**Exploring the Nature of Teacher Questioning within Challenging Tasks for Inducing Conceptual Change**

Tierney Kennedy

Kennedy Press

tierney@kennedypress.com.au

**Abstract**

Recent research has considered how to support teachers using challenging tasks in mathematics with students who struggle. Teacher questioning in response to correct or incorrect answers has been identified as an important element for maintaining the cognitive load. This paper examines the nature of teacher questioning within challenging tasks in which struggling students were noted to change their own conceptions and proposes a minor change to include a questioning phase within the Launch-Explore-Summarise structure by Lappan et al. (2006). It presents evidence from a two-year study in which the combination of conceptual change questioning with challenging tasks led to substantial gains for low-performing students across six primary schools on standardised tests compared with Education Department expectations (*d* = 0.7).

**Introduction**

Grappling with challenging tasks supports conceptual thinking and making connections in mathematics, thus producing strong overall learning gains in student mathematics learning (Boaler & Staples, 2008; Stein & Lane, 1996). However, research literature regarding the use of challenging tasks with low-performing students indicates a strong tendency for teachers to reduce the cognitive demand in tasks when they perceive that students may struggle (Stein & Lane, 1996; Sullivan et al., 2006). Recent research projects examining the role of enabling prompts in supporting teachers to maintain cognitive load have made considerable inroads into addressing this difficulty (Sullivan et al., 2006; Sullivan et al., 2013), however teachers still express concerns with regards to addressing students’ misconceptions and alternative conceptions that are exposed by challenging tasks (Son & Kim, 2015).

Teacher questioning in response to correct or incorrect answers has been identified as a significant factor for engaging students in challenging tasks (Boaler & Staples, 2008). Juxtaposition of teacher questioning with discrepant events (Swan, 2001) has been suggested as an appropriate method for addressing alternative conceptions and instigating conceptual change within challenging tasks (Kennedy, 2015; Kennedy, 2018). Previous research by Kennedy (2015), linked the Launch-Explore-Summarise (LES) structure for challenging mathematics tasks (Lappan et al., 2006) with Protocol for Conceptual Change Discussion (PCCD) in science (Erilymaz, 2002), and considered the use of conceptual change questioning within the Explore phase of challenging tasks.

This paper further examines the nature of the questioning used within Kennedy’s 2015 study and proposes a model for its inclusion within the LES lesson structure model (Lappan et al., 2006) based on the results of a two-year study (Kennedy, 2018) which showed substantial student gains on standardised testing (see *Figure 1* in Background to Previous Studies). It is underpinned by assumptions that for learning to be effective, students need to think deeply, connect ideas and be challenged (Boaler & Staples, 2008); and that when new information conflicts with learners’ existing conceptual understanding, it is either rejected outright or accommodated by changing the underlying conceptions (Posner et al., 1982; Resnick, 1983).

**Theoretical Model**

The LES structure designed by Lappan et al. (2006) for using challenging tasks within mathematics lessons shares several structural similarities with the PCCD structure developed by Erilymaz (2002) for use in science lessons to expose and challenge alternative conceptions (Kennedy, 2015). In examining both structures, the following similarities were identified (Kennedy, 2015):

Launch phase

Both approaches launch with the posing of a challenging problem. Within the PCCD model teachers use challenging problems to identify students’ alternative conceptions. This identification, termed ‘exposure’ by Erilymaz (2002), involves predicting results prior to conducting scientific experiments.

Explore phase

The explore phase from the LES structure involves student experimentation and grappling with the challenging task (Lappan et al., 2006). Extending prompts may be provided if the challenge is not high enough, and enabling prompts provide support when students struggle while maintaining the cognitive load (Sullivan et al., 2006; Sullivan et al., 2014). The explore phase, while mirrored in the PCCD structure, includes an additional focus on experimentation to create discrepant events and provoke cognitive conflict (Erilymaz, 2002; Kennedy, 2015). Teacher questioning draws student attention to the discrepancy between prediction and outcomes of the experiment, encouraging students to grapple with the inconsistencies observed (Erilymaz, 2002; Swan, 2001). At a definable point during this discussion cognitive conflict reaches disequilibrium (Resnick, 1983), whereby students reject their initial predictions and accommodate the new information, leading to conceptual change (Posner et al., 1982).

Summarise phase

Both the LES and PCCD approaches also draw on student discussion, with a plenary summarising phase led by the teacher that draws together different student ideas and formalises knowledge (Lappan et al., 2006; Kennedy, 2015). Erilymaz (2002) and Sullivan et al. (2014) shared similar findings in that students were encouraged to connect different aspects together and explore pathways to generate solutions.

**Background to Previous Studies**

Using the combined LES and PCCD structures, Kennedy (2015) examined 20 video-recorded and transcribed incidents in which students were observed to change their own conceptions during challenging tasks across eight mathematics lessons. Of particular note to this paper were findings that, “as a student’s alternative conception was identified, the questions became more pointed, exposing the disparity between prediction and observation… Successive questions formed sequences which appeared to narrow the available options and produce a logical process by which a student’s idea could be evaluated.” (p.77).

Figure 1 Additional months growth by lowest 20% of students on PAT M testing (Source: Kennedy, 2018)

This research led to the development of a two-year project to evaluate the effectiveness of combining challenging tasks with conceptual change questioning on the mathematics gains for low-performing students across six South Australian primary schools (Kennedy, 2018), for one lesson each week. Data analysis of student results on Progressive Achievement Tests developed by the Australian Council for Educational Research (PAT M), including paired student t-tests, produced a large mean effect size of *d*=0.7 (Cohen, 1988) over and above the baseline expectations for two years of growth published by the Education Department (DECD, 2016), across all experimental groups, consistent for each year of the study (Kennedy, 2018). Applying the time-indexed approach to effect size for mathematics interventions developed by Lee et al. (2012), data pooled across both years of the study showed an additional gain of 27 months for years 3-5 students above the two-year Education Department expectations, and an additional gain of 29 months for years 4-6 students (Kennedy, 2018) – see *Figure 1*.

**Methodology**

As discussed in a previous study (Kennedy, 2015), eight mathematics lessons in which the researcher used the LES structure to pose and explore challenging problems with students in each of the grades from prep to year seven were recorded using three video cameras and four microphones. 20 incidents, all lasting between three and eight minutes were selected in which conceptual change was noted to occur (Kennedy, 2015). For the purpose of the current study, one incident from year four (4m 7sec) was selected for further analysis, transcribed, and coded line-by-line using a social constructivist approach to Grounded Theory outlined by Charmaz (2008) to identify themes.

Results and Discussion

The incident selected involved a year four student determining whether rearranging two sets of two identical right-angled triangles made the resultant shapes bigger, smaller or congruent in area. During this incident the teacher posed 45 questions (including questions implied non-verbally). The following themes emerged from coding both the verbal and non-verbal questions posed:

1. Asking student to *judge* between a few options without further explanation: “Which is bigger now?” (24 questions - five verbal and 19 implied non-verbally), usually following a minor change in the orientation of the congruent triangles. Each time the question was posed the student responded by either choosing one shape (19 times: 12 of these responses were made with surety and seven without surety or with cognitive conflict), or by stating that they were the same size (Five times: three with surety and two without surety or with cognitive conflict). An explanation as to why the student selected one shape over the other was not required, simply a judgement.
2. Repeating the *student’s statement back as a question* for clarification or to encourage further explanation (11 questions). 10 times the teacher repeated back the student’s exact statement but as a question, and once the teacher varied the wording in the original statement slightly and asked it as a question. For example, at 17 seconds, the following interaction took place following a *judgement* question:

Student, “Then the triangle – the triangle is always bigger than the rectangle.” Teacher, “The triangle is always bigger than the rectangle?”

This approach appeared to encourage the student to clarify or explain further.

1. Reflecting on the *nature of the change* (7 questions, all asked at the point of disequilibrium). “Am I changing the size?” was asked four times, then led to “Am I changing the amount of paper?” which was asked three times once the student showed signs of cognitive conflict.
2. Two *leading* questions were asked in succession once the student had shown evidence of cognitive conflict: “How much paper is there?” and “Does it matter how I arrange the paper – does that change the amount of paper?”. One more Leading question was asked at the point of disequilibrium and appeared to lead directly to accommodation, “Which one looks bigger? Which one is actually bigger?”

When examining the interaction between the teacher’s questions and the student’s responses, three interesting findings emerged. Firstly, the teacher continued to use discrepant events and questioning requiring a *judgement* even after the student had correctly answered, “They’re the same size”. While noting the “correct” answer, the teacher also noted that both sets of triangles had been arranged to form the same shape, so changed the orientation of one set of triangles and repeated the *judgement* question. When the orientation changed, the student reverted from this “correct” answer to decide that the triangle was larger than the rectangle. This finding implies that a correct answer is not a reliable indication of conceptual change. It also underpins the importance of the second finding, that the teacher did not provide a qualification to the student’s answers for any *judgement* questions prior to disequilibrium. Instead, the teacher *repeated the student’s own statement back as a question* and invited further thinking with discrepant events. It was only after disequilibrium had been achieved and questions that caused the student to reflect on the *nature of the change* had been asked, that the teacher responded with a qualification and *leading question*: “I agree, it looks different. Which one looks bigger? Which one is actually bigger?” By delaying making a qualification on the student’s judgement, the teacher appeared to encourage the student to continue thinking, thereby maintaining the cognitive load of the challenging task.

The final finding is in relation to the timing and nature of the questioning phase within the LES structure. In all eight lessons examined, an initial phase of conceptual change questioning took place as soon as students had made their first conjecture or guess at the challenging problem, prior to deeper exploration. This questioning phase, lasting between three and eight minutes, took place between the Launch and Explore phases of the LES structure and included all students from the class, whether their initial responses to the challenging task had been correct or incorrect. Following this phase, students elected to either:

1. Return to explore the problem including changing their initial answer
2. Remain with the teacher if they thought their initial answer was correct (this group included students who required extending prompts as well as students who had not understood that their answers were incorrect)

Students with correct answers were asked to prove that their ideas worked and were also provided with extending prompts to use once the proof was completed. For these students, the short conceptual change questioning phase appeared to act as a foil which enabled them to identify why their own answers were correct. A future paper is planned which shares the results of this approach on standardised testing data for the highest 20% of students in the second year of the two-year project reported on by Kennedy (2018). For the second group of students who remained with the teacher, Enabling Prompts and further questioning were provided to encourage exploration and conceptual change.

**Conclusion**

Teacher questioning in response to both correct and incorrect answers appears to play an important role in maintaining the cognitive load in challenging tasks. In examining eight video-taped lessons on challenging tasks based on the LES structure in which conceptual change was noted to occur, a defined phase of conceptual change questioning lasting between three and eight minutes, was observed to take place between the Launch and Explore phases. When examining one questioning incident in detail, clear themes of asking the student to make a *judgement*, *repeating back the student’s statement as a question*, and reflecting on the *nature of the* *changes* made emerged. Further examination revealed that teacher questioning continued in response to both correct and incorrect answers by the student, and that the teacher did not provide a qualifying statement or use *leading questions* until after disequilibrium was observed. Further research is recommended to determine whether the patterns observed in teacher questioning from this study can be generalised.

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