
Fractal Analysis of the Performance of Tertiary Teachers and the Academic Performance of Their Students

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Abstract

This study investigated the performance of faculty in instruction, research, and extension and its ability to predict the performance of students. There were 73 regular faculty members from the College of Arts and Sciences of the Bukidnon State University whose performance were taken from their Performance Evaluation System (PES) rating during the first semester of school year 2013-2014. A total of 715 sample students from a population of 3,285 were proportionately extracted from each faculty's students using Slovin's formula. The academic performances of students were their grade point average in their respective subjects from their corresponding teachers during the semester. Ruggedness of the data on the performance of faculty in instruction accounts for 87% of the ruggedness of the data on the academic performance of their students. Likewise, 67% and 62% of the ruggedness of the data on the academic performance of students were accounted for by the ruggedness of the data of the performance of teachers in research and extension, respectively. It is concluded that differences of the performance of the faculty in instruction, research and extension impact on the differences of the academic performance of the students.

Keywords: Fractal analysis, fractal dimension, robust measure, performance of teachers, performance of students

Introduction

In the tertiary level, teachers are mandated to perform their four functions which are instruction, research, extension and production. Every semester, these teachers are rated using the Performance Evaluation System (PES). They are evaluated in instruction by the dean, the chairperson, students, peers and the teachers themselves. In research and extension teachers are evaluated by the same group excluding the students and peers. The results form the basis of their performance.

Many teachers complain that teaching competes with their other work such as

conducting research, doing extension, and preparing instructional materials for their production function. There are those who indicate that they value their teaching responsibilities highly. In 1998 for example, 72.8 percent of 33,785 faculty at 378 colleges and universities in the United States of America, indicated that their interests were "very heavily in" or "leaning toward" teaching, while only 27.1 percent indicated the same primary interest in research (Sax, Astin, Korn, & Gilmarin, 1999).

At Bukidnon State University, the faculty members are evaluated in their teaching

performance according to: *beginning the lesson, clarity of presentation, pacing of lesson, student participation, conclusion of lesson, selection and use of instructional materials, preparation and performance, and routine management*. In research, extension and production, it is the dean and the teachers themselves who are the raters.

Performance of students is a common gauge to measure the effectiveness of their teachers. Although there are several factors that are contributory to the students' learning, their teachers get the most of it. Austero (2011) found that there are student-related, parent-related, school-related and teacher-related factors. Likewise, Hattie (2003) found that the major source of variance in students' achievement are the students who account for 50% of the variance of achievement, home which accounts for about 5-10% of the variance, school that also accounts for about 5-10%, and the teachers who account for 30% of the variance. It was suggested that focus should be given to the greatest source of the variance that can make a difference – the teacher. There is a need to ensure that this greatest influence is optimized to achieve positive effects on the learner.

There are already many researches conducted on the performance of teachers and students in the secondary and the elementary level, but none has been conducted at the tertiary level. Also, in these studies conducted, researchers utilized mean comparisons and/or relationships on the data. This kind of analysis approximates only the inclusion of the scores that are closer to each other and neglects the extreme value scores. Thus, the present researchers conceptualized this study using fractal analysis.

Fractal analysis is an analysis that assesses the fractal characteristics of data. It consists of several methods to assign a fractal dimension and other fractal characteristics to a dataset

applying nontraditional mathematics to patterns that defy understanding with traditional Euclidean concepts. It is an analysis using fractal statistics which is concerned with data irregularities repeated at different scales and generalizing the concept of variances. It measures complexity using the fractal dimension.

Conceptual Framework

Performance of teachers in their functions on instruction, research, extension and production could affect the academic performance of their students. Measuring teacher quality involves teaching preparation and confidence (Darling-Hammond, 2003), experience and knowledge (Goe, 2007), pedagogical skills, position, attitude, as well as organized and managed classroom skills (Waxman, Goldhaber, & Brewer, 2003), and by the impact of teachers on the academic achievement of their students (Rice, 2003).

The competence of the teachers in the four functions of instruction, research, extension and production in the educative process is a strong indication of their professional commitment according to Angeles (2010). He added that a balanced performance of these inherent functions could lead to a better performance of the students.

Another concept to consider is the fractal dimension. Nuhfer (2010) said that a fractal form is complex, but although it has the illusion of being randomly irregular and seemingly impossible to quantify at first sight, this intimidating complexity has an order within, that provides a means to understand the form in surprising ways. Order of fractal forms consists of complex forms built from recursive operations on a small unit called a generator. Additionally, Leamson (1999) stated that fractals provide important insights to understanding much about education because

learning occurs by increasing the strength of synaptic connections usually through repeated use. Growth of these connections, much like growth of a tree, produces immensely complex forms by recursive growth of a simple generator into branching patterns.

Education is replete with fractal characteristics in both space and time, probably because neural networks, like blood vessels, are fractal networks. In a space, physical brain changes include growth of such networks in the process of becoming educated. Any natural temporal patterns in time are fractal. Relationships between students' performance and measures of teachers' performance in instruction, research, extension and production are complex. The performance of students and all other educational endeavors of teachers arise from the brain's branching neural networks. Fractal thinking proves useful to many educational endeavors (Leonard & Akersten, 2004).

Abrami and Rosenfield (2007) stressed that affective feelings largely control responses to rating items associated with the general experience with the class. The teacher is surely a major contributor to such feelings. Perception of a course experience depends heavily on what individual students bring to class within their neural networks as expectations and levels of intellectual sophistication. In contrast, a fractal thinker anticipates that a summative student evaluation will be a very honest expression of satisfaction, which is largely an affective trait, but which has some connection with the cognitive domain. He added that fractals provide a damning exposure of the practice of employment of single global questions as the over dominating basis for an accurate evaluation. Because teaching is a learned behavior, evaluation of teaching is an evaluation of the neural networks a faculty member has developed to deal with those practices. This activity is also true for the

achievement of students. The neural network is fractal, so our problem of the performance of teachers and students can be framed as one of understanding a complex fractal form.

Statement of the Problem

This study investigated the performance of the tertiary level teachers in their functions which are instruction, research and extension in relation to the academic performance of their students measured in terms of their grade point average in Science and Mathematics during the first semester of school year 2013-2014. Specifically, this study answered the problem, "Do the differences of the performance of teachers in instruction, research, and extension impact on the differences of the academic performance of their students?"

Definition of Terms

To provide a good understanding of the study, the following terms are theoretically or operationally defined:

Performance of Teachers. Performance of teachers refers to a measure or rating obtained from their Performance Evaluation System (PES) rated by the dean, chairperson, the teacher himself/herself, five peers, and students. It is composed of the following indicators: instruction, research and extension.

Performance of Students. Performance of students refers to the Grade Point Average (GPA) of students handled by the teacher during the first semester of school year 2013-2014.

Fractal Analysis. Fractal analysis is an analysis used for data that are self-similar, heterogeneous or rugged with fractional dimensions. It is a statistical analysis of fractal

observations based on breaking down the data into fractional or smaller scales (Padua, 2014).

Fractal Statistics. Fractal statistics is a statistics concerned with data irregularities repeated at different scales, generalizing the concept of variances. The quantitative model for fractal statistics is based on the following:

- A random observation x is said to behave in a fractal distribution if it obeys a power-law:

$$f(x) = \frac{\lambda - 1}{\theta} \left(\frac{x}{\theta}\right)^{-\lambda}, \theta = \text{minimum}\{x\}, \lambda > 1$$

- The exponent λ is called the fractal dimension of the distribution: The higher the λ is, the more irregularities or fluctuation can be observed.

Methodology

This study was conducted at the College of Arts and Sciences (CAS) of Bukidnon State University (BSU) during the first semester of school year 2013-2014. The CAS has five departments, namely the Mathematics Department (Math), the Natural Sciences Department (Nat Sci), the Information Technology Department (IT), the Social Sciences Department (SSD) and the Language and Letters Department (L & L). There was a total of 73 regular faculty members during the first semester of school year 2013-2014. Of this number, 15 were from the Mathematics Department, 13 from the Natural Sciences Department, 8 from the Information Technology Department, 12 from the Language and Letters Department and 25 from the Social Sciences Department. Sixty-six (66) percent of these faculty members were females while 34% were males. These faculty members have 21 units of regular teaching load with an average of six units overload.

The faculty members' performance was taken from the teachers' Performance Evaluation System rating during the first semester of school year 2013-2014. A total of 715 sample students from a population of 3,285 was proportionately extracted from each faculty's students using Slovin's formula. Their academic performances were their grade point average (GPA) in their respective subjects from their corresponding teachers during the semester.

The data were analyzed using fractal analysis. It started with the computation of the fractal dimension (λ). The raw data were arranged from lowest to highest to test if the α^{th} percentile of the distribution obeys $\int_{\theta}^{x\alpha} f(x)dx = \alpha$. After which we solved $\int_{\theta}^{x(\alpha)} f(x)dx = \alpha$ that gives:

$$\lambda_{(\alpha)} = 1 - \frac{\log(1-\alpha)}{\log\left(\frac{x\alpha}{\theta}\right)}$$

Solving for the scale, $S = \frac{1}{\log\left(\frac{x\alpha}{\theta}\right)}$, we obtained:

$$\lambda_{(\alpha)} = 1 - \log(1 - \alpha)S$$

This led us to find the fractal spectrum. The fractal spectrum (FS) is a visual and graphical representation of the changes in the fractal dimension (λ) as a function of scales (s). The scale is $S = \frac{1}{\log\left(\frac{x}{\theta}\right)}$. These computations were done using Excel where the values of the mean, the standard deviation (sd), the fractal dimension (λ), the Coefficient of Variation (CV) and the fractal correlation were obtained.

Results and Discussions

Table 1 presents the values of the fractal dimensions (λ) of the data on the performance of teachers and students.

Table 1
Values of λ on the Performance of Teachers and Students

	Teachers λ			Students λ
	Instruction	Research	Extension	
IT	26.78841	3.88539	4.241535	5.98364
L&L	8.661405	1.989737	5.101877	5.021661
Math	7.43726	2.027574	3.330319	2.784807
NatSci	19.13179	6.071717	3.290719	4.085761
SS	10.42808	3.086301	1.658602	4.517186
Overall	7.099476	1.938601	1.544833	3.006083
CAS				

As shown in Table 1, the overall value of the fractal dimension (λ) in instruction is greater than its allowable limit for the dataset considered as a fractal. The range of the value of the fractal dimension is $0.60 \leq x \leq 3.40$ (Padua, 2014). Only the Mathematics Department obtained a fractal data in research and extension and the corresponding grades of their students. This means that the dataset can be analyzed together with the overall data for the CAS using fractal analysis. The fractal dimension of the dataset describes the variability or roughness of the data.

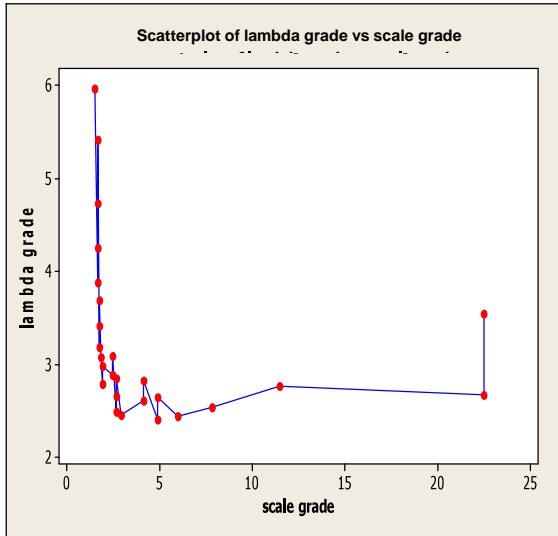
Another consideration for the dataset analyzed using fractal statistics is the value of the coefficient of variation (CV). Padua (2014) stressed that when the variance in the data exists, it is linearly related to the fractal dimension (λ). This value can be used as a descriptor of variability or roughness of the data. He added that if $CV \geq 1$, then the fractal dimension is a better descriptor of variability or roughness. The values of the CVs on the performance of tertiary teachers and their students of the five departments of the CAS are presented in Table 2.

Table 2
Values of the Coefficient of Variation (CV) on the Performance of Teachers and Students

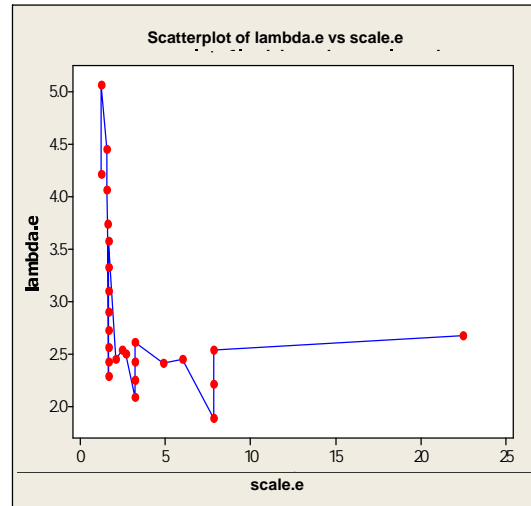
	Teachers C V			Students CV
	Instruction	Research	Extension	
IT	0.59	1.85	0.73	0.63
L&L	0.41	0.94	0.53	0.55
Math	0.48	0.88	0.71	0.53
NatSci	0.50	1.48	0.43	0.58
SS	0.44	1.76	0.43	0.47
Overall	0.47	1.19	0.55	0.56
CAS				

As shown in the table, only the performance of teachers in research obtained a CV that indicates that the appropriate descriptor of variability or roughness of data is the fractal dimension (λ). Performances of teachers in instruction and extension, as well as the performance of students obtained a CV of < 1 . Thus, the researchers assessed the ruggedness of the data at each scale (S) by looking at λ_s . These are presented in Figure 1.

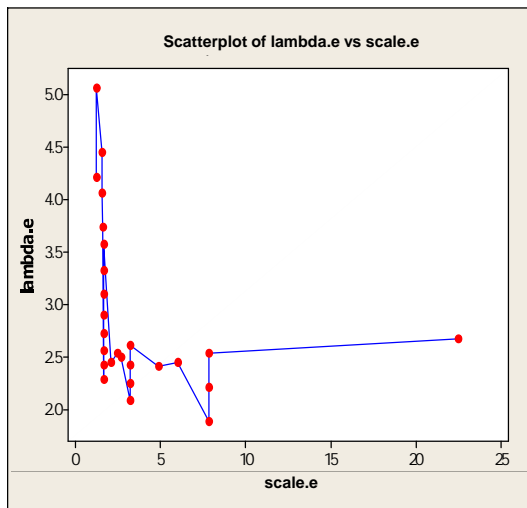
The four spectra in the figure show the different scales that illustrate the different groupings of the performances of the faculty of the CAS in their functions and the performance of their students. As can be seen in the figure, the spectrum of the performance of the students got the same scales in the spectrum of the performance of teachers in instruction. As observed by the researchers, teachers with higher rating in instruction gave higher grades to their students. Conversely, teachers with lower rating in instruction correspondingly gave



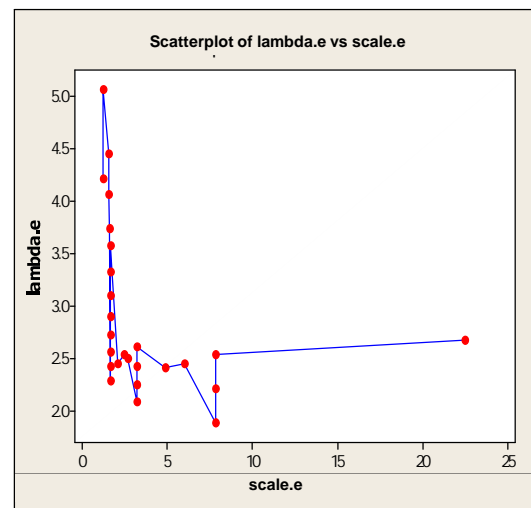
Spectrum of the Performance of Students



Spectrum of the Performance of Teachers in Extension



Spectrum of the Performance of Teachers in Research



Spectrum of the Performance of Teachers in Instruction

Figure 1. Scatterplot of the spectra of the performances of teachers and their students.

lower grades to their students. These figures explain how the performances of students and teachers induced ruggedness and fragmentation.

Table 3 presents the correlation of fractal dimensions of the performance of students and the performance of teachers in instruction, research and extension. The square of the correlation coefficients or the coefficient of determination was obtained for easy interpretation of the results.

Instruction, which is considered as the main function of the teachers, got the highest coefficient of determination r^2 than their other functions, followed by research and extension. This means that 87% of the variation in the performance of the students can be accounted for by the variation of the performance of teachers in instruction. The data in the table further show that 67% of the variation in the performance of students can be accounted for by the variation of the performance of teachers in research and 62 % of the variation of the performance of students can be accounted for by the variation of the performance of the teachers in extension.

The results imply that the performance of teachers in instruction has the highest impact to the differences in the performance of students. As can be noted, the contents of the evaluation of teaching performance instrument used by the students include the following items: beginning the lesson, clarity of presentation, pacing of lesson, student participation, conclusion of lesson, selection and use of instructional materials, preparation and

performance, and routine management. These indicators if done by the teachers could lead to a better performance of students. Teachers are aware of how they should carry out the teaching-learning process as this instrument is presented during the orientation of newly hired teachers.

Performance of teachers in research which accounts for 67% in the variation of the performance of students indicates that its ruggedness is brought about by the time allotment of the teachers in the conduct of research. At the same time not all of the teachers' researches are geared towards the improvement of the teaching-learning process. It then follows that the differences in the performance of teachers in research has less impact on the differences in the performance of students.

In like manner, extension which is another inherent function of tertiary teachers, obtained a performance which accounts for 62% in the variation of the performance of their students. This indicates that the roughness of the data can be attributed to the activities which did not complement the academic activities of the students. Though students were also involved in the extension activity so they can share their expertise to the community, most of the extension programs have nothing to do with the academic activities of the students.

Findings and Conclusions

The ruggedness of the data on the performance of teachers in instruction accounts

Table 3
Correlation of Fractal Dimension

	Performance of Teachers in Instruction	Performance of Teachers in Research	Performance of Teachers in Extension
r^2	0.87	0.67	0.62

for 87% of the ruggedness of the data on the performance of their students. Likewise, 67% and 62% of the ruggedness of the data on the performance of students were accounted for by the ruggedness of the data of the performance of teachers in research and extension, respectively.

Based on the findings of the study, it is concluded that the differences in the performances of teachers in instruction, research and extension impact on the differences of the performance of students.

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