BLENDED TEACHING STYLES: ITS INFLUENCE IN FRACTAL STUDENT ACHIEVEMENT

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ABSTRACT: *This study has adopted the Grasha-Riechmann model to assess the preferred teaching styles as self-reported by a group of mathematics faculty members at a state university of higher education. The teaching styles have become a mechanism used to convey how teachers define and carry out their instruction. This study aimed to examine how these styles were utilized, implemented, and influenced students' achievement. Statistical fractal analysis was used to examine students' test scores. Results have presented evidence that styles are blended, and the implementation level depends on the learning needs or preferences. There is a likelihood that the blended styles are utilized both in a teacher-centered and a student-centered learning method. It has clear indications that teachers have leveraged the blended styles so that its implementation could have reduced the learning variability and positively affect scores. The fractal dimension quantifies this variation, which is evident in the scores. The large fractal dimension indicates greater teacher control in the learning process. This numerical information provides a better understanding for teachers of the hidden dimensions in the learning outcomes of their students. Although teaching styles are inherent in mathematics education, only a few have indicated effective blended styles; it also demonstrates how it affects student achievement. This paper calls for a comprehensive study of teaching style preferences involving behavioral variables: social and cultural, integrated into the cognitive aspects to provide a generalized style, and utilizing fractal statistical analysis. The results could have pedagogical implications in mathematics education.*

Keywords: Grasha-Riechmann model, teaching style, statistical fractal analysis, fractal dimension

1. INTRODUCTION

Higher education systems have struggled to produce better-equipped teachers for 21st-century learning amidst the ever-changing education system landscape. Various studies and public policy-making institutions have undertaken high-priority initiatives to bring better-prepared teachers into the teaching-learning process. Indeed, effective teaching is difficult to define. However, there are several ways to exhibit at least one. Teachers could create an optimum learning environment by utilizing a variety of teaching styles. According to Grasha [1], teachers display behavior patterns that affect the entire teaching and learning process. The most exciting aspect of teaching styles is the mechanism responsible for shaping the learning process since the teacher's personal qualities provide direction and guidance to achieve optimal learning. Teachers employ multiple approaches such as demonstrating ways of thinking (that is, teaching activities can be interactive), provide role modeling by illustration (which is true in a problem-solving scenario), and sustain the entire learning process.

However, a learning environment itself is a complex dynamical system that needs the best suitable methods to address its prevailing problems. One emerging framework is the application of chaos theory in the educative process. For instance, fractal analysis has become increasingly popular [2]. A plethora of scientific literature has shown that chaos theory is perfectly intertwined with fractals. It seemed that the application of this theory in teaching styles is less investigated. There is a broad application of fractals in higher education [3]. Raye [4] has indicated that education systems exhibit self-similarity property at varying levels and fractal dimensions. This phenomenon is called fractals [5; 6]. When we observe and grasp a teaching behavior closely, we would always find more specific behavior when we zoom on every minute detail [7; 2; 8; 4]. That is, each level tends to have similar characteristics as the original. Raye [4] further said that a fractal pattern emerges as a fractal organization. Hence, a teaching-learning system constitutes a fractal behavior. In the case of teacher style, the model of Grasha [1] outlines five positive preceptor styles the expert, formal authority, personal model, facilitator, and delegator. Each style is associated with specific teaching and behavior roles that tend to complement specific learners' styles. This paper's gap is how teaching styles are utilized and implemented when student achievement has fractal properties.

Fractals

Mandelbrot [5] coined the word *fractals*, describing them as natural occurrences or phenomena. Mandelbrot asserts that nature is fractal: cloud formation, the structure of the trees and the forest, earthquake patterns, weather systems, heartbeat, and bloodstream of living organisms [6]. The humans' cognitive ability is indeed fractal (see [8]). Fractals having self-similar properties are quantified through a non-integer numerical value called fractal dimension [11; 12; 13]. In the classroom setting, the student's natural behavior is considered 'chaotic' and hence fractal. For example, test scores exhibit fractal. It can be observed that there are more low scores than high scores. This observation is true for data sets in a classroom, precisely a copy at an institutional level, then at a national level up to the global level. The spread of these scores is measured in terms of their intrinsic dimension [14]. The larger the intrinsic dimension, the larger the hidden information in a given data set [15; 16]. Hence, teachers must intervene in the learning process, which could be in a teaching style.

The concept of fractals was used in several papers. Padua [17] first proposed statistical fractal analysis. Other research involved analyzing earthquake patterns, education, and poverty indices [18]. Fractal representation conveys the complex structure of the teacher education curriculum that reflects the same phenomenon's self-similar properties within the system [19]. Hence, the analysis of education process data through statistical fractal methods would help motivate new insights from the phenomenon.

Teaching Style Model

Grasha [1] has identified five basic teaching styles based on a single dimension of teacher versus student-oriented that are pervasive in classroom teaching to promote learning. These are (1) expert-the teacher’s possession of knowledge and expertise that students need in any learning situation, (2) formal authority-the teacher’s possesses status among students because of knowledge and role as a faculty member, (3) personal model- the teacher believes in "teaching by example" and establishes a prototype for how to think and behave, (4) facilitator-emphasizes the personal nature of teacher-student interactions, (5) delegator-the teacher is concerned with developing students' capacity to function in an autonomous fashion where students work independently, and the teachers act as a resource person.

According to Grasha [1], teachers have ways to set up their instructional designs, and that these styles would converge into groups of styles called clusters. Each model requires control of tasks, build relationships, degree of sensitivity to students' learning styles, and teaching methods. Cluster 1 is the blending of teaching styles expert-formal authority. Cluster-2 blends the personal model-expert-formal authority styles. Cluster 3 blends the styles facilitator-personal model-expert, and cluster 4 is the blending of delegator-facilitator-expert. Generally, these styles are grouped into a teacher-centered which comprises the cluster on the expert-formal authority-personal model, and the student-centered learning method comprising the cluster facilitator-personal model-expert.

Ford II et al. [20] have adopted the Grasha-Riechmann teaching style inventory to assess a different perspective in healthcare processes and client outcomes. The study shows that the coach (i.e., the teacher) used a blended approach to match the clients' preferred but multiple learning styles effectively. The dominant teaching styles were facilitator and delegator. The results have suggested that styles form from different perspectives and contexts. In a way, there should be a match between a teaching style and a learning style. Accordingly, this is not easy to achieve since styles may have changed over time. This behavior is likely accounted to fractals because patterns repeat at different scales or levels. Hence, statistical fractal methods could provide considerably valuable insights in this context.

The present study has adopted the Grasha-Riechmann model to assess the teaching style self-inventory. The same instruments were used by Ford II, Robinson, & Wise [20]. Arbabisarjou, Akbarilakeh, Soroush, & Payandeh [21] used the same to validate the model. Teacher's styles define the persons' enduring personal attributes and behavior in implementing the educative processes, positively affecting student learning (i.e., [22]). This research anchors the constructivist and behaviorist learning theories, which posits that mathematics students actively construct meaning and that cognition influences the entire learning process through interaction with the learning environment. This framework provides insights into how the teachers demonstrate their styles provide teaching qualities to enhance the dynamic and quality of student learning outcomes. The computed probability of the occurrence of a teaching style or a cluster of styles implemented by a given teacher would measure how much utilization a particular style or a cluster of styles. Hence, this study answers the following research questions: What are the teaching styles of the selected group of mathematics teachers? And, how likely are the teaching styles affect the fractal student achievement?

2. METHODOLOGY

Participants of the Study

This research is a descriptive study that assessed the teaching styles of sixteen mathematics faculty members in a state university of higher education institutions. These teachers are highly qualified enough who have at least 75% of them have completed their respective master's degrees either in mathematics or pure/applied mathematics, with sufficient teaching experience (i.e., at least five years) to handle mathematics courses from the foundation to major subjects. They taught algebra and trigonometry, calculus, applied statistics, and other courses related to pure and applied mathematics. At least seven of them teach in graduate school, both at master and doctoral levels. The students under each teacher likewise participate in this research. Each of the teachers has at least thirty students per class during the conduct of this study. The students’ test results provide numerical information on student achievement.

Research Instruments

The main instrument used was the Grasha-Riechmann teaching style inventory [1]. It is available online for those who wish to take a self-inventory. The items of the questionnaire underwent a reliability test and obtained a Cronbach's alpha of 0.8803. Construct reliability measures the degree of consistency between the items in the questionnaire and the intended measure [23]. The secondary instruments were the researcher-made achievement tests used by each teacher on their respective students. The course subjects likewise underwent reliability tests. The results obtained Cronbach's alpha: algebra (0.7734), trigonometry (0.7983), and applied statistics (0.8693). The achievement tests have are not the same for each subject.

Data Gathering Procedure

This study has adequately observed the research protocol of the university in compliance with the ethical guidelines set by the university’s research unit. The selected teachers provide self-reported teaching styles at the onset of this study. Each teacher has selected a particular class intended for this research, a choice in algebra, trigonometry, and applied statistics. A pretest was administered at the onset of the semester in their respective classes, and then a post-test (i.e., student achievement) toward the end of the semester. Regardless of how each class is recited, it took about fifty-four hours or five months to complete their classes. The student achievement test results were carefully analyzed using statistical fractal analysis. The results of the teaching style self-inventory are also computed based on the scoring guide.

Statistical Fractal Analysis

This study used fractal statistical analysis to measure the fractal dimensions in student achievement test results and teaching style inventory results. Kumaraswamy et al. [14] suggest that a fractal dimension describes the "spread" of data from dynamic changes in the variation of scores, and it serves as critical information of the hidden characteristics of the data. The mathematics test scores typically behave a fractal since small values are abundant and repeated at different scales. Fractal distributions follow the power-law probability density function [24; 17]

$$(1)\ f(x) = \frac{\lambda - 1}{\theta} \cdot \left(\frac{x_i}{\theta}\right)^{-\lambda}, \lambda > 1, \theta > 1, x \geq \theta$$

where λ is the fractional exponent (usually referred to as the fractal dimension) and is computed numerically based on the data sets, and θ is the minimum value of the random observations x_i $(i = 1, 2, ...)$. The algorithm used in this study is based on the algorithm used by Padua [17].

$$(2)\ \lambda = 1 + (\bar{y})^{-1}, \bar{y} = \frac{1}{n}\sum_{i=1}^{n} \log\left(\frac{X_i}{\theta}\right),\ \ \theta = \min\{x_i\}$$

3. RESULTS

Fractal Dimensions of Student Achievement

Table 1 presents the achievement test results for each of the sixteen teachers under investigation. The mean scores are provided in the pretest and post-test. In the assumption of the fractal properties of test scores, the fractal dimensions λ were computed both in the pretest and post-test. The test of normality was used to determine how test scores behave from the pretest to the post-test. It used the Kolmogorov-Smirnov test at a 5% significance level. The test static K.S. is computed; the p-values determine whether scores follow the Gaussian distribution if the normality test is significant and is indicated in table 1.

Table 1. Student Achievement Test Results

Teacher	*Pretest*			*Post-test*		
	Mean	λ	*Is the test normal ?*	*Mean*	λ	*Is the test normal ?*
1	11.19	2.329	Yes	12.27	2.534	No
2	10.03	1.871	Yes	13.32	2.315	Yes
3	8.08	2.542	Yes	15.16	2.371	Yes
4	6.94	1.860	No	7.48	1.776	No
5	7.23	1.817	Yes	9.382	3.335	No
6	7.74	2.698	Yes	8.08	1.776	Yes
7	9.71	2.634	Yes	22.62	1.987	Yes
8	13.79	2.930	Yes	11.66	2.235	Yes
9	10.80	2.372	Yes	10.30	2.478	Yes
10	7.83	2.578	No	9.58	2.623	No
11	9.64	2.196	No	12.64	2.136	No
12	10.68	2.081	Yes	14.34	1.837	Yes
13	10.88	2.421	No	17.36	1.713	Yes
14	8.42	2.016	Yes	8.91	2.339	No
15	22.37	2.157	No	22.03	2.001	Yes
16	11.85	1.953	Yes	13.39	4.630	Yes

Table 1 shows the mean raw scores from the students, the computed fractal dimension using (2), and the test of normality results. Test scores tend to behave a normal distribution when the p-value of the Normality test is greater than the 0.05 level. The main results show the following from the pretest to post-test: thirteen out of sixteen or 81.25% of the teachers have improved students' scores; eight of sixteen or (50%) have made changes in the fractal dimensions, that is, either a reduction or an increase; eleven of them (68.75%) have depicted normal distribution in the pretest; however, the number is reduced to ten in the post-test. Of the 13 teachers who have improved scores in the post-test, seven of them (53.84%) have reduced the fractal dimensions, and six of them (46.15%) have not. Of the seven teachers who have improved scores with a reduced fractal dimension in the post-test, five of them (71.42%) have depicted normal distribution scores. Thus, the overall effects in student achievement have indicated that the improved scores in the post-test have also reduced fractal dimensions and that the scores obey the normal distribution.

Teaching Styles

The results of the teacher's self-reported teaching style inventory are depicted in Figure 1. The computed style mean scores are as follows: expert $(M = 4.375)$, formal authority $(M = 4.195)$, personal model $(M = 4.109)$, facilitator $(M = 4.133)$, and delegator $(M = 3.836)$. The results suggest that these teachers have utilized different and varied approaches, strategies, styles in their respective classes. The teachers' styles have distinct clustering. It is also evident that no single teacher utilized a specific style. The information suggests that the teachers under study have indicated high scores in their respective styles. That is, they have a strong belief that they exhibit these styles in their classes. The results have also revealed that expert style has become their primary teaching style. The secondary styles were in the order formal authority, facilitator, personal model, and delegator. Moreover, the scores appear to converge at high points, as shown in Figure 1.

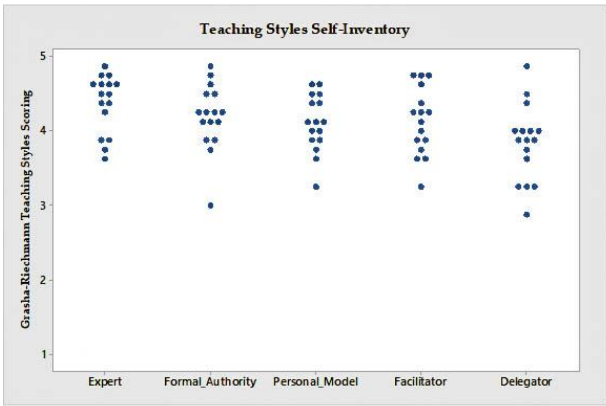

Figure 1. Plots of Self-reported Teaching Styles

As depicted in figure 1, the expert style is seemingly divided into two groups; that is, above high and below high. The same observation is given for the formal authority style and the personal model style. The facilitator style seems homogeneous and trivial to these selected teachers. However, the delegator style is seemingly varied over as compared to other selected styles. The overall results have indicated that the teaching styles are clustered as follows: only two of out of sixteen (12.50%) belong to cluster 1, that is, the blending of expert-formal authority styles; five out of sixteen (31.25%) are in cluster 2, that is, the blending of expert-formal authority-personal model styles; there are four teachers (25%) in cluster 3, that is, the blending of facilitator-personal model-delegator-expert styles; likewise four teachers (25%) belong to cluster 4, that is, the blending of delegator-facilitator-expert styles. In effect, the results have indicated that the teaching styles belong to the cluster on the expert-formal authority-personal model. That is, at least half of the participants are using the teacher-centered learning approach. Thus, the overall effects reveal that these teachers utilize both teacher-centered learning and a student-centered learning approach in different levels of implementation.

Likelihood of Teaching Styles Utilization

Table 2 presents the probability that a particular teaching style was utilized and implemented by each teacher in their respective classes. The probability is based on the Gaussian density function. For this group of teachers, the overall mean and standard deviation are computed for each teaching style model as parameter estimates of the probability distribution. The obtained numerical values quantify the said utilization. Following the Grasha model, the teaching method is provided as shown after the computation of the respective probabilities and where the primary and secondary styles are given in the results.

Table 2. Probability of Utilizing a Teaching Style

Teacher	*Expert*	*Formal Authority*	*Personal Model*	*Facilitator*	*Delegator*	*Teaching Method*
1	0.3743	0.5490	0.7553	0.8613	0.6256	Student
2	0.7392	0.8928	0.7553	0.6019	0.5304	Teacher
3	0.0545	0.2370	0.3879	0.1989	0.1262	Student
4	0.6257	0.4378	0.5162	0.7034	0.6256	Student
5	0.0999	0.0038	0.0127	0.1311	0.3401	Student
6	0.8319	0.7525	0.9101	0.6019	0.6256	Teacher
7	0.0272	0.1597	0.1037	0.1311	0.1262	Teacher
8	0.6257	0.5490	0.1748	0.2845	0.5304	Teacher
9	0.7392	0.5490	0.2710	0.3845	0.6256	Teacher
10	0.9001	0.2370	0.9101	0.9134	0.9788	Student
11	0.5000	0.4378	0.2710	0.0256	0.4333	Teacher
12	0.7392	0.8320	0.8453	0.9134	0.9027	Student
13	0.7392	0.9359	0.5162	0.2845	0.1262	Teacher
14	0.0999	0.4378	0.3879	0.6019	0.5304	Student
15	0.5000	0.5490	0.8453	0.9134	0.8538	Student
16	0.8319	0.7525	0.5162	0.4930	0.0303	Teacher

In table 2, half of the teachers utilized either teacher-centered teaching method (50%) and student-centered teaching method (50%) approaches. Of the eight teachers in the teacher-centered method, five (62.50%) are in cluster 2 teaching styles, and three of them (37.50%) have improved students' scores with normally distributed and a reduced fractal dimension. For the eight teachers using the student-centered approach, two (25%) have improved students' scores, normally distributed, and with a reduced fractal dimension. It appears that teacher-centered learning is the dominant teaching approach for these teachers that influence student achievement.

In summary, this study has revealed the following: First, not a single teaching style dominates for each teacher; the styles are blended, and the level of implementation depends on the students' learning outcomes. Second, it is thought that a fractal dimension quantifies the different learning levels vital to teaching styles. A fractal dimension reduction suggests less learning variability, and it is indicative of learning success. Third, the utilization of the blended teaching styles affects student achievement so that the scores have improved following the normal distribution and have a reduction in fractal dimension.

4. DISCUSSION

On teaching styles

This paper adopted the Grasha-Riechmann model [1] to assess the teaching styles of the sixteen mathematics teachers. To understand how the teaching style model is utilized in the mathematics classroom setting, each teacher has provided a self-reported inventory before the conduct of this study and then determines how these styles are implemented in each class. Although styles differ in context and subject matter, mathematics in higher education generally requires an instructional design to capacitate students' problem-solving skills. Teaching should be well-grounded in philosophical underpinnings from Piaget's constructivism to Bruner's discovery learning and Schon's problem solving and reflection. Thus, in teaching mathematics, blended styles of cluster 2 are necessary; that is, the teacher provides role modeling and coaching to utilize their expertise for their students to develop and then apply the required skills and demonstrate their knowledge in mathematics. The underlying theory is based primarily on behaviorist learning. Learning is influenced by social, cultural, cognitive, and other environmental factors [25]. According to Grasha [1], the teaching methods associated with cluster 2 involve role modelings by illustration and direct example, such as getting students to obtain answers and coaching.

The present findings provide evidence to support [20] that each primary style relies on the secondary style and hence the blending of styles [26]. This blending allows the learners to motivate to strive toward success in learning. The instructional process associated with mathematics teaching in cluster 2, for instance, requires a blend of the personal model, expert, formal authority. Teaching methods usually require to demonstrate skills and processes such as the task to work in problem-solving. The teacher may implement either a deductive or inductive method. The teacher may utilize Polya's problem-solving method (e.g., [27, 28]). At the onset, the teacher may provide a concept, vocabulary, and skills. Details could be presented through illustrations or examples from personal experience and other presentations related to scenarios from students' lives. Then the students could solve similar problems independently and adapting the demonstrated methods with careful guidance from the teacher. However, there is a need to provide adequate skills for students to accept responsibility to obtain what they learn. In general, mathematics teaching in cluster 2 has the teaching elements in motivation, prior knowledge, enhancement, and experience. It is a challenge for mathematics teachers since skills also vary from one group to another.

Moreover, the high variation of learning ability of students requires careful style implementation. The teachers need to be responsible in all their teaching activities, as demonstrated in their styles. They need to equip themselves with the desired skills and ability and become sensitive to students' learning abilities, infuse emotional maturity for students to handle feedback, and aid motivation. Likewise, teachers require high control in the learning process to achieve optimal outcomes. In this way, teachers would significantly contribute to developing their students' required skills in mathematics.

Influence of teaching styles in fractal student achievement

Teaching methods associated with cluster 2 styles require role modeling through illustration, direct example, and effective coaching. These blended styles have indeed influenced student achievement so that scores have improved from the pre-test to post-test and that these scores obey the normal distribution. It has the following implications: teaching styles are always characterized as dynamic. When students have a large fractal dimension, the teacher tends to impose greater control. For example, when a group of students has a large fractal dimension, their abilities vary significantly. In this case, the teacher may utilize cluster 1 style dominating the expert-formal authority blending. Cluster 1 is teacher-centered, where the teacher tends to provide and control the learning activities and where the students are expected to receive whatever inputs are undertaken. But when common understanding is being established, the teacher may shift to cluster 2 and or cluster 3 styles. However, the degree of variability still depends on one group to another. According to Grasha [1], the interest of the teachers is to assist students in acquiring foundational knowledge. Either teacher-centered or student-centered learning approach, the foundational knowledge needed by the students is through the authority of the teacher.

Another implication is that teaching effectiveness, although distinct and varied, is not found in every teacher. A few can exhibit effective teaching and blended styles. This paper has found at least three (37.5%) of them. This type of teacher can blend both teacher-centered and student-centered effectively as an integrated approach to accommodate the learning preference of their students. According to Shead et al. [29], the diversity of learning preferences is greatly influenced by the students' life experiences and other environmental factors. Hence, it would take an experienced teacher to recognize such diversity and implement the required teaching style. However, additional study is required across a wider group of teachers and students to capture styles in different contexts and subject matter and validate this study's claims.

Further, Reimann [25] suggests that behaviorist theories of learning provide a framework to describe the hidden dimensions of learning. However, [14 has indicated that a fractal dimension describes the hidden dimension of the data. The results imply that converting student achievement into fractal dimensions allows better information of the hidden and mysterious learning process [25].

5. CONCLUSION AND RECOMMENDATION

The teaching styles of the sixteen selected mathematics teachers in a higher education institution have self-reported that they prefer the styles of the order expert-facilitator-formal authority-personal model-delegator. These styles underpin the behaviorist learning theory over constructivism. In their mathematics classes, the methods implemented are more in cluster 2 blended teaching styles: role modeling, coaching, personal model, expert, and formal authority. There is a likelihood that the blended styles are utilized both for teacher-centered and student-centered methods. It implies that the implementation of the style is dependent on the learning needs or preferences. There are groups of students in mathematics education that require more teacher control and need implementation of the necessary cluster styles. The fractal dimension quantifies the learning variability, which is evident in the scores. Such information provides a better understanding of teachers in the learning outcomes of their students. In the light of these results, utilizing blended styles is a demanding task; however, only a few could exhibit teaching effectiveness. Nevertheless, there is a certainty that the demonstrated teaching styles have a positive impact on student achievement.

This study provides a framework to understand better the importance of teaching styles in the students' learning outcomes; however, the general style remains unknown. It recommends pursuing a comprehensive study of teaching style preference in mathematics education involving other behavioral variables such as social and cultural aspects integrated into the cognitive factors in a broader group of samples and utilizing fractal statistical analyses. The future results could have pedagogical implications in mathematics education.

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