DIVERSITY IN ENGINEERING UNDERGRADUATE EDUCATION: A CASE FOR NONCOGNITIVE VARIABLES IN ENGINEERING ADMISSIONS

R.W. Brennan[1,3], H. Clitheroe[1], A.K. Deacon[2], M. Eggermont[1], N. Larson[2], T.A. O'Neill[2], W.D. Rosehart[1]
[1]Schulich School of Engineering, University of Calgary
[2]Department of Psychology, University of Calgary
[3]rbrennan@ucalgary.ca

Abstract **–** *In this paper we investigate a noncognitive assessment tool that can be used in conjunction with traditional, cognitive approaches (e.g., high-school averages) to undergraduate engineering admissions. The motivation for this work relates to the Schulich School of Engineering's desire to attract students who bring a wide range of interest and abilities based on cultural, race, gender or other aspects of diversity. Our hope is that a holistic approach to admissions will provide us with a means to consider a broader, more diverse student population, while still providing good predictors of student success in first year engineering.*

We describe a pilot study where all students student in the Schulich School of Engineering's first year engineering design and communication course were asked to complete the Noncognitive Questionnaire (NCQ) at the beginning of the Fall 2014 term. The results of this survey are then compared to overall student performance at the end of the Fall 2014 term to gauge the correlation between NCQ scores and student performance. The result of our study show that the NCQ is most useful for transfer student admissions where the population is non-homogeneous (i.e., arriving from a variety of institution, various age and experience levels), while average grade is the best predictor of student success for high-school admissions.

Keywords: holistic admissions, diversity, student success.

1. INTRODUCTION

Like other engineering schools in Canada, the University of Calgary's Schulich School of Engineering uses high school grades in mathematics, science, and language arts as its main admission criterion. This approach is straightforward, easy to defend, and ensures that only the highest achieving academic students are admitted to first year engineering. In recent years we have seen a steady increase in demand for seats in engineering along with a corresponding steady increase in our high-school admission average cut-off (e.g., in Fall 2014 the cut-off was 87%). As a result, many potential students, who are for all practical purposes academically qualified (e.g., students with high school average in the low- to mid-eighties), are effectively blocked from studying engineering at the Schulich School of Engineering.

Although unfortunate for these potential students, this policy is consistent with the high-school average admission criterion. However, this admission policy may not be consistent with the School's desire to attract students who bring a wide range of interest and abilities based on cultural, race, gender or other aspects of diversity. In other words, if we are missing a broader pool of students who are, arguably, academically qualified, we may also be missing out on the opportunity to increase diversity in the student population (by limiting the population of students who are considered admissible). The question of appropriate admission criteria is not unique to the Schulich School of Engineering, and has been the subject of considerable research in the engineering education community (e.g., [1-3]).

In this paper, we investigate a noncognitive assessment tool that can be used in conjunction with our traditional, cognitive approach (high-school averages) to admissions. The tool, the Noncognitive Assessment Questionnaire (NCQ) [4], has been widely validated as an assessment approach to predict grades, retention, and graduation for nontraditional and traditional students [5]. The NCQ was designed expressly to assess the following eight noncognitive variables:

1. positive self-concept,
2. realistic self-appraisal,
3. successfully handing the system,

4. preference for long-term goals,
5. availability of strong support person,
6. leadership experience,
7. community involvement, and
8. knowledge acquired in a field.

The purpose of this study is to assess the efficacy of noncognitive assessment as a tool for predicting undergraduate student success in first year engineering. In this paper, we describe a pilot study where all students in the first year engineering design and communication course (Engineering 200) were asked to complete the Noncognitive Questionnaire (NCQ) at the beginning of the Fall 2014 term. The results of this test are then compared to overall student performance (grade point average) at the end of the Fall 2014 term to gauge the correlation between NCQ scores and student performance. Our hope is that the NCQ can provide an additional criterion in our engineering admission process that will allow us to consider a broader, more diverse student population.

The section provides an overview of the study that was performed using the NCQ survey. We follow this with a discussion of the results of the study in Section 3, then provide our conclusions in Section 4.

2. DESIGN OF THE STUDY

2.1. The NCQ Survey

In order to pilot the Noncognitive Questionnaire (NCQ), an online survey was conducted at the beginning of the Fall 2014 term (September 2014) using the Survey Monkey tool [6]. Since all students participating in the survey had already been admitted to the Schulich School of Engineering, our goal was to administer the survey as early as possible to simulate a first year admissions survey.

The survey, provided in Appendix A, was designed to take no more than 20 minutes to complete In order to provide incentives to complete the survey, $5 gift cards (from a national coffee shop) were offered to the first 200 participants.

The survey questions are linked directly to each of the eight cognitive variables noted previously [4]:

1. NCQ1- Positive Self-Concept (Q4, Q6, Q7, Q8i, Q9c, Q9g): the applicant's confidence, self-esteem, independence, and determination;
2. NCQ2 - Realistic Self-appraisal (Q6, Q8a, Q9a): the applicant's ability to recognize and accept his or her strengths and deficiencies, especially in academics, and works hard at self-development to broaden his or her individuality;
3. NCQ3 - Successfully Handing the System (Q8g, Q9b,Q9f): the applicant's ability to understand the role of "the system" in life and to develop a method of assessing the cultural demands of the system and respond accordingly;
4. NCQ4 - Preference for Long-term Goals (Q5, Q8b, Q8h): the applicant's persistence, patience, long-term planning, and willingness to defer gratification and success in college;
5. NCQ5 - Availability of Strong Support Person (Q8d, Q9d, Q9e): the applicant's having a strong support network, help, and encouragement, and the degree to which the applicant relies solely on her or his own resources;
6. NCQ6 - Leadership Experience (Q8c, Q8f, Q10): the applicant's skills developed (or influence exercised) from his or her formal and informal leadership roles;
7. NCQ7 - Community Involvement (Q8e, Q10): the applicant's identification with a cultural, geographic, or racial group and his or her demonstrated activity within that community grouping;
8. NCQ8 - Knowledge Acquired in a Field (Q5, Q10): the applicant's experiences gained in a field through study and beyond the classroom. It pays particular attention to how the applicant gains nontraditional views of the field.

The questions listed in Appendix A very closely match the questions suggested by the authors of the NCQ survey [4], with only minor modifications for a Canadian audience (e.g., "B.Sc." instead of "B.S.", "About 50% of university students …" instead of "About 50% of college students …"). However, one exception relates to NCQ3: the NCQ identifies this variable as "Understands and Deals with Racism", whereas we have changed the variable to "Successfully Handing the System". Our rationale for this change is to try to move the focus away from race related differences between applicants, towards broader differences that may be encountered by non-visible minorities, mature students, etc. More specifically, the three questions used for NCQ3 in our survey are:

- Q8g – "I expect to have a harder time than most students at this school" (same as the original NCQ3 question),
- Q9b – "I expect that it will be difficult for me to fit in with other students at this school" (modified from "to encountering racism" to "to fit in with other students"), and
- Q9f – "I want a chance to prove myself academically" (same as the original NCQ3 question).

As well, the following questions were removed from the NCQ3 scoring:

- "the university should use its influence to improve social conditions in the state", and
- "if course tutoring is made available on campus at no cost, I would attend regularly".

The method used to score the survey can be found in [4]. For the majority of the questions, the approach is very straight forward, and simply involves tallying scores. However, open-ended questions such as Q5, "please list three goals that you have for yourself right now", require the scorer to individually code each response based on a scoring rubric.

2.2. Research Question

In order to determine if the NCQ is suitable as a first year admission tool, we explored the following research question:

Does the Noncognitive Questionnaire predict student success in first year engineering?

3. RESULTS AND DISCUSSION

The NCQ survey (shown in Appendix A) was opened to all Schulich School of Engineering students enrolled in Engineering 200 "Engineering Design and Communications" during the first week of the Fall 2014 term and was run for one week. During this period, 235 responses (41% response rate) were received.

Student responses to the survey were compared across three cohorts:

- High School Admissions (HS): these students were admitted directly from high school based on their high school grade average;
- Transfer (TRN): these students were admitted from other post-secondary institutions (other universities, colleges, polytechnics) based on their grade point average (GPA);
- Internal Transfer (CF1, CF3): these students were admitted into Engineering from other programs at the University of Calgary (e.g., Science).

As well, students were compared by gender in each of the cohorts noted above. In order to allow for a comparison across all cohorts, the transfer GPA's were converted to a percentage value by normalizing the GPA range with the high school grade percentage range. As well, we considered the following cases as outliers: students with a Fall 2014 GPA of zero, or students for whom we were missing high school or transfer GPA data. All outlier data was removed from the analysis.

The data was analyzed using Pearson's correlation coefficient to determine the relationship between admission average and Fall 2014 GPA, and NCQ scores and Fall 2014 GPA.

For the entire group of students, the admission average and the Fall 2014 GPA were positively related, $r(235) = 0.438$, $p < 0.01$. The relationship between NCQ scores and Fall 2014 GPA were not significant for any of the NCQ variables except NCQ8 "knowledge acquired in a field": $r(235) = 0.142$, $p < 0.05$. Figure 1 shows the scatter plot for the admission average and Fall 2014 GPA.

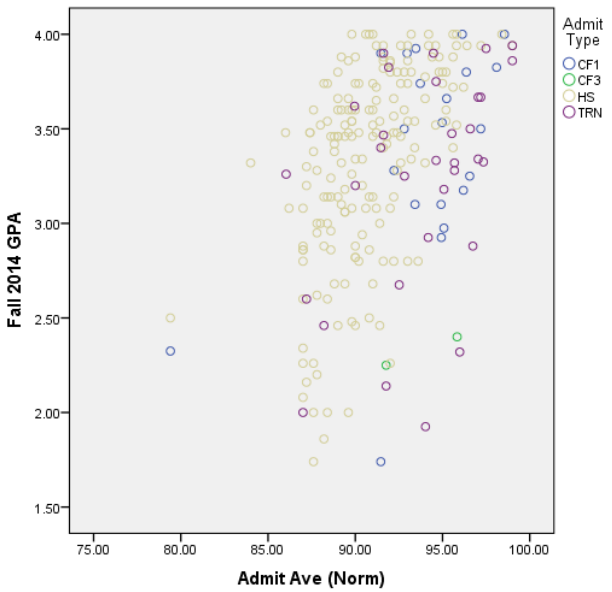

Fig. 1. Relationship between admission average and Fall 2014 GPA for the entire group.

Although the correlation to NCQ8 "knowledge acquired in a field" is relatively weak, it is interesting to see that there is a statistically significant correlation between this variable and student success in Fall 2014. The scoring of this variable focuses on students' involvement in extracurricular activities that develop leadership, teamwork, communication, and experience with technical and academic subjects related to engineering. It is encouraging to see that these types of extracurricular activities can have a positive relationship on success at university despite many applicants (understandable) focus on curricular activities.

When separated from the entire group, the high school cohort shows an even stronger correlation between high school grades and Fall 2014 GPA ($r(180) = 0.532$, $p < 0.01$) and no significant relationships between NCQ and Fall 2014 GPA. It is not surprising that the noncognitive variables do not play a big role in predicting student

success for this cohort: this is a relatively homogeneous group of students, the majority of whom come from local high schools, are all of a similar age, and share a similar social/economic environment. Although the correlation is not as strong, the internal transfer student cohort also shows a similar pattern: moderate correlation with admission average and no significant correlation with NCQ.

When the external transfer students are separated from the entire group, we see a moderate-to-strong relationship between admission average and Fall 2014 GPA ($r(32) = 0.463$, $p < 0.05$) and an equally moderate-to-strong relationship between NCQ and Fall 2014 GPA. In this case, NCQ2 "realistic self-appraisal" is significant ($r(32) = 0.402$, $p < 0.05$) for the entire cohort, and shows an even stronger correlation for the female transfer cohort ($r(18) = 0.474$, $p < 0.05$).

These results appear to support the view that noncognitive assessments can be used as a predictor of student success with diverse populations of students. In this case, neither the transfer average nor the NCQ score are strong predictors of student success, but both are significant at a moderate level (i.e., $r > 0.30$). Combined, the two assessments can potentially be used to provide a better assessment of student success than entrance grades alone.

In order to test the idea of combining the admission average and NCQ2 criteria, the two measures were added together with equal weighting to create a new combined (Ave. & NCQ2) measure with a range from 0 to 2.

Despite being a relatively simple means of combining the criteria (e.g., no weighting was used), the new criterion shows a much stronger relationship with Fall term student performance. Figures 2 and 3 provide a comparison a single and a combined criterion respectively. For the transfer student cohort, admission average and Fall 2014 GPA have a moderate-to-strong relationship ($r(32) = 0.463$, $p < 0.05$) while the combined (Ave & NCQ2) admission criterion and Fall 2014 GPA are strongly related ($r(32) = 0.506$, $p < 0.01$).

It is also interesting that NCQ2, "realistic self appraisal" is the significant variable for this cohort. Given that this group of students comes from a wide range of academic backgrounds and life experiences (this cohort is typically older than our high school cohort), it is important that these applicants are able to recognize and accept their strengths and deficiencies, especially in academics, and work hard at self-development to broaden their individuality.

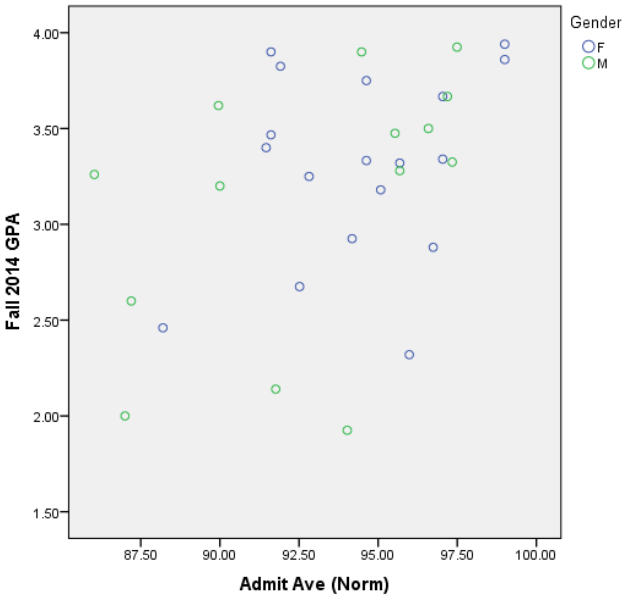

Fig. 2. Relationship between admission average and Fall 2014 GPA for the transfer admission group.

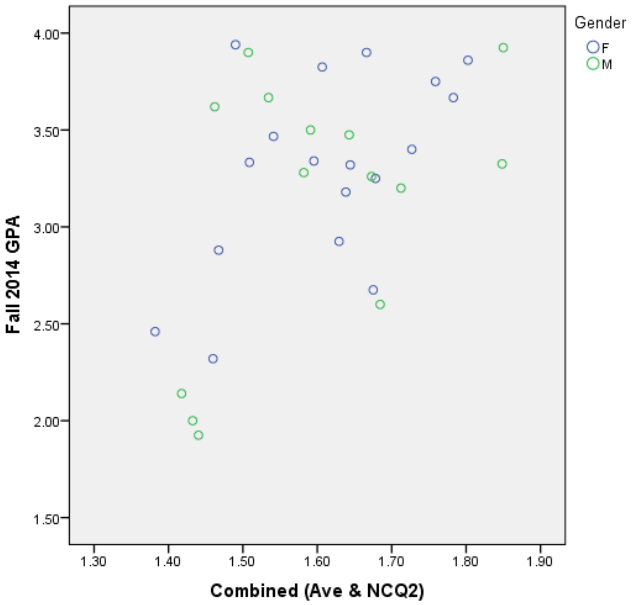

Fig. 3. Relationship between the combined admission average + NCQ2 criterion and Fall 2014 GPA for the transfer admission group.

4. CONCLUSIONS

The result of our study show that the Noncognitive Questionnaire can be used to predict student success in first year engineering. However, the NCQ is most useful for transfer student admissions where the population is

non-homogeneous (i.e., arriving from a variety of institution, various age and experience levels), while average grade is the best predictor of student success for high-school admissions. As well, it should be noted that this study only supports the use of the NCQ in combination with admission averages and not as a sole predictor of student success.

Although the results did not support using the NCQ as a predictor of student success for our high school cohort, it is important to note that we cannot conclude that the NCQ cannot be used for this purpose. In our study, we were limited to a population of students who were already admitted to engineering school with very high admission averages. The high admission average for these students may result in one variable being restricted in the analysis. Future studies with a broader admission cohort (e.g., tracking students who missed the engineering cut-off, but were admitted to another faculty), would likely provide more complete results on the NCQ's efficacy.

Finally, our study was limited to comparing admission criteria to first term (i.e., Fall 2014) grades. We hope to expand this study in the near future to include student performance in the entire first year program.

Acknowledgements

The authors wish to thank the Suncor Energy Foundation and the Schulich School of Engineering for their generous support of this research. As well, we would like to thank the students of Engineering 200 (Fall 2014) for their commitment to improving engineering education, and especially for their thoughtful responses to the survey questions.

References

[1] B.F. French, J.C. Immekus, & W.C. Oakes, "An examination of indicators of engineering students' success and persistence", *Journal of Engineering Education*, vol. 94 no. 4, pp. 419-425, 2005.

[2] Q. Li, H. Swaminathan, & J. Tang, "Development of a classification system for engineering student characteristics affecting college enrollment and retention", *Journal of Engineering Education*, vol. 98, no. 4, pp. 419-425, 2009.

[3] B.M. Holloway, T. Reed, P.K. Imbrie, & K. Reid, "Research-informed policy change: a retrospective on engineering admissions", *Journal of Engineering Education*, vol. 103, no. 2, pp. 419-425, 2014.

[4] W.E. Sedlacek, *Beyond the Big Test: Noncognitive Assessment in Higher Education*, Jossey-Bass, 2004, 288 pp. {ISBN: 978-1118660577}

[5] P.C. Kyllonen, A.A. Lipnevich, J. Burrus, & R.D. Roberts, "Personality, motivation, and college readiness: a prospectus for assessment and development", *ETS Research Report ETS RR-14-06*, 2014.

[6] Survey Monkey, *Online Survey Tool*, 2015, Available as of 8 April 2015 from https://www.surveymonkey.com/

APPENDIX A: NCQ Survey

Q1 – Q4 Demographic Information

Q4 How much education do you expect to get during your lifetime?

- College, but less than a bachelor's degree
- B.Sc. or equivalent
- One or two years of graduate or professional study (master's degree)
- Doctoral degree such as MD, PhD, and so on

Q5 Please list three goals that you have for yourself right now:

Goal #1:	
Goal #2:	
Goal #3:	

Q6 About 50% of university students typically leave before receiving a degree. If this should happen to you, what will be the most likely cause?

- Absolutely certain that I will obtain a degree
- To accept a good job
- To enter military service
- It will cost more than my family can afford
- Marriage
- Disinterest in study
- Lack of academic ability
- Insufficient reading or study skills
- Other (please specify)

Q7 Please list three things that you are proud of having done:

I am proud to have:	
I am proud to have:	
I am proud to have:	

Q8 Please indicate the extent to which you agree or disagree with each of the following items. Respond to the statements below with your feelings at present or your expectation of how things will be.

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
a) It should not be very hard to get a B (3.0) average at this school.					
b) I get easily discouraged when I try to do something and it doesn't work.					
c) I am sometimes looked up to by others					
d) If I run into problems concerning school, I have someone who would listen to me and help me.					
e) There is no use in doing things for people; you only find that you get it in the neck in the long run.					
f) In groups where I am comfortable, I am often looked to as leader.					
g) I expect to have a harder time than most students at this school.					
h) Once I start something, I finish it.					
i) When I believe strongly in something, I act on it.					

Q9 Please indicate the extent to which you agree or disagree with each of the following items. Respond to the statements below with your feelings at present or your expectation of how things will be.

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
a) I am as skilled academically as the average applicant to this school.					
b) I expect that it will be difficult for me to fit in with other students at this school.					
c) People can pretty easily change me even though I thought my mind was already made up on the subject.					
d) My friends and relatives don't feel I should go to university.					
e) My family has always wanted me to go to university.					
f) I want a chance to prove myself academically.					
g) My high school grades **don't** really reflect what I can do.					

Q10 Please list offices held and/or groups belonged to in high school or in your community.

1:	
2:	
3:	