An interactive, multivariate projection model for the alignment of teacher demand and supply for schools in the Gauteng Province of South Africa: a disaggregated approach

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Abstract

This paper reports on the conceptualisation of a multivariate interactive computerised teacher demand and supply decision support model of projection for the Further Education and Training band (FET) of public schools for the Gauteng Province of South Africa. This model was conceptualised with the view to enabling policy makers to make projections that estimate aggregate or disaggregate teacher supply and demand. A reductionist methodological approach was used in this inquiry with the intention of reducing the ideas surrounding teacher supply and demand into a discrete set of variables reflected in a multivariate model. It also reflects a deterministic philosophy of cause and effect, as variables are manipulated within the model. Knowledge is developed in this inquiry through the development of multiple numeric measures of the objective reality of teacher supply and demand. The main contribution of this inquiry is the computerised disaggregated teacher supply and demand projection model. This model not only contributes to the knowledge base of educational planning and forecasting, but provides a clearer picture of the complex variables involved in teacher supply and demand as well.

Key words: Teacher supply, teacher demand, multivariate projection model.

Introduction

The main purpose of a teacher supply and demand study should be to improve the education of all learners by helping policymakers create targeted policies that ensure all learners are taught by high-quality qualified teachers, all of the time. Understanding the actual extent of the need for qualified teachers is the first step in ensuring that there is a qualified teacher in every classroom (Reichardt, 2003). Specific legislative and institutional changes that have been made to include all teacher education as a national and not a provincial responsibility confounds the situation in South Africa further (Lewin, Sayed & Samuel, 2003; Jansen, 2004). In our opinion, provincial policymakers are better equipped to use teacher demand and supply information to help solve problems within a specific context based on data rather than anecdotes. A key advantage of a provincial teacher demand and supply analysis is that it identifies issues specific to a given province (Reichardt, 2003). For example, a national average of 8.3% for unqualified teachers may be very different in each province. Kwazulu Natal may have 30% unqualified teachers, while Gauteng may only have 3%. In this paper, we propose that targeted interventions by each province based on provincial figures, rather than national figures, are far more accurate.

The events leading up to the conceptualisation of this project must be explained firstly. In the early 1990s there were 120 teacher training colleges in South Africa, collectively training 80 000 students (Parker, 2003). In 1995 The Ministry of Education commissioned the first-ever National Teacher Education Audit. The audit report highlighted the mismatch between teacher supply and demand, with a clear oversupply in 1994 (Hofmeyr & Hall, 1995). In response to the National Audit, the White Paper of 1997 set out an education transformation policy that included a decrease in the number of teacher education training colleges in South Africa (Gauteng Department of Education, 1997). As a result of this policy, the Minister of Education merged certain teacher training colleges and proceeded to close others. By 2001, the remaining 27 teacher training colleges were incorporated into universities and technikons (Jansen, 2002). Teacher training college closures subsequently resulted in a decline in teacher supply,

due to a significant reduction in enrolment of pre-service (PRESET) teachers (Jansen, 2002; Reddy, 2003). The National Education Audit in 1994 found that there were 26 000 newly qualified teachers, and predicted that by 2004 numbers would increase to 31 000 (Hofmeyr & Hall, 1995, p43). The actual figures for 2004 showed only 6 000 students graduated as newly qualified teachers. More recent figures also highlight a shortage of teachers, but the complexities of the issue are often overlooked (Chisholm, 2009). To this end we must first elaborate on teacher demand and supply.

Teacher demand consists of a growth in demand and the demand for replacement. The growth in demand for teachers is determined by the growth in learner numbers, and the post provisioning norm (PPN) or learner-educator ratio (LER) that is applied institutionally. The demand for teacher replacement is determined by the in-service attrition rate, which can manifest in teachers retiring, in teachers seeking employment in other sectors, and so on. The National Teacher Education Audit (Hofmeyr & Hall, 1995) calculated a single average Learner-Educator Ratio (LER) for primary and high schools of 34:1. This is an aggregated ratio that provides no disaggregated detail of the learning phases that were operational in 1994, namely; Junior Primary, Senior Primary and the subject specialisations in the secondary schools. A single aggregated LER for the entire schooling system may indicate no shortages. This is exactly what prompted the statement from the education department in 2005 regarding teacher supply and demand, which stated that there was ‘no quantitative shortage’ at that time. However, there may be imbalances and over supplies in certain phases that effectively mask under supplies in others. It would be far more meaningful and revealing to disaggregate the LERs, to set one ratio for each phase, and then to analyse each phase separately. Green, Parker Deacon and Hall (2011, 113) concur that while previous studies have been able to point to overall enrolment and graduation patterns, they have not been able to disaggregate the figures to show enrolment and graduation patterns for specific phases of schooling, and for specific subjects.

The Education Department had partially responded to this by setting a separate LER for primary schools and for high schools. Resolution 3 of 1996 and the Education Laws

Amendment Act No 100 of 1997 were adopted by the Education Labour Relations Council in 2000 and were based on the phasing in of a LER of 40:1 at all primary schools and 35:1 at all secondary schools. These norms were deemed affordable under budget projections and were intended to retain the total teacher stock at 1996 levels of 360, 000 (Crouch & Perry, 1999). This resulted in a decrease in the number of state-paid teachers. The effect of this was to pass the financial burden of the reduced numbers of teachers employed from the state to the parents. School Governing Body (SGB) teacher posts, which are funded by the schools, trebled from 10, 931 in 1996 to 29, 939 in 2000. This constituted 8% of all teachers employed in public schools in 2000 (Crouch & Lewin, 2003). These SGB teachers helped maintain a single aggregated LER for primary and high schools in Gauteng of 34:1, and 33:1 for the country as a whole. To quote more recent figures, the 2009 national ratio across all phases of schooling was set by the Department of Education (2009, 4) at 32,6:1. A problem with the Gauteng LER of 34:1 is that it is not disaggregated into phases and bands, such as the FET band. There is a need to disaggregate it further to calculate whether there are imbalances across the phases and bands, and to determine if the ratio of 34:1 is the best to ensure quality education.

If the LER ratio 34:1 is too high for quality education, then it is masking teacher shortages. An analysis of the Organisation for Economic Co-operation and Development (OECD) indicators for 2006 shows that the average public high school LER for 30 countries, including Australia, Europe, the United Kingdom and the United States of America, was 13,4:1 (Organisation for Economic Co-operation and Development, 2006). South Africa may have a huge shortage of teachers when compared to other countries. In 2006 for example, South Africa had 367, 188 teachers in public schools and 12 million learners (Department of Education, 2006). If South Africa had to demand a LER of 13,4:1 the country would be short of more than 500, 000 teachers. We would require a 150% increase in the number of teachers. If LERs are translated into class size, approximately 6 additional learners need to be added to the relevant LER (Hofmeyr & Hall, 1995). This is because a number of teachers, such as principals, deputy-principals, heads of departments and librarians, are involved in non-teaching activities in the schools. For example, a LER of 34:1 yields a class size of approximately 40 learners (20

in the OECD 2006 indicator countries). The average South African class sizes are already double the international average. There is evidence that class size reductions are particularly beneficial for learners from disadvantaged backgrounds (Santiago, 2002), and this is particularly relevant seeing that the majority of learners in South Africa are from disadvantaged backgrounds. In 2006, the president of the National Professional Teachers Organisation of South Africa (NAPTOSA) believed a class size of thirty or fewer learners was ideal for teachers to provide quality education. A class size of 30 translates into a LER of 24:1. Based on the 2006 figures, an LER of 24:1 translates into a minimum aggregate shortage of more than 100, 000 teachers in South Africa, and about 20, 000 teachers in Gauteng. Splitting these aggregate LER totals between phases and bands would be a starting point of a disaggregated analysis. However, phase and band shortages, or over supplies of teachers, cannot merely be assessed by an aggregate head count of teachers and learners using a given LER. The disaggregation must be taken further. Factors, such as teacher attrition rates, teacher qualifications and teacher subject specialisations within each phase and band must also be analysed.

In 2005 the teacher in-service attrition rate in South Africa was estimated at between 5 and 5.5%. A more recent report confirms that this figure is still around 5% (Centre for Development and Enterprise, 2011). In 2005 this translated to between 17 000 and 20 000 teachers lost each year, and current figures according to the CDE report are estimated at 20, 500 per year. By taking growth in learner numbers into account, this results in a more realistic figure of 25, 000 (Centre for Development and Enterprise, 2011). In 2007 the National Department of Education called for PRESET institutions to qualify 20, 000 teachers annually, but no attempt was made to disaggregate these figures. This lack of disaggregation is problematic. What if the 20, 000 teachers lost were 10, 000 Mathematics and 10, 000 Physical Sciences teachers, and the 20 000 qualifying teachers were all Geography teachers? Aggregately, the lost teachers and qualifying teachers would be in equilibrium, reflecting no quantitative shortages. Disaggregated figures indicate shortages of Mathematics and Physical Sciences teachers, and an oversupply of Geography teachers.

In addition to growth in demand for teachers and the demand of replacement, we believe another factor needs to be added into the calculation of teacher demand. This factor will be called *qualified demand*. Qualified teachers have a noticeable impact on the quality of education (Nilsson, 2003). Teacher quality affects failure rates (Naidoo & Lewin, 1998) and the future career paths of learners, and can influence the economy. A study conducted in 1989 (Pouris, 1989) and another study conducted in England, Australia, Canada, China, Japan, Portugal from 1991 to 1994 found that the most important reason for learners following careers in science, engineering and technology was the quality of science teaching at school (Woolnough, 1991, 1994a, 1994b). Accordingly, the issue of under qualified teachers is raised in this inquiry.

A qualified teacher is one that is both academically and professionally qualified. An under-qualified teacher is regarded as having less than a matric or Senior Certificate Examination (SCE) pass, and a three-year teaching diploma or degree (Hofmeyr & Hall, 1995). In 1994, the national teacher audit showed that 36% of teachers were under-qualified (Hofmeyr & Hall, 1995). Calculating from the PERSAL database, in 2000, 22% of teachers were under-qualified (Bot, 2005). By 2005 under-qualified teachers had fallen to 8.3 % of the workforce, but this still translates into an aggregate figure of 30, 000 teachers. This aggregate figure could be misleading. For example, a qualified teacher teaching outside their phase or subject of expertise is effectively under-qualified in that phase or subject. The Centre for Development and Enterprise report (2011:10) confirms that this is still the case and many teachers who are qualified to teach certain subjects, including scarce subjects, such as mathematics, do not actually teach those subjects. Many teachers of mathematics are not qualified to do so, and many of those who are qualified are not teaching mathematics. The Centre for Development and Enterprise (2011) notes that this is not a new observation, and cites an instance where, in 2005, the Department of Education found that 44% of teachers, qualified to teach a scarce subject (e.g. mathematics) were actually teaching other subjects. Currently there could be many qualified teachers who are teaching a subject outside of their area of specialization who are, in fact, not qualified to do so. We assert that the unqualified teachers should be added

to disaggregated teacher shortage numbers, as this will provide a more realistic picture of demand for qualified teachers

Teacher supply is the next topic of concern. Teacher Training College closures in South Africa resulted in a decline in teacher supply linked to a significant reduction in the enrolment of pre-service teachers (PRESET). Higher Education Institutions were also forced into mergers (Jansen, 2002), resulting in a shift from large staff numbers at former teacher education institutions to significantly fewer institutions and fewer staff with increased workloads (Reddy, 2003). The decline in PRESET student enrolments of 24,3% between 1999 and 2003 led to the prediction of a severe shortage of teachers over the next decade (Crouch & Perry, 2003). As an example, Crouch and Perry (2003) suggested that 30, 000 newly qualified teachers would be required annually by 2010. These numbers are aggregated totals and are severely lacking in the nature of outputs. They do little to inform us about phase, band, learning area, and subject qualification numbers. To put Crouch and Perry's estimate into perspective, in 2009 the Department of Basic Education (2009, 24) estimated that only between 6, 000 and 8, 000 teachers were graduating per annum. Furthermore, the nature of the graduate outputs is unknown. According to Kruss (2008, 190), historical trends, since 1994, also show a significant decline in enrolments in initial teacher education programmes. Despite this, graduation numbers also seem to have stabilised since 2004 (Green, Parker, Deacon & Hall, 2011, 113). In order to assist policymakers in quantifying qualifying teachers across the different phases, and bands, there is a need to identify student specialisations. Furthermore, for supply and demand analyses, the number of qualifying teachers per phase, and band, need to be adjusted to take cognisance of those who never teach. Pre-service attrition is a term we will use for the group of newly qualified teachers that never end up teaching.

A number of newly qualified teachers never teach. The Department of Education (2005:51) predicted that around one-third of teacher graduates do not plan to teach within South Africa, or at all. They move into more lucrative areas of employment or leave the country. A sample study in 2005 conducted in Kwazulu-Natal on newly qualified

teachers indicated that 28% were going to teach abroad and 7.4% were not going to teach at all. This high rate of pre-service attrition means qualifying teacher numbers in HEI teacher education programmes are unreliable proxies for the actual supply of teachers. Only those newly qualified teachers that actually teach can be added to the available supply pool of teachers.

The supply pool of teachers should not only include newly-qualified teachers that actually teach, but also qualified teachers that are not currently teaching and still wish to teach. For example, Statistics South Africa's Labour Force Survey of February 2001 showed that 119, 421 trained teachers were working, but not as teachers. Some authors argue that this large stock of people who have been trained as teachers, but are currently not working as teachers (working elsewhere, retired, unemployed), means that the pressure to train teachers is somewhat diminished (Crouch & Perry, 2003). This could be misleading, since it would be far more indicative to find out how many of these actually wish to teach, since they may never wish to teach in the first place. It may be more accurate to include teachers that have shown an interest in wanting to teach, for example qualified teachers who have contacted the DoE and are on a database of those wishing to teach. It is important that this departmental database maintains a detailed disaggregated record for each teacher.

Disaggregated detail would highlight over/under supply of teachers in each phase, learning area, Language of Learning and Teaching (LoLT), and subject, which, in turn, would enable informed decisions to be made regarding PRESET intakes. There is a need to reach a point where policymakers can set PRESET targets per subject, phase and learning area. In the current South African curriculum, the LoLT for the Foundation phase learners is the mother tongue of the learner. The Intermediate and Senior phases have eight learning areas, while FET offers many subjects. The imperative should be for PRESET targets to accommodate these demands.

Aims of the inquiry

The main aim of this inquiry is to develop a model of projection for the Further Education and Training band of public schools in Gauteng. Our multivariate interactive computerised model of projection may assist policy makers to provide forecasts for current disaggregated demand and supply of teachers in specific subject in the FET band. A further aim is to align the projected disaggregated FET teacher supply with the projected disaggregated FET teacher demand. Our model will also allow for the testing of scenarios by manipulation of the projection model variable inputs.

Conceptualising a projection model for teacher supply and demand

A South African projection model was developed in 2003 to project teacher demand and supply (Crouch & Perry, 2003). The design of this model resulted in aggregate teacher numbers for supply and demand for the entire spectrum from Grade 1 to Grade 12. For example, the projections suggested a looming imbalance between teacher supply and demand by 2006, when 20, 000 new teachers per year would have to be trained. It fails to disaggregate the 20, 000 teachers into phases, learning areas, mediums of instruction and subject specialisations. In particular it also ignores the aspect of qualified demand. Accurate targeted interventions would be impossible using an aggregate model, such as this one.

A computer-based mathematical disaggregated teacher demand model was developed in 2004 by the Canada-South Africa Teacher Development Project for the Gauteng Education Department, and was used to estimate the number of teachers needed in each phase of the Foundation, Intermediate, Senior and the FET bands. The model highlighted the need for teachers in the core FET subjects, but raised a number of concerns. A major problem with this model was that it assumed that the in-service attrition rate was constant at 5.1 % across the phases, FET subjects, and LoLT. As explained previously, the in-service attrition rate varies substantially across these different categories, and has a significant influence on projection numbers of replacement teachers. For this reason it must be as accurate as possible. The 2004 model also ignores the pre-service attrition rate. The pre-service attrition rate could be as high as 40 %, which means that PRESET

first year intake numbers could be 40% lower than they should be. The 2004 model also failed to include growth in demand for teachers. In 2006, growth in demand was estimated to be 0.5% (Department of Education, 2006).

Furthermore, other inaccuracies may result when future teacher demand numbers in the model are calculated using current values. For example, the model uses current learner enrolment numbers and current in-service attrition rates. For this reason trend analyses of learner numbers and attrition rates need to be built into a new projection model.

A more accurate assessment of FET disaggregated teacher supply and demand requires a dynamic teacher supply and demand projection model. The model must be an analytical and interactive decision support model that will provide multiple disaggregated projection scenarios by manipulation of the variable inputs. The variable inputs should include learner-to-educator ratios, in-service attrition rates, learner subject enrolment totals, PRESET student throughput rates, percentage of PRESET students entering per subject and qualifying, and pre-service attrition rates. Because PRESET takes four years, the model must project four years into the future. The model must allow for data and variables to be updated annually. The model should enable the DoE to become an active participant in teacher supply and demand decisions, such as the provision of bursaries to PRESET students based on the model projections of disaggregated demand.

A design to conceptualise a teacher demand and supply model

A reductionist approach is used in this inquiry with the intention of reducing the ideas surrounding teacher supply and demand into a discrete set of variables reflected in a multivariate model. It also reflects a deterministic philosophy of cause and effect as variables are manipulated within the model. Knowledge is developed in this inquiry through the development of multiple numeric measures of the objective reality of teacher supply and demand.

The national Department of Education (DoE) and the provincial Gauteng Department of Education (GDE) showed an interest in this inquiry with a view to extending it to all provinces, and consequently offered to make the information from their various databases available. Datasets containing information on all teachers working in Gauteng were thus obtained from the following databases:

- The Department of Education (DoE) Educational Management Information System (EMIS) database, which produces an annual statistical publication called School Realities. The data are from the survey conducted on the 10th school day. It provides information on learner enrolments and LERs, all per phase, band and province.
- The DoE also produces a more comprehensive annual statistical publication database, called Education Statistics in South Africa at a Glance. This also contains information on learner enrolments and teachers, but also matric learner subject enrolment.
- The National Personnel and Salary Management System (PERSAL) database contains detailed information on teachers. Attrition rates were calculated by a longitudinal comparison of the database from one year to the next and observing numbers of teachers who were on the payroll in one year and removed in the next year.
- The GDE database of qualified unemployed teachers who wish to be employed.
- The South African Council of Educators (SACE) database of registered teachers in South Africa. This database was used to develop a teacher qualification profile.
- The higher education Deans Forum annual teacher supply database on PRESET throughput and qualification rates per phase and FET subject specialisation.
- The PERSAL Teacher Appointment database, which was compared with graduating PRESET student lists to obtain information on pre-service attrition rates and the number of qualifying PRESET students actually entering the classroom.

Data analysis included analysis of the teacher supply and demand variables and analysis of the resultant multivariate projection model. Both independent and dependent variables were identified. To project or forecast demand and supply independent variables, we used quantitative trend analysis on both cross sectional and longitudinal (time-series) data. Historical databases were analysed statistically to provide actual annual growth rates for each variable. The annual growth rates for each variable were used to calculate a weighted moving average (exponential smoothing) growth rate for each variable (Gardner, 1985). The following formula was used in finding the weighted moving average:

$$\text{Weighted MA} = w_{\mathbf{1}}.D_{\mathbf{t}} + w_{\mathbf{2}}.D_{\mathbf{t-1}} + \ldots w_{\mathbf{n}}.D_{\mathbf{t-n}}$$

where the weights (w) are any positive numbers such that: $w_1 + w_2 + \ldots w_n = 1$.

MA=moving average
t=current year
D=annual growth rate
n is the number of years used in the calculation.

Using the extrapolation technique of linear projection, weighted average growth rates were applied to the last known year figures and projected forward to estimate values in future periods (Armstrong, 2001). Weighted average variable growth rates and projections can be updated annually as new data becomes available.

Regarding dependent variables, teacher demand is made up of growth in demand, the demand of replacement, and any shortfall in demand of qualification. Calculating the annual disaggregated growth in demand of teachers per subject entails dividing the increase in total school learner enrolments per subject by the average number of learners taught per teacher per week. For example, data on learner enrolments per subject for Grades 10, 11 and 12 in 2008 were compared to enrolments in 2006 and 2007. The differences divided by the average number of learners taught per week provide the teacher growth demand (or reduction if learner numbers fall).

Annual disaggregated demand of teacher replacement was measured as the total number of teachers per subject that left teaching. Data on resignations, deaths and retirements were analysed by linking the data longitudinally across 2006 and 2007 to provide information on the number of teachers leaving the profession per subject.

Demand for qualified teachers was calculated by dividing the total learner enrolment per subject by the average number of learners taught per week by a teacher. The answer is the number of qualified teachers required in each subject, or the demand of qualified teachers per subject. This qualified demand must be compared to the number of qualified teachers per subject currently making up the teacher workforce. If the qualified demand in a subject exceeds the total qualified teacher numbers in that subject of the current workforce, a shortage is evident. For example, in 2006 the total number of learners in the FET band in Gauteng was 383, 851 (Department of Education, 2006). Hypothetically, if 150, 000 were registered for Mathematics, and we calculate 240 as the average number of learners taught per week by each Mathematics teacher, then Gauteng would require 625 qualified Mathematics teachers (150 000 divided by 240). If the current teacher workforce had 500 qualified Mathematics teachers, the qualification shortage would be 125.

Trend analysis in the growth of demand, the demand of replacement, and any shortfall in qualified demand will be graphically displayed showing longitudinal fluctuations over time and average rates will be determined. Adding the growth and replacement totals per subject to any qualified shortage provided the annual disaggregate demand for teachers required in each subject. The disaggregated demand was used to inform the disaggregated supply of teachers.

The disaggregated supply of FET teachers is made up of pre-service teacher (PRESET) graduates per subject wishing to teach added to the pool of qualified unemployed teachers per subject wishing to teach. The number of PRESET graduates in four years time can be determined by the throughput rate of the first year registrations less the

number of the graduates that do not wish to teach. Graduate throughput rates were calculated from the Deans Forum data. A sample check survey of the PERSAL salary database provided estimates of pre-service graduates not wishing to teach. A pre-service attrition rate was calculated from pre-service graduates not wishing to teach as a percentage of total graduates. Regarding the pool of qualified teachers who are currently not employed in teaching, many may already have other employment in other fields, while others may have no intention of teaching again. As a result of this, numbers of qualified teachers that are no longer employed as teachers and appearing in publications, such as the Annual Household Survey, may be misleading. The only teachers we can include in the supply from the unemployed qualified pool are those that display a wish to be employed. These are the teachers who appear on departmental databases made up of actual applications for employment but are currently unemployed.

When combining the independent and dependent variables the projection model must be able to predict teacher shortages, and oversupply, in each subject of the FET band, while taking into account the language of classroom instruction. The model must be able to calculate the current disaggregated demand, the future disaggregated demand, the future disaggregated supply, and the current first year PRESET disaggregated supply numbers required to meet the future disaggregated supply.

For the current disaggregated demand projections, the model includes the major variables and the values they will be based on. These are shown in Table 1.

Table 1: Current Disaggregated Teacher Demand Variables

Projection	Variable	Based on
Current disaggregated teacher demand	Current Disaggregated teacher demand	Learner subject enrolments in current year and the average number of learners taught per teacher per week

In South Africa, current teacher demand estimates have been used in the past as a basis for the number of first year PRESET student teachers required. This is inaccurate, since the current first year intake will only qualify four years later and a reduced number will qualify. Compounding the problem is that fact that demand may be very different in four years time. A more accurate calculation for the current first year intake would be to project the current demand four years hence. This gives the teacher supply required in four years time. To calculate the current first year intake that will meet this supply, the teacher supply in four years must be increased by two factors. The first factor incorporates the percentage of teacher graduates who never teach, or pre-service attrition. The second factor incorporates the student throughput rates from first to fourth year. The increase due to these factors would result in a significantly different first year intake to what is estimated at present.

For the future disaggregated demand projections, the model includes the major variables and the values they will be based on. These are shown in Table 2.

Table 2: Future Disaggregated Teacher Demand Variables

Projection	Variable	Based on
Future disaggregated teacher demand	Future Disaggregated teacher Growth demand	Learner enrolment numbers based on past trends and the average number of learners taught per teacher per week in four years time
	Future Disaggregated teacher Replacement demand	Teacher in-service attrition rates in four years based on past trends in resignations, retirements, deaths

To achieve a balanced teacher demand and supply, the future projected disaggregated supply should match the future projected disaggregated demand. One of the key aspects of a projection model should be the prediction of the current first year PRESET disaggregated supply intake required to meet the future disaggregated supply.

For the current first year PRESET disaggregated supply intake projections, the model will include the major variables and the values they will be based on shown in the Table 3:

Table 3: Current First Year PRESET Disaggregated Supply Intake Variables

Projection	Variable	Based on
Current first year PRESET disaggregated teacher supply	Future Disaggregated teacher supply	Future disaggregated teacher demand in four years
	Teacher graduates that never teach	Teacher graduate drop-outs or pre-service attrition in four years based on past trends
	PRESET student dropout	PRESET student dropout from first to fourth year based on past trends

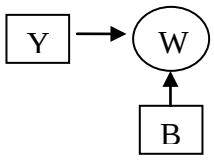
The projection model must be dynamic in the sense that changing variable trends must automatically feed into the model to update future projection numbers. The model must also allow for interactivity, whereby different scenarios involving various combinations and values of the variables will be tested to provide forecasts that can then be used to design, or test, policy. To prevent teacher shortages, and oversupply, in the various FET subjects, it is important that the total supply of teachers per FET subject is informed by the disaggregated teacher demand. The Gauteng Education Department will be able to influence the PRESET higher education institutions by offering rewards, such as bursaries linked to the disaggregated teacher demand numbers. A multivariate projection

model will assist the GDE with the calculations of the disaggregated teacher demand and supply.

In a multivariate causal model analysis, the teacher demand and supply causal model contains complex relationships between multiple dependent and independent variables that are inter-related by groups of linear equations. To handle this complexity, structural equation modeling (SEM) was used in this inquiry. The structural equation modeling (SEM) software called AMOS 17 (Analysis of Moment Structures) was used for the multivariate analysis. AMOS integrates a graphical interface with an advanced computing engine. Using path diagrams, AMOS has the capacity to incorporate multiple linear equations, and can show the complex relationships and collective strengths amongst the many variables of the model, using causal paths. Path diagrams are like flowcharts and play a fundamental role in SEM by displaying variables interconnected with lines. The lines indicate which independent variables cause changes in dependent variables, which are referred to as causal flows.

For example, in the linear equation W=Y÷B, W represents the number of teachers that can be employed, Y represents the number of learners enrolled, and B is the LER. W is the dependent variable because it depends on the values of Y and B, whereas Y and B are the independent variables.

In path diagrams, independent variables are shown in rectangles or squares, and dependent variables in circles or ovals. The equation W=Y÷B would be shown in a path diagram as:



Causal flow is shown as arrows pointing from the independent variables to the dependent variable. Each linear equation path diagram is grouped and drawn into one structural equation model showing the complex inter-linking between them. AMOS tests the strength of the variable relationships and how well the data fit this complex structural linear equation model. The results may be used to modify the model if necessary.

In summary regarding the design of the inquiry, Figure 1 shows a graphical representation of the quantitative design procedures used in the inquiry. The model portrays the sequence of the research activities in the study, specifies the projection instrument, data collection, and analytic procedures, and lists the products resulting from each of the phases of the inquiry.

Phase	Procedure	Product
Projection Instrument Development	• Identify supply and demand variables • Develop mathematical equations for variables • Inductively link independent and dependent variables • Translation of causal path model into computer model	• Independent and dependent variables • Linear equations • Teacher S & D multivariate causal path model • Computer projection model
Quantitative Data Collection	• Historical education databases (n=pop)	• numeric datasets
Quantitative Data Analysis =Demand and Supply variables =Multivariate Causal Path Model =Computer Projection Model	• cross sectional and longitudinal trend analysis • exponential smoothing of annual growth rates • linear projection extrapolation • Multivariate path analysis using SEM software called AMOS 17 • Translation of causal path model into computer model	• Annual growth rates for variables • Weighted moving average growth rates for variables • Projected future values for variables • SEM model of causal paths showing complex relationships amongst variables • Computer teacher supply and demand projection model
Confirmation or adjustment of model	• Scenario testing of model • Interpretation of results	• Final model • Discussion • Implications • Future research

FIGURE 1: Visual Model for Quantitative Design Procedures

Findings and discussion

The physical contribution of this inquiry is the computerised disaggregated teacher supply and demand projection model. The model has separate pages for key result graphs and parameter setting boxes allowing for quick changes to key variables. The model adds new insights for educational policy dialogue and planning by enabling users to test and observe the impact of different policy decisions. It also enables users to interact directly with the model to create their own scenarios. One is also able to generate the current first year PRESET number requirements per FET subject at training institutions and link the bursaries awarded to the teacher demand per FET subject. A major advantage is the ability to balance teacher supply and demand per FET subject to prevent shortages or oversupply, but on a more technical level it is also possible to use the model to understand variable relationships using the visual screen flow diagrams, and even to visualize variable trends from the graphic time line graphs. Various simulations are possible to test a variety of scenarios and may go a long way to help understand problems that can arise from bad data. The model can also be applied in educational settings that aim to teach about the dynamics of teacher supply and demand, and will help administrators in education make more informed decisions about the allocation of the education budget.

In general, this supply and demand model not only contributes to the knowledge base of educational planning and forecasting, but provides a clearer picture of the complex variables at play in teacher supply and demand as well. A key advantage of a provincial teacher demand and supply analysis is that it identifies issues specific to a given province (Reichardt, 2003). For example, a national average of 8.3% for unqualified teachers may be very different in each province. Kwazulu Natal may have 30% unqualified teachers, while Gauteng may only have 3%. Targeted interventions by each province based on the provincial figures, rather than national figures, are made to be far more accurate when using this model.

This model clearly illustrates how issues of teacher supply and demand differ when they are viewed aggregately or disaggregately. Past demand and supply estimates in South Africa have focused on aggregate information only. For example, past research indicated that South Africa needed to qualify 20, 000 new teachers annually, but failed to clarify numbers into areas of specialisation per province (Department of Education, 2007). In South Africa, the curriculum dictates that teachers specialise in phases such as the Foundation, Intermediate, Senior and the General Education and Training (GET) and Further Education and Training (FET) bands. Within these phases and bands teachers specialise further, such as learning areas in the senior phase and subjects in the FET band. Qualifying an aggregate of 20, 000 new teachers annually may still not overcome a shortage in specialised areas, such as Mathematics and Physical Sciences. To be more revealing, each teacher specialisation must have its own supply and demand estimates. In other words, we contend that teacher demand and supply estimates must be disaggregated. Within the FET band, teacher demand and supply must be disaggregated among the different subjects. This disaggregation must also extend to the provincial level. Provincial specific information will be more relevant to the needs of provincial policymakers than national information and will ensure that policies respond to provincial specific issues. The National Policy Framework for Teacher Education and Development (Department of Education, 2007) has identified these weaknesses and states that ‘departments will be required to determine how many new teachers are needed by qualification, phase, language, subject and district’.

From this study it is apparent that current teacher demand and supply estimates must not only be disaggregated, but must also be projected into the future. It takes a minimum of four years to qualify a teacher, which means that the current first year intake of PRESET teachers will only meet the teacher demand prevailing in four years time. The teacher demand in four years time may be very different from current demand. Subsequently a projection model, as proposed in this paper, is needed to match the current teacher supply first year intake with future teacher demand.

Furthermore, the lack of detailed teacher supply and demand analyses, and projection models, in South Africa has prompted the National Policy Framework for Teacher Education and Development (Department of Education, 2007) to state that 'improved analysis and planning are needed to provide regular, reliable and detailed information on teacher supply and future requirements. Using the model proposed in this paper, targeted interventions can easily be introduced to impact on the supply and demand'. To this end, a disaggregated projection model would not only simplify forward planning by projecting teacher demand in the FET subjects in four years time, but would also avoid the need to create costly incentives, such as stipends, for non-existent teacher supply problems in certain subjects. It will be valuable in providing information to prospective teachers about subjects likely to have the most vacancies, and will also enable more accurate interventions regarding the annual supply of teachers in each subject to meet future demand by manipulating the present intake of pre-service teachers.

A broad goal of the National Policy Framework (Department of Education, 2007) is "to achieve a dynamic balance between the number of teachers entering and leaving teaching each year". With a disaggregated projection model, as proposed in this paper, total teacher supply could potentially approximate total teacher demand in each subject in the FET band.

Dedication and Acknowledgements

Sadly, the first author of this paper Gavin Marchant passed away just before the completion of the study, leaving the proposed model open for comment and review. The Education community mourns the loss of a wonderful thinker and scholar. Gavin, you will be missed.

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computerised teacher demand and supply decision support projection model for the Further Education and Training band (FET) of public schools for the Gauteng Province of South Africa.

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