Evaluating effective mathematics teaching in secondary schools in Bangladesh using a value-added model

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In Bangladesh, despite significant progress in access, equity and public examination success, poor student performance in mathematics in secondary schools has become a major concern. An extensive review of research has shown that teachers account to a large extent for student learning and achievement gains. Although educational research has emphasised the importance of evaluating teacher effectiveness for improving students' achievement, few studies have measured teacher effect on students' achievement in Bangladesh and similar country-contexts. Thus, the purpose of the study was to investigate the value-added effect of mathematics teachers in secondary schools in Dhaka, Bangladesh. A cross-sectional cohort research design was employed, using a purposive sampling (N= 380) of all schools within the Dhaka Metropolitan City (DMC), extracted from the 5,867 schools under the jurisdiction of the Board of Intermediate and Secondary Education (BISE), Dhaka. Secondary source data for Junior Secondary Certificate (2010) and the Secondary School Certificate (2013) were obtained from BISE Dhaka and analysed using Education Value-Added Assessment System (EVAAS). The 380 schools of the DMC were ranked according to the calculated value-added score, and the top twenty schools identified. As the first study to evaluate secondary mathematics teachers' direct effect on students' mathematics learning in Bangladesh, it contributes important insights about teacher effect that can be used to inform the development of evidence-based policy and practice for improving teaching quality in Bangladesh.

Introduction

Since 1990 successive governments of Bangladesh have made concerted efforts to fulfil constitutional obligations and have undertaken "international commitments to ensure the achievement of 'education for all' goals and targets for every citizen by the year 2015" (Rahman, Hamzah, Meerah & Rahman, 2010, p. 115). Thus, various government and non-government initiatives have achieved significant progress regarding access to both primary and secondary education, including more schools and teachers, curriculum revision and increased enrolment rates, especially for girls in secondary education (Rahman et al., 2010). For example, net enrolment rates in primary education increased more than 10% in the decade 2005-2014 (Bangladesh Bureau of Educational Information and Statistics [BANBEIS], 2014). Not surprisingly, during 2004-2010, there was also an increase of 7% in the net enrolment rate of secondary education (BANBEIS, 2014; UNESCO, 2007).

Despite significant progress in access, equity and public examination success, poor student performance in English and mathematics in secondary schools has become a major concern for government, education practitioners and the public in Bangladesh (Ahmed, Nath, Hossain & Kalam, 2006; Nath et al., 2007). For example, poor student performance in year eight (Junior Secondary Certificate) and year ten (Secondary School Certificate) public examinations has been attributed to consistently high failure rates in English and mathematics.

A large body of research (e.g. Hattie, 2003; 2009) has shown that teachers are key contributors to school and student academic performance. Several studies (see Ahmed et al., 2006; Nath et al., 2007) have also attributed poor student performance and low-quality education to poor instructional practices of teachers as one of the main reasons in Bangladesh. Over the decades, educational effectiveness research has seen a growing interest in evaluating teachers' effects on student achievement growth (Braun, 2005; Little, Goe & Bell, 2009; Lockwood et al., 2007) and use the information to improve student performance.

Therefore, in the educational context of Bangladesh, it is critical to evaluate teacher effectiveness to improve on students' academic achievement. However, evaluating teacher effectiveness on students' achievement had been overlooked in Bangladesh and identifying teaching effectiveness has not been the subject of systematic investigation, and consequently, very little is known about teacher effectiveness on student learning in this country.

Several methods have evolved for measuring teacher effectiveness (e.g., classroom teaching observations, principals' evaluations, student ratings of teacher performance, teacher self-reports, and student test scores) as new insights into effective teaching have been gained, and newer methods have endeavoured to overcome the weaknesses of preceding methods of evaluation. Recently, the increased availability of data in which student academic achievement is linked to teachers, along with improvements in statistical methods for analysing data, enable researchers to investigate better the value-added connections between teaching and learning (Stronge, Ward & Grant, 2011). The emergence of value-added models has enabled direct assessing of teachers' effect on student achievement, as measured by gains on standardised tests (Hershberg, Simon & Lea-Kruger, 2004; Little et al., 2009; Stronge et al., 2011). These provide improved evidence regarding the effects of the classroom teacher on students' learning that were previously extremely difficult to obtain with other measures (Goe, Bell & Little, 2008; Stronge et al., 2011)

Considering the paucity of studies and the strengths in using a value-added model to estimate the teacher effects on student learning (Braun, 2005; Murphy, 2012; Weisberg, Sexton, Mulhern & Keeling, 2009), the undertaking of further studies is important. Such investigations will provide important insights, potentially leading to improvements in the quality of education in Bangladesh. Therefore, the present study was conducted to examine the value-added impact that secondary school mathematics teachers had on the students' mathematics learning.

The article comprises four parts. The first presents relevant contextual information about the education system in Bangladesh, the second reviews relevant literature and explains the research question developed to guide the study. This is followed by a description and rational for the methods employed. The last part reports and discusses the results, and outlines implications for further research and practice.

General education system and learning assessment in Bangladesh

The general education system in Bangladesh consists of primary education (five years), secondary education (seven years), and tertiary education. A student aged 6-10 years is enrolled in five years of compulsory primary education at either a government registered non-government or a fully independent primary institute (or school). At the end of primary school (or grade 5), learning achievement is assessed at a national public examination known as the Primary School Certificate (PSC) examination. A student who successfully passes the PSC is eligible to continue her/his education at the secondary level.

Secondary education includes two stages, the secondary stage (or grades 6-10) and higher secondary stage (or grades 11-12). The secondary stage is further divided into the junior secondary (or grades 6-8) and senior secondary (or grades 9-10). At the end of the junior secondary stage (or grade 8), the learning achievement of a student is assessed at a public examination, known as the Junior School Certificate (JSC). A student who passes the JSC may proceed to the senior secondary stage (grades 9-10) and be enrolled in a secondary school. At the end of the senior secondary stage (or grade 10) learning achievement is assessed at the public examination, known as the Secondary School Certificate (SSC). All public examinations of the secondary education in general stream are conducted by eight education boards.

Students who succeed in passing the SSC examination may continue to the higher secondary stage. At the completion of two years of higher secondary education, student learning achievement is assessed at the Higher Secondary Certificate (HSC) examination, and if successful, a student may proceed to tertiary education attending a higher education institute, a public or private university.

Teacher effectiveness

Defining teacher effectiveness

The literature on teacher effectiveness is extensive and diverse. This is reflected in the number of definitions which seem to depend on a host of variables, such as who is defining the term, who the learners are, the subject matter, and the methods of investigation. Despite these differences, most researchers agree that the critical criterion for determining teacher effectiveness is student learning outcomes (Barry, 2010; Reynolds, 1995). However, the effects of teaching on student learning are diverse and can be differentiated into three broad domains: affective, psychomotor, and cognitive outcomes (Guskey, 2013; Sammons, DeLaMatre & Mujtaba, 2002; Seidel & Shavelson, 2007). Affective outcomes (Krathwohl, Bloom & Masia, 1964) refer to the social, emotional and attitudinal aspects of learning. Psychomotor outcomes (Simpson, 1966) refer to specific skills or behaviours in certain technical fields (e.g., physical education). Cognitive or academic outcomes (Bloom, Englehart, Furst, Hill & Krathwohl, 1956) refer to gains in academic achievement measured either by standardised tests or teacher developed specific tests (Guskey, 2013; Hunt, 2009). Cognitive outcomes provide the foundation of a school's academic curriculum, and may vary across subject areas and span a broad range of subdomains in each subject area (Guskey, 2013). Most studies of teacher effectiveness have focused on academic outcomes (Guskey, 2013; Sammons et al., 2002; Seidel & Shavelson, 2007). Adopting a cognitive perspective, Little and colleagues (2009) defined teacher effectiveness as the ability of the teacher to develop student learning gains measured by standardised achievement tests. However, the author cautioned that though the definition covers one of the most important aspect of teacher ability, it is not to be considered a comprehensive view of teacher effectiveness (Little et al., 2009). Given the definition, teacher effectiveness is defined in this study as teacher's contribution to produce gains in students' standardised test scores.

Teacher effectiveness research and its relationship to student achievement

Over the past four decades, as new insights have been gained and successive researchers have endeavoured to overcome the weaknesses of preceding investigative approaches, the concept of teacher effectiveness has become broadened. In the early 1960s, researchers (e.g., Coleman et al., 1966) examined direct links between inputs such as teacher personality, and outputs such as academic achievement, ignoring the process variables (i.e., teaching practices), to explain differences in student performance, but had limited success (Borich, 1998; Muijs, Reynolds & Kyriakides, 2016). Hence, since the late 1960s most researchers (e.g., Brophy & Good, 1986; Emmer, Evertson & Anderson, 1980; Good, Grouws & Ebmeier, 1983; Mortimore, Sammons, Stoll, Lewis & Ecob, 1988) shifted the focus on investigating the relationship between teaching practices and student academic achievement by using an input-process-product framework. In an input-process-product framework, the inputs are teacher characteristics, including teacher background characteristics such as teacher qualifications and experience. The processes are classroom teaching practices, whilst student academic achievement (most often measured by student performance on standardised tests) represents the 'output'. Teacher effectiveness research (e.g., Good & Grouws, 1979a; 1979b; Mortimore et al., 1988) based on the input-process-product model have investigated the relationships between teacher characteristics, the actions and practices of teachers, and student achievement.

The literature of teacher and schools effectiveness research (e.g., Creemers & Kyriakides, 2012; Hattie, 2009) had established firmly that while schools are significant and important, the classroom level or the teacher explains a greater proportion of the variance in student learning and performance (Chapman, Muijs, Reynolds, Sammons & Teddlie, 2015; Houtveen, Grift & Creemers, 2004). Hattie (2009) in his meta-analysis noted that among the major sources accounting for student achievement are teacher, student, home, peer, school, and principal, and that the greatest source of variance is teachers (30%), next to the students themselves (50%).

Moreover, some studies have attempted to determine the variability in student learning that can be attributed to the impact from a highly effective teacher. For example, Stronge and Ward (2002), in an urban Virginia school district, revealed that students of the most effective teachers scored at least 30 points higher than the state's standard score in mathematics whilst their peers with less effective teachers scored 24-32 points below the standard. Similar findings by Slater, Davies and Burgess (2009) showed that students of a highly effective teacher had almost a full year's learning growth over peers with less-effective teachers. Kane, Taylor, Tyler and Wooten (2011) estimated that a student who began the academic year at the 50th percentile and was assigned to top-quartile teacher had three percentile points higher in reading and two points higher in mathematics by the end of the academic year, compared with a student who began at the same percentile but was assigned to a bottom-quartile teacher.

Measures of evaluating teacher effectiveness and value-added model

A number of different strategies have been used to identify effective teachers. The measures that identify effective teachers based on their classroom activities include classroom observation, principal evaluations, student ratings of teacher performance, teacher self-reports (e.g., surveys, teaching logs and interviews) and analyses of classroom products such as student assignments and test scores (Goe et al., 2008). Another prominent method that evaluates teachers based on their contribution to student achievement, particularly on their test scores, is commonly termed as the 'value-added model' (Aaronson, Barrow & Sander, 2007; Kane & Staiger, 2008; Rivkin, Hanushek & Kain 2005).

Though the most widely used model has been classroom observation (Little et al., 2009), there has been a growing interest in value-added models to estimate the effects that teachers have on student learning (Chetty, Fredman & Rockoff, 2011; Little et al., 2009; Murphy, 2012). For example, In the Unites States, several school districts (e.g. Dallas, Los Angeles and Washington D.C.) have been using VA measures to evaluate their teachers and taking appropriate action to enhance their effectiveness (Chetty et al, 2011; Goe, 2008). Scholars (e.g. Drury & Doran, 2003; Goe, 2008; Hershberg et al., 2004; Little et al., 2008; McCaffrey, Lockwood, Koretz & Hamilton, 2003) have discussed reasons for the increasing popularity of using value-added models to estimate the teacher and school effects on student learning. For example, Goe (2008) noted that a value-added model provides a relatively objective and inexpensive technique to estimate the proportion of variability in student learning attributable to teachers, and is useful in determining which teacher characteristics matter for student learning. Other reasons include: it can portray clearer pictures of student learning as a growth-based system, compared with attainment-based accountability systems of adequate yearly progress provisions (Braun, 2005; Murphy, 2012); and the method is superior to the traditional measures (e.g. principal evaluation) of teacher effectiveness that are based on subjective evaluation (Weisberg et al., 2009).

Moreover, empirical evidence (e.g. Chetty et al, 2011; Staiger, Gordon & Kane, 2006; Hanushek, 2009) suggests that teachers identified as effective based on value-added model can increase student achievement. For example, Chetty and colleagues (2011) found teachers with high value-added scores who were transferred to new schools increased achievement at their new schools in accordance with predictions. Students assigned to high value-added scored teachers in their elementary or middle school years are more likely to improve long term student outcomes, for example, attending higher-ranked colleges. The study also revealed that replacing a teacher having a lower value-added score with an average value-added teacher would result in a significant increase in a students' lifetime income (Chetty et al., 2011).

However, there exist fundamental concerns and views that may bedevil using a value-added model to measure of teacher effectiveness. For example,

- such measures provide limited insight into what teaching practices matter for student learning which is needed to guide instructional development (Goe, 2008).
- random assigning of students to teachers for measuring teacher effectiveness is rarely feasible (or ethical) and effectiveness of the school and teacher is estimated under less than ideal conditions (Braun, 2005; Goldhaber & Anthony, 2004; Rothstein, 2009).
- a plausible risk of correct model specification in value-added models due to little consensus within the field about which model specifications produce the most accurate value-added model (Murphy, 2012).

Several value-added models have been developed, including the Dallas Value-added Accountability System (DVAAS), the Rate of Expected Academic Change (REACH), and the Education Value-added Assessment System (EVAAS) (McCaffrey et al., 2003). The EVAAS is the best known and most widely used approach (Ballou, Sanders & Wright, 2004; Braun, 2005). The EVAAS is highly parsimonious and uses all the test information available for a given cohort of students, and the identities of the school and teachers (Ballou et al., 2004; Braun, 2005). The basic model of EVAAS is an equation that includes the history of student test scores to estimate the effectiveness of the teacher (Ballou et al., 2004; Braun, 2005). However, the EVAAS has been criticised for not controlling for socioeconomic status (SES) and other background factors such as ethnicity and gender (Kupermintz, 2003; Linn, 2001). However, research evidence (e.g., Ballou et al., 2004) has not supported these contentions.

Research question

To address the purpose of the study, i.e. to estimate the direct effects of schools and teachers on student mathematics achievement, a value-added model, specifically the EVAAS, was used and a single research question was developed: *What are the 20 highest performing secondary schools in mathematics within Dhaka Metropolitan City (DMC), Bangladesh.* The question refers, firstly to measuring the output, i.e. the performance of all secondary schools of the DMC through the teachers' value-added effect on students' mathematics learning growth according to standardised tests, then secondly to identifying twenty highest performing schools according to their value-added performance.

Data collection and sampling

To address the research question, a cross-sectional cohort research design was adopted, and a purposive sampling was used in the study. Permission was obtained from the

Chairman of the Board of Intermediate and Secondary Education (BISE), Dhaka to access to the database containing students' mathematics grades in the JSC in 2010 and the SSC in 2013. Specifically, the database included the mathematics grades for all students who completed the JSC 2010 and SSC 2013 and attended the 5,867 secondary schools administered by the BISE, Dhaka (BANBEIS, 2014). As the student population in these databases was very large, a purposive sample comprising the mathematics grades of all students who attended the 380 schools within the Dhaka Metropolitan City (DMC) only were extracted from the database for the JSC 2010 and SSC 2013.

To extract the sample using a Microsoft *Excel 2010* spreadsheet, students were sorted by the secondary school attended, and the schools were grouped according to the geographical location within the BISE, Dhaka. This enabled the researcher to isolate and extract the sample of secondary schools located within the DMC for further analysis. Thus, the sample comprised the mathematics grades for students in the JSC 2010 and SSC 2013 who attended the 380 high schools in the DMC.

Validity and reliability of data

There are several reasons why the BISE, Dhaka database of student mathematics grades for JSC 2010 and SSC 2013 used in the analysis provide a source of valid and reliable data. BISE, Dhaka is responsible for and administers the JSC and SSC public examinations and follows rigorous procedures in the administration of the examination and analysis of student papers. For example, the BISE selects a number of schools to act as examination centres and directs students to attend an examination centre which is not the school attended. Invigilators include teachers from the school nominated as an examination centre and external supervisors monitor examination activity at each centre. Once the examination is over, identifying student information is separated from answer sheets (which includes student registration numbers), and sent to the BISE, Dhaka following strict administrative procedures and processes. Student papers are marked ranging from 0-100 and are converted into grades, ranging from F to A^+ (see Table 1).

Data analysis procedure

Preparation of data for analysis

Once the sample of schools, (and student grades) was identified, a number of steps were required to prepare the data for the analysis. The first step required manually working through the data (51,541 students) to match student cohort data for the JSC 2010 with the SSC 2013. To facilitate matching of student cohort data, the BISE student registration number for external examinations was used. The matching process yielded a total of 51,434 students in the cohort for the JSC 2010 and the SSC 2013 who attended the 380 schools in the DMC. Thus, there were 107 unmatched students who did not complete the SSC 2013.

Table 1: Individual subject grade, score range, and grade point average

Grade	Range of scores	GPA
A+	80-100	5
A	70-79	4
A-	60-69	3.5
B	50-59	3
C	40-49	2
D	33-39	1
F	00-32	0

The next step required the conversion of student grades in mathematics in the JSC 2010 and SSC 2013 to coded scores. The seven grades A+, A, A-, B, C, D, and F were coded as 5, 4, 3.5, 3, 2, 1, and 0 respectively, as shown in Table 1.

EVAAS equation employed for data analysis

The EVAAS approach and estimation technique provided by Braun (2005) and Ballou et al. (2004) were used for data analysis follows. The basic model of EVAAS is an equation,

$$y_t^k = b_t^k + u_t^k + e_t^k \quad \ldots 1(a)$$

that expresses the score of a student (y_t^k) at the end of a particular grade (*k*) in particular year (t) as the sum of three components: district mean test score in year *t*, grade *k* = b_t^k, teacher effect/contribution of the grade *k* teacher to the year *t* test score = u_t^k, and systematic and unsystematic variations or error in year *t*, grade *k* = e_t^k. It is assumed that the teacher effect is the same for all the students in the class and attributable to the teacher of the class.

When the student moves in the next year (t+1) to the next grade (k+1), then the equation is,

$$y_{t+1}^{k+1} = b_{t+1}^{k+1} + u_t^k + u_{t+1}^{k+1} + e_{t+1}^{k+1} \quad \ldots 1(b)$$

and has four components: district average for that grade and year = b_{t+1}^{k+1}, teacher effect for that year = u_{t+1}^{k+1}, teacher effect from the previous year = u_t^k, and systematic and unsystematic error of that year = e_{t+1}^{k+1}.

It is assumed that the teacher effect for the previous year persists undiminished into the current year and the components of the unspecified variations in the two years are unrelated to each other. All variables in equations 1(a) and 1(b) pertain to the same student and subject. Teacher effects are subscripted with years, and the model does not constrain teacher effectiveness to be constant over time. Thus, 'teacher effects' are teacher-within-year effects (Ballou et al., 2004). Finally, subtracting equation 1(a) from equation 1(b) and after rearranging, we find the teacher effect after one year,

$$u_{t+1}^{k+1} = (y_{t+1}^{k+1} - y_t^k) - (b_{t+1}^{k+1} - b_t^k) - (e_{t+1}^{k+1} - e_t^k)$$

Braun (2005) suggested that to make this formulation intuitively plausible and attractive, the error terms could be ignored. Thus, the teacher effect after one year (e.g., t+1) is,

$$u_{t+1}^{k+1} = (y_{t+1}^{k+1} - y_t^k) - (b_{t+1}^{k+1} - b_t^k)$$

This is, the difference between the gain experienced by the student in that year and the average gain in the district for that same year.

Applying a similar method and assuming that in the consecutive two years the student is taught by the same teacher(s) and the gain in student's scores and district average are measured in two tests scores (e.g. year *t*-test score $= u_t^k$ and year $t+2$ test score $= u_{t+2}^{k+2}$), the teacher effect after two years is,

$$u_{t+2}^{k+2} = (y_{t+2}^{k+2} - y_t^k) - (b_{t+2}^{k+2} - b_t^k)$$

Results

The value added-analysis for the cohort data was conducted using the EVAAS equation outlined above and the steps described below.

The first step was to calculate school means of student mathematics scores in the JSC (2010) and SSC (2013) for each of the 380 schools. The results of this step for the 20 highest performing secondary schools are displayed in columns 2 and 3 in Table 2.

The second step was to obtain the mean gain in mathematics scores for each school over two years (i.e., JSC 2010 to SSC 2013). The means of student mathematics scores in each school in the JSC 2010, shown in Table 2 as (y_{2010}^8), were subtracted from means of student mathematics scores in each school in the SSC (2013), shown in Table 2 as (y_{2013}^{10}). It should be noted, in Bangladesh, students passing the JSC examinations continue with a further two years of schooling and sit the SSC examinations at the beginning of the following year. Thus, the equation for this calculation was:

$$(y_{2013}^{10} - y_{2010}^8)$$

The results of this step are shown in Table 2, column 4.

Table 2: Twenty highest performing secondary schools in mathematics within DMC based on value-added scores (JSC, 2010 - SSC, 2013).

School name	School mathematics performance SSC 2013 (y_{2013}^{10})	School mathematics performance JSC 2010 (y_{2010}^{8})	School gain $(y_{2013}^{10} - y_{2010}^{8})$	DMC gain $(b_{2013}^{10} - b_{2010}^{8})$	Value added score (u_{2013}^{10})	School rank (VAA)
Seam	4.61	1.87	2.74	0.83	1.91	1
Tasin	3.63	1.20	2.43	0.83	1.60	2
Nakib	4.43	2.02	2.41	0.83	1.58	3
Chadni	4.88	2.50	2.38	0.83	1.55	4
Abida	4.07	1.79	2.28	0.83	1.45	5
Hamida	3.90	1.76	2.14	0.83	1.31	6
Kanta	4.42	2.30	2.12	0.83	1.29	7
Drishti	3.43	1.33	2.10	0.83	1.27	8
Khan	4.09	2.05	2.05	0.83	1.22	9
Sumon	3.53	1.52	2.01	0.83	1.18	10
Tinni	3.31	1.34	1.97	0.83	1.14	11
Mahbub	3.94	1.98	1.96	0.83	1.13	12
Refat	3.80	1.85	1.96	0.83	1.13	13
Megh	3.98	2.03	1.95	0.83	1.12	14
Aruna	4.64	2.69	1.95	0.83	1.12	15
Protik	4.23	2.28	1.95	0.83	1.12	16
Angela	4.03	2.11	1.92	0.83	1.09	17
Raihan	4.56	2.64	1.91	0.83	1.08	18
Nipa	3.88	1.97	1.91	0.83	1.08	19
Shahid	3.67	1.77	1.90	0.83	1.07	20

In the third step, the means of student mathematics scores in the DMC in the JSC 2010 and SSC 2013 were calculated. As before, the mean gain in mathematics scores was calculated by subtracting the mean in the JSC 2010 from the SSC 2013 in the DMC. This is represented by the equation:

$$(b_{2013}^{10} - b_{2010}^{8})$$

The fourth step was to calculate the value-added score for each school by subtracting the DMC gain from the gain of each school. This calculation is represented by the equation:

$$u_{2013}^{10} = (y_{2013}^{10} - y_{2010}^{8}) - (b_{2013}^{10} - b_{2010}^{8})$$

In this equation, u_{2013}^{10} is the value-added score. Appendix 1 shows that value-added scores for the 380 schools ranged from 1.91 to -2.58, and descriptive analysis revealed the mean value-added score was .24, with a standard deviation of .56. Closer examination of Appendix 1 showed 209 schools were value-adding above the mean (i.e., $M > 0.24$), and 171 schools were value-adding below the mean (i.e., $M < 0.24$).

Figure 1 shows the frequency distribution of value-added scores for the 380 secondary schools. The distribution of scores is negatively skewed and leptokurtic, and there are several outliers (e.g., school ranked 380).

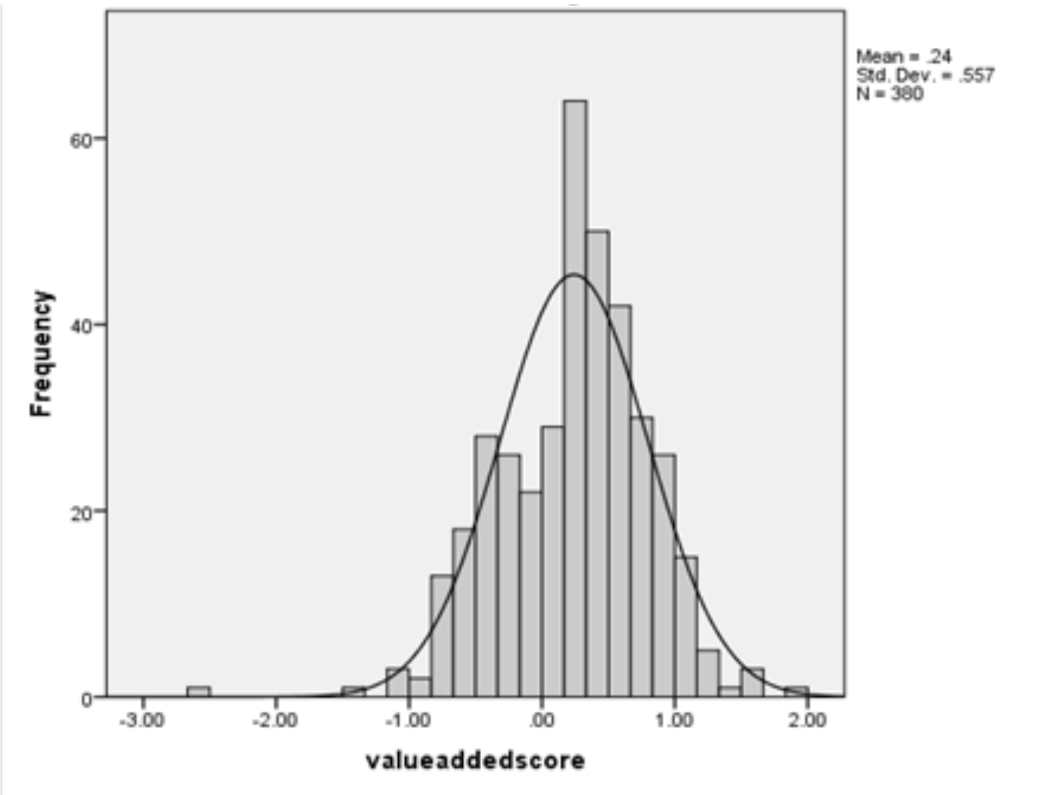

Figure 1: Frequency distribution of value-added scores for 380 secondary schools

The last step was to rank each school according to their value-added scores, followed by identifying the 20 highest performing schools. Table 2 displays the twenty highest performing schools (using pseudonyms to maintain confidentiality), JSC 2010 and SSC 2013 data, school gains, district gain, and value-added scores.

It can be seen from Table 2 that value-added scores of the twenty highest performing schools ranged from 1.91 to 1.07. Descriptive analysis showed mean value-added score of 1.27, and standard deviation equal to .23. Comparison with the value added scores of each school (Table 2) indicated eight of the 20 highest performing schools value-added above the mean (i.e., M ≥ 1.27) and 12 were value-adding below this level

Table 3 displays minimum and maximum value-added scores, means and standard deviation for the 380 schools and the 20 highest performing secondary schools. Table 3 suggests a wide gap in the mean value-added score (a difference of 1.03) between the mean of the 380 schools (*M =.24*) compared to the mean of the 20 highest performing schools (*M = 1.27*).

Table 3: Descriptive statistics of the 380 secondary schools and the 20 highest performing secondary schools in mathematics within DMC

Schools	Minimum	Maximum	Mean value added score	Standard deviation
380 schools	-2.58	1.91	.24	.56
20 highest schools	1.07	1.91	1.27	.23

Table 4 summarises the demographic characteristics of the 20 highest performing secondary schools in mathematics within the DMC. It should be noted all top performing schools were private schools. Table 4 shows most of these schools (13) catered for grades 1 to 10, and the minority (3) catered for grades 6 to 10, and others (4) catered for grades 1 to 12 No patterns are evident in terms of the size of the schools from the descriptive analysis.

Table 4: Characteristics of 20 highest performing secondary schools in mathematics within DMC

School	School grades	Secondary students (number)			Secondary teachers (number)	
		Male	Female	Total	Maths	Total
Seam	1-10	500	0	500	4	18
Tasin	1-10	400	350	750	9	27
Nakib	1-12	795	275	1070	8	42
Chadni	6-10	100	150	250	2	12
Abida	1-10	0	550	550	3	15
Hamida	1-10	0	780	780	3	18
Kanta	1-10	453	706	1159	2	27
Drishti	1-10	68	12	80	1	10
Khan	1-12	550	450	1000	5	22
Sumon	1-10	166	157	323	5	13
Tinni	6-10	220	300	520	3	12
Mahbub	1-10	234	249	483	5	16
Refat	1-10	285	215	500	2	24
Megh	1-10	0	250	250	2	14
Aruna	1-12	0	350	350	3	11
Protik	1-10	289	360	649	1	12
Angela	1-10	0	1268	1268	8	60
Raihan	6-10	292	360	652	4	18
Nipa	1-12	514	359	873	4	42
Shahid	1-10	0	195	195	2	11

Notes. School type 1-10 refers to combined primary and secondary grades; 6-10 refers to secondary grades only; 6-12 refers to combined secondary and higher secondary grades; and 1-12 refers to combined primary, secondary and higher secondary grades.

In addition, as can be seen in Table 4, four schools have more than 1000 students, nine schools have less than 500, and seven schools have more than 500 but less than 1000 students. Table 4 shows most secondary schools (n = 17) have less than five mathematics teachers and three have more than five teachers. While Table 4 suggests congruence between the size of the student population and the number of mathematics teachers in schools, the exception is Kanta secondary school which had a student population of more than 1000 and two mathematics teachers.

Discussion

Characteristics of top performing schools

The findings of the value-added analysis of the current study are the identification of the schools whose teachers produced high gains in students' mathematics achievement. The results showed the 20 highest performing secondary schools in mathematics had value-added scores ranging from 1.91 to 1.07, (*M* = 1.27, *SD* = .23). The mean value-added score of the 20 highest performing schools was 1.03 above the mean value-added scores computed for the population of 380 secondary schools, (*M* = .24, *SD* = .56) within DMC, Bangladesh. Further, the 20 highest performing secondary schools shared one notable characteristic, they were all private schools. Apart from this, descriptive statistical analysis showed no other clear patterns among the 20 highest performing schools. For example, the size of the student population ranged from 80 to 1268 students, most schools (17) employed up to five mathematics teachers (which did seem to be determined by the size of the student population, more than half (13) schools catered for students in grades 1-10, one-fifth (4) schools catered for students in grades 1-12 and three schools catered for students in grades 6-10.

Using value-added model to assess teacher effectiveness

The study is the first that measured teacher effectiveness using a value-added model. The results of the study revealed that the twenty schools identified as the top performing schools in the study (see Table 1) did not belong to any of the best schools of the Board of Intermediate and Science Education (BISE), Dhaka in the relevant exam year. Moreover, the records of the last twenty years of BISE, Dhaka evidence the same. One of the main reason for such significant variance includes the difference in the method of evaluating school performance. The evaluation method of the education boards is based on student achievement scores where each school is given a score considering the number of highest grade (i.e. GPA 5) achievers, number of total examinees and passed examinees, and total GPA of the school.

Besides, although it may be convenient to adopt a single measure of teacher effectiveness, several scholars (e.g., Ayres, Dinham & Sawyer, 2004; Smith, Baker, Hattie & Bond, 2008) recommended using multiple measures to determine teacher effectiveness, including test-based (e.g., student academic achievement scores) and non-test-based measures (e.g., classroom observations) in the identification of effective teachers. Coe and colleagues (2014, p.3) argued: "a single source of evidence may suggest the way forward, but when it is confirmed by another independent source it starts to become a credible guide".

Limitations

It is recognised the study has at least two limitations. The first is related to the sampling. The use of a purposive sampling strategy that focused on identifying the 20 highest performing secondary schools in mathematics within Dhaka, Bangladesh would have excluded schools of students' achieving outstanding results in other subjects due to teacher value-added effectiveness. Further, schools were chosen because they were located within the metropolitan area and this excluded other secondary schools within Dhaka, Bangladesh. Thus, the findings may not be totally representative, nor generalisable to the population of secondary schools within Dhaka, Bangladesh.

The second limitation concerns the impact of private tutoring on the measured students' mathematics achievement of the study. Private tutoring is a common phenomenon in Bangladeshi education context (Hamid, Sussex & Khan, 2009). Though investigation in relation to private tutoring in mathematics is rare in Bangladesh, several scholars (e.g. Hamid et al., 2009; Mahmud & Bary, 2017; Manzoor, 2013; Shihab & Sultana, 2017) have revealed the reasons and necessity of private tutoring in English for secondary students in Bangladesh, and its positive association with their academic achievement in English. Thus, it is possible to have the contributions from private tutoring shaping students' mathematics achievement, though it is difficult to isolate private tutors' contributions from the school teachers' contributions.

In summary, it is recognised the study has a number of limitations, the findings need to be interpreted cautiously and there is a need for further investigation. However, notwithstanding the limitations of this study, it contributes new insights about secondary teacher effectiveness in Bangladesh.

Directions for future research

The study provides the first value-added assessment of effective secondary mathematics teachers in Bangladesh and serves as a base for future studies of teaching effectiveness. Future studies need to include multiple measures that can capture everything that a teacher contributes to the academic, social, and behavioural growth of students. Advocates of value-added models (e.g. Goe et al., 2008) suggest adding other methods of teacher effectiveness to a value-added model as the value-added scores of teachers may provide information about a teacher's contribution to student learning but unable to offer guidance on how to improve a teacher's teaching performance.

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Appendix 1: School ranking based on value-added score for schools in Dhaka metropolitan area (N = 380)

School rank	Value-added score	School rank	Value-added score	School rank	Value-added score	School rank	Value-added score
1	1.91	49	0.86	97	0.60	145	0.42
2	1.60	50	0.85	98	0.60	146	0.42
3	1.58	51	0.84	99	0.60	147	0.41
4	1.55	52	0.83	100	0.60	148	0.41
5	1.45	53	0.82	101	0.59	149	0.41
6	1.31	54	0.81	102	0.59	150	0.41
7	1.29	55	0.81	103	0.58	151	0.41
8	1.27	56	0.80	104	0.58	152	0.40
9	1.22	57	0.80	105	0.58	153	0.40
10	1.18	58	0.80	106	0.58	154	0.39
11	1.14	59	0.78	107	0.57	155	0.39
12	1.13	60	0.78	108	0.56	156	0.39
13	1.13	61	0.77	109	0.56	157	0.38
14	1.12	62	0.77	110	0.56	158	0.38
15	1.12	63	0.76	111	0.55	159	0.38
16	1.12	64	0.76	112	0.55	160	0.38
17	1.09	65	0.75	113	0.55	161	0.38
18	1.08	66	0.75	114	0.55	162	0.37
19	1.08	67	0.75	115	0.55	163	0.37
20	1.07	68	0.75	116	0.54	164	0.37
21	1.07	69	0.73	117	0.53	165	0.37
22	1.05	70	0.72	118	0.53	166	0.36

School rank	Value-added score	School rank	Value-added score	School rank	Value-added score	School rank	Value-added score
23	1.05	71	0.72	119	0.52	167	0.36
24	1.01	72	0.72	120	0.52	168	0.36
25	1.01	73	0.71	121	0.52	169	0.35
26	0.99	74	0.71	122	0.51	170	0.35
27	0.98	75	0.71	123	0.51	171	0.35
28	0.97	76	0.68	124	0.50	172	0.34
29	0.97	77	0.68	125	0.49	173	0.33
30	0.96	78	0.68	126	0.49	174	0.33
31	0.95	79	0.67	127	0.48	175	0.33
32	0.95	80	0.67	128	0.48	176	0.33
33	0.93	81	0.67	129	0.48	177	0.33
34	0.93	82	0.67	130	0.47	178	0.32
35	0.93	83	0.66	131	0.47	179	0.32
36	0.92	84	0.66	132	0.47	180	0.32
37	0.91	85	0.65	133	0.46	181	0.32
38	0.91	86	0.65	134	0.46	182	0.32
39	0.90	87	0.65	135	0.46	183	0.32
40	0.89	88	0.64	136	0.46	184	0.32
41	0.89	89	0.63	137	0.45	185	0.31
42	0.89	90	0.62	138	0.45	186	0.30
43	0.88	91	0.62	139	0.45	187	0.30
44	0.87	92	0.62	140	0.44	188	0.30
45	0.87	93	0.61	141	0.44	189	0.30
46	0.86	94	0.61	142	0.43	190	0.30
47	0.86	95	0.61	143	0.43	191	0.30
48	0.86	96	0.60	144	0.43	192	0.30
193	0.29	241	0.15	289	-0.17	337	-0.47
194	0.29	242	0.15	290	-0.18	338	-0.47
195	0.29	243	0.14	291	-0.20	339	-0.47
196	0.28	244	0.14	292	-0.20	340	-0.47
197	0.28	245	0.14	293	-0.21	341	-0.47
198	0.28	246	0.13	294	-0.21	342	-0.49
199	0.28	247	0.13	295	-0.22	343	-0.50
200	0.28	248	0.12	296	-0.22	344	-0.52
201	0.27	249	0.12	297	-0.22	345	-0.52
202	0.27	250	0.12	298	-0.23	346	-0.53
203	0.27	251	0.12	299	-0.24	347	-0.54
204	0.26	252	0.11	300	-0.25	348	-0.56
205	0.26	253	0.10	301	-0.25	349	-0.57
206	0.26	254	0.10	302	-0.26	350	-0.57
207	0.26	255	0.08	303	-0.27	351	-0.58
208	0.26	256	0.08	304	-0.27	352	-0.59
209	0.25	257	0.08	305	-0.29	353	-0.62
210	0.25	258	0.08	306	-0.29	354	-0.63

School rank	Value-added score	School rank	Value-added score	School rank	Value-added score	School rank	Value-added score
211	0.25	259	0.07	307	-0.30	355	-0.63
212	0.24	260	0.07	308	-0.30	356	-0.65
213	0.24	261	0.06	309	-0.31	357	-0.65
214	0.23	262	0.06	310	-0.31	358	-0.66
215	0.23	263	0.05	311	-0.31	359	-0.66
216	0.23	264	0.02	312	-0.32	360	-0.67
217	0.23	265	0.02	313	-0.32	361	-0.68
218	0.22	266	0.00	314	-0.33	362	-0.69
219	0.22	267	-0.02	315	-0.34	363	-0.69
220	0.22	268	-0.02	316	-0.34	364	-0.71
221	0.22	269	-0.04	317	-0.34	365	-0.74
222	0.21	270	-0.05	318	-0.35	366	-0.74
223	0.21	271	-0.05	319	-0.35	367	-0.74
224	0.21	272	-0.05	320	-0.36	368	-0.76
225	0.20	273	-0.07	321	-0.36	369	-0.76
226	0.20	274	-0.08	322	-0.36	370	-0.77
227	0.19	275	-0.10	323	-0.37	371	-0.79
228	0.19	276	-0.11	324	-0.38	372	-0.82
229	0.19	277	-0.11	325	-0.39	373	-0.83
230	0.19	278	-0.11	326	-0.40	374	-0.88
231	0.19	279	-0.12	327	-0.40	375	-0.96
232	0.18	280	-0.12	328	-0.42	376	-1.06
233	0.18	281	-0.12	329	-0.43	377	-1.12
234	0.18	282	-0.12	330	-0.43	378	-1.14
235	0.18	283	-0.13	331	-0.43	379	-1.45
236	0.17	284	-0.14	332	-0.44	380	-2.58
237	0.17	285	-0.14	333	-0.45		
238	0.16	286	-0.15	334	-0.45		
239	0.16	287	-0.16	335	-0.46		
240	0.15	288	-0.16	336	-0.46		

Note: The names of the schools are omitted to preserve confidentiality.

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