Teacher Knowledge and Classroom Practice: Examining the Connection

Michael Gilbert and Barbara Gilbert

This paper extends existing research regarding content knowledge for teaching (CKT) and the role it plays in advancing student learning. Two teachers, with high and low measured CKT respectively, are observed on the same day teaching similar content. Many studies have recently been published linking student achievement to teacher's CKT and many US schools have begun including CKT measures in teacher hiring and retention decisions. Teaching observed for this study illustrates that content can be taught effectively by teachers across the spectrum of CKT levels, but observable and significant differences in teaching leads to important questions for in-service and pre-service teacher educators.

Keywords: Classroom practice; Content knowledge for teaching; Teacher effectiveness; Teacher learning

Conocimiento del profesor y práctica en el aula: estudio de su conexión

Este artículo amplía la investigación existente sobre el conocimiento del contenido para la enseñanza (CKT) y su papel en el progreso del aprendizaje del alumno. Dos profesores, con medidas altas y bajas de CKT respectivamente, fueron observados el mismo día enseñando contenidos similares. Numerosos estudios publicados recientemente relacionan el logro de los estudiantes con el CKT del profesor y muchos colegios estadounidenses han empezado a considerar medidas de CKT en la toma de decisiones para la contratación y permanencia de profesores. La enseñanza observada en este estudio muestra que el contenido puede ser enseñado efectivamente por profesores con niveles distintos de CKT. No obstante, se observan diferencias significativas en la enseñanza que conducen a cuestiones importantes para formadores de profesores en formación y en ejercicio.

Términos clave: Aprendizaje del profesor; Conocimiento del contenido para la enseñanza; Efectividad del profesor; Práctica en el aula

Gilbert, M., & Gilbert, B. (2013). Teacher knowledge and classroom practice: Examining the connection. *PNA*, *7*(2), 51-61.

The single greatest factor determining student achievement is the quality of the teaching National Comprehensive Centre for Teaching Quality (n.d.). This paper extends current research about teacher effectiveness into content knowledge for teaching and the role it plays in advancing student learning. Specifically, we examine the connections that exist between teacher's CKT and classroom practice. The research reported here was part of a larger case study of participants in a National Science Foundation project that investigates feasible models of implementing formative assessment in mathematics.

The paper researches and extends the construct of CKT, the mathematical knowledge and skill unique to teaching (Ball, Thames, & Phelps, 2008). This construct is based on the understanding that, just as many professions require effective practitioners to possess skills that are distinctive to their work, effective teaching requires not only a deep understanding of mathematical procedures and concepts, but also of the learning trajectories and emerging knowledge of students in schools. Mathematics teachers use CKT to identify how mathematical tasks relate to and build upon one another, recognize salient features of tasks, and include understanding how a shift of features of a task can aid (or hinder) the development of additional ideas, concepts, or procedures. We seek to further our understanding of the way that teachers' CKT influences teaching practice and resulting ability to teach effectively.

Conceptual Framework

It is generally accepted that mathematics teachers' effectiveness is influenced by the mathematical knowledge they possess. For example, when teachers differentiate problems to challenge and/or provide additional scaffolds for students, their understanding of mathematics allows them to: (a) listen to students' explanations of unconventional solution strategies and quickly determine whether or not they are likely to lead to generalizable approaches, (b) press student thinking through appropriate questioning, and (c) create or select formative and summative assessment problems that are mathematically appropriate for the class.

Over the past two decades, research studies suggest that while individuals with bachelor's degrees in mathematics may have a specific kind of knowledge, they often lack what Ma (1999) described as a profound understanding of fundamental mathematics, that is, a deep understanding of basic mathematical ideas. And yet, a major factor in increased student achievement is a knowledgeable, skillful teacher (National Commission on Teaching and America's Future, 1996). In fact, Darling-Hammond and Ball (1998) conclude that teacher quality accounts for 40% of the variation in student achievement. Knowing how to respond appropriately to students' questions and develop the ability to choose or create questions and problems targeting specific mathematical concepts is at the centre of the content knowledge needed for teaching (Ball, 2003). Studies involving teachers of elementary students have found that improving their mathematical knowledge for teaching significantly affects students' learning of mathematics (e.g., Hill, Rowan, & Ball, 2005). At question is how best to conceptualize and implement appropriate components of mathematics content, pedagogy, and other aspects of teaching to pre and in-service teacher education.

METHODOLOGY

This study is a comparative case study of two teacher participants in a professional development project. The project included 32 teachers from 15 schools in a Pacific coastal district. Both of the teachers reported on in this study taught in the same school. Overall, the project teachers participated in five days of full-cohort professional development in June, 2008 and four days in June, 2009; five half-day follow up sessions during the 2008-2009 and 2009-2010 school years; and at least three coaching visits per year from project staff.

Data collection included the University of Michigan's Learning Mathematics for Teaching (LMT) instrument to measure any change in participants' CKT. This test was administered at the beginning of the summer institute in Year 1, after one year of participation, and again at the end of the project. The content strands of this test include items intended to assess teacher's fluency with determining and interpreting patterns, functions, expressions, equations, and representations. The instrument consisted of 29 responses in the form of multiple-choice questions. Project-created student pre and post-tests were administered to all of the participating teachers' students in September and May of both years. Analysis of the second year's student data has not been completed and is not included in this analysis.

The two teachers involved in this case study, Elina and Keoni, were chosen because, although they worked closely together (they both taught Grade 7 and met daily to plan their lessons), they represented the upper and lower quartiles of scores on the LMT. Both Elina and Keoni were observed a total of five times each year over a two-year period. Their pre-service coursework was similar, and completed at the state university. They are both relatively new teachers, with five and three years of teaching experience; and, on the teacher pre-survey, they both reported a high level of satisfaction with their ability to work with technology.

Two researchers conducted each observation, with one person charged with following the progress of the discussion and tracking the questions asked by the teacher and the students, the number of teacher/student and student/student interchanges, and the mathematical content of the interchanges. The other researcher tracked the mathematical trajectory of the class. Immediately following each observation, the two researchers met to debrief, compare notes, and create a single document to authenticate the pedagogical and mathematical path of each lesson. Interactions were classified as teacher-generated or student-generated. Questions which elicited a limited set of specific and correct answers were categorized separately from questions that led to discussion of underlying mathematical concepts. Questions were also categorized by direction (teacher to student, student to teacher, or student to student).

RESULTS

The LMT scores are shown in Table 1. The test was administered three times. The same form was given at the beginning of the project and again after one year of participation. A post-test was given at the end of the project.

Table 1
LMT Scores

Student	Pre-test 1 June 2008	IRT scale score	Pre-test 2 May 2009	IRT scale score	Post-test May 2010	IRT scale score
Elina	76%	0.381756	83%	0.723952	93%	1.517683
Keoni	48%	-0.73437	48%	-0.73437	74%	0.348509
Project totals	70%		78%		78%	

We recognize the limitations of reporting percentage scores for individuals and the small number of participants in this study. The figures are reported only for purposes of comparison within the data set. Keoni's score was unchanged on the second test, although he did change eight answers on the second test iteration. Elina's score increased with each test, and she had among the highest scores for each test.

The importance of the growth in both of their scores is seen as a predictor of student achievement. For each one point gain on all project teacher's post-test scores in Year 1, their students achieved 0.448 higher points on the student post-test after accounting for the influence from the other teacher variables (Olson, Im, Slovin, Olson, Gilbert, Brandon, et al., 2010). The results of the student test are shown in Table 2.

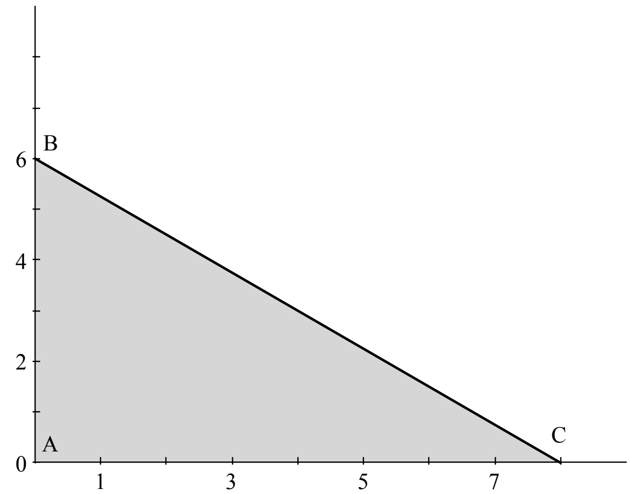
Table 2
Student pre and post Test Results

Student	Average number of correct responses Fall 2008	Average number of correct responses Spring 2009	Difference post-pre
Elina	13.9	19.2	5.3
Keoni	14.2	16.7	2.5
Project total	14.0	16.0	2.0

These student scores are from the first study year, the year in which Keoni's CKT score did not change. The data show that the increase in the number of correct responses in both cases is above the project average. In particular, Elina's students averaged a gain of over five correct answers on the post-test (among the greatest improvement of all participant teachers), although Keoni, with one of the lower scores on the first two test administrations, also showed improvement. We were curious to investigate the circumstances behind the fact that, in spite of low CKT, Keoni was an effective teacher who improved student learning. This motivated us to carefully review our observations of Elina and Keoni.

The case study findings reported here are from two observations (one each for Elina and Keoni) done on a single day late in the fall of the second year. The observation from this day was very representative of all of our observations of them, and the results we report could easily have come from other observations. An additional statistic that should be reported is the number of mathematical errors made while teaching (an error was coded as a mathematically incorrect statement made to the class). Overall, Keoni coded an average of 2.6 mathematical errors per class, while Elina made 1.4 errors. As was their usual schedule, Elina and Keoni had met daily during their planning time to jointly discuss and plan instruction. We will restrict our discussion to the explication of one activity for each teacher. In Elina's case we will examine the focus problem she did at the beginning of the class. With Keoni, we will look at the discussion of a homework problem from the previous day that was reviewed in class.

Elina's teaching style is to move through classroom work very quickly. Students have to attend very carefully to keep up. There is no "catch up" time built into her class. If students fall behind at any point, they may miss critical information. In this class, the focus problem asked students to find the true statement about ΔXYZ from a list that related to ΔABC (Figure 1). The scale factor from ΔABC to ΔXYZ is given as 4.



1. The area of ΔABC is 16 times the area of ΔXYZ
2. The area of ΔABC is $1/4$ the area of ΔXYZ
3. The area of ΔABC is 4 times the area of ΔXYZ
4. The area of ΔABC is $1/16$ the area of ΔXYZ

Figure 1. Triangle ABC

Elina begins the activity by displaying the task using the document camera. She is very comfortable using technology to project student responses for all to see. The text says "Using the following similar figures identify the true statements. Hint: Find the areas of both triangles". She wants the students to input answers on their calculators and send them to her. In the following transcripts, E represents Elina and Si represents the students.

1 *E:* Send me the area of triangle ABC. She counts down 10, 9, 8… Send.

2 *E:* Send me the area for triangle XYZ. Counts down from 10… Send.

3 *E:* Last question… Send me the numbers of the questions that you thought were true. [students appear a bit confused.] Send me the ones that you thought were true. 10, 9, 8… Send.

4 [After looking at the submitted responses (she has not displayed them on the screen for the rest of the class), Elina recognizes that many students are confused.]

5 Can somebody remind us how to find the area of a triangle?

6 *S1:* Base times height.

7 *E:* One half base times height… [Pauses] Does $1/2$ make a big difference?

8 *S2:* Yes.

9 [Elina now shows the student responses for the area of triangle ABC. 11 out of 19 responses show 24, the correct answer.]

10 [Looking at the screen, Elina notes that there are 3 responses of 48.]

11	*E:*	What did these 3 people forget to do? [pointing at 48]
12	*S3:*	Divide.
13	*E:*	Some people forgot to divide by two.
14	*E:*	Let's take a look at this one… 11. Five responses of 11. How many of you just added? [No one responds]…
15	*E:*	That's something we may have to review… huh?… the area of triangles.
16	*E:*	On #1, is ABC being multiplied by 4? [Several student respond with "no".]
17		[Elina works through the solution aloud and determines that it is true.]
18	*E:*	What is this question asking? #1, which stated that the area was 16 times larger.
19	*S2:*	You can fit 16 ABC triangles into XYZ.
20	*E:*	No, but close. [This is true, but not what the question asked. Elina did not clarify this point.]
21	*S4:*	ABC is bigger than XYZ. [This is not true.]
22	*E:*	Is this true or false? [Several students say "false".]

In Keoni's class, there was very little full class discussion and his primary teaching method was to provide instructions to the full group, circulate between individual tables, and answer student questions. The task for the day involved scaling a rectangle on a grid by a scale factor of $1/4$. The rectangle is shown in Figure 2.

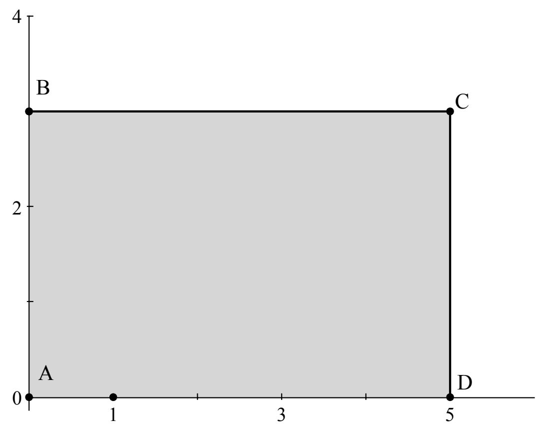


Figure 2. Rectangle ABCD

As Keoni begins the activity, he goes over the instructions. He tells them that they will need to answer numbers 1 and 2 before they can answer the rest of the questions. He carefully tells students that for some of them this is a review of how to draw the figures on a grid, but that because some students don't know how to do this, they will revisit how to draw the figure. Keoni is giving students very detailed instructions about how they are to proceed. The first instruction asked the students to plot the points. The second asked students to dilate the original figure by $1/4$ using the point A as the origin. The rest of the worksheet asked the students to describe what needed to be done to perform the dilation. Students are required to get Keoni's approval for the first portion of the task before they can move on to the next step. He sets a timer for 10 minutes and tells students to draw the figures. As Keoni goes around the room and checks students' answers, he asks a couple of students if they mind moving to other tables to share their process and thinking with other students.

When the timer rings, most of the students are still struggling to identify the points on the grid. Keoni goes to each table and makes sure that they are able to draw the figure correctly before he allows them to proceed to the next step. As he has students check their points, they catch that several individuals have mislabeled the figures. Once they correct their labels, Keoni lets them check off that problem.

Next, he asks the class if dividing by $1/4$ is the same as multiplying by 0.25. Several students say "yes". Keoni gives students 20 minutes to do the rest of the questions. After three minutes, he stops the work and tells the class that everyone is having some difficulties and they're going to go over the problem step-by-step: "What I'm noticing is that you're not working as a team. We need to figure out how we can work this out together so that we can figure it out as a team … together."

After Keoni says this, two girls who had correctly solved the problem get up from their seats and go to the other side of the table to help their table partners find the solution. Several students at another table also begin helping a table partner who is struggling. Keoni allows students "an extension of the time", telling the class that they should "figure out what your teammates need to catch up to you and answer the remainder of the questions". Two girls at a front table are persistent in their effort to help a girl who is clearly struggling. Several groups had huddled together and are working on the problem. Students actively respond to Keoni's call to work together and are engaged in finding a solution.

Discussion

The difference between the two classrooms is striking. Elina was relentlessly efficient. She had very specific classroom procedures and rules that she expected students to follow without deviation. Several times she told students, "Let's not waste time… yeah?" As seen in Lines 1 and 2 above, she followed many tasks with a countdown from 10 to keep the class moving forward. Her style in responding to incorrect student answers was similarly direct (see Line 7). Her instruction followed a characteristic pattern, in which she quickly reviewed responses, comments or made corrections, and then moved on. Although she constantly asked questions and listened to student feedback, it was clear that

Elina was the focal point of this classroom. This is clearly seen in Lines 19-21, and although the student's response was accurate, Elina chose to keep students focused on the side lengths being multiplied by 4.

Elina's interactions with individual students tended to be brief and to the point. Her CKT was evident in both her interactions with students and with the mathematics. Questions were largely funnelling (Wood, 1998), and seemed intended to move students in a set direction. She did not need to mask her understanding of the content by making broad, general statements. Rather, her comments were driven by a predetermined solution strategy. While Elina maintained a strict focus, students did feel comfortable teasing her (the boys in particular).

Keoni was also quite intentional about each step in the process of instruction, but his focus was more on the social nature of the learning community. He consistently reminded students that they had a responsibility to their groups. Keoni reinforced a culturally appropriate community dynamic. In contrast to Elina, Keoni often gave students an extension of time so that they might complete their work. His major press was to create a collaborative community of students engaged in the mathematics. Unfortunately, Keoni's lack of appropriate CKT allowed many students to leave the classroom unsure of how to solve this particular problem. To understand the difference between relative change (multiplicative) and absolute change (additive) is a major source of misunderstanding for students when scaling. This activity led students to think additively and will likely cause them to have misconceptions later. Keoni was unable to resolve this situation. Also, several times when discussing the scaling activity he referred to sides as congruent, not corresponding, a major mistake that might also lead to later confusion for the students.

Conclusion

The challenge for this study is to derive conclusions from two dimensions of data, CKT and pedagogical practice, which seriously compound traditional comparison methods. Although CKT has been qualified as a valid predictor of teaching effectiveness and student achievement, there remain other factors that also positively influence teaching effectiveness. In this study, Elina's CKT was measurably greater, as was her student's achievement. But higher student scores may also be the result of Elina's pedagogical style, which was demonstrably different from Keoni's. Conversely, the classroom environment developed in Keoni's class did result in student learning, in spite of a lack of specific mathematical direction and a greater number of mathematical mistakes.

This preliminary study was undertaken to investigate an interesting discrepant case, and to define parameters for future research. Recognizing CKT is closely linked to classroom practice: How do we increase the CKT of in-service teachers with relatively high effectiveness but low content knowledge? Further, since pre-service teacher course work largely concentrates on pedagogy with limited CKT focus, we continue to question what might be done to improve CKT of pre-service teachers. We posit that improvements for pre-service and in-service teacher education lie in our ability to understand (a) how CKT is supported by pedagogical practices, (b) how pedagogy can advance CKT, and (c) possible connections that will result in more effective practice. We believe that future research should study more than teacher content knowledge or pedagogical practice in isolation. Without attempting to mandate a course of study and practice that devalues either CKT or supportive pedagogy, our continued challenge is to learn enough about the intersection of CKT and pedagogical practice to support teacher learning from both perspectives.

REFERENCES

Ball, D. L. (2003). What mathematics knowledge is needed for teaching mathematics? *Secretary's Mathematics Summit*. Washington, DC. Retrieved February 15, 2008 from http://www.ed.gov/rschstat/research/progs/mathscience/ball.html.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389-407.

Darling-Hammond, L., & Ball, D. L. (1998). *Teaching for high standards: what policymakers need to know and be able to do.* Philadelphia, PA: Consortium for Policy Research in Education.

Hill, H., Rowan, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, *42*(2), 371-407.

Ma, L. (1999). *Knowing and teaching elementary mathematics.* Hillsdale, MI: Lawrence Erlbaum Associates.

National Commission on Teaching and America's Future. (1996). *What matters most: Teaching for America's future*. New York, NY: Author.

National Comprehensive Centre for Teaching Quality. (n.d.). Retrieved from http://www.tqsource.org/about.php.

Olson, J., Im, S., Slovin, H., Olson, M., Gilbert, M., Brandon, P., et al. (2010). Effects of two different models of professional development on students' understanding of algebraic concepts. In P. Brosnan, D. B. Erchick, & L. Flevare (Eds.), *Proceedings of the 32nd Annual Conference of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 1479-1487). Columbus, OH: The Ohio State University.

Wood, T. (1998). Alternative patterns of communication in mathematics classes: Funneling or focusing? In B. Steinbring & A. Sierpinska (Eds.), *Language and communication in the mathematics classroom* (pp. 167-178). Reston, VA: National Council of Teachers of Mathematics.

This document was originally published as Gilbert, M., & Gilbert, B. (2011). Examining the connection between teacher content knowledge and classroom practice. In B. Ubuz (Ed.), *Proceedings of the 35th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 417-424). Ankara, Turkey: PME.

Michael Gilbert
University of Massachusetts
Mike.Gilbert@umb.edu

Barbara Gilbert
Harvard University
barbara_gilbert@gse.harvard.edu

Recibido: enero de 2012. Aceptado: marzo de 2012
Handle: http://hdl.handle.net/10481/22366