Mathematics Education Research Journal 2006, Vol. 18, No. 2, 11-26

Applying the Rasch Rating Scale Model to Gain Insights into Students' Conceptualisation of Quality Mathematics Instruction

Kelly Bradley, Shannon Sampson and Kenneth Royal
University of Kentucky

Teacher quality has become a national policy concern in the US, especially in mathematics. This study provides insights into the conceptualisation of high quality mathematics teaching from the perspective of approximately 750 students in grades nine through twelve. Results from Rasch analysis yield information about the quality of the *Mathematics Quality Survey* constructed for this study and the hierarchy of items representing varying levels of quality as perceived by the students. Group interviews with teachers and open-ended responses from students are used to support the findings. This study lays the groundwork for understanding the difference between being qualified and being a quality teacher.

Teacher quality has become a policy concern internationally. Researchers (e.g., Brown, 2002) have argued that "teacher quality is emerging as the most important ingredient in students' achievement" (p. 4). Before teacher quality can be assessed or evaluated, it must be operationalised. Arguably, the process should begin with those who know the classroom best – the teachers and the students. This year-long study of mathematics education was undertaken at a south eastern, United States public high school (grades 9 – 12). It emphasised the importance of the affective domain: specifically, what characteristics and qualities students associate with quality mathematics instruction. After all "students and their learning should become the focus of everything we do … from the instruction that we provide, to the intellectual climate that we create, to the policy decisions that we make" (Cross, 1998, cited in Frye, 2005, sec. 2, para. 1).

Surveys are the most common method of collecting self-reported data and continue to be one of the most popular research methodologies for graduate studies and published papers in education (Babbie, 1992; Gay, 1981; Nardi, 2006). Even so, within the field of education, the development of instruments to assess affective domain constructs has been problematic (Aiken, 1996). Bond and Fox (2001) write,

> Operationalizing and then measuring variables are two of the necessary first steps in the empirical research process. Statistical analysis, as a tool for investigating relations among the measures, then follows. Thus, interpretation of analyses can only be as good as the quality of the measures (p. xvi).

Quality of the measurement tool—here a survey instrument—should play a fundamental role in the analysis of the data it produces; however, this element is often overlooked. This study addresses that concern through the use of a Rasch rating scale model to operationalise quality mathematics

instruction as perceived by students. It thereby demonstrates a practical application of an emerging methodological tool.

Defining and Measuring 'Quality'

The literature repeatedly mentions 'quality' as it relates to teachers and teaching. Unfortunately, quality is a vague term that often means different things to different people. Much of the literature identifies characteristics and attributes of individuals as synonymous with quality teachers and teaching (e.g., Chambers, 1987; Evertson, Emmer, & Brophy, 1980; McKinney, 1987; Sullivan & Mousley, 1994). Bishop, Hart, Lerman, and Nunes (1993) warn "there is the danger that an analysis of the actions that identify an effective teacher can become merely a list of desirable attributes" (p. 66). To state it another way, quality teaching is sometimes confused with a checklist of characteristics. Other definitions of quality teaching range from "what should be taught and how knowledge should be imparted to the kinds of knowledge and training teachers should possess [e.g. Leinhardt, 1989; Westerman, 1991]" (Lewis et al., 1999, p. 1). Lewis et al. (1999) and Stoldosky (1996) contend that the notion of teacher quality is so complex there is little consensus on what teacher quality is and/or how to measure it.

Still, other researchers and organisations have attempted to define quality teaching and what constitutes a quality teacher. The literature consistently cites teaching practices, teacher preparation and teacher qualifications as key concepts. In the United States, the *No Child Left Behind* (NCLB) legislation seems to equate quality with qualifications, requiring that teachers be "highly qualified." This is defined as those who possess full certification, including a bachelor's degree, and demonstrated knowledge in all subjects taught (Smith, Desimone, & Ueno, 2005). Lewis et al. (1999) also define quality mostly by reference to teacher preparation and qualifications. Others (e.g., Carnegie Forum on Education and the Economy, 1986; Holmes Group, 1986; National Commission on Teaching and America's Future [NCTAF], 1996) have found teachers' professional preparation to be critical to improving elementary and secondary education. Oakes, Franke, Quartz, and Rogers (2002), specifically interested in teacher quality in an urban context, argue quality teachers are both "skilled classroom practitioners" and "public intellectuals who work for educational equity and access through multiple forms of democratic participation" (p. 229).

The Australian Association of Mathematics Teachers (AAMT) has identified three domains for quality: (a) professional knowledge, (b) professional attributes, and (c) professional practice (AAMT Standards, 2002). Professional knowledge includes vast, general knowledge for use in professional work. Professional attributes include enthusiasm and commitment to various communities with continual desire for improvement, both personally and for students. Professional practice consists of intentional techniques that lead to positive learning outcomes for students. These domains provide a relevant and useful framework for conceptualising a quality teacher.

There is a great deal of overlap between the aforementioned definitions. Each provides insights as to what a teacher should aspire, both personally and professionally, and what a teacher should be both intrinsically and extrinsically. It is within this framework that the researchers investigated quality as it relates to teachers and teaching.

Measuring 'quality' is perhaps as wide-open a task as defining it. Lewis et al. (1999) suggest there are four types of approaches to measuring teacher quality: (a) classroom observations of teacher practices; (b) written examinations intended to measure teacher content knowledge, literacy and pedagogy; (c) student scores as performance measures; and (d) surveys of teachers' attitudes, perceptions, practices, and qualifications. Simon (2004) notes most research in this field consists of qualitative methodologies. According to Xin, Xu, and Tatsuoka (2004), a number of the quantitative studies pertaining to teacher quality face problems with measurement.

Content Knowledge and Pedagogy

The literature consistently presents content knowledge as critical to quality teaching. In studies with high achieving students in challenging mathematics courses, research suggests the teacher's content knowledge is a major factor (Ma, 1999; The Education Trust, 1998). Olson (2000) found "students whose teachers know their subjects perform better than students whose teachers lack subject-matter preparation" (p. 5). Numerous studies have corroborated the importance of content knowledge (Eisenhart et al., 1993; Johnson, 1995; Lee, Meadows, & Lee, 2003; Liekin & Winicki-Landman, 2001; Manouchehri, 1998; Manouchehri & Goodman, 1998.)

Lappan (2000) stresses content knowledge is not simply knowing one's academic discipline. In her research, she identified 12 domains of knowledge and experience that are essential for good teaching and teacher education programs. She argues: "It is not just the amount of engagement with content that matters. [It is also] the quality of the experience, the ways in which teachers know what they know, [that] matter" (p. 323). She goes on to say teachers must develop a sense of self efficacy (both a sense of self-worth and success) because research (e.g., Ashton & Webb, 1986; Woolfolk, Rosoff, & Hoy, 1990) has shown teachers with high levels of self efficacy produce higher performing students, demonstrate more patience for struggling students, and are generally more responsive to students.

Koency and Swanson (2000) add that content knowledge is only one piece of the puzzle. Numerous studies have identified the importance of teachers' understanding of mathematical pedagogy (Eisenhart et al., 1993; Johnson, 1995; Lee, Meadows, & Lee, 2003; Manouchehri & Goodman, 1998; Swafford, Jones, & Thorton, 1997; Swafford, Jones, Thorton, Stump, & Miller, 1999). Lee, Meadows, and Lee (2003) argue content knowledge and pedagogy are not necessarily mutually exclusive, as they found the combination of the two, which they termed pedagogical content knowledge, to be a strong predictor of teaching practices in mathematics. The research of Lockheed and Komenan (1989) supported this, finding teaching practices to be more

important than a teacher's education, experience and certification in Nigeria and Swaziland.

Consequences for student learning connected to quality teaching/teachers

A substantial body of research pertains to the relationship between teacher preparation and experience and student learning and student attitudes toward mathematics. Fetler (2001) and Darling-Hammond (2000) found a positive relationship between teacher preparation and student achievement. According to Brown (2002), the number of years an individual has been teaching is associated with an increase in teacher quality. The U.S. Department of Education (2000) suggests students learn more from experienced teachers. Darling-Hammond's research corroborates this finding and adds that new teachers are generally less effective teachers than those who have been teaching for at least five years. This suggests it is imperative to train and encourage young teachers to maximise their teaching potential.

Teachers play a fundamental role in shaping student attitudes toward mathematics. According to the Australian Education Council (1991), "children come to school enthusiastic and eager to learn mathematics and leave school with quite negative attitudes" (p. 31). Willoughby (2000) concurs mathematics typically is taught in a way that makes students dislike both mathematics and the process of learning it. Numerous articles stress the importance of professional development and its impact on improving students' attitudes and achievement, not to mention improving teacher quality. Wenglinsky (2000) found "in math, students whose teachers have received professional development in working with special populations outperform their peers by more than a full grade level" (p. 7). Moreover, "students whose teachers have received professional development in higher order thinking skills outperform their peers by 40% of a grade level" (p. 7).

Another important finding regarding student learning and quality teachers and teaching includes the fact that American states with the highest performing students also have the highest percentage of well-qualified teachers (Darling-Hammond, 2000; Provasnik & Young, 2003). Provasnik and Stearns (2003) point out the importance of having a high-quality mathematics teacher in the 8th grade. They found a correlation between the quality of the teacher and increased student opportunity to be in a high quality learning environment, even after controlling for such factors as student background and ability level. Similar to Darling-Hammond's concept of qualified, high quality is identified by certification, degree, experience, exposure to key mathematics concepts and self-confidence in regard to teaching.

Objectives

The purpose of this study was twofold: to inquire about students' specific perceptions of quality high school (grades 9 – 12) mathematics

instruction and to evaluate the measurement properties of the *Mathematics Quality Survey* constructed for that inquiry. The study demonstrates how the Rasch rating scale model effectively addresses these purposes. Research was guided by the overarching research question: What factors do students perceive to be associated with high quality mathematics teaching?

Method

Response Frame

The study was conducted at a public high school, consisting of students in enrolled in grades 9 – 12, in the southeast United States. The school was selected for a number of reasons. Two of the most important criteria were the student demographic variables and results from state mathematics assessments. These provided reasonable evidence that those students within the school represented a wide range of mathematics ability. The students in the school were 76% white, 13% African-American, 6% Hispanic, 2% Asian, less than 1% Native American, and 2% other ethnicities. Twenty six percent of the students received federal aid to help pay lunch fees, and 7% of students were classified as having limited English proficiency.

All mathematics teachers in the school were invited to participate in the study and six of the thirteen opted to do so. The participating teachers agreed to administer the student survey to their classes following the research protocol which included anonymity of the students, meaning teachers could not review their individual responses.

Instruments

A *Math Teacher Quality* survey, originally constructed in 2002 (Bradley & Loadman, 2005) was revised by the researchers after a thorough review of the literature and current teacher evaluation tools utilised within the school system. The pencil-and-paper questionnaire was a selected response survey. The instrument included the following sections: introduction, demographics and qualities of good teachers. The survey instrument contained 32 short statements for which respondents provided their level of agreement utilising a 4-point Likert-type scale where 1 = *strongly disagree*, 2 = *disagree*, 3 = *agree* and 4 = *strongly agree*. There were also open-ended questions for respondents to provide additional feedback. For example, students were asked to list the two qualities they felt were most associated with the best mathematics teachers and were also asked to describe the best mathematics teacher they knew.

The introduction explained the goal of the survey and informed respondents that only the researchers would review their individual responses and that only aggregate information would be reported. Finally, the survey included directions for how to submit the survey upon completion and a note of appreciation for participants' time. The demographic variables were selected in response to the literature review and to gain an overall picture of the

response sample. Specific variables of interest included: typical mathematics performance, sex, current academic rank, and ethnicity and enrolment in English language development courses. All demographic variables were self-reported.

The original instrument on qualities of the best teachers were addressed in statements related to the research and studies of Black and Howard-Jones (2000), Murphy (1990), and Tamblyn (2000), as utilised in Bradley and Loadman (2005). The researchers updated the instrument to include current literature and measures used by the school system to evaluate new teachers (Kentucky Education Professional Standards Board, 2004). In order to address the variable of interest and for added opportunity to assess the validity of the hierarchy, students were asked to identify qualities they associated with the best teachers they know.

The questionnaire concluded by thanking the respondents for their time. Respondents were also asked to provide any additional comments related to their responses to the survey. The updated scannable, pencil-and-paper survey was created using eListen survey and data collection software (Scantron, 2005). eListen software allows researchers to create custom surveys and to deploy them to the World Wide Web, e-mail, hand-held devices and/or paper, and it provides the infrastructure to collect and store the data from completed surveys in a database. In this study, the researchers deployed the survey to paper and collected data by scanning completed surveys.

Procedure

Teachers completed the questionnaire in the fall of 2004 and administered it to their students in February of 2005. Data were entered into eListen software utilizing the data pump option, were exported into Excel for clean-up prior to analysis, and entered into WINSTEPS software (Linacre, 2005) to conduct a Rasch analysis. After ensuring the data acceptably fit the Rasch model, the researchers produced item hierarchy maps for the students. The researchers presented the results to the teachers in a focus group in the spring. In the focus groups, one researcher led the discussion, beginning with a set of questions, and expanded the discussion through follow-up questions and probing. The second researcher took detailed notes of the discussion. Teachers discussed their expectations for the hierarchy, their reactions to the results, and their speculations as to why some of the results differed from their expectations.

Teachers participated in two focus groups during the school year, one in February and one in May. In February teachers discussed their ideas about what quality teaching entails and their thoughts about how quality is evaluated. In May, the teachers discussed the results from the questionnaires and the assessment.

Data Analysis

The self-administered survey was completed by 729 mathematics

students in grades 9 – 12 from among 6 teachers of mathematics. Data were analysed using WINSTEPS (Version 3.57) (Linacre, 2005) adopting the polytomous "Rating Scale" model.

Fit of the data to the model, the rating scale structure and the quality of the individual items were examined. Survey items and students identified as not fitting the model through an investigation of rater (student) and item fit statistics were identified to determine if certain items should be removed to produce a teacher quality measurement instrument that could be used in future studies. Following this, the researchers examined the item hierarchy. To support this examination, the research team reviewed notes from these focus groups as well as open-ended responses to the survey to identify common themes as well as ideas that were both convergent and divergent to the quantitative analysis.

Results

Given careful attention to the instrument, a preliminary review of the Rasch results was conducted prior to interpreting the findings in response to the research question and stated objectives.

Review of the Mathematics Quality Survey

WINSTEPS software produces diagnostic information about the use of the categories in the rating scale. It is expected that category measures increase as the category labels increase from disagreement to agreement. Furthermore, in this study, items were selected because the literature suggested they were indicators of teacher quality. Thus, students should agree with the items.

By summing observed counts across categories, Table 1 shows that students selected either category 3, *agree*, or 4, *strongly agree*, at a rate of 80%. Students were much less likely to *disagree* or *strongly disagree* with statements, only selecting category 1 and 2 at a rate of 17%. While the tendency to *disagree* is outside of the expectation of response pattern and warrants further investigation, the expectation of the model for category measures to increase is satisfied.

Table 1
Category Measures

Category	Category Label	Observed Count	Percent	Category Measure
1	Strongly Disagree	620	3	-3.04
2	Disagree	3214	14	-1.12
3	Agree	10704	47	0.96
4	Strongly Agree	7550	33	3.33

The analysis moved to an examination of the raw scores, measures, and mean square fit statistics for the survey items. Only one item fell outside the

reasonable range, with an outfit mean square value of 2.59: *(15) The best mathematics teachers I know assign homework on a regular basis.* Table 2 displays the student responses to this item that differed from the Rasch model's expectations. The fourth column, Standardised Residual, indicates the degree to which it differed. Many of the students who were very likely to agree with the survey items in general disagreed with this item. This item was not removed from the scale for this study, but the related results were interpreted with caution.

Table 2
Most Unexpected Responses for Item 15

Student	Response	Expected Response	Standardised Residual
145	1	3.93	-11.27
379	1	3.88	-8.64
302	1	3.65	-5.26
719	2	3.82	-4.68
688	1	3.53	-4.60
599	1	3.43	-4.25
183	1	3.40	-4.15
467	1	3.40	-4.14
50	1	3.37	-4.06
486	2	3.77	-4.06
85	2	3.77	-4.06
40	1	3.34	-3.97
21	1	3.34	-3.97
475	1	3.33	-3.94
692	1	3.31	-3.89
326	2	3.74	-3.82
602	1	3.28	-3.81
460	1	3.25	-3.74
277	1	3.25	-3.74

Mathematics Teacher Quality Hierarchy

Figure 1 displays the hierarchy of qualities as rated by the students. The qualities at the top were least associated with the best mathematics teachers and those at the bottom were most associated.

The items easiest to endorse included: *(26) knowledgeable in mathematics; (2) recognise every student has the right to be educated; (6) provide a safe atmosphere for students; (16) have the ability to communicate with all students, regardless of ethnicity or heritage; (7) are honest; (3) practise fairness to all students; and (1) have high expectations for students.* The hardest to endorse for students were: (11) *use resources beyond the textbook, (14) emphasise the importance of mathematics in real life, (13) individualise instruction, (20) sponsor extracurricular activities, (31) use student results on state assessments to guide planning and instruction, (25) have a quiet classroom, and (12) incorporate technology in their instruction on a regular basis*.

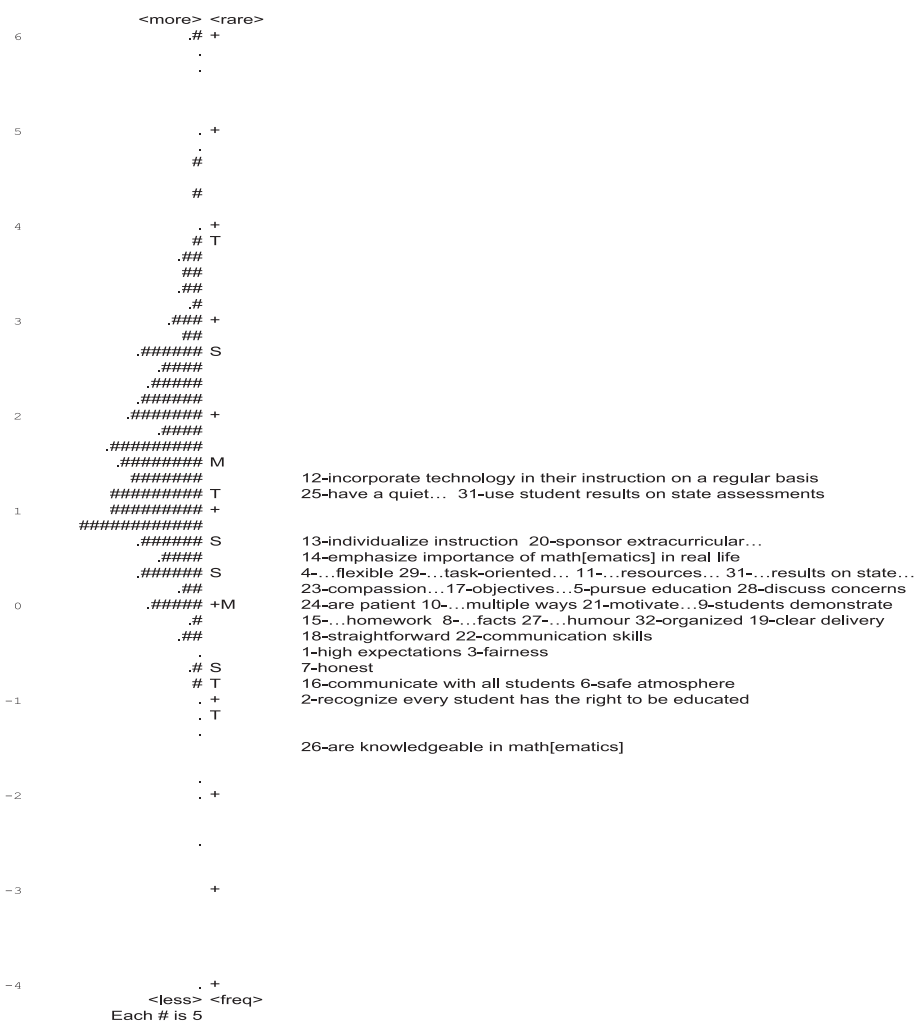

Figure 1. Hierarchy of qualities of the best mathematics teachers.

Open-ended Responses

In addition to the Likert-type questions, the survey also contained questions that requested open responses. These responses were reviewed to support the quantitative analysis. Students were asked to finish the sentence, "I would describe the best math[ematics] teachers I know as …". Of the over 750 anonymous student responses, there were only 15 students who did not complete the statement. Also, of the students responding to the prompt and choosing not to do so, there was a mix of students who reported that they enjoyed and did not enjoy mathematics. In accordance with the Rasch hierarchy, the students generally reported the best mathematics teachers they

knew as being competent at the job and having good rapport with students. More than half of the responding students referenced teacher knowledge in mathematics when describing the best teachers they knew; with this, many specifically referenced the importance of having a mathematics degree and continually learning how to improve mathematics teaching. Other themes included enjoyment of teaching, high expectations coupled with a dedication to assist students in reaching those expectations, good organisation, and strong communication skills. A few students listed a specific teacher, some of whom were their current teachers and others from as far back as primary school.

Under the umbrella of good rapport with students, students mentioned qualities such as sense of humour, patience, approachability, honesty, compassion, and good listening skills. One female student wrote, I would describe the best math[ematics] teacher I know as "a teacher that wants to help you succeed that teaches you in a fun sort of manner. I seem to learn better when I am having fun in the classroom. These teachers are very bright and want to help you become a better student and be all that you can be." Similarly, another student described the best math[ematics] teacher as "Patient. Math[ematics] is difficult. If the teacher is patient and understanding of a student's problems and willing to go over the lesson again the student won't get frustrated as easily. They will be more willing to learn the material and ultimately like math[ematics] better because they get it." Others value "motivational instructors who teach encouragingly and whose priority is teaching the material successfully rather than finishing the book or material on time" and "someone who will listen to their students' questions and be able to help them."

Supporting high expectations, students noted that the best teachers do what it takes to help students learn. From the students' perspective this includes motivating students to learn, being hands-on, being willing to work with students outside of class, varying teaching methods, using real-world activities, assigning homework and utilising technology. One student described the best mathematics teachers as "compassionate, though not pushovers, who require kids to pass; strongly gifted in mathematics yet constantly pushing to expand their understanding; giving yet not requiring homework; enjoyable and humorous but still capable of flunking when necessary."

Within the theme of good organisation, students commented the best teachers are well-planned, sometimes strict, deliver lessons and curriculum that have been well thought-out, but are also flexible enough to adapt lessons and curriculum as necessary. "The best math[ematics] teachers I know always have a planned and organised use of class time. They explain the material clearly and regularly review it so students don't forget it. They follow a pattern for how class time is spent so students know what to expect."

Many students commented on the importance of strong communication skills, writing that the best teachers clearly explain mathematics concepts using multiple approaches. Some students noted the importance of teachers enjoying their work; one student described the best math[ematics] teacher as "a fun person who enjoys their job enough to make their students enjoy it also." The summary of comments mirrors the Rasch hierarchy, reiterating the

significance of the teacher-student relationship and the importance of the teacher's care for the individual student.

Discussion

Quality of the Scale

The only item with unacceptable fit to the Rasch model was *(15) The best mathematics teachers I know assign homework on a regular basis.* In determining why this item might not fit the expectations of the Rasch model, the researchers found that over 60% of students who were agreeable to most items either disagreed or strongly disagreed with this item. The researchers determined that homework is often not popular among students regardless of their opinions about the teacher assigning it, so this item may be less related to qualities of teachers and more related to student preferences. For future use of the instrument, this item would be removed.

Student Perceptions

Consistent with the emphasis on teacher preparation in the literature, students valued teacher knowledge of mathematics as the most important quality of the best mathematics teachers. Students gave the most importance to qualities associated with teachers' interaction with them. It seems that quality instruction is viewed within the spectrum of teachers' caring about the students, making the effort to connect with them as individuals and treating all students fairly. The Oakes, Franke, Quartz, and Rogers (2002) finding that individuals working for educational equity and access are typically quality teachers as well as the AAMT (2002) emphasis on teachers' commitment to various communities reiterates this.

Students appear to be less interested in teaching practices that might be viewed as being tangential to their learning, such as use of technology [for technology's sake], use of assessment results to drive instruction and sponsoring extracurricular events. Still considered important, but among the less valued qualities among the students is the emphasis of mathematics in real life. This may be explained with Lappan's (2000) finding that teacher use of what they know is what matters most. Students seem to care that the mathematics they are learning is meaningful and important for future success in school and beyond. Students do not directly equate that concept to real life examples.

Teacher Reactions

When asked to reflect on the empirical hierarchy in the May focus group, the teachers' responses reflected the lack of consensus in the literature regarding the definition of teacher quality and how to measure it. Teachers said, "We know being a highly qualified teacher is important, but it's not well

defined. It's vague", and "It seems like we're usually evaluated on the qualities that are easiest to quantify, especially in a short period of time." In reviewing the students' item hierarchies of teacher quality, the teachers generally agreed with their students' perceptions of quality. They were surprised to find that students rated *use of technology* lowest on the scale, even though they also ranked it among the least important indicators of quality in a parallel survey they had completed. In the May teacher interview group, the teachers surmised this may be a matter of different understandings of what technology is. Teachers stated that technology is not a consistent construct, so while one individual views using an overhead projector as technology, another may view handheld calculators as technology and even others may only view computer-based activities as technology. These multiple interpretations may have contributed to the low ranking of technology in defining high quality teachers.

Teachers observed that administrators place a great deal of importance on outcomes that are easily quantified such as state test scores and behaviours that they can observe quickly. The teachers noted the administrators spent only a few minutes in their classrooms, and that use of technology was typically mentioned in their reviews. Many of the behaviours the teachers and students considered to make high quality teachers are not easily quantified, especially in a short amount of time, so they commented they do not place very much weight in the evaluations conducted by their administrators when considering their own quality as teachers.

In discussing how they discern their quality as educators, the teachers all indicated they considered their personal judgments to be most important, followed closely by the opinions of their peers. This discussion led to conversations about policy implications and hypotheses to explore in future studies. The researchers developed two testable hypotheses for further investigation:

(H1) Satisfying one's own expectations is the most important aspect of assessing quality, followed closely by those of one's peers (other teachers).

(H2) Hierarchy maps related to factors associated with quality teaching will not align across the K – 16 mathematics community.

Conclusion

Research in the area of quality mathematics instruction sheds light on the issues pervading mathematics classrooms and curriculum today. The information presented can support mathematics teachers and school administrators, as well as the educational research community. High quality mathematics education impacts children within and beyond the classroom, preparing them for employment, higher education and the challenges of daily life.

This study works to conceptualise and operationalise quality mathematics instruction and effective learning at the high school level. The researchers in this study value research communities, with specific emphasis on the growing network of faculty, teachers, students and administrators.

Thus, they sought to engage the teachers in the study as members of the research team instead of simply paid participants. The study presents a fundamental argument for the need to include classroom teachers and students in the policy-making process. Often the best sources leading to data-driven policy decisions are overlooked or not respected.

While colleges and universities often use student evaluations to measure teacher quality, student insights are rarely considered in evaluating quality teaching in grades K - 12. The scale developed through this study lays the groundwork for student evaluations of the quality of their teachers. Using it in reference to individual teachers would provide information about how their conceptualisations compare with student conceptualisations of their best teachers.

As quoted in *No Dream Denied*:

> The ability to create and maintain a strong professional learning community in a school is limited not by teacher supply, but by high turnover among the teachers who are already there—turnover that is only aggravated by hiring unqualified or under prepared individuals to replace those who leave (National Commission on Teaching and America's Future, 2003, p. 8).

To ensure that every student has the opportunity to learn from experts, or highly qualified teachers, it is important for educational researchers to continue to identify areas of need and for educational institutions and educational policy makers to implement changes to address them.

Acknowledgment

This research was supported by a Kentucky Education Professional Standards Board Teacher Quality Grant.

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Authors

Kelly D. Bradley, Department of Educational Policy Studies and Evaluation, 131 Taylor Education Building, University of Kentucky, Lexington, KY 40506-0001, USA. Email: <kdbrad2@uky.edu>

Shannon O. Sampson, Department of Educational Policy Studies and Evaluation, 131 Taylor Education Building, University of Kentucky, Lexington, KY 40506-0001, USA. Email: <shannon.sampson@uky.edu>

Kenneth D. Royal, Department of Educational Policy Studies and Evaluation, 131 Taylor Education Building, University of Kentucky, Lexington, KY 40506-0001, USA. Email: <kdroya2@uky.edu>