TEACHER QUALITY AND STUDENTS' ACHIEVEMENT IN MATHEMATICS: AN OVERVIEW

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ABSTRACT

Students' achievement in Mathematics has led to a sustained analysis of how teacher quality influences their performances. The paper focuses on identifying and describing the role of Mathematics teachers' quality on students' achievement. It has been argued that there is a need to examine how Mathematics teachers who are new to the classroom construct and structure their knowledge base (National Council of Teachers of Mathematics, 2000). The paper also seeks to find the answer weather the various qualities attributed to a teacher is measurable.

Introduction

Opportunity to learn is among the most important influences on student achievement, yet the empirical basis for knowing what is taught in schools is surprisingly weak (Andrew, 1989). Most of the educational reforms in the country today are geared towards improving the quality and quality of education in elementary, secondary and tertiary institutions of our learning. Little has been done in the area of teacher quality. This study examines teacher quality and students achievement in Mathematics in terms of measurability. Previous research has identified three fundamental abilities that lecturers seek to change during the course: (1) technical skills; (2) professional competence; and (3) professional attitudes. A three ability framework (3AF) has been developed to compare students' assessments of the change in these abilities with the instructor's perceptions of change (Tony, 1999). Is there any positive correlation between a teacher's quality and students achievement? If the answer to this question is YES, then what are the possible indices that could be use to measure the teacher's quality? We consider how the returns to the quality of education in Nigeria today *are* confounded by differences in the quality of performance and whether the effects of quality are confounded by its correlations with quantity.

Mathematics Teaching and the Role of Teacher Quality

According to Chinnapan (2003), recent research, particularly about the development of expertise in Mathematics teaching, indicates that there are three major components relating to the knowledge base of teachers and enabling them to perform their role effectively. These are:

1. teacher 'Mathematical content knowledge;
2. the organization of this knowledge; and
3. the blend of knowledge of content and pedagogy.

Mathematical content knowledge includes information such as mathematical concepts, rules and associated procedures for problem solving. The organization of the content knowledge refers to the links that the teachers construct between the various components of content knowledge. The blend of content and pedagogical knowledge includes understanding why some children experience difficulties when learning a particular concept, while others find it easy to assimilate, knowledge about useful ways to conceptualize and represent a chosen concept (Feiman, 1990), the quality of explanations that teachers generate prior to and during instructions (Leinhardt, 1987), and characteristics of the learners. This latter knowledge has also been labeled as pedagogical content knowledge (Shulman, 1986) that teachers need to integrate their posits own knowledge of mathematics with understanding about the nature of learning and the learner in order to design effective learning environment.

Other researchers that are interested in improving children's mathematical performance have argued that the quality of teacher's knowledge is accessed and exploited during planning for a lesson and instruction (Dark & Peterson, 1986; Lawson & Chinnapan, 1994; Schoenfeld, 1992).

The Measurability of Teacher Quality

The quality of teaching and learning should be considered as crucial elements. This is why educators and researchers have been debating over the years which school variables influence student achievement. According to Darling - Hammand (1999) citing Coleman, *et al.,* (1966: 325) some research has suggests that "Schools bring little influence to bear upon a child's achievement that is independent of his background and general social context". Other evidence suggests that factors like class size (Glass, Cohen, Smith, Filby 1982; Mosteller, 1995), teacher qualifications (Ferguson, 1991), school size (Haller, 1993). While teacher experience, teacher preparation programs and degrees, types of teacher certification, specific course work taken in preparation for the profession, and teachers own test scores (Rice, 2003)

It has been reported that in America, as new standards for student learning have been introduced across the states, greater attention has been given to the role that teacher quality plays in student achievement (National Commission on Teaching and America's Future, 1996)

However, Darling - Hammand (1999) opines that variables presumed to be indicative of teachers' competence which have been examined for their relationship to student learning include the following;

i. measures of academic ability;
ii. years of education;
iii. years of teaching experience;
iv. measures of subject matter,
v. teaching knowledge;
vi. certification status; and
vii. teaching behaviours in the classroom

The Teachers' Academic Ability and Intelligence

Previous studies conducted as far back as 1940's have found positive correlations between teaching performance and measures of teachers' intelligence (which was usually measured by IQ) or general academic ability (Rostker, 1945; Skinner, 1947), must relationships are small and perhaps statistically insignificant. However, other studies have suggested that teachers' verbal ability is related to student achievement (Coleman' *et al.,* 1966; Hanushek, 1971). This verbal ability has been hypothesized to be more sensitive measure of teachers' ability to convey ideas in clear and convincing ways (Murnane, 1985).

The Teachers' Knowledge of the Subject Matter

This is another variable that could possibly be related to teacher effectiveness. The studies of teachers' score on the subject matter tests of the National Teacher Examinations (NTE) have found no consistent relationship between this measure of subject matter knowledge and teacher performance as measured by students' outcomes or supervisory ratings. Most studies show small, statistically insignificant relationships both positive and negative (Andrews, Blackmon, &

Mackey, 1980). However, Ashton & Crocker (1987) found only 5 of 14 studies they reviewed exhibited a positive relationship between measures of subject matter knowledge and teacher performance. Other studies indicated that students of fully certified mathematics teachers experienced significantly larger gain in achievement than those taught by uncertified mathematics teachers (Hawk, Coble, & Swanson, 1985).

The Teacher's Knowledge of Teaching and Learning

Studies have found a stronger and more consistently positive influence of education coursework on teachers' effectiveness. Ashton & Crocker (1987) found significant positive relationships between education coursework and teacher performance in four out of seven studies they reviewed. Study of student's mathematics and science achievement found that teacher education coursework had a positive effect on student learning (Monk's, 1994).

In his contribution in describing the importance of teacher knowledge of teaching and learning Byrn (1983: 14) states:

> It is surely plausible to suggest that in so far as a teacher's knowledge provides the basis for his or her effectiveness, the most relevant knowledge will be that which concerns the particular topic being taught and the relevant pedagogical strategies for teaching it to the particular types of pupils to whom it will be taught. If the teacher is to teach fractions, then it is knowledge of fractions and perhaps of closely associated topics which is of major importance - - - -. Similarly, knowledge of teaching strategies relevant to teaching fractions will be important.

The Teacher's Teaching Experience

On the teacher teaching experience, other studies of the effects of teacher experience on student learning have found a relationship between teachers' effectiveness and their years of experience (Murnane & Philips, 1981), but not always a significant one or an entirely linear one. While, Rosenholtz (1986) states that many studies have established that inexperienced teachers are typically less effective than more senior teachers.

The Teacher's Certificate Status

Certification or licensing status is a measure of teacher qualification that combines aspects of knowledge about subject matter and about teaching and learning. Darling-Hammond (1999) reports that in a review of research, Everton, Hawley, and Zlotnik (1985:1) state:

> The available research suggests that among students who become teachers, those enrolled in formal preserves preparation programs are more likely to be effective than those who do not have such training. Moreover, almost all well planned and executed efforts within teacher preparation programs to teach students specific knowledge or skills seem to succeed, at least in the short run.

The Teacher's Behaviours and Practices

Studies on the aspects of teaching effectiveness that may be related to teacher education, certification, status, and experience, do not reveal much about teachers' behaviours or abilities that makes the difference in how their students perform (Darling-Hammond, 1999). Research on teachers' personality traits and behaviours has produced few consistent findings (Druva, & Anderson, 1983) with the exception of studies finding a recurring positive relationship between student learning and teachers' "adaptability", "flexibility" and "creativity" (Walberg, & Waxman, 1983). However, Darling-Hammond (1999) citing Hamachek (1969) opines that most of the teachers that are successful are those who are able to use a range of teaching strategies and interaction styles, rather than a single, rigid approach. This finding is consistent with and supports other research finding on effective teaching, which suggests and encourages that effective teachers adjust their teaching style to fit and respond to the needs of different students and the demands of different instructional goals, topics, and methods (Doyle, 1985).

In addition to the teacher's ability to create and adapt instructional strategies, various research studies have linked student learning to variables such as teacher clarity, enthusiasm, task-oriented behaviour, variability of lesson approaches, and students opportunity to learn criterion material. Teachers' abilities to structure material, ask higher order questions, use students ideas, and probe students comment have also been found to be important variables in what students learn (Good, & Brophy, 1986).

The Research Efforts Made Using Econometric Model and Estimation Strategies on Teacher Training, Teacher Quality and Students Achievement

Given their contribution on teacher training, teacher quality and student achievement, Hariss and Sass (2008) used Econometric Model and Estimation strategies to measure teacher's productivity on students' achievement.

According to them to empirically measure the impact of education and training on teacher productivity it is necessary to first develop a model of student achievement.

Hariss and Sass (2008) begin with general specification of the standard "educational production function" that relates student achievement to vectors of time-varying student/family inputs (*X*), classroom – level input (*C*), school inputs (*S*) and time – invariant student/family characteristics (*Y*):

$$A_{\mu} = \lambda A_{\mu\text{-}1} + \alpha_1 X_{\mu} + \alpha_2 C_{\mu mi} + \alpha_3 S_{mi} + y_1 + \xi_{\mu} \qquad \text{Eqn (1)}$$

The subscripts denote individuals (*i*), classrooms (*j*), schools (*m*) and time (*t*).

The equation is a restricted form of the cumulative achievement function specified by Boardman and Murnane (1979) and Todd and Wolpin (2003) where the achievement level at time (*t*) depends on the individual's initial endowment (e.g. innate ability) and their entire history of individual, family and schooling inputs. All these are based on implicit assumptions underlying the education production function specified above. Thus, it is assumed that the cumulative achievement function does not vary with age, is additively separable to be constant over time and the impact of parental inputs on achievement, along with the impact of the initial individual endowment on achievement, induce a (student-specific) constant increment in achievement in each period.

Hariss and Sass (2008) also used

$$A_{\mu} = \lambda A_{\mu\text{-}1} + \beta_1 X_{\mu} + \beta_2 P_{\text{-}\mu mi} + \beta_3 T_{kt} + \beta_4 S_{mi} + Y_1 + \delta_k + \phi_m + V_{\mu} \qquad \text{Eqn (2)}$$

to measure the administrative experience of the school principal. Taking into consideration, the time-invariant school inputs captured by a school fixed component, ϕ. where V_{it} is a normally distributed, mean zero error; T_{kt} is the vector of time varying teacher characteristics; β is the vector of co-efficient on time-varying teacher characteristics.

In terms of estimation they regard equation 2 by ordinary least squares (OLS) as problematic since the error term is correlated with lagged achievement, rendering biased estimates of the regression coefficients. In order to avoid this bias Harris and Sass (2008) further focus on estimating models where λ is assumed to equal one (1) and thus, the dependent variable is A_{μ} - $A_{\mu-1}$ or the student achievement gain:

$A_{\mu} - A_{\mu-1} = \Delta A_{\mu} = \beta_1 X_{\mu} + \beta_2 P_{-\mu mi} + \beta_3 T_{kt} + \beta_4 S_{mi} + Y_1 + \delta_k + \phi_m + V_{\mu}$ Eqn (3)

Implying that the decay rate on prior inputs is zero; also signifying that school inputs applied at any point in time have an immediate and permanent impact on cumulative achievement. This is perhaps a strong assumption because Harris and Sass (2008) must test whether changes in the assumed value of Lambda (λ) affect their results.

Now, lets look at the computational issues related to the estimation of equation 3 which Harris and sass (2008) termed to be computationally challenging since it includes three levels of fixed effects vis-à-vis individual students (V_i), teachers (δ_k) and schools (ϕ_m). Using standard fixed effects method here will eliminate one effect by demeaning the data with respect to the variable of interest (e.g. deviations from student means). They also believe that additional effects must be explicitly modeled through the inclusion of dummy variable regressors if their data should includes tens of thousands of teachers and thousands of schools, such standard methods are infeasible.

However, Harris and Sass (2008) combine two different approaches to solve the computational problem associated with estimating a three level fixed effect model through the following methods:

i. **Spell Fixed Effects Method:** This is proposed by Andrews, et al (2004) combining the teacher and school fixed effects into a single effect $\eta_{km} = \delta_k + \phi_m$. This combined effect is said to represents each unique teacher/school combination or "spell". Thus, the education production function becomes;

$$\Delta A_{\mu} = \beta_1 X_{\mu} + \beta_2 P_{-\mu mi} + \beta_3 T_{ki} + \beta_4 S_{mi} + Y_1 + \delta_k + \eta_{\lambda m} + V_k \quad \text{(Eqn 4)}$$

ii. **Iterative fixed effects estimator:** Iterative fixed effects estimator; recently proposed by Arcidiacono, *et al* (2005). The Arciacono *et al* methods is used to estimate the fixed effect for each individual by calculating each individual's error, in each time period (i.e. actual outcome minus the individual's predicted outcome) and then compute the mean of these errors for each individual overtime. With each estimate, the individual fixed effects are recomputed and the process is iterated until the coefficient estimates converge.

Therefore, taking deviations from the teacher-school spell means, the achievement equation now becomes:

$$(\Delta A_{\mu} + \Delta A_{\lambda m}) = \beta_1(X_{\mu} - X_{\lambda m}) + \beta_2(P_{-\mu mi} - P_{\lambda m}) + \beta_3(T_{ki} - T_{\lambda m}) + \beta_4(S_{mi} - S_{\lambda m})^{-1} + (Y_1 - Y_{\lambda m}) \quad \text{Eqn (5)}$$

where the overbar and *km* subscript denote the mean of the relevant variable over all students effect and all time periods covered by the teacher *k* at school *m*. subtracting the demeaned student effect from both sides equation 5 now becomes:

$$(\Delta A_{\mu} - \Delta A_{\lambda m}) - (Y_1 - Y_{\lambda m}) = \beta_1(X_{\mu} - X_{\lambda m}) + \beta_2(P_{-\mu mi} - P_{\lambda m}) + \beta_3(T_{ki} - T_{\lambda m}) + \beta_4(S_{mi} - S_{\lambda m})^{-1} \quad \text{Eqn (6)}$$

Here, equation 6 is estimated by the ordinary least squares (OLS), using initial guesses for the individual effects. This inturn produces estimates of β_1, β_2, β_3, and β_4 which are used to calculate predicted outcomes for each individual and in turn also update the estimated individual effects.

Yet, despite the giant efforts put forward by researchers in the like of (Hariss and Sass (2008); Arcidiacono, et al (2005); Andrews, et al (2004); Boardman and Murnane (1979)) in providing us with formulas on how to compute certain variables associated to school, teacher and students achievement. A lot need to be done if each and every quality attributed to a teacher needs to be measured. Certainly, this is daunting challenge.

The Challenge

Darling - Hammond (1999) states that it seems logical that teachers' abilities to handle the complex tasks of teaching for higher - level learning are likely to be associated to varying extents, with each of the variables reviewed above: verbal ability, subject matter knowledge, understanding of teaching and learning, specific teaching skills and experience in classroom, as well as interactions among these variables. In addition, consideration of fit between the teaching assignment and the teacher's knowledge and experience are likely to influence teachers' effectiveness.

Yet, the crucial question whether the teachers' quality is measurable still remain unanswered because up-till today there is no standardized instrument, indices or evaluation model with which to measure these variety of qualities. An answer must be found to this crucial question if each of the mentioned crucial elements that constitute the quality of a teacher is to be measured, how do we qualify a good teacher? What characteristics will qualify a good Mathematics teacher? How much impact on student achievement can the society school, administrators and parent expect? And what are the means of making sure that all students receive the benefit of good Mathematics teachers? Hence, the challenge.

Suggestions

- It is certainly true that teachers' quality has a bearing on students' achievement. Government reforms should be geared towards improving teachers' quality.
- The government should introduce a special fund for pre-service and in-service Mathematics teacher education.
- The Mathematical Association of Nigeria (MAN) researchers, mathematics educators and educationists should as a matter of urgency introduces a model that could effectively be use in measuring teacher quality.
- The Federal, State and Local governments differ greatly in the levels of funding they allocate to pre-service and in-service education, thus, the need for uniformity, consistency and sustainability should be encouraged in that direction.
- The TRC is serving as a licensing authority for the teachers. It has now become TRC's responsibility to champion the cause of change for teachers' salary to equal that of the medical doctors, Federal judges or even far better.

Conclusion

For teachers to meet the changing demands of their profession, they must be ready to learn and relearn their profession. Professional development and collaboration with other teachers should be considered to be strategies for building capacity for effective teaching, particularly in a profession that demands changing and expansion continuously. Workshops and conferences are however been regarded as traditional approaches to professional development and are been criticized for being relatively ineffective just because they typically lack connection to the challenges, teachers face in their profession.

The writers of this paper suggest that unless indicator(s) is/are carefully designed and implemented that could provide the basis for measuring teachers' quality. The teacher quality would continue to have ad vast effect on students' achievement.

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