WHY LEARNING STYLES MATTER FOR STUDENT ACHIEVEMENT IN COLLEGE ECONOMICS

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ABSTRACT

This paper explores the link between student achievement and student learning styles in a college microeconomics course, based on the Dunn and Dunn model of learning styles. The Productivity Environmental Survey (PEPS) is utilized to measure learning style preferences for twenty elements. Factor analysis is applied to reduce the multidimensional preferences to a smaller set of common factors that identify analytic, global or indifferent learning styles. The common factors are used as explanatory variables to measure the correlation between student achievement and their learning styles. The empirical methodology developed in this study also provides a test of the internal validity of the Dunn and Dunn model, the construct validity of the PEPS instrument and the predictive validity of the model. The authors explain how the results of the current research could be utilized to more generally enhance student achievement in the instruction of introductory economics and potentially other subject matter.

Introduction

Instructors of college economics courses are devoting more of their time to teaching (Becker and Watts, 2001). This is a positive development in the field of economics if one accepts David Colander's assertion: "Teaching is the most important thing that economists do." (Colander 2006, p. vii) But, contrary to other fields of higher education, economics instructors continue to predominantly utilize the chalk-and-talk method of teaching (Becker and Watts 2001). The chalk-and-talk teaching method utilizes lectures with supporting notes, equations and graphs written on the chalkboard.

Dunn (2000) hypothesizes that this chalk and talk method of teaching ignores differences in students' learning styles and the potential increase in student achievement associated with matching instructors' teaching methods with students' learning styles. It is ironic that the practitioners of the discipline devoted to the study of efficiency principles are implicitly accused of being inefficient in their approach to teaching that discipline. According to the Dunn and Dunn learning styles methodology (Dunn, 2000), the optimal method of teaching is the method that most closely matches students' learning styles. Learning styles are composed of multidimensional preferences for elements within environmental, emotional, sociological, physiological and psychological strands.

This paper tests whether student achievement actually is enhanced, as Dunn (2000) argues, depending on the extent to which the method of teaching matches students' learning styles. Through the use of factor analysis to extract students' learning styles, the methodology developed in this investigation is an improvement over previous research methods (e.g., Terregrossa, Englander and Englander 2008) utilized to identify

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the relationship between students' learning styles and their achievement. A high degree of multicollinearity inherently exists among the twenty learning style elements comprising each student's learning style profile. To ameliorate this problem, factor analysis is used to extract meaningful learning style measures which are devoid of inherent statistical anomalies resulting from the high degree of interrelationships that characterize various learning style preference elements.

The Dunn and Dunn model (Dunn 2000) hypothesizes that global, analytic or indifferent (i.e., a combination of the global and analytic) learning styles correlate with inherent preferences for certain discriminating elements within the five strands. In this study, the Dunn, Dunn and Price (2006) Productivity Environmental Survey (PEPS) is utilized to measure students' preferences for the twenty elements within the five strands. Student achievement, measured by examination scores, is regressed against the learning style factors, in addition to other student characteristics. In this way, the statistical association of students' learning styles with student achievement is estimated.

The empirical methodology developed in this study also provides important insight regarding both the efficacy of the Dunn and Dunn paradigm and the construct validity of the PEPS instrument. In this case, construct validity refers to the extent to which the PEPS instrument measures students' learning styles in a way that corresponds to the Dunn and Dunn paradigm. If the PEPS instrument differentiates between global, analytic and indifferent learners, then factor analysis should identify a distinctive pattern of the discriminating learning style elements for students aligned with each of the alternative learning styles in a way that is consistent with the Dunn and Dunn model. With respect to the efficaciousness of the Dunn and Dunn paradigm, if the empirical methodology predicts differences in student achievement attributable to differences in students' learning styles that are embodied in the extracted factors, then the Dunn and Dunn paradigm is supported. Such an outcome would create an opportunity for instructors to enhance student achievement by using an instrument such as the PEPS to identify the mix of learning styles of the students in a class and then tailoring teaching methods and strategies accordingly.

Literature Review

Economists disagree about the importance of utilizing pedagogical principles to enhance student achievement. Colander (2006), states, "Educationalists focus on the structure of, not the content of, education; I see structure as secondary and content as central…Any consideration of teaching that does not put content first…has serious problems". In contrast, Frank (2007) stresses the relative importance of the manner by which economic content is taught: "The form in which ideas are conveyed is important. Perhaps because our species evolved as storytellers, the human brain is innately receptive to information in narrative form." Reich (2000) stated, "We're creating a one-size-fits-all system that needlessly brands many young people as failures, when they might thrive if offered a different education whose progress was measured differently." Implicit in Reich's statement is the notion that if students are instructed in a way that more closely matches their learning styles, rather than in a homogeneous manner, students may be more successful academically and thus better equipped to be successful in a changing economy.

An increase in academic achievement associated with matching teaching styles with learning styles is not new to the field of economics. Charkins, O'Toole, and Wetzel (1985) estimated the impact that the divergence of instructors' teaching styles and students' learning styles had on student achievement and attitude in introductory economics courses. The results of their study indicated that students learned more, and had a more positive attitude toward learning, the smaller the divergence between teaching and learning styles. Brokaw and Merz (2000) examined the effects that both learning styles and student behavior have on student achievement in principles of microeconomics courses. Their results indicated that the students whose learning styles matched their instructors' "chalk and talk" style had significantly higher grades than those students whose learning styles did not match. In general, they found that when a student's learning style matches the instructor's teaching style, student achievement improved by half a letter grade.

Coffield, Moseley, Hall, and Ecclestone's (2004) comprehensive review of learning styles models emphasizes that an instructor wishing to utilize a learning style approach must decide which of the many different learning style theories or approaches is to be adopted. Praise and criticism of each of the learning style models abounds. Coffield et al. (2004) examine thirteen of the most influential learning styles models, including the Dunn and Dunn model, with a particular focus on the validity, reliability and practical application of the alternative models. With regard to the Dunn and Dunn model, Coffield et al. (2004), conclude, "Despite a large and evolving research programme, forceful claims made for impact are questionable because of limitations in many of the supporting studies and the lack of independent research on the model." This assessment echoes earlier criticisms offered by Kavale, Hishoren, and Forness (1998). However, Coffield et al. (2004) report that the Dunn and Dunn model meets one critical criterion: predictive validity--the extent to which a set of scores predicts an expected outcome. Milton Friedman (1953), stated, "The only relevant test of the validity of a hypothesis (model) is comparison of its prediction with experience." Thus, the fact that Coffield et al. (2004) find that the Dunn and Dunn model exhibits predictive validity seems to lend credence to the Dunn and Dunn paradigm.

Hawk and Shah (2007) examined five prominent learning style models and instruments, including the Dunn and Dunn model and PEPS instrument. Hawk and Shaw (2007, p.10) report, "There is solid support for instrument validity and reliability for the LSI [Kolb (1979) model learning style instrument]…and PEPS instruments…If cost is not a constraining factor then the LSI and PEPS …would give the most valid and reliable coverage of student learning styles…". Hawk and Shaw (2007, p.11) suggest,

> "knowledge of the overall learning style profile of classes allows us to make adjustments to our learning approaches as the profile changes from course to course and across semesters. We believe that student performance improves as a result of our use of the learning style instruments, although we have no empirical data of our own to support that belief."

Utilization of information regarding the learning style profile of a cohort of students to tailor pedagogy to enhance student achievement is consistent with the Dunn and Dunn learning styles methodology (Dunn 2000). Given the impracticality of

designing a teaching strategy that matches each student's learning style, Dunn (2000) suggests an alternative method that allows instructors to capitalize on students' learning style preferences. The method involves the use of the PEPS instrument to "identify individual and group patterns among students' learning style preferences and develop teaching style strategies to respond to those patterns" (Dunn 2000, p. x).

The Dunn and Dunn Learning Styles Model

An individual's learning style is determined by a combination of environmental, emotional, sociological, physiological and psychological elements. The environmental elements include noise (background silence versus music or conversation), light (soft or bright lighting), temperature (cool or warm), and design (informal versus formal seating) (Dunn, 2000).

The emotional elements include motivation (self-directed versus external), persistence, responsible (conformity to societal norms) and structure (preference for internal or external direction). Sociological elements reflect with whom each student prefers to learn and the preferred manner in which the material is learned. Analytic learners prefer to learn alone, while global learners prefer to learn in pairs, with peers, or as part of a team. The manner in which the material is learned refers to whether students learn with an authoritative adult or with a collegial individual. This element also refers to whether a student likes to learn using a variety of methods or by using established routines.

Physiological elements include perceptual modalities. Some students learn better with print material (visual), with lectures (auditory), by touch (tactual) or by doing (kinesthetic). Also included are preferences for intake (snacks), time of day and mobility (moving around while learning as opposed to sitting still.)

Psychological elements refer to the ways students absorb and process new information. This includes global versus analytic learning approaches. "Analytics learn more easily when information is presented step by step in a cumulative sequential pattern that builds toward a conceptual understanding. Globals learn more easily when they understand the concept first and then concentrate on the details, or are introduced to the information with, preferably, a humorous story replete with examples and graphics." (Dunn and Dunn, 1993).

According to the Dunn and Dunn model (Dunn 2000) analytic and global learners have different environmental, emotional, sociological, physiological and psychological preferences. The model hypothesizes that preferences for noise, light, design, persistence, and intake distinguish analytic learners from global learners (Dunn, 2000).

Analytic learners learn best in a quiet, brightly lighted and formal learning environment. They prefer to start and finish one project at a time, and do not snack while learning. Global learners learn best with background noise, soft light in a relaxed learning environment. They simultaneously work on several projects, take frequent breaks, and enjoy snacks when learning. Global learners prefer new and difficult information to be introduced anecdotally, especially in a way that humorously explains how the lesson relates to them. Hence, five of the twenty learning style elements from the PEPS survey instrument can be utilized as discriminators in order to categorize a student as an analytical learner or a global learner: preference for noise, preference for light, preference for formality of design in the location where the studying/learning takes

place, preference for being persistent (avoiding interruptions while studying), and preference for food or drink intake while studying. The five elements are listed separately in Table 1 along with the correlation that each element is hypothesized to have with the ability of analytical and global learners to perform well under the respective conditions.

Table 1: The Discriminating Elements to Distinguish Analytic and Global Learners and the Hypothesized Relationship to Each Category

Discriminating Element	Analytic Learners	Global Learners
Noise	Negative	Positive
Light	Positive	Negative
Design	Positive	Negative
Persistence	Positive	Negative
Food Intake	Negative	Positive

Applying Analytical and Global Teaching Methods

The following example elucidates alternative pedagogical methods that may be utilized to accommodate analytic and global students in the principles of microeconomics course. Say, for example, that the ultimate goal of the lesson is for the students to understand how a market establishes an equilibrium price.

Method 1. Analytic Teaching Method--At the start of the analysis, the instructor provides a detailed list that includes dates of all reading, written and mathematical assignments, quizzes and tests. The instructor explains that consumer preference theory will be developed to derive a demand curve that represents consumers' marginal willingness and ability to pay for a good. Students are introduced to the abstract theory of indifference curves, budget constraints and constrained optimization techniques. Next, the instructor explains that the theory of the firm is utilized to derive a short-run production function from which the total, average and marginal cost curves are derived. The notion of a perfectly competitive market structure is introduced and the supply curve for the typical firm within the industry is derived. The economic profit, break-even, economic loss, and shut-down cases are analyzed. The industry supply and demand curves are derived from the individual firms' supply curves and individual consumers' demand curves. Finally, the equilibrium price is determined by the intersection of the industry supply and demand curves. At each stage of the analysis, the instructor writes the outline of the lesson on the chalkboard and highlights and defines key words. Each principle is reinforced with numerous examples, sidebars, and numerical illustrations. In this way, price theory proceeds from one distinct, easily digestible, sequential segment to another, ultimately leading to a comprehensive understanding of price determination in a market system that is more consistent with the analytic learning style.

Method 2. Global Teaching Method--At the start of the analysis the instructor explains to the students that, in light of the Obama administration's social commitment to the development and utilization of alternative fuels, increased fuel efficiency and reduced emissions, consumers in the United States have chosen Toyota's Prius as the "hybrid

superstar." It has been predicted that the 2010 model will have a combined city-highway rating of fifty miles per gallon which not only is better than any car sold in the U.S., but, particularly for the wealthier students, is 400 percent better than the Lamborghinni Murcielago Roadster (Garrett, 2009). Following the informative and perhaps humorous anecdote regarding a current market development in an industry that produces a good for which virtually all students have personal experience, knowledge and interest, the instructor asks the students to divide into teams and asks the teams to predict the market price of the 2010 Prius. To begin the analysis, the instructor utilizes the brainstorming method that guides students to list the important factors, i.e., demand and supply, which may determine the price. Next, the instructor suggests that the students visit local Toyota dealerships, search websites such as Toyota.com, Edmunds.com or Kelly's Blue Book (kb.com), search for information from such publications as Car and Driver magazine, Consumer Reports, New York Times Automobile section, the Bureau of Economic Analysis' Survey of Current Business, utilize websites such as Hoovers Online and Standard & Poor's Industry Survey. Finally, the instructor suggests that each team create a poster board, Power-Point presentation, conduct a dramatization, or utilize any other creative method to convey and support their analysis and prediction to the class. In this way, price theory is taught in the context of an important current social issue that is meaningful and relevant to the students' lives, a teaching method that is consistent with the global learning style.

Empirical Analysis

Data for the 125 students in the study were collected from eight sections of the same introductory microeconomics course that were taught by the same economics instructor over the four semesters from Spring 2003 through Fall 2005. There were 221 students enrolled in those eight sections of a campus at a university in the northeast.[2] The introductory microeconomics class in which the subject students were enrolled is the first semester of a two course economics sequence that is required of all business majors. Typically, only about five percent of the students in that class are non-business majors. The business program is accredited by AACSB.

The Productivity Environmental Preference Survey (PEPS) (Dunn, Dunn and Price 2006) instrument, based upon the Dunn and Dunn learning styles methodology (Dunn 2000), is used to identify student preferences for the twenty elements comprising five strands of the learning style model. The PEPS, designed to identify how college students and other adults learn and perform in their academic and occupational pursuits,

[2] Among the 221 students enrolled in the eight introductory microeconomics sections, there were twelve students who withdrew during the respective semesters and eighty-four non-participants, leaving 125 students who chose to participate in the student and complete the PEPS survey and consent to allow access to their student records for SAT and other data. The eighty-four non participants were comprised of (a) students who were not present on the single class meeting when the PEPS survey and the consent forms were distributed and (b) a relatively small number of students who chose not to complete the forms (Keeping a separate record of even the exact number of students who chose not to complete the forms would have been inconsistent with university Institutional Review Board procedures). Nevertheless, a t-test for the comparison of exam score means between the 125 participants and the eighty-four non-participants was undertaken and revealed no significant difference between the performances of those two groups. This finding suggests a reasonable comparability between the participant and non-participant groups.

is a self-report composed of 100 questions that can be completed in approximately twenty minutes. Each question is designed to identify an individual's preference regarding each of the environmental, emotional, sociological, physiological, and psychological elements.

For example, to determine their preference regarding sound, an environmental element, students are asked to answer whether they strongly disagree, disagree, are uncertain, agree, or strongly agree to a series of statements, such as:

1. I can block out noise or sound when I work.
2. I prefer to work with music playing.
3. Noise or extraneous sound usually keeps me from concentrating.
4. I can block out most sound when I work.

In a similar manner, preferences regarding all environmental, emotional, sociological, and physiological elements are identified.

The preferences that embody each student's inherent learning style likely are characterized by multicollinearity. In other words, each student's learning style profile is composed of a unique, interrelated web of preferences for the twenty multidimensional learning style elements. As the Dunn and Dunn model (Dunn 2000) hypothesizes, an individual's learning style may be characterized by a global thought process, an analytic thought process, or by a combination of the two thought processes, referred to as an indifferent thought process. To the extent that a student's inherent learning style aligns with one or another thought process, there is a certain interrelated pattern of preferences for at least five of the twenty learning style elements, particularly, but not limited to, preferences for sound, light, design, persistence and intake. Moreover, multicollinearity most certainly exists among the separate variables measuring student preferences for three of the physiological elements--time-of-day, late morning and afternoon.

If multicollinearity exists among the learning style preference variables, when used as explanatory variables in a linear regression model to estimate their partial correlation with student achievement, the partial correlation coefficients would be unbiased, but their standard errors would be artificially large and the t-statistics would be artificially reduced. As a result, any statistical tests on the partial correlation coefficients would be misleading and unreliable. Therefore, in order to utilize the learning style elements as explanatory variables to correctly estimate their statistical relationship with student achievement, it first is necessary to remove the multicollinearity that characterizes students' learning styles elements. Factor analysis is used to transform the learning style elements, which are correlated with one another, into a smaller set of uncorrelated factors that maintain the essence of the each student's learning style profile.

Factor analysis decomposes the information contained in student preferences for the numerous learning style elements into smaller set of uncorrelated common factors that maintain and reflect the inherent characteristics of the original learning style elements. Each learning style element (X) is assumed to be a linear combination of a set of common factors (F) and a component (U) that is unique to the element as described in the following equation 1:

$$Eq.1: X_i = b_{i1}F_1 + b_{i2}F_2 + \cdots + b_{ij}F_j + \cdots + b_{im}F_m + U_i ,$$

i = 1, 2,…20, representing the 20 learning style elements, where X_i is the i^{th} learning style element, F_j is the j^{th} common factor, b_{ij} is the standardized correlation coefficient

between the learning style element i and the common factor j, referred to as the factor loading, and j = 1, 2, …m, m representing the number of common factors. U_i is the component unique to the leaning style element. The total variance for each element is composed of the common-factor component variance, referred to as the communality, and the component variance unique to each variable, referred to as the specific part.

In the factor analysis, the number of common factors is determined by the percentage of total variance (eigenvalue) that is explained by the each common factor. A rule of thumb in determining the number of factors is that a factor with an eigenvalue of less than one would not be used because it accounts for less than the variation explained by a single variable. However, there is no generally accepted rule for selecting the number of common factors and the number of factors may also be influenced by the pattern of variables that are subsumed by each factor. It has been further observed that extracting more factors than the number dictated by the above rule of thumb carries less methodological risk than extracting a smaller number of factors (Wood, Tataryn, and Gorsuch 1996). The factors' eigenvalues, the percentage of variability explained by each factor, and their cumulative explained variability are reported in Table 2.[3]

Table 2: Eigenvalues of the Five Extracted Learning Style Factors

Factors	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Eigenvalue	2.808	2.048	1.852	1.078	0.876
Variability (%)	14.042	10.241	9.258	5.391	4.379
Cumulative Variability %	14.042	24.283	33.541	38.932	43.311

The five extracted factors cumulatively account for over forty three percent of the variation in the twenty leaning style elements. Although the fifth factor accounts for less than the variation explained by a single variable, it is included in the analysis because it aligns with the analytic learning style identified in the second stage of the factor analysis. The factor loadings, which are the standardized correlation coefficients between each learning style element and the five extracted factors, are reported in Table 3.

[3] The "principal factor analysis" method was employed as the extraction method for the factor analysis. Principal factor analysis extracts the factors in such a way that they are independent of one another. This method is distinct from principal component analysis. However, a further rotation of the factors was not undertaken given the satisfactory pattern of the underlying learning style elements within the factors that emerged from that process.

Table 3: Factor Loadings for the Five Extracted Learning Style Factors

Variable	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Motivation	-0.651	-0.153	0.583	0.053	-0.232
Responsible (Conforming)	-0.621	-0.355	0.305	0.138	-0.157
Persistence	-0.615	-0.033	0.505	0.028	-0.055
Kinesthetic	-0.532	0.544	0.162	0.095	0.264
Time of Day	-0.531	-0.216	-0.393	0.004	-0.007
Late Morning	-0.485	0.093	-0.458	-0.233	-0.155
Tactile	-0.411	0.503	-0.050	-0.228	-0.141
Light	-0.337	0.203	0.189	-0.017	0.544
Authority Figures	-0.233	0.576	-0.174	0.326	0.276
Intake	0.136	0.575	0.242	-0.133	-0.300
Alone/Peers	0.096	0.569	-0.292	0.584	-0.063
Mobility	0.178	0.464	0.138	-0.242	-0.278
Visual	-0.100	0.396	-0.024	-0.761	0.096
Structure	0.122	0.347	0.086	-0.091	0.184
Several Ways	-0.008	0.296	-0.032	0.282	-0.242
Auditory	-0.182	0.247	0.059	0.190	-0.193
Afternoon	0.669	0.113	0.736	0.056	0.273
Noise	-0.028	0.075	0.285	0.103	-0.248
Temp	0.123	0.002	0.075	-0.098	-0.108
Design	-0.297	-0.146	-0.017	-0.026	0.553

In order of relative importance, the emotional elements, including motivation, responsible/conforming and persistence, and the physiological elements, including time-of-day, late morning and tactile, align strongly with the first factor (F1). The environmental preference for light also aligns strongly with F1. The physiological elements, including kinesthetic, tactile, intake, mobility and visual, and the sociological elements, including alone/peers and authority figures, and one emotional element, structure, align strongly with the second factor (F2). The physiological elements of afternoon, late-morning and time-of-day, followed by the sociological elements of motivation, persistence and responsible-conforming align strongly with the third factor (F3). The physiological element of visual followed by the sociological elements of alone/peers and authority figure align strongly with the fourth factor (F4). The environment elements of design, light and noise, and the physiological element of intake strongly align with the fifth factor (F5).

Although many of the learning style elements strongly align with the five extracted factors, the alignments do not necessarily identify alternative learning styles. To determine whether the five extracted factors discern alternative learning styles, it is necessary to focus on the sign and statistical significance of the factor loadings of the learning style elements hypothesized by the Dunn and Dunn model (Dunn 2000) to differentiate global, analytic and indifferent learners. The five discriminating learning style elements include the environmental preferences for noise, light, design, the emotional preference for persistence and the physiological preference for intake. The

factor loadings and their p-statistics of the discriminating learning style elements are reported in Table 4.

Table 4: Factor Loadings and P-values of the Extracted Factors for the Five Discriminating Learning Style Elements

Element	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Noise	-0.028a (0.756)	0.075g (0.408)	0.285g (0.001)*	0.103g (0.252)	-0.248a (0.005)*
Light	-0.337g (0.000)*	0.203a (0.023)*	0.189a (0.035)*	-0.017g (0.852)	0.544a (0.000)*
Design	-0.297g (0.001)*	-0.148g (0.105)	-0.017g (0.849)	-0.026g (0.773)	0.553a (0.000)*
Persistence	-0.615g (0.000)*	-0.033g (0.715)	0.505a (0.000)*	0.028a (0.761)	-0.055g (0.543)
Intake	0.136g (0.131)	0.575g (0.000)*	0.242g (0.007)*	-0.133a (0.140)	-0.300a (0.001)*

Notes: 1. p-values are in parentheses; 2. a starburst (*) denotes statistical significance; 3. an (a) denotes an analytic learning style characteristic and a (g) denotes a global leaning style characteristic.

The first factor is strongly indicative of the global learning style. Four of the five factor loadings, three of which are statistically significant, have a negative sign which is consistent with the global leaning style. The second factor is weakly indicative of the global learning style. Four of the five factor loadings have a negative sign which is consistent with the global learning style, but only one, intake, is significant. The factor loading associated with light, an environmental element, is significant, but the positive sign is consistent with the analytic learning style. The third factor is indicative of the indifferent learning style. Three factor loadings, noise, design and intake, have expected signs that are consistent with the global learning style. The factor loadings for the intake and noise elements are significant. The factor loadings for the persistence and light elements have positive signs which are consistent with the analytic learning style and both are significant. Therefore, the evidence indicates a combination of the global and analytic learning styles. The fourth factor is weakly indicative of the global learning style. Three of the factor loadings have the expected sign consistent with the global learning style, but none are significant. The fifth factor is strongly indicative of the analytic learning style. Four of the factor loadings have signs consistent with the analytic learning style, all of which are significant. The alternative learning styles aligned with the extracted factors via factor analysis are summarized in Table 5.

The factor analysis has identified and differentiated all three learning styles hypothesized by the Dunn and Dunn model, including the global, analytic and indifferent learning styles. The extracted factors align in distinguishable patterns that are consistent with the learning style elements hypothesized by the Dunn and Dunn model to differentiate alternative learning styles (i.e., global, analytic and indifferent). These results then directly address the criticisms by Coefield (2004) et al. and Kavale (1998) regarding the lack of empirical verification of the identification of alternative learning styles made by the Dunn and Dunn model (Dunn 2000).

Table 5: Alternative Learning Styles Identified by Factor Analysis

FACTOR	ASSOCIATED LEARNING STYLE
Factor 1	Strongly Global
Factor 2	Weakly Global
Factor 3	Indifferent
Factor 4	Weakly Global
Factor 5	Strongly Analytic

In the final stage of factor analysis, the factor loadings are used to generate factor scores for each student. In this way, factor analysis transformed each student's original, collinear preferences for the multidimensional learning style elements into independently distributed factor scores that embody each student's inherent learning style. The factor scores subsequently are used as explanatory variables in a multivariate linear regression model to estimate the correlation between student learning style and student achievement. The standardized beta coefficients of this regression model are also estimated to determine the relative importance of the alternative, control variables.

The Least Squares Regression model is described by equation 2:

$$Eq.2: SA_i = b_1 + b_2F1_i + b_2F2_i + b_3F3_i + b_4F4_i + b_5F5_i + b_6Gender_i + b_7CreditsCompleted_i + b_8SAT_i + b_9SATRatio_i + b_{10}ED1_i + b_{11}ED2_i + b_{12}SD1_i + b_{13}SD2_i + b_{14}SD3_i + b_{15}SD4_i + b_{16}SD5_i + b_{17}SD6_i + b_{18}SD7_i + e_i$$

where student achievement (SA_i), the dependent variable, is equal to the i^{th} student's number of correct responses to each of three semester exams. Since there are 125 students, there are 375 observations. The learning style extracted factors, F1 to F5, summarized in Table 5, represent the students' alternative learning styles.

A dummy variable accounting for gender (set equal to one for female students) is included on the basis of the research of Kane and Spizman (1999), Durden and Ellis (2003) and Krohn (2005) indicating that males tend to perform better, *ceteris paribus*, in economics courses than females. The inclusion of credits completed follows from the earlier research of Borg and Shapiro (1996), Durden and Ellis (2003) and Ballard and Johnson (2004) who found a positive and significant relationship between class year or credits completed and student performance in economics courses. The total of each student's SAT math and verbal scores are included in order to account for differences in overall student ability in explaining differences in performance. The issue of the most appropriate measure to account for variations in student ability has been addressed by Grove, Wasserman and Grodner (2006). The ratio of each student's SAT math score to SAT verbal score, SAT Ratio, is included in order to examine whether a student would have an advantage in introductory microeconomics if that student has relatively strong math abilities, as found by Durden and Ellis (2003) and Ballard and Johnson (2004).

Table 6: Least Square Regression Output

Variable	Coefficients	Standard Error	t-stat	p-value	Beta Coefficients
Intercept	1.722	2.746	0.630	0.531	0.000
ED1	0.240	0.544	0.440	0.659	0.023
ED2*	1.768	0.544	3.250	0.001*	0.166
Gender	-0.122	0.502	-0.240	0.808	-0.012
Credits Completed	-0.007	0.012	-0.570	0.569	-0.028
SAT Total*	0.017	0.002	9.240	<.0001*	0.432
SAT Ratio	-0.295	1.290	-0.230	0.820	-0.010
Strongly Global--Factor 1*	-0.772	0.243	-3.180	0.002*	-0.149
Weakly Global--Factor 2	-0.106	0.256	-0.410	0.679	-0.019
Indifferent--Factor 3*	0.471	0.236	2.000	0.047*	0.091
Weakly Global Factor 4	-0.273	0.261	-1.050	0.296	-0.048
Strongly Analytic--Factor 5	-0.405	0.284	-1.430	0.155	-0.066
SD1	0.183	0.866	0.210	0.833	0.014
SD2	0.743	0.943	0.790	0.431	0.051
SD3*	2.782	0.984	2.830	0.005*	0.169
SD4	-0.280	1.035	-0.270	0.787	-0.016
SD5*	-2.000	0.990	-2.020	0.044*	-0.126
SD6	-0.449	0.902	-0.500	0.619	-0.031
SD7	-1.211	0.953	-1.270	0.204	-0.078

Notes: 1. A starburst (*) denotes statistical significance, 2. R-Squared = 0.3029, Adjusted R-Squared = 0.2677, 4. Standard Error of Regression = 4.299, 5. F-statistic$_{(18, 356)}$ = 8.59 and its p-value < 0.0001.

Dummy variables (ED1 and ED2) are also included to account for the slight differences in the number of questions and possible differences in the difficulty of the questions on the three different exams given in the introductory microeconomics course. The third exam serves as the base. Finally, dummy variables (SD1 – SD7) are included to account for differences among the eight alternative class sections in which a student may have been enrolled. The eighth section serves as the base. The residuals, e_i, were tested and found to be independently and normally distributed with a constant variance and a mean equal to zero. The regression results are reported in Table 6.

The adjusted R-Squared result indicates that the regression model explains nearly twenty-seven percent of the variation in student exam performance. The F-statistic is significant at the .0001 level of significance with 18 and 356 degrees of freedom, an indication that the model fits the data well. The coefficient for Gender is not statistically significant. The coefficients for ED1, credits completed, and SAT Ratio also are not statistically significant. The partial correlation coefficient associated with the variables ED2, SAT Total, Strongly Global learning style, Factor1, and Indifferent learning style, Factor 3, SD3 and SD5 are statistically significant. The coefficient of the ED2 variable represents the marginal difference between the student's second midterm test grade and

the third midterm test grade. The positive coefficient indicates that students performed significantly better on the second exam relative to the third exam. This result may be attributed to a more challenging final exam or the greater academic demands placed on students at the end of the semester, including, for example, several final exams, term papers and oral presentations. The positive coefficient for the SAT Total variable, a proxy for academic ability, indicates that students with a relatively higher academic ability attain a higher level of achievement in the principles of microeconomics course.

The coefficients for the Strongly Analytic learning style variable, Factor 5, and the Weakly Global learning style variables, Factors 2 and 4, are negative but insignificant. Although they are statistically insignificant, the negative coefficients imply that students with weakly global and strongly analytic learning styles were at a disadvantage in taking this microeconomics principles course. The coefficient associated with the Strongly Global learning style variable, Factor 1, is negative and statistically significant, indicating that this presentation of microeconomic principles was not congruent with, and does not enhance achievement for, students with the global learning styles. For the Indifferent learning style variable, Factor 3, the coefficient is positive and significant, indicating that this presentation of microeconomic principles was congruent with, and enhances achievement for, students with an indifferent learning style.

A somewhat surprising result was that two of the section dummy control variables, SD3 representing one of the two Spring 2004 sections and SD5 representing one of the Fall 2004 sections, were statistically significant—directly related to performance in the former case and inversely linked to performance in the latter case. This result suggests that when all of the other variables of the model, such as SAT as a measure of student ability or the learning style profile of the class, are held constant, students in those two sections performed significantly differently than students in the other sections. Perhaps this can be explained in terms of a favorable or unfavorable chemistry that may develop over the semester between the students and the instructor. Perhaps a given group of students develops its own "personality" or interaction dynamics which may either be conducive to or hinder the overall performance of those students in the class.

With regard to the relative importance of the alternative explanatory variables' contribution to achievement, the configuration of the standardized beta coefficients suggests that the student's total SAT score is ranked first. For every one standard deviation increase in the student's total SAT score, there is a .432 standard deviation increase in student achievement. By comparison, as the alignment of a student with the strongly global learning style increases by one standard deviation, the student's achievement decreases by .149 standard deviations. And as the alignment of a student with the indifferent learning style increases by one standard deviation, the student's achievement increases by .091 standard deviations.

Summary and Conclusion

According to the Dunn and Dunn (2000) model of teaching and learning, the optimal method of instruction is that method that matches students' learning styles. It is hypothesized that students whose learning styles are congruent with the teaching style of the instructor will have a higher level of achievement relative to students whose learning styles are incongruent. The Productivity Environmental Preference Survey (PEPS)

instrument, designed to correspond to the multidimensional Dunn and Dunn paradigm, is utilized to identify students' learning styles. The Ordinary Least Squares regression method then is utilized to examine the statistical association between student achievement and their learning styles

Five common factors were extracted via factor analysis that corresponded to the three leaning styles that characterize the Dunn and Dunn model. The Dunn and Dunn model hypothesizes that an individual's learning style is inherently composed of a unique, interrelated web of multifaceted biological, environmental and psychological elements. If the interrelated learning style elements are used as explanatory variables in regression analysis, then their estimated partial correlation coefficients are unreliable in a hypothesis testing framework. Therefore, factor analysis was utilized to untangle the interrelated web of learning style elements and transform each student's learning style into several complex factors variables that embody the essence of the original learning style but are devoid of multicollinearity.

The statistically significant results of the factor analysis indicate that the extracted factors align with the discriminating elements in distinguishing patterns hypothesized by the Dunn and Dunn model (Dunn 2000) to differentiate global, analytic and indifferent learners. This result is important because it supports the construct validity of the PEPS. In other words, the results of the factor analysis indicate that the PEPS instrument measures students' learning styles in a way that corresponds to, and therefore supports, the logical structure of the Dunn and Dunn paradigm.

The learning style factors subsequently were regressed against student achievement to measure the correlation between students' achievement and their learning styles. Student achievement was measured as the number of correct answers for three midterm examinations. The regression model controlled for differences in students' gender, aptitude, maturity, and for possible differences in the class cohort and the rigor of the examinations.

For the extracted factors found to be statistically meaningful in the factor analysis, including the strongly global, strongly analytic and indifferent leaning styles, only two factors were significant--the indifferent learning style factor (directly linked to performance) and the strongly global learning style factor (inversely linked to performance). The negative coefficient for the strongly analytic learning style factor was not significant. These results indicate that the instructor's teaching method was congruent with, and enhanced achievement for, students with an indifferent learning style, and was incongruent with, and did not enhance achievement for, students with the global learning styles. For students with analytic learning styles, no significant relationship between the instructor's teaching method and student performance emerged.

Our results indicate that the learning style characteristics of students do appear to have a significant relationship to the students' achievement. We believe that a reasonable inference from these findings is that the manner in which economic knowledge is conveyed to students by instructors, particularly the congruence of that manner to the learning style of the students, can be expected to systematically influence the performance of those students in learning the material. That inference is inconsistent with the view of Colander (2006), but supports the views of Frank (2007) and Reich (2000). We also believe that our paper addresses some of the criticisms leveled against the Dunn and Dunn methodology by Kavale et al. (1998) and Coffield et al. (2004).

These critics point to a lack of independent, peer-reviewed research aimed at empirical verification. This study has attempted such a verification and offers empirical support of the efficacy of the Dunn and Dunn methodology.

These results suggest a three step process to make productive use of the Dunn and Dunn model in a college setting. The first step, to be performed very early in the semester, would be to take an inventory the learning style preferences of the students in a class with the use of the PEPS instrument. A second step would be to interpret those results with the use of factor analysis so that a clearer picture of the student learning style preferences with respect to global, analytic or indifferent learning style patterns can emerge. The final step would be to fashion the appropriate mix of teaching style methods and strategies to address the learning style pattern that is revealed by the process undertaken in steps one and two. Our results suggest that such a three step approach should facilitate a meaningful increase in the student learning of economics, and perhaps the material offered in other academic disciplines. In an era when higher real tuition costs are putting greater pressure on administrators and faculty to devise more effective approaches to achieving their educational missions, we believe that this research allows economics (and other) instructors to not only better teach, but also to better practice, the concept of economic efficiency.

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