AC 2008-2708: PREDICTING ACADEMIC SUCCESS FOR FIRST SEMESTER ENGINEERING STUDENTS USING PERSONALITY TRAIT INDICATORS

Paul Kauffmann, East Carolina University

Paul J. Kauffmann is Professor and Chair in the Department of Engineering at East Carolina University. His industry career included positions as Plant Manager and Engineering Director. Dr. Kauffmann received a BS degree in Electrical Engineering and MENG in Mechanical Engineering from Virginia Tech. He received his Ph.D. in Industrial Engineering from Penn State and is a registered Professional Engineer.

Cathy Hall, East Carolina University

Cathy W. Hall is a professor in the Department of Psychology at East Carolina University. She received her BA degree in psychology from Emory University and a Ph.D. in from University of Georgia. Her experience includes positions as a school psychologist, director of the school psychology program at Fort Hays State University, and psychologist in Kelly Psychological Service Center. Her research interest include resiliency in relation to adjustment and metacognition.

Gene Dixon, East Carolina University

Gene Dixon is an assistant professor in the Department of Engineering at East Carolina University. He received a BS in Material Engineering from Auburn University, an MBA from Nova Southeastern and a PhD in Industrial and System Engineering and Engineering Management from the University of Alabama – Huntsville. His professional experience includes positions with Chicago Bridge and Westinghouse. General research interests focus on engineering management and related processes. Specific interests include the role of leaders and followers in the leadership process.

John Garner, East Carolina University

John Dail Garner is a Lecturer in the Department of Engineering at East Carolina University. Mr. Garner received an MS in Mechanical Engineering from North Carolina State University. His research interests include recruitment and retention in engineering education, as well as energy production and conservation in agriculture.

Predicting Academic Success for First Semester Engineering Students Using Personality Trait Indicators

Abstract

The dual factors of attracting and retaining talented students in the areas of science, technology, engineering and mathematics (STEM) are critical issues for building the technology work force. When students enter colleges/universities and declare an engineering major, retention becomes the primary focus. Retention of talented students is a significant issue in engineering programs and improvement of retention rates can be a powerful tool in increasing the number of engineering graduates needed for national and global competitiveness. A number of studies have examined predictors of success for entering freshman engineering students including SAT scores and high school performance. The goal of this present work is to identify other personality factors that are critical for retention. Knowing this information, timely and targeted intervention can be applied to improve student success. The area of internal motivation is often proposed as a success factor and generally studies have neglected this area due to the difficulty in measuring and evaluating. This study considers the results of the Big Five and locus of control tests given to a group of first semester engineering freshmen. Factors of these tests were evaluated as tools to measure student motivation to succeed. The levels of these traits were then employed in a multifactor linear regression model to predict overall grade point average for the first semester. The study found that two of the Big Five factors along with locus of control were significant prediction variables for first semester grade point average.

Introduction

Retention of engineering students is a continuing concern among university academic programs nationwide. In improving retention, engineering educators have spent significant effort in identifying relationships between various measures of success and prediction variables in the hope of identifying focused interventions to improve student success.

A variety of multi-variable models have been developed to predict various measures of student success using a range factors. These studies examined the use of high school grade point averages (GPAs) and scores on standardized tests to predict student performance.[1, 2, 3] In assessing the field of engineering in particular, Takahira, et al.[4], found that the primary factors associated with persistence in an engineering statics course were GPA and SAT-math scores. Another study reported a positive effect of an entrepreneurship program on GPA and retention.[5] Other models have been more complex. Student success and persistence were examined by French et al. using hierarchical linear regression.[6] They examined both quantitative variables (SAT scores, high school rank, university cumulative grade point average) and qualitative variables (such as academic motivation and institutional integration). For measures of success they used junior and senior GPA, university enrollment and major enrollment over six and eight semesters. The study found that SAT scores, high school rank, and gender were significant predictors of GPA and that an orientation course was not a significant factor in predicting college success.

Zhang, et al.[7] evaluated a number of factors and their impact on engineering student success as measured by graduation rate. Using a multiple logistic regression model and data from nine institutions, they examined the impact of high school GPA, gender, ethnicity, quantitative and verbal SAT scores, and citizenship and their impact on graduation. The study reports that high school GPA and quantitative SAT score were the only significant factors for all models tested and the significance of other predictors varied among institutions.

This research has expanded to examine personality measures as predictors of college success. For example, one study examined cognitive and psychological variables to assess the freshmen GPA of 70 college women with higher predicted GPA , both high school GPA and academic self-concept formed a strong model that predicted 56% of the variance in GPA. For college women with lower predicted GPAs, the factors of internal locus of control and amount of effort put into work accounted for 46% of the variance. [8]

In a recent study, cognitive and personality factors were explored in relation to time to degree. [9] Data collected over a six-year period showed locus of control significantly contributed to obtaining an undergraduate degree in a timely manner. However, metacognitive skills, action behaviors related to academic success, and high school GPA were the three factors that emerged as predictors of college GPA. This research supported Borkowski's [10, 11] model of academic achievement based on the dimensions of metacognition and affective factors. Metacognition involves a knowledge of learning strategies and using these strategies in an effective and efficient manner. The affective component involves factors such as self-efficacy, motivation, and locus of control. Research supports the role of metacognitive strategies as a direct influence of academic success as measured by GPA, but internal control also plays an indirect role.

The goal of this present work is to complement this literature by more closely examining personality factors which may be contributors in predicting academic success over the first two years of engineering. Generally, student success or failure, as measured by GPA accomplished in this time period, results in changes in major or withdrawal from the university; the actions which result in retention failures for the engineering program. Consequently, the primary focus of this study is to determine which variables can predict freshmen and sophomore GPA. With this information, program faculty can identify, implement and evaluate the efficacy of, interventions to improve retention. The next section provides background information about the university and the engineering program which conducted this study.

Background Information

East Carolina University is the third largest institution in the sixteen member University of North Carolina System with a student enrollment in excess of 24,000. Over the last decade, there has been a major shift in the economic base of eastern North Carolina. ECU has been an engine of development and progress in the region, primarily due to a medical school, a planned dental school, and the leading College of Education in North Carolina. To further enhance the university's capability, an engineering program was approved and accepted its first students in fall 2004 into a systems engineering concentration. Engineering management and bio process engineering were added in 2005, with biomedical engineering in 2006.

The new program faced several challenges. The region's ability to maintain economic momentum and grow technology driven businesses is, in large part, dependent on attracting and retaining engineering expertise. However, local, national and global firms often have difficulty attracting and retaining engineers in a region that is primarily comprised of rural towns and small cities. The ability to grow local engineering and technology talent, with family roots in the region, was identified as an important element in addressing this issue. In addition, many students come from small, rural communities and are often first generation college students. As a result, retention was expected to be a significant challenge during program startup and student performance has been closely tracked relative to data gathering and analysis.

Purpose of the Study

An essential goal for the new engineering program was to create an applications based learning environment that would produce retention and graduation rates which outperform national standards. To meet this program goal, a primary focus of the program faculty has been to identify factors (student characteristics) which are indicators of future academic success or, conversely, failure. Identification of success factors can provide a significant tool to identify the most effective interventions, the students who will benefit most from these interventions, and accelerate the positive impact of the Engineering Learning Community (ELC) on student performance.

Several interventions are already under way. For example, in fall 2007, the first ELC was initiated. This program allows incoming freshman students to live together in a community environment within campus housing. In addition, a special offering of a college success class (COAD 1000) taught by engineering faculty was initiated. However, these efforts are broadly focused and it is essential that they contain precisely targeted activities.

As a starting point in improving retention, previous research examined indicators of future engineering program success which are found in the high school record at the time of application for admission.[12] This work identified high school grade point average (GPA) as a consistent and significant predictor of grade point average for college level engineering students. This study extends that starting point by examining the ability of personality trait measures to predict GPA. Specifically, this paper examines these research questions:

- Can GPA for freshman engineering students be predicted using personality traits?
- Specifically, can the locus of control and Big Five traits serve as a starting point in this analysis? If so, what factors are statistically significant?
- Based on these results, what strategies can be proposed to improve GPA performance and enhance retention results?

Personality Trait Indicators

This study employs two measurement tools for personality indicators. The first is commonly called the Big Five personality indicator. Psychologists define the "Big Five" personality traits as broad factors or dimensions of personality, discovered through empirical studies.[13] These factors are often defined as follows:[14]

- Extraversion (sometimes called Surgency). This broad dimension encompasses specific traits such as being talkative, energetic, and assertive.
- Agreeableness. This dimension includes traits like sympathetic, kind, and affectionate.
- Conscientiousness. People high in this trait tend to be organized, thorough, and planning oriented.
- Neuroticism (sometimes reversed and called Emotional Stability). Neuroticism is characterized by traits like tension, moodiness, and anxiety.
- Openness to Experience (sometimes called Intellect or Intellect/Imagination). This dimension includes having wide interests and being imaginative and insightful.

This study applies two specific instruments to measure the Big Five personality traits. The Revised NEO Personality Inventory (NEO-PI-R) is an instrument that measures an individual's major dimensions of personality.[15] This instrument employs a sixty question format which addresses the overall five factors. Participants read each statement and rate it on a Likert scale from 1 (strongly disagrees) to 5 (strongly agrees). The responses are compiled and scored to characterize the individual's personality. This test categorizes participants as high or low in each of the five domains: Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Research supports the NEO-PI-R's construct validity for its domains and factors. Reliability of the NEO-PI-R was assessed using a three month test-retest design. Coefficient alphas for Neuroticism, Extraversion, Openness, Agreeableness and Conscientiousness were 0.79, 0.79, 0.80, 0.75, and 0.83 respectively, $p < .001$. [16] In addition, a seven-year longitudinal study using the full NEO-PI-R tested long-term stability. For the five-domain scale, coefficient alphas that ranged from 0.63 to 0.81 were found for both men and women.[15]

The second instrument was the Ten Item Personality Inventory (TIPI).[17] The TIPI was developed to provide a brief measure of the Big-Five personality dimensions and has been found to have adequate convergence with widely used Big-Five measures in self reports; test-retest reliability; and, patterns of predicted external correlates. This tool was selected to evaluate a test instrument which may provide a more compact tool for engineering educators.

Rotter[17] is credited with the original locus of control concept which reflects a generalized belief concerning who or what influences events from internal to external control: Internal control describes the belief that control of future outcomes resides primarily in oneself. On the other hand, external control refers to the expectancy that control is outside of oneself, either in the hands of powerful other people or due to fate/chance. In the context of engineering education, an internal locus of control would describe a student who believes he/ she is capable of controlling future success by hard work, study, attendance, and similar efforts. On the other hand, a student with an external locus of control believes that study and class attendance may be outweighed by the random chance of the wrong questions appearing on a test.

The Nowicki-Duke Locus of Control Scale[18] was used to assess internal versus external attributions. The scale consists of forty yes or no items that are summed to indicate the respondent's perceptions of external control. Higher scores indicate a more external locus of control whereas lower scores indicate a more internal locus of control. The items were derived from the Nowicki-Strickland Internal-External control scale for children.[18] In an analysis of twelve studies, Nowicki and Duke [19] reported that reliabilities of the scale ranged from 0.74 to 0.86. The same study reported test-retest reliability of 0.83 over a six-week period. Validity of the scale was also supported with a correlation of 0.68 with Rotter's scale of internal-external control.

The following section describes the methodology and results of these test results in predicting GPA.

Methodology and Results

This section describes results of predicting student GPA using results of the Big Five personality test, the shortened Gosling version, and the Locus of Control test employing a multivariable, linear regression model. Equation (1) describes the general model form with five predictor variables as noted for the Big Five model described above, where GPA is the dependent variable, A_0 is a constant, the b_i terms are multipliers, and the x_i terms are the explanatory or predictor variables. The predictor variables and the dependent variable are described in Table 1.

$$GPA = A_0 + b_1x_1 + b_2x_2 + b_3 x_3 + b_4 x_4 + b_5 x_5 \qquad (1)$$

Using a step wise regression approach, starting with the full prediction model including all five explanatory variables, GPA at the end of the first and second year for the 2004 entering class and GPA for the end of the first year for the 2005 entering class were predicted using the linear model described in equation (1). Predictors were removed in sequential steps based on least significance as a model factor, as indicated by a t distribution score. Details of the results are described in the following sections.

Table 1: Summary of Regression Model Variables (Big Five Model)

Dependent Variable	**Description**	**Scale**
GPA- grade point average	Cumulative grade point average of freshman and sophomore engineering students at the end of spring semester.	Continuous from 0 to 4.
Predictor variables	**Description**	**Scale**
Extraversion	Broad dimension encompasses specific traits such as being talkative, energetic, and assertive.	Test score normalized on 0 to 1 scale
Agreeableness	Includes traits like sympathetic, kind, and affectionate.	Test score normalized on 0 to 1 scale
Conscientiousness	People high in this trait tend to be organized, thorough, and planning oriented.	Test score normalized on 0 to 1 scale
Neuroticism	Characterized by traits like tension, moodiness, and anxiety.	Test score normalized on 0 to 1 scale
Openness to Experience	Dimension includes having wide interests and being imaginative and insightful.	Test score normalized on 0 to 1 scale

<u>Big Five Model: Prediction of First Semester GPA</u>

The first test of the linear regression model involved use of the NEO-PI-R test results to predict the GPA of a group of first semester engineering freshmen. Using a stepwise regression approach, the five factor regression model in equation (1) was reduced one factor at a time based on the significance of the factor as evidenced by the t distribution value. Table 1 shows the NEO –PI-R model and Table 2 contains the shortened TIPI model GPA prediction capability. In both cases the consistent most significant factor at each step was the trait of conscientiousness. The models varied slightly in the second most significant factor. NEO indicated agreeableness while TIPI showed openness. In each case, these factors are significant in the third position and remain to the end of the third step in the factor elimination process. In both models, neuroticism and extroversion were insignificant.

Table 1: NEO GPA Prediction Model

	Stepwise Regression Sequence				
	1	2	3	4	5
R-squared	14.32	14.32	13.97	13.11	11.42
neuroticism	0.31	0.31			
T-Value	0.38	0.42			
extroversion	0				
T-Value	-0.03				
openness	0.8	0.8	0.7		
T-Value	0.74	0.75	0.67		
agreeable	**0.95**	**0.94**	**0.83**	**0.84**	
T-Value	**0.95**	**1**	**0.93**	**0.95**	
conscientious	**1.82**	**1.82**	**1.8**	**1.74**	**1.99**
T-Value	**2.07**	**2.09**	**2.09**	**2.04**	**2.46**

Note: Two most significant predictor variables in bold.

Table 2 TIPI GPA Prediction Model

	Stepwise Regression Sequence				
	1	2	3	4	5
R-Squared	16.5	16.5	14.93	13.32	12.24
neuroticism	-0.57	-0.57			
T-Value	-1.02	-1.05			
extroversion	-0.66	-0.66	-0.57		
T-Value	-1.18	-1.2	-1.06		
openness	**1.03**	**1.03**	**0.83**	**0.63**	
T-Value	**1.33**	**1.35**	**1.11**	**0.87**	
agreeable	-0.01				
T-Value	-0.02				
conscientious	**1.64**	**1.63**	**1.7**	**1.65**	**1.78**
T-Value	**2.49**	**2.61**	**2.74**	**2.66**	**2.94**

Note: Two most significant predictor variables in bold.

Locus of Control as a Predictor

Since locus of control (LOC) is a single factor predictor, a simple linear regression model was employed to test the capabilities for GPA prediction. Per Table 3, the LOC regression model is significant and LOC is a significant prediction variable at the +99% confidence level.

Table 3 LOC GPA Prediction Model

ANOVA						
	df	*SS*	*MS*	*F*	*Significance F*	
Regression	1	4.85	4.85	8.76	0.0043	
Residual	64	35.458	0.554			
Total	65	40.31				
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0.985	0.429	2.29	0.0251	0.127	1.84
LOC	2.051	0.693	2.96	0.00432	0.666	3.43

Big Five Model with Locus of Control: Prediction of first semester GPA

Since several factors in the Big Five Models and LOC were shown above to be significant predictors of GPA, a best subsets regression scheme was used to select the best two GPA predictors with LOC and Big Five Factors (PPI version) combined. Table 4 indicates again that for single factors, LOC and conscientiousness are the two best predictors in single variable models. Similarly, for the best combinations of two factors, LOC and Conscientiousness together are the best set of two factor GPA predictors followed by conscientiousness and agreeableness.

Table 4 Combined GPA Prediction Model

		Included in Model					
Step	R- squared	neuroticism	extroversion	openness	agreeable	conscientious	LOC
1	0.234					**X**	
2	0.15						**X**
3	0.306					**X**	**X**
4	0.266				**X**	**X**	

Results and Next Steps

This analysis in this section shows promise for additional study and refinement of this first step in exploration of these personality trait models.

- Tables 1 and 2 indicate conscientiousness in the big five model is a significant factor in a multi variable, linear model. However the total explained variation, as demonstrated by r squared, is lower than desirable. This indicates other prediction factors should be explored for inclusion in the model to complement conscientiousness.
- The ANOVA analysis in Table 3 indicates that the single factor regression model involving LOC is significant at +99%.
- Table 4 indicates the most promising two factors to include in the next phase of model research may be LOC and conscientiousness from the big five model.

Based on these promising results, in our next steps we plan to proceed with the following model refinements:

- Gather additional personality indicator information from seniors and juniors and perform an analysis similar to this paper to determine consistency of factor importance for students who have generally demonstrated success by completion of two years of an engineering program.

- Explore integrating our previous work[12] (which studied HS GPA, class rank, and SAT scores) with personality trait factors. Our previous model demonstrated high r squared and this step will examine potential improvement based on determining the complementary nature of personality traits and high school performance in predicting academic success of freshmen.
- Explore non linear models which may be more successful in predicting academic performance compared to linear models.

Conclusions

Since all survey respondents did not answer every question, this data analysis represents results from sample sizes ranging from 48 to 67 freshman engineering students. Although this reflects results for a small group and a single semester, the significance of these results provide strong encouragement of the potential for continued study of these models over future semesters. It is critical to develop and explore approaches to enhance the important traits to the extent possible. Figure 1 shows one possible concept in this regard. Engineering students fall generally into one of four quadrants based on scores in Big Five conscientiousness and LOC. Students who are in quadrant I are resilient survivors and the focus on these students is to maintain and build their commitment to an engineering career. The danger here is to lose a possible engineer to a change of major.

Some quadrant II and quadrant III students may be capable of some level of characteristic development. Realistically, the literature of personality traits indicates the difficulty of major and significant changes. As a result, focus should be placed in these quadrants on the students whose scores place them close to quadrant I. For example, a Quadrant II student might benefit from a requirement to attend a seminar in confidence building coupled with the importance of study skills and attendance. These two topics could be mutually reinforcing and produce improved academic performance. Quadrant IV students are those with the lowest possibility of significant change since two personality traits must be considered.

This research will continue, along with our current retention efforts, to find ways to impact the successful completion of the critical freshman and sophomore years of engineering.

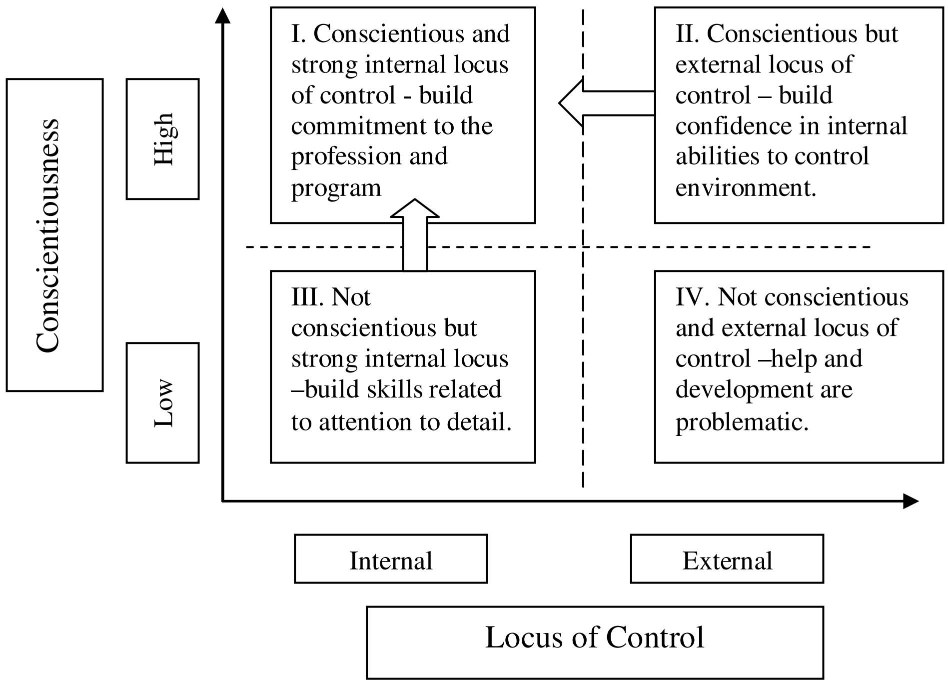

Figure 1 Possible Retention Strategies

References

1. Fleming, J. "Who will succeed in college? When the SAT predicts Black students' performance." *Review of Higher Education*, 25(3), 2002, pp. 281-296.
2. Hoffman, J. L. The impact of student co curricular involvement on student success: Racial and religious differences. *Journal of College Student Development,* 43(5), 2002, pp. 7I2-7'39
3. Zheng, J. L., Saunders, K. P., Shelley II, M. C., & Whalen, D. F. (2002). Predictors of academic success for freshmen residence hall students. *Journal of College Student Development*, 43(2), 267-283.
4. Takahira, S., Goodings, D., and Byrnes, B., "Retention and Performance of Male and Female Engineering Students: An Examination of Academic and Environmental Variables," *Journal of Engineering Education*, Vol. 88, 1998, pp. 297-304.
5. Ohland, Matthew W., Sharon A.Frillaman, Guili Zhang, Catherine E. Brawner, and Thomas K. Miller. "The Effect of an Entrepreneurship Program on GPA and Retention." *Journal of Engineering Education*, Oct. 2004, pp. 293-301.
6. French, B., Immekus, J., and Oakes, W., "An Examination Of Indicators Of Engineering Students' Success And Persistence," *Journal of Engineering Education,* 2005, pp.419-422.
7. Zhang, G., Anderson, T.J. , Ohland, M.W., and Thorndyke, B.R., "Identifying Factors Influencing Engineering Student Graduation: A Longitudinal and Cross-Institutional Study," *Journal of Engineering Education,* Vol. 93, 2004, pp. 313–320.
8. Kanoy, K. W., Wester, J. L., and Latta. M. (1989). Predicting college success of freshmen using traditional, cognitive, and psychological measures. *Journal of Research Development in Education*, 22(3), 65-70.
9. Hall, C., Smith, K., & Chia, R. (in press). Cognitive and personality factors in relation to timely completion of a college degree. College Student Journal.
10. Borkowski, J. G., Carr, M., Rellinger, L., & Pressley, M. (1990). Self-regulated cognition: Interdependence of megacognition, attributions, and self-esteem. In B. Jones & L. Idol (Eds.), *Dimensions of thinking and cognitive instruction* (pp. 53-92). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.
11. Borkowski, J. G., Chan, L. K. S., & Muthukrishna, N. (2000). A process oriented model of metacognition: Links between motivation and executive functioning. In G. Schraw & J. Impara (Eds.), Issues in the

measurement of metacognition (pp. 1-42). Lincoln, NE: Buros Institute of Mental Measurements, University of Nebraska.
12. Kauffmann, Paul, Tarek Abdel-Salam, and John Garner. "Predictors of Success in the First Two Years- A Tool for Retention." Proceedings of the *American Society of Engineering Education Annual Conference*, Honolulu, June 2007.
13. Goldberg, L. R. "The Structure of Phenotypic Personality Traits." *American Psychologist*, 48, 1993, pp., 26-34.
14. Srivastava, S. (2006). "Measuring the Big Five Personality Factors." Retrieved December 15, 2007 from http://www.uoregon.edu/~sanjay/bigfive.html.
15. McCrae, R. R., Costa, P. T., & Busch, C. M. (1986). Evaluating comprehensiveness in personality systems: the California Q-set and the five-factor mode. *Journal of Personality*, 54, 430-446.
16. Costa. P. T., Jr., & McCrae, R. R. (1992). Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) professional manual. Odessa, FL: Psychological Assessment Resources.
17. Gosling, S. D., P. J. Rentfrow, and W. B. Swann, Jr. "A Very Brief Measure of the Big Five Personality Domains." *Journal of Research in Personality*, 37, 2003, pp. 504-528.
18. Rotter, J. B. "Generalized expectancies for internal versus external control of reinforcement." *Psychological Monographs*, 80, 1966, whole issue.
19. Nowicki, S. & Strickland, B. (1973). Nowicki-Strickland Internal-External Locus of Control Scale (Available from Dr. Stephen Nowicki, Psychology Department, Emory University, Atlanta, GA 30322).
20. Nowicki, S., & Duke, M. P. (1974). A locus of control scale for college as well as non-college adults. *Journal of Personality Assessment*, 38, 136-137.