Int. J. Engng Ed. Vol. 17, No. 1, pp. 89–92, 2001
Printed in Great Britain.
0949-149X/91 $3.00+0.00

Group Embedded Figures Test and Academic Achievement in Engineering Education*

TERRANCE P. O'BRIEN, SUSAN M. BUTLER and LEONHARD E. BERNOLD
Box 7801, 602 Poe Hall, North Carolina State University, Raleigh, NC 27695–7801, USA.
E-mail: terry_obrien@ncsu.edu

This study was conducted to investigate cognitive style patterns among students in a lower division engineering course and differences in the academic performance of those students related to differences in their cognitive styles. The Group Embedded Figures Test was administered to 130 undergraduate engineering students enrolled in CE 214 Engineering Mechanics-Statics at North Carolina State University. Analysis of variance was used to examine differences in academic achievement of students in relation to their different cognitive styles. The findings identified a highly skewed distribution on the cognitive style scale, with the vast majority being highly analytic. In addition, students who manifested an analytic (field independent) cognitive style achieved significantly higher grades in the course than those with a Global cognitive style.

INTRODUCTION

THIS STUDY is the second in a series of studies involving a collaboration between the College of Engineering and the College of Education and Psychology at North Carolina State University. The overall goal of this research program is to improve curriculum and instruction in engineering education. A similar study, using the Myers-Briggs Type Indicator, was published in an earlier issue of this journal [1]. Portions of the theoretical framework for this study were presented at the 10th International Conference on College Teaching and Learning and that paper was published in 'Selected Papers' from that conference [2]. This research is part of a comprehensive research program established at North Carolina State University called the Southeastern University and College Coalition for Engineering Education (SUCCEED), sponsored by the National Science Foundation.

PURPOSES OF THE STUDY

The purposes of this study were to investigate cognitive style patterns among students in a lower division engineering course and related differences in the academic performance of those students. The course selected for the study is required of all undergraduate students in the College of Engineering and is well-known for the rigorous nature of the curriculum. Concerns among engineering faculty regarding the difficulty students experienced in the course provided the impetus for a series of investigations. Since the curriculum for the course is considered by the faculty to be appropriate, they initiated a collaborative effort with faculty in the College of Education and Psychology to investigate the extent to which variation in student achievement might be associated with variables related to the realm of education; in this instance, cognitive styles. The specific research questions were:

1. What patterns of cognitive styles were evidenced among students enrolled in the lower division engineering course?
2. Were significant differences in academic achievement among students in the engineering course associated with differences in the cognitive styles of students?

FIELD DEPENDENCE THEORY OF COGNITIVE STYLES

Cognitive styles have been defined as 'information processing habits representing the learner's typical mode of perceiving, thinking, problem solving, and remembering' [3, p. 188]. Human cognition, including cognitive styles, is highly relevant to many important educational concerns involving teaching and learning. A variety of motivational strategies and environmental factors may enhance learning, but cognition represents the core of the learning process. Cognitive styles, as compared to variables in the affective or physiological domains, seem to be most relevant to variables associated with academic achievement.

Herman Witkin's field dependence model of cognitive styles is considered to be one of the

* Accepted 20 March 2000.

most well-established and widely researched models in the field [4]. Assessed by the Group Embedded Figures Test (GEFT) [5], among other instruments, field dependence involves the construct of cognitive perception. In this theory, cognitive style is a measure of the extent to which an individual can overcome the effects of irrelevant background elements when consciously focusing on a learning task or activity [6]. 'A field-independent learner can easily overcome background elements and readily focus on the learning task, while a field dependent learner will have trouble overcoming the effects of background elements and experience difficulty in focusing on the learning task' [7].

Field-independent learners are highly analytical in perceiving and processing information; in fact they are often referred to in the literature as 'analytic thinkers'. They exhibit a tendency to organize information into manageable units and appear to possess a greater capacity for the retention of information. These individuals prefer and typically use problem-solving techniques, organization, analysis and structuring when engaged in learning and working situations [8]. Field dependent learners are more global and holistic in perception and information processing; in the literature they are frequently referred to as 'global thinkers'. They tend to accept information as it is presented or encountered and rely to a great extent on memorization. They also manifest a clear tendency to use social frames of reference to determine their own attitudes, feelings, and beliefs [6].

In traditional educational environments, it would appear that analytic thinkers and learners would be more successful when dealing with abstract and complex subjects or functioning in unstructured situations. Global learners, in contrast, may be more successful in highly structured situations or in situations that require interaction with other individuals.

RESEARCH METHODOLOGY

To identify cognitive styles, the Group Embedded Figures Test (GEFT) was administered to 130 undergraduate engineering students enrolled in three sections of a lower division engineering course. Final numeric end-of-course grades were used as the measures of student achievement. Basic descriptive statistics were used to assess cognitive style patterns among students. Analysis of variance (ANOVA) was used to examine differences in academic achievement among students in the course associated with differences in cognitive styles. Cognitive styles served as the independent variable, while numeric end-of-course grades functioned as the dependent variable in the analysis of variance. Due to unbalanced cells in the resultant data, the General Linear Models Procedure in SAS [9] was used to complete the analysis of variance.

RESULTS

To examine the patterns of cognitive styles among students in the engineering course, we used two different coding systems commonly used by researchers studying the GEFT. It is possible for scores on the test to range from 0 to 18. Initially, we used the standard convention of categorizing students whose scores ranged from 0 to 9 as Global, and students whose scores ranged from 10 to 18 as Analytic. This standard coding system yielded the following profile of cognitive styles among the 130 students in the sample: 110 (85%) Analytic and 20 (15%) Global. Clearly, the sample was highly skewed with the preponderance of Analytic learners/thinkers. This distribution was atypical when compared to distributions of GEFT scores obtained from other samples. It also deviated substantially from the data developed by Witkin [5] which suggested that in the general population one would obtain a distribution of scores that would approximate a normal distribution or bell curve. When this coding scheme was utilized, ANOVA yielded no significant differences in academic achievement between the two groups of engineering students.

To examine the data further, we used another popular coding system in the literature which creates three categories: students whose scores ranged from 0 to 6 were categorized as Global, 7 to 12 as Middle, and 13 to 18 as Analytic. This coding convention is based on the premise that if there is a normal distribution on this scale in the general population most individuals are somewhere in the middle, between $+1$ and -1 standard deviations from the mean. Further, those in the middle of the distribution are likely to exhibit characteristics of persons with both cognitive styles. Those individuals whose scores are closer to either end of the continuum should be more likely to exhibit traits and behaviors congruent with those espoused by the field dependence theory. Using this coding scheme, we identified the following profile: 99 (76%) Analytic, 25 (19%) Middle, and 6 (5%) Global. When this coding scheme was used, ANOVA yielded a highly significant difference among the groups ($F = 5.26$, $p = 0.006$). Those students categorized as both Analytic and Middle scored significantly higher on end-of-course grades than did those students categorized as Global. Analytic and Middle students did not score significantly different from one another, but both achieved significantly higher than the Global students. In fact, the mean end-of-course grade for the Global students was below the minimum passing grade for the course. The means for the other two groups were at levels that would have been interpreted by faculty as a grade of 'C' (average) or higher.

DISCUSSION

The findings in this investigation may hold some important implications for engineering education, professional education in general, and perhaps for the advancement of theory in the cognitive styles literature. The relatively small sample size and the unbalanced cells in the analysis of variance, however, must temper any conclusions or speculations that may be drawn from these findings.

One of the most striking findings was the overwhelming dominance of the Analytic style in the profile of this group of engineering students. In context of what we know about such distributions in the general population, this distribution in quite astonishing. We are aware of no other studies using the GEFT with any other populations that yielded distributions that departed so greatly from a bell curve. Do individuals who exhibit strong Analytic cognitive styles naturally gravitate toward the various disciplines in engineering? If so, this might have implications for engineering faculty as they consider recruitment efforts and, possibly, admissions decisions. This also suggests that it may be important to conduct similar research in other professional education programs. Should other dramatic patterns emerge in those programs, educators in those programs may develop a better understanding of the nature of individual differences among their student populations.

The findings concerning the nature of the cognitive styles profile become even more intriguing when viewed in relation to the significant difference in academic achievement between Analytic and Global learners/thinkers. This finding can be viewed from at least two different perspectives. One might conclude from this finding that the GEFT may be used as a predictor of academic success in engineering education, and possibly other professional education programs. At least in this study, it seems that the Global students were a distinct minority and were actually the ones most likely to fail the course. This perspective might lead one to consider using the GEFT as a screening mechanism in making admissions decisions to programs in engineering education.

Another view might note that this study was not an investigation in which the differing needs and preferences of Analytic and Global students were analyzed and used as the basis for providing students with different types of learning opportunities congruent with their respective styles. Perhaps such an approach would reduce the variance in academic achievement and help all students become more successful in the course. This view was espoused by O'Brien, et al. in the first report in this series: 'Engineering educators have a responsibility both to their students and their profession to respond in substantive and meaningful ways to research into the nature of individual differences' [1, p. 315].

The results of this study are also interesting in that they are very similar to those found in the first study in this series using the Myers-Briggs Type Indicator (MBTI) [1]. In that investigation researchers discovered another unusual distribution of engineering students along the 'Sensing-Intuition' dimension of the MBTI. Engineering students in that study exhibited the following profile: '60 (72%) Sensing-Perception, 23 (28%) Intuitive-Perception' [1, p. 313]. This profile was also inconsistent with earlier research, especially that conducted by McCaulley [10].

When one studies the characteristics supposedly associated with these different styles or types, the similarities between the Analytic and Intuitive styles, and the Global and Sensing styles are remarkable. Perhaps we are measuring the same two-dimensional cognitive construct using two different instruments. We think the hypothesis of a two-dimensional construct related to cognitive perception is also supported theoretically by research using other theoretical models and measurement instruments. Two, in particular, seem especially relevant. David A. Kolb's 'Learning Style Inventory' [11] and Anthony F. Gregorc's 'Style Delineator' [12] are both based on models which include a theoretical dimension which ranges from 'Abstract' to 'Concrete.'

We believe there is strong reason to speculate that the Abstract, Analytic, and Intuitive styles measure one dimension of a two-dimensional construct and that Concrete, Global, and Sensing styles measure the other. Research is needed to administer some or all of these instruments to the same group of participants. Factor analysis could then be performed on the resultant data to examine empirically potential correlation among the instruments as well as the underlying factor structure that may be present when they are studied collectively.

REFERENCES

1. T. P. O'Brien, L. E. Bernold and D. Akroyd, Myers-Briggs Type Indicator and academic achievement in engineering education, *Int. J. Eng. Educ.*, **14**, 5 (1998) pp. 311–315.
2. T. P. O'Brien, S. M. Butler and L. E. Bernold, Field dependence, contextual learning, and academic achievement in engineering education, selected papers from the *10th International Conference on College Teaching and Learning*, (1999) pp. 127–134.
3. S. Messick, The criterion problem in the evaluation of instruction: Assessing possible, not just intended, outcomes, in W. C. Wittrock and D. E. Wiley (eds.) *The evaluation of Instruction: Issues and Problems* (1970) New York, NY: Holt, Rinehart Winston, pp. 183–202.

4. T. P. O'Brien and N. C. Wilkinson, Cognitive styles and performance on the National Council of State Boards of Nursing Licensure Examination, *College Student Journal*, **26** (1992) pp. 156–166.
5. H. A. Witkin, P. K. Oltman, E. Raskin and S. A. Karp, *Group Embedded Figures Test*, Palo Alto, CA: Consulting Psychologists Press, Inc. (1971).
6. H. A. Witkin, Cognitive style in academic performance and in teacher-student relations, in S. Messick, et al. (eds.) *Individuality in Learning*, San Francisco, CA: Jossey-Bass (1976) pp. 38–72.
7. A. R. Collins, B. J. White and T. P. O'Brien, The relationship of cognitive style and selected characteristics of vocational education teachers, *College Student Journal*, **26**, 2 (1992) pp. 167–173.
8. H. A. Witkin, C. A. Moore, D. R. Goodenough and P. W. Cox, Field-dependent and field-independent cognitive styles and their educational implications, *Review of Educational Research*, **47** (1977) pp. 1–64.
9. SAS Institute, *SAS User's Guide: Statistics* (5th ed.) SAS Institute, Cary, NC. (1988).
10. M. H. McCaulley, The MBTI and individual pathways in engineering design, *Engineering Education*, **80** (1990) pp. 537–542.
11. D. A. Kolb, *Learning Style Inventory*, Boston, MA: Hay/McBer (1999).
12. A. F. Gregorc, (1982) *Gregorc Style Delineator*, Maynard, MA: Gabriel Systems.

Terrance P. O'Brien, Professor and Interim Head, Department of Curriculum and Instruction, College of Education and Psychology, North Carolina State University, received a Bachelor of Science in Secondary Education (1972) and a Master of Science in Education (1977) from Old Dominion University, Norfolk, Virginia. Received a Doctor of Philosophy in 1981 from The Ohio State University, Columbus. Dr. O'Brien has been a faculty member in Colleges of Education at The Ohio State University, Auburn University, and North Carolina State University. He has published extensively in educational and psychological journals on relationships between cognitive styles and academic achievement in a variety of educational environments.

Susan M. Butler, Assistant Professor, Department of Mathematics, Science and Technology Education, College of Education and Psychology, North Carolina State University received a Bachelor of Science in Medical Technology (1981) and a Master of Science in Secondary Science Education (1993 from Florida State University, Tallahassee. Received a Doctor of Philosophy in 1997 from Florida State University. Dr. Butler has been a faculty member in the Department of Curriculum and Instruction since 1998. Her research specialty is problem-based learning.

Leonhard E. Bernold, Associate Professor, Department of Civil Engineering, North Carolina State University, is a native of Switzerland. He received a diploma in Civil Engineering from the Swiss Institute of Technology in 1978, a Master of Science in Industrial Management from Georgia Tech in 1983, and a Ph. D. in Construction Engineering and Management from Georgia Tech in 1985. Dr Bernold spent five years as an Assistant Professor at the University of Maryland before assuming his present position in 1991. As the founder and director of the Construction Automation and Robotics Laboratory, he is involved in several innovative projects and conducts NSF sponsored research in engineering education.