2006-2632: A MATHEMATICAL MODEL TO IDENTIFY PRE-TURNOVER MINDSET IN SOPHOMORE STUDENTS AT THE UNIVERSITY

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"Measuring STEM Attrition in an Engineering College"

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ABSTRACT

Academic institutions seek to understand why Science, Technology, Engineering and Math (STEM) students are leaving their programs and transferring into other majors. Previous research has identified multiple reasons for the student retention problem including attitudes toward the engineering field, student's self-confidence levels, quality of instructor interactions, and robustness of the STEM curriculum. Some researchers suggest that more standardized quantitative measures for departmental environments need to be created, and more appropriate quantitative measurements need to be applied to studying STEM student attrition. This study demonstrates a methodology that will begin to fulfill this need. This paper reports the results of a study conducted at the University of Nebraska-Lincoln that used this methodology to evaluate measures affecting sophomore engineering students' attrition. Results presented demonstrate that certain measures affect attrition in the College of Engineering & Technology (CoE&T) at the University of Nebraska.

INTRODUCTION

Academic organizations spend millions of dollars each year to recruit students into STEM majors. The National Science Foundation and other organizations have allocated funds to increase the enrollment of STEM students. Administrators may be able to avoid negative consequences to universities and students by identifying the STEM students who are experiencing high levels of Cognitive Turnover.

Jones (2001) defined Cognitive Turnover (CT) as a mind-set that is created by a combination of turnover cognitions brought about by the negative impacts of burnout. Turnover is the voluntary cessation of membership in an organization by an individual who receives current or future compensation for participating in that organization (Mobley 1982). Turnover has cognitive indicators that predicate eventual departure. Chemiss (1980) defines burnout as "a syndrome of inappropriate attitudes toward others and toward self often associated with uncomfortable physical and emotional symptoms." Maslach (1976) observed that burnout "appears to be a factor of organizational turnover, absenteeism, and low morale.

While everyone may manifest this mind-set periodically, excessive CT (eCT) may be detrimental to the individual and the organizations they belong to. Subtle acts such as absenteeism, poor quality, and lack of discretionary effort are related to burnout and are common precursors to a person quitting an organization and become another turnover statistic. This research theorizes that eCT condition occurs when a person is absorbed with the thoughts of turnover created by organizationally driven burnout. For engineering students non-committal types behavior may originate from student stress and burnout created by class structure, administrative neglect, or lack of advisory support.

BACKGROUND

The Statistical Evaluation of Cognitive Turnover System (SECtCS) methodology was created by the lead author (Jones 2001) and was previously used to measure and evaluate Cognitive Turnover (CT) in engineering knowledge workers. The results demonstrated four valid constructs for a heterogeneous group of engineers across multiple companies. Results also included Statistical Process Control Charts that demonstrated both "in control" CT respondents and "out of control" CT, or eCT respondents

Most undergraduate engineering students are susceptible to quitting engineering programs in the first two years of the program (Feldman 1998). Because of this fact, the test populations for this research were engineering students who are in the first two years of their engineering programs. This would include undergraduates that are 2nd semester freshmen, and 1st and 2nd semester sophomores. This study's test population consisted of 1st semester sophomores.

The objective of this study was to use the SECtCS methodology as a tool to identify students with eCT and identify measures that lead to student attrition. The central hypotheses tested are which measures of CT are valid for sophomore engineering students in the CoE&T at the University of Nebraska, and what is the magnitude of those measures. The process involved questionnaire development and regression model development which is explained using descriptive statistics. Lessons learned and future opportunities for usage of the proposed methodology are discussed. This information can be used for future research that may help reduce STEM student attrition.

RESEARCH METHODOLOGY

There are 6 phases of the SECtCS methodology. The 6 Phases of the SECtCS methodology are displayed in Figure 1.

Figure 1: 6 Phases of the SECtCS Methodology

1. PHASE 1 – DEVELOP TEST INSTRUMENT – Develop a customized test instrument (questionnaire) for the knowledge worker population, administer the questionnaire, and collect and record scores. Conduct reliability testing on the questionnaire. This testing continued until the questionnaire was reliable. (SECtCS Analyzer)
2. PHASE 2 – DEVELOP MATHEMATICAL MODEL – Use the data collected in phase 1 and incorporate it into a mathematical model to give a valid CT index score. (SECtCS Modeler)
3. PHASE 3 – (Not in study) STATISTICAL PROCESS CONTROL CHARTS – Use data from the model developed in phase 2 for the statistical measurement of individuals with respect to all respondents and identify at-risk CT index scores. (SECtCS Evaluator-i) Establish a tracking mechanism for "at-risk," and "low-risk" respondents. The respondents are required to retake the questionnaire every 3 months in order to monitor changes. They will also report if they become actual turnover.
4. PHASE 4 (Not in study) – INTERVENTION – Educate, implement, monitor and develop solution. (SECtCS intervention)
5. PHASE 5 (Not in study) – INTERVENTION MEASURMENT – Re-measure the respondents after they have been subjected to the intervention and compare to the results of phase 3. (SECtCS Evaluator-r)
6. PHASE 6 (Not in study) – RESULTS OF INTERVENTION – Document the results and conclusions and add to solutions database

   -Intervention Note: The intervention, like organizational mentorship, has to be coordinated for effectiveness. The intervention contributors must be provided guidelines so there will be data consistency. These guidelines will also allow for efficient collection of feedback.

PHASE 1 TEST INSTRUMENT DEVELOPMENT (SECtCS questionnaire)
The summated rated scale methodology was used to create the SECtCS questionnaire. Summated rated scales have good psychometric properties and are well-developed scales that have good reliability and validity. A well-devised scale is usually quick and easy for respondents to complete and typically does not induce complaints. The questionnaire was developed grouping questions into construct, or measurable variables that relate to CT.

Constructs
Constructs were developed using burnout and turnover questions. Burnout is commonly assessed using the Maslach Burnout Inventory (MBI) (Maslach and Jackson 1981). The MBI is a widely accepted questionnaire that has been used for numerous burnout studies that and has been proven both reliable and valid. It generally measures 3 areas; depersonalization, personal achievement, and emotional exhaustion, which relate burnout to the respondents' physical well-being. See Exhibit 1 for a description of burnout constructs. Turnover refers to individuals who voluntarily exit an organization within a particular period of time. Because of time and sampling constraints, it has been difficult for organizations to measure turnover (also called attrition). Previous research has shown that certain job-related factors, or constructs, have been demonstrated to be correlated with employee attrition. Such measures are useful in the context of studying retention-related interventions because they may provide specific measurement on related items so results can be determined over relatively short periods of time. The 8 main constructs related to turnover are general satisfaction with engineering major, goals, comfort, challenge, future financial rewards, relationships, resource adequacy, and perceived ability to get a job. See Exhibit 1 for a description of turnover constructs.

Exhibit 1. General Definitions of Constructs

Cognitive Turnover Determinant	*Construct*	*Construct Definitions*
Burnout	Depersonalization	Distancing oneself from others
Burnout	Personal Accomplishment	Performing well on things that matter
Burnout	Emotional Exhaustion	Ability to cope in high stress situations
Turnover	Overall Major Satisfaction	Satisfaction with engineering major that determines turnover
Turnover	Goals	Feeling that goals are attainable and have meaning
Turnover	Comfort	The space and physical conditions of the job are adequate to perform at the job
Turnover	Challenge	Feeling that engineering is not boring and has reasonable challenges
Turnover	Future Financial Rewards	Financial Compensation will be reasonable and fair from effort made in engineering studies
Turnover	Relationships	Ability and willingness to work with others students and faculty
Turnover	Resource Adequacy	Organization provides adequate supplies and resources to graduate and get a job
Turnover	Perceived ability to get a	Opportunity for fair chance at competitive

	job	engineering jobs in the marketplace

The foundations for the SECtCS questionnaire were questionnaires that have been proven valid and reliable from previous studies. The Minnesota Satisfaction Questionnaire, MSQ (Lofquist and Dawesl, 1967), is one of the most widely used measures of organizational satisfaction. The Facet-Specific Job Satisfaction Questionnaire, FSJSQ, (Cook, Hepworth, Wall, and Warr, 1989), is commonly used in measuring specific organizational satisfaction items. The items, each measuring a "facet" as indicated in the scale's title, were previously used in a 1973 survey, and a similar measure was employed in 1969 (Cook et al., 1989).

Reliability

Coefficient alpha (Cronbach, 1951) is a measure of internal consistency of a scale. The values of coefficient alpha are positive, taking values from 0 to 1.0, where larger values indicate higher levels of internal consistency. Nunnally (1978) and Spector (1992) provide an accepted rule that coefficient alpha should be at least 0.70 for a scale to demonstrate internal consistency. Coefficient alpha, commonly referred to as Cronbach's alpha, reflects internal-consistency reliability for the constructs in this study.

The coefficient of determination, R square, is commonly used in research to measure the adequacy of regression models. It can also be looked at as the proportion of variation in the dependent variable "explained" by the model. In general higher the R square the more acceptable, the model. Stepwise regression was used at an alpha level of 0.05 for our regression analysis. The final regression model was evaluated using R square for the models ability to determine future CT index scores from the questionnaire.

PHASE 1 RESULTS

The present study consisted of development and administration of a survey conducted at the University of Nebraska in fall 2004 investigating the CT index levels for sophomore engineering students. Respondents were asked to score their level of CT on a scale from 1 to 10 after they were given descriptions on the levels of CT. Respondents were assured that their answers would remain anonymous. Next, respondents were asked to rate the level of influence of each factor on a scale of 1 (strongly agree) to 5 (strongly disagree) on statements that indicated how they felt about their situation. An example was "My College is concerned about giving everyone a chance to perform well." On specific job satisfaction questions the scale of 1 to 5 represented 1 (very dissatisfied) to 5 representing (very satisfied). An example was, "In my engineering college, how do I feel about my potential for getting a job in the future." The mean values were calculated for each sub-scale and the overall scale.

TEST POPULATION STATISTICS

A study sample of more than 200 sophomore engineering students at UNL was taken. The questionnaires were distributed to the engineering students in a required sophomore seminar course. The test population consisted of respondents who were classified as sophomore engineering students enrolled at UNL in the fall of 2005. Respondents were chosen and questionnaires were collected over a 1-month time period. All participants voluntarily filled out a questionnaire. A total of 200 engineering students were asked to participate in this study Surveys with incomplete responses were deleted. A sample of 130 questionnaires returned; each

representing an individual engineering student. The response rate was 65 percent. In order to examine the data for normality, skew ness, and kurtosis, tests were performed and destructive outliers from incomplete surveys were excluded reducing the sample to 127.
The respondents' average age varied from 19 to 42 with a mean age of 20. The GPA ranged from 2.0 to 4.0 with a mean of 3.54. In the study there were 12 females, which represented almost 10 percent of the test population.

These questions were drawn from earlier questionnaires in order to yield a simple instrument that was easy to administer. The initial version of the questionnaire and rating scale was pilot tested and critiqued by other researchers and undergraduate students. After feedback from other researchers, ambiguous or confusing items were identified and eliminated. Using SPSS, the data were analyzed to determine the main effects and interactions between the different constructs and CT classifications. An analysis of reliability for each construct was done to reduce the number of questions and provide a satisfactory internal consistency score determined by the Cronbach's alpha. After the elimination of confusing questions, an item factor analysis was performed using Cronbach's alpha and the initial 109 question questionnaire was reduced to 62 questions.

The construct reliability coefficient, Cronbach's alpha, was determined for each construct. Questions were deleted in order to attain a desirable coefficient alpha for each of the eleven constructs. Items were successfully deleted from constructs from the original set, in order to improve reliability. The final questionnaire was reduced from 105 questions to 62 questions. This included 4 to 10 questions from each of the 11 constructs. The results are shown in Exhibit 1.

Exhibit 1. Revised Coefficient Alpha

	Initial no of questions	Revised no of questions	Revised Cronbach's Alpha
Depersonalization	5	4	0.548
Emotional Exhaustion	9	6	0.816
Personal Achievement	8	6	0.645
Major Satisfaction	11	6	0.806
Challenges	10	5	0.789
Comfort	10	7	0.705
Financial Assistance	11	8	0.757
Goals	11	5	0.621
Perceived Ability to Graduate	10	5	0.770
Relationship with other students	10	5	0.783
Resource Adequacy	10	5	0.793

The mean value for each construct of turnover and burnout was determined. The mean test scores from the questionnaire constructs were calculated from the values attained from the responses to questions. Some questions were reverse scored, meaning "1" represented very satisfied and "5" represented not very satisfied and "1" represented strongly agree and " 5" representing strongly disagree as opposed to the opposite. This required the reverse scored questions to be transposed for consistent scoring. The mean value and standard deviations are listed in Exhibit 2.

Exhibit 2. Construct Means and Standard Deviations

Construct	Mean	Std Deviation
Depersonalization	3.04	0.42
Emotional Exhaustion	2.94	0.37
Personal Achievement	2.93	0.41
Major Satisfaction	3.04	0.42
Challenges	2.65	0.37
Comfort	2.88	0.47
Financial Assistance	2.62	0.39
Goals	3.23	0.30
Perceived Ability to Graduate	2.46	0.47
Relationship with other students	2.80	0.42
Resources	2.57	0.46

Note: These scores are measured on a 5-point Likert scale with 1 representing not very satisfied and 5 representing very satisfied or 1 representing strongly disagree and 5 representing strongly agree.

PHASE 2 - MODEL DEVELOPMENT

Multiple linear regressions were used to develop the SECtCS model. Each model was examined to ensure no violations of assumptions occurred including multi-collinearity and heteroscedacity.

Dependent Variables

The dependent variables were the test subject's Cognitive Turnover classifications and scores. CT was the only dependent variable being measured and its scores ranged from 1 to 10. Respondents were given both a verbal and written description of the CT and the levels of CT. Next they were asked to classify themselves as a CT or non-CT and score their level of CT on a scale from 1 to 10 for the study. A description of each range is given in Exhibit 3 below.

Exhibit 3

Score	*CT*	*Considering Leaving*	*Description*
1-2	No	No	Not burned out
3-4	No	Occasionally	Light burnout
5-7	Yes	Open for other	Medium to High

8-10	Yes	majors Strongly considering other majors	High

Note: CT scores range from 1 to 10, with 1 representing low level of Cognitive Turnover and 10 representing high levels of the CT.

Independent Variables

The turnover and burnout constructs measured on the questionnaire were the independent variables that were used to determine the dependent variable, or the CT index.

REGRESSION MODEL RESULTS

The result of the regression analysis is shown on the ANOVA table. The ANOVA results are shown in Exhibits 3 and 4.

Exhibit 7A. Multiple Regression Revised Results

Variable	DF	Sum of Squares	Mean of Squares	F-Value	Signif F
Regression	11	71.506	6.501	1.456	0.202
Residual	29	129.470	4.464		
Total	40	200.976			

Exhibit 4. Final Variables in the Model

Variable	B	SE B	Beta	T	Sig T
Emotional Exhaustion	-0.833	1.423	-0/137	-0.586	0.563
Personal Achievement	1.485	1.172	0.270	1.268	0.215
Depersonalizatio n	-1.869	1.022	-0.348	-1.829	0.078
Goals	2.558	1.442	0.344	1.774	0.087
Comfort	0.035	1.241	0.007	0.028	0.978
Challenges	1.873	1.600	0.309	1.171	0.251
Financial Assistance	-0.027	1.696	-.005	-0.016	0.987
Relationship w other students	-0.446	1.650	-0.84	-0.270	0.789
Resource Adequacy	0.662	1.726	0.137	0.383	0.704
Perceived ability to graduate	1.611	1.538	0.337	1.048	0.303
Major satisfaction	-0.223	0.590	-0.285	-0.377	0.709

(CONSTANT)	-3.483	5.036		-0.692	0.495

Final Mathematical Model (SECtCS Model)

All of the variables / constructs had a significant effect on the CT index. Goals, Challenges, Depersonalization, Perceived ability to graduate and Personal Achievement were the most significant for engineering students in our study.

From our study the mathematical model for predicting CT for engineers was given by the following equation.

F(x) = -0.833(Emotional Exhaustion) +1.485(Personal Achievement) –1.869(Depersonalization) + 2.558 (Goals) + 0.035 (Comfort) + 1.873(Challenges) – 0.027(Financial Assistance) – 0.446 (Relationships with other students) + 0.662 (Resource Adequacy) + 1.611 (Perceived Ability to Graduate) – 0.223 (Major satisfaction) - 3.483 ....(1)

The function F(x) will be a number between 1 and 10. Scores that are approximately 1-4, represent low cognitions to leave and generally low burnout indications. Scores 5-8 represent moderate burnout and leaving cognitions. Scores 9 and above, represent eCT which may lead to detrimental burnout if departure is not eminent. (Refer back to Exhibit 6A for chart)

The following table exhibits the five most valid constructs for the model and describes the impact of each construct on the model.

Exhibit 8. Model Translation Description

Construct	*What it measures*	*Type of Effect*
Goals	Feeling that goals are attainable and have meaning	Largest direct impact on CT. If you set unreasonable goals you will have a high CT index score
Challenges	Feeling that the classes is not boring and has reasonable challenges	Direct impact on CT. If you feel the school work is too challenging then you will have a higher CT index score
Depersonalization	Distancing oneself from others	Has largest OPPOSITE effect on CT. If you feel that you are involved as part of the team you will have a lower CT index score
Perceived Ability to	Opportunity for good	Has direct effect on

Graduate	to fair chance to graduate	CT. If you believe you can graduate you will have a higher CT index score
Personal Achievement	Performing well on things that matter	Has direct effect on CT. This means if you believe you perform well your CT index score will be higher

STUDY LIMITATIONS

Some limitations to this research were the sample size and questionnaire biases. This study used only 130 engineering students at UNL. This should be taken into account when utilizing the model for possible sample bias. Currently, more populations are being targeted for further validation of the mathematical model.

Questionnaire biases can occur when implementing the testing of the questionnaire. Respondents may not answer the questionnaire honestly if they feel threatened by what will happen if they score on the high end of the index. The researchers recommend utilizing tools such as a digital simulator or online questionnaire software to offset some of the fears of being identified and the possible ramifications attached. Future research will include the development of a Manager's checklist which will allow managers to observe specific behaviors enabling the manager to score the employee for CT. You may also contact the researchers for the latest index scoring model

RESULTS AND DISCUSSION

Our findings yielded several lessons learned and recommendations. First, measurement is crucial so that engineering colleges can assist the students in graduating. The direct and indirect costs of losing engineering students directly impact engineering colleges and the nation's productivity. Second, analyses of the empirical data on the CT indices presented here suggest that administrators need to focus their current practice away from solely financial measures and toward providing goal management, training in handling a challenging curriculum, reduce isolated tasks that cause depersonalization and increase team activities, evaluate graduation perceptions, increase recognition of personal achievement, and promote the future job opportunities with an engineering degree. The high measure of depersonalization may suggest that when students perform traditional class work that consists of isolated tasks they may tend to have a higher CT index.

This finding supports the use of teams with engineering students (knowledge workers). The use of teams with engineering students has been on the rise over the last decade. This increase is due in part to pressure from the corporate environment and the Accreditation Board for Engineering and Technology (ABET) requirement for education institutions seeking accreditation to establish that students graduating from their programs are able to function on multi-disciplinary teams [4].

The faculty may be able to improve this component with team-based tasks. Personal achievement on CT indices suggests that recognition of knowledge workers can have a strong effect on CT. The other two significant variables were the perceived ability to graduate and challenges. This may not be under the direct control of college administrators.

One opportunity for improvement that colleges miss is giving feedback to students. Organizations may consider addressing the problems with performance analysis, identify and provide viable interventions with techniques like benchmarking, and communicate with students about possible solutions. By using the SECtCS methodology, engineering colleges have a tool for identifying some of the main components of the CT. The first two phases allow the organization to identify the most significant measures of eCT for the chosen group of knowledge workers. The complete methodology, which is not fully presented in this article, is designed to measure relevant components of eCT, re-measure implemented solutions effectiveness, document efforts, and provide feedback.

By implementing the methodology the engineering administrator can create an appropriate mathematical model in conjunction with group-specific questionnaires to generally measure the CT level of their engineers. This SECtCS modeler created in Phase 2 can be utilized to identify unproductive student measures or variables specific to that college. This group-specific questionnaire and model should be utilized for existing students where the organizations find it hard to measure but require innovation in order to retain a competitive advantage. Implementation of other phases of the methodology is not recommended without further direction from the researchers.

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