaphor as if it were "a technique that can be applied in every situation in the same way" (van de Pol, Volman, & Beishuizen, 2010, p. 272). Scaffolding has often been studied as in the moment interactions between teacher and pupil/student (Anghileri, 2006; van de Pol et al., 2010). However, for enacting and studying the scaffolding of longer-term

processes such as establishing of norms, there is a need to understand scaffolding that would account for this time dimension (cf. Mercer, 2008).

Goos (2004) argues that norms of participation in a mathematical inquiry classroom are based on assumptions that mathematical thinking is an act of sense-making and that mathematical inquiry relies on habits of reflection and self-monitoring. However, students struggle with having a “taken-as-shared sense of *when* it is appropriate to contribute” and “the actual *process* by which students contribute” (Yackel & Cobb, 1996, p. 461, emphasis in original). The teacher and students’ practices are therefore inter-linked. Under Goos’ assumptions, the teacher could model for students what these practices look like and encourage them to take some ownership for developing mathematical solutions. In doing so, students need to be willing to take risks, for example by sharing incomplete ideas. If the teacher consistently judged student contributions as correct or incorrect, students would be less likely to contribute partial or emerging ideas. To encourage risk-taking, the teacher could withhold judgement on students’ suggestions and elicit comments and critique from peers. Goos suggested that students would then more likely begin to offer conjectures and critique without teacher prompting. Other practices from literature on classroom talk and collaboration include the need for active listening, explaining and justifying to peers and building on others’ ideas (McCrone, 2005; Mercer, 1996). The literature also points to the continuous work required by the teacher to establish classroom norms (Yackel & Cobb, 1996); in this paper we explore how these norms can be scaffolded over a school year.

## Methodology

### *Participants and Data*

The data presented in this paper come from a three year project on argumentation in primary mathematics and statistics. This paper focuses on data from one teacher Kaye Bluett (pseudonym) and her 26 Year 4 students (9-10 years old). The students represented a range of performance levels, with several students receiving additional learning support. Each student had a laptop or iPad with these devices used in many of the lessons. Kaye was an experienced teacher who taught mathematical inquiry for a number of years.

The focus of data was on the collective development (Towers, Martin & Heater, 2013) of norms and practices of inquiry and consisted primarily of semi-structured interviews with the teacher and videotaped lessons over eight months. In the interviews, Kaye was asked about her intentions for developing students’ norms and practices, to reflect on progress and to discuss plans for the following term. Video data were collected in four units designed or modified by the teacher:

*Term 1: Problem solving.* Students solved closed multi-step problems, individually first, shared in pairs, then discussed solutions in class. (Three lessons videotaped, March)

*Term 2: What is the best route for a ‘walking school bus’?* Students collected and analysed data on how far they lived from school, then designed a route for a walking school bus ([www.walkingschoolbus.org](http://www.walkingschoolbus.org)). (Three lessons videotaped, June.)

*Term 3: How far does a paper airplane fly?* Students built a paper airplane from instructions and worked in groups to determine how far their planes typically flew. (Six lessons were videotaped, August.)

*Term 4: How long does it take to read a book?* Students designed a method to collect data on the time it took to read part of a book and then inferred how long it would typically take to read an entire book. (Five lessons videotaped, November.)

### Data Analysis

Data went through non-linear phases of analysis adapted from Powell, Francisco and Maher (2003), although described here sequentially. In the *first phase*, logs were created of each audio and video file to catalogue content. Timestamps and/or screen shots assisted with visualisation of class discussion and small group work. Sections with potentially rich excerpts were flagged, with emphasis placed on identifying excerpts in which the teacher explicitly scaffolded classroom norms and practices, students attempted to apply these practices, or missed opportunities were noted. In the *second phase*, flagged episodes were transcribed and annotated to note how the particular episode illustrated an example or outcome of scaffolding. In the *third phase*, each episode was reviewed again in reverse order (last video first and first video last) to seek traces of how later examples of classroom discussion practices were developed. This was important to seek the beginnings of and follow up on the results of teacher's intentions, diagnoses and specific actions to promote inquiry norms. Insights were tagged with phrases to assist with identifying emerging threads through the data. The audio files and videos were reviewed again in their entirety to seek further examples that may not have been obvious previously. *Finally*, a few episodes were selected to succinctly illustrate norms being developed or practiced.

### Results

We start with a classroom episode in which students were functioning well in their developing mathematical inquiry practices, independently from the teacher. Following, the development of these practices was tracked from the start of the year to observe how the teacher slowly scaffolded this development through particular teaching strategies.

#### *Term 4: Established Norms*

A key goal of scaffolding is to be able to hand over responsibility to learners. We begin with an episode near the end of the school year when students were finalising their solutions to answer the inquiry question, *What is the typical time it takes for a Year 4 student to read a book?* The children had learned formal and informal statistical terms such as centre, typical, spread, shape, gap, and “clump” (but not their calculations)—notions that go beyond what is usually taught in Australian Year 4 classrooms. Students prepared a draft poster of their inquiry solution to give to another group to critique. The teacher rotated between groups but had not yet arrived at this group, so one may consider these students as working independently. In the episode below, Wes and Shane offered feedback to Jake, Jonah and Emma.

- Wes: For your table I was maybe wondering like you could write like, be a bit more specific, like time to read a chapter and then like ... [calculating] total time reading the book in minutes or something. Because I don't really know what you're talking about.
- Jake: I don't even get it (what we wrote)! Total time? What's the total time? (Mocking themselves for not showing this information on their poster.)
- Wes: ... On your diagram here I really like how you made your answers [data] into colours and put it on [a graph], it really is easier [to read] now. ... Um, what's like the pattern in your data? [Jake: um. (thinking)] Like range, spread.
- Jonah: There. (Points at graph)
- Shane: Put some borders in between the – (he can't think of the word “clump”)
- Wes: And you've got it really nicely set out.

Shane: Yeah it's really nice, but put ... barriers where most of the data is ... because I can't see where it's bunched. (24:17, Classroom video 24 November 2014)

Wes and Shane provided the second group with feedback on how they could improve the presentation of their solution to the inquiry. Wes' language was tentative and respectful in telling the group that there wasn't enough detail to "know what you're talking about". The boys took the risk to challenge the detail shown by the second group, implying that it was a normal practice. Jake's jovial response suggested he did not find Wes' feedback as a personal criticism; and queried how his group could have missed such important information (how they calculated how long it took to read a book). The feedback given by Wes and Shane was non-trivial and genuinely provided the second group with ways to improve their final results. They also gave positive feedback on what the second group had done well, recognising the importance of both kinds of feedback. The students used terms they had learnt to describe distributions (range, spread, clump) and ways to show an interval to estimate the answer (borders or barriers around "where most of the data is" to show "where it's bunched").

These episodes showed one group's exchange as they worked independently to provide genuinely useful feedback to one another. We argue that this exchange provides evidence that the group was tacitly demonstrating a number of inquiry norms such as active listening, justifying and explaining to peers, sharing incomplete ideas, building on the ideas of others, and questioning and challenging ideas. There was no teacher present during this exchange, suggesting that these students were practicing these skills independently (a wireless mic was next to them with the researcher filming from several feet away; the students were used to her presence). We are not claiming that all students demonstrated this level of exchange, and clearly Emma's voice was absent from this particular exchange. However, nearly all groups were observed to be functioning in a similar fashion independently, with the teacher rotating between groups.

### *Term 1: How the Scaffolding Process Started*

The children did not arrive at the start of the year with fluency with these norms. In order to answer our research question, we return to the first term (March 2014). Given our focus on long-term scaffolding, we highlight the teacher's strategies to foster inquiry norms among the children. In an interview before the first lesson, Kaye explained her intentions for beginning to develop the classroom norms and practices.

I guess it is with classroom culture – it's got to be a model. It's got to be having ways, being creative in ways to ensure everyone is working collaboratively, that everyone is having their say, that everybody's opinions are feeling valued. ... Having those strategies when things are not working ... [means] you can come and specifically target those elements. (10:35, Interview 7 March 2014)

One strategy that Kaye used to develop classroom norms was to create posters that would help build a language around practices she was expecting. For example one laid out her expectations for quality "classroom talk" with roles for the listener ("Active listeners reflect on others' ideas"), speaker ("clear audible speakers") and group members ("active contributors"). Another poster reminded students that there was more than one way to solve a problem; everyone was expected to think; all ideas were valued; and ideas could be questioned or challenged respectfully. From these models, the teacher regularly acknowledged positive behaviours when she saw them. This simple act was intended to reinforce these behaviours as valued so that students would adopt them independently. In the following episode, Kaye Bluett explained to students what it meant to be an "Active Listener". She elaborated on the responsibilities of both the speaker and the listener from

the classroom posters. By providing them with language for their behaviours, “Active Listeners” could become part of the classroom discourse to articulate these expectations.

Mrs Bluett: When we have quality classroom talk in this room, it needs all of you to be *active listeners*. And I’m looking around the room and I’m seeing some really active listeners. They’re giving me that body language, they’re looking at me and you’re taking in what I’m saying. ... Now today I had two or three groups on the floor working brilliantly at classroom talk. So congratulations to those six people. In fact something Bill did, (to Bill) you might want to share with everybody, what did you and your partner do for classroom talk?

Bill: Sat beside each other, and um, gives you more of an idea of the story.

Mrs Bluett: Yes, so they were sharing. And ... instead of Bill sitting facing his partner, he and his partner actually sat side-by-side. ... So when Jonah was reading, Bill could hear what he was saying but he could also *see* what he was saying. So he was actively listening, he was giving himself every opportunity to question what Jonah was saying and [be] an active contributor. (0:41, Classroom video 12 March)

Using students as examples to reinforce what she valued was a regular occurrence in Mrs Bluett’s class. The teacher frequently used phrases such as “I like the way that students are...” as a way to scaffold the norms she was expecting. In doing so, she was diagnosing and responding to students in the moment. To further empower students towards an ownership of these behaviours (shifting them towards independence) she had the students themselves explain what they did. Once Bill told the class what he and Jonah were doing, Mrs Bluett re-expressed Bill’s words to develop and improve students’ language of the norms. Thus re-stating is another strategy for scaffolding by diagnosing and responding to students’ expressions of their behaviours. Her exemplification of Bill and Jonah went beyond their visible actions to highlight implications of these actions; it was not the specific actions she wanted students to copy, but the intentions of the actions.

Following this exchange, students moved into pairs to share their work on a problem posed to the class. Kaye felt that developing initial norms of working, speaking and listening collaboratively would be more effective with a series of problems that were shorter in duration and less open-ended. They were told to share their individual solution to their assigned partner and were expected to practice active listening. Most groups had difficulty; for example, groups sat face-to-face with students reporting “at” one another, but not listening. The teacher rotated between groups and stopped the class occasionally as they were working to remind them what they were to be doing and to include a mild level of accountability. Norms require long-term development with ongoing support; therefore, students initially needed to be reminded regularly of expectations.

In their first attempt, students demonstrated the challenges of developing “active listening”; their attempts did not yet try to make meaning of the speaker’s intent, as would be expected in an inquiry classroom. However, these initial attempts were important. First, they legitimised the practice of listening to peers, which is not typically a norm in mathematics classrooms. Second, they provided a starting point from which the teacher could diagnose and respond to their progress over time. As expected, norms do not develop quickly but require a concerted effort by the teacher throughout the year. The explicit nature of the teacher’s talk and her actions in Term 1 were important as students: were introduced to *what* norms were expected using explicit frameworks, discussed *how* they were to engage in norms through teacher modelling and co-construction, and *developed* these norms through practice and valuing by the teacher. These strategies, only some of which are mentioned here, did not end with the close of Term 1, however they sometimes became tacit as they moved from ideas into practices.

### Term 2: Intermediate phase of scaffolding inquiry norms

Developing norms in a classroom which practices mathematical inquiry takes a substantial commitment from the teacher to scaffold students (Yackel & Cobb, 1996). A focus was on giving students repeated experiences during the year to practice norms. Maintaining and developing norms is a different pedagogical skill than initiating them. Kaye now wanted students to begin to practise more advanced skills such as building on others' ideas and taking intellectual risks by sharing incomplete ideas, which require students to be already somewhat proficient at active listening. In one lesson, students were making sense of data each had generated about themselves about how far they lived from school. The teacher took the class outside to create a physical dot plot of their collective data. Kaye had a number of skills and concepts she hoped to develop in this lesson, including extending students' initial strategy of organising the data into two groups and further improving their inquiry norms. In the excerpt below, we focus on scaffolding Kaye used to promote her students to adopt talk around generating ideas. Students were seated in two groups organised by Chloe: students who live less than 5 km from school and students who live more than 5 km from school.

Mrs Bluett: What is the typical distance that students [in this class] live from school? If I look at the way that Chloe has organised our data can we answer that question now?

Chloe: Yes. (pause) Not exactly.

Mrs Bluett: If I ask people how far they live from school, what would I expect the answer to be from what we've just seen here? Jinny? (24:08, Classroom video 17 Jun 2014)

In an inquiry classroom, ideas are public rather than personally owned. Mrs Bluett acknowledged Chloe's contribution as a starting point and used the inquiry question to prompt students to challenge and/or build on Chloe's initial idea. Chloe herself then cast doubt on her idea. Rather than answer, Mrs. Bluett's sought others to respond.

Jinny: Maybe we should put the groups into 0.1 or 1 [km] sets. If we mix them altogether [in just two groups] it will be harder to organise.

Mrs Bluett: All right at the moment, can I say that students in [this class] typically live less than five kilometres from the school? [Jinny: No.] (To the class) Could I say that? (Mostly students initially respond yes, but then expressed some disagreement)

Chloe: Yes you could!

Mrs Bluett: ... *Why* could I say it? (25:31)

Jinny suggested that it may be better to organise them into smaller categories by tenths or whole kilometre distances rather than two large groups. The teacher rephrased the overarching question, prompting students to decide if the current arrangement in two groups would allow them to answer this question or if Jinny's suggestion should be considered. There was an expectation that students justify their answers, so rather than just acknowledge Jinny and Chloe's responses, she pushed the class to explain the reasoning.

Chris: Because there's more people in this [<5km] group.

Mrs Bluett: Because there's a whole lot of people here. ... So I *can* say students [in our class] typically live less than five kms from the school. But Jinny is saying that I can make my answer *better*. Jinny wants us to make the answer better by doing *what*? (26:06)

The teacher had created an environment where students were encouraged to think and reason without worrying whether their answer was correct or complete. This invitation to "think aloud" as ideas are formed can encourage students to take risks to share their incomplete ideas. By acknowledging that Chloe's idea was an improvement over unorganised data, Mrs Bluett affirmed that this did answer the question; but suggested that

an answer to the question was not enough. She returned to Jinny's contribution to model what it meant to build on others' ideas and pushed students to explain why Jinny's statement improved on the current solution of putting students into two groups.

Whole class discussions like this were not happenstance. Mrs Bluett explicitly worked to extend students' developing practices to become norms by (1) giving them opportunities in context to use the practices which they had adopted, such as active listening, explaining and justifying to peers and expecting there to be more than one way to do a problem; and (2) modelling, co-constructing and reinforcing what appeared to be more advanced practices, such as sharing incomplete ideas, respectfully challenging suggestions and building on the ideas of others, all of which required greater intellectual risk-taking.

The scaffolding the teacher undertook to move them forward required her to reflect on the progress they had made, then develop focused strategies to improve students' work. Kaye discussed this lesson in an interview at the end of the unit:

They all had how far they live from school and we were all in a big group, "Okay, how are we going to make sense of this data? ... [And then] somebody came up with, "We could split them into kilometre groups and we could go from 1 to 11." ... I need to see more of this risk-taking. I need to see more of sharing of ideas and then building and working it through. (5:02) ... [Next semester I plan] just pulling back a little bit, so that we can start letting them perhaps meet a few of the challenges and hit a few more walls. (12:25, Interview 27 June 2014)

In the interview, Kaye noted that students still needed work in intellectual risk-taking. She saw the need to elicit more independence from students in the inquiry by "pulling back a little bit", allowing them to "hit a few more walls".

### *Summary*

At the end of the year, Kaye reflected on the progress students had made in response to the scaffolding during the year.

The whole purpose of what we've been building on all year has been you know, taking kids right from that very first stage of having no real notion of what it means to talk with each other and through all the different inquiries we've been doing, to bring us to this. (0:14) ... That constant scaffold to try and, making sure that they're on the right page and to try and move forward. ... It doesn't matter what we're doing. ... I think it's just a culture that's developed (12:41, Interview 3 Dec 2014)

In order to build towards the independence observed in the excerpt at the beginning of the paper, there was a long road of explicit scaffolding undertaken by the teacher. Her commitment of a "constant scaffold" regardless of what they were doing (i.e., daily and across subject areas) was critical for developing mathematical inquiry norms in her classroom.

## Discussion

In this paper we addressed the question: *How can a teacher scaffold the development of norms and practices in mathematical inquiry over time?* In answer to this question we first illustrated students' inquiry practices and norms late in the year, and then analysed the scaffolding process from Term 1 onwards. In line with our view on scaffolding as entailing frequent diagnoses, responsive actions and gradual handover to independence, we focused our analysis on the teacher's diagnoses and intentions of how to respond to what she had observed. These strategies included the use of posters with expectations, frequent reminders of the norms, positive feedback, and many opportunities to enact practices.

The analysis suggests that the meaningful and long-term scaffolding process helped to foster the practices the teacher chose to develop. The teacher's scaffolding responded to

Yackel and Cobb's (1996) challenge of the taken-as-shared mechanics of norms: both *how* to respond and *when* it is appropriate to do so. Kaye Bluett's strategies were meaningful rather than formulaic in that it was not the strategies themselves, but the norms she chose to develop which was the focus of her energies. In term 1, for example, instead of telling students to engage in active listening, she aimed to persuade them of its utility by introducing the reasoning behind active listening and creating contexts in which active listening made sense. Students' successes were validated, which encouraged their adoption. Later in the year, students showed greater comfort with these practices which facilitated the introduction and development of more advanced norms. The time between the excerpts in term 1 and term 4 was nearly nine months, a non-trivial amount of time.

As a case study, our analysis is considered a proof of principle: It is possible to achieve this, and our results illustrate some key ingredients of this teacher's approach. However, case studies have limited generalisability. Working across a diversity of classrooms or on larger scale would therefore be an important topic for future research.

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