Using Strengths of First-Year Engineering Students to Enhance Teaching

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Abstract

Using a five year longitudinal study, the main attributes that the incoming first-year engineering students at MacEwan University possess were found to be analytical, creativity, ingenuity, learner, group work, and work strategies. Analysis of the data has shown that students with a higher number of core "engineering strengths" had a better chance of succeeding to second year. A comparison of these strengths with the attributes of a "model engineer" was made showing shortfalls for the first-year engineering transfer students studied being: leadership, communication, ethics, professionalism, and social/global analysis skills. Finally, we discuss how to foster the growth of first-year students to ensure that they are well rounded and successful in moving forward in their careers.

Introduction

Annually thousands of students enter first-year engineering, each having their own distinct personality type. They are then taught by instructors using pedagogical methods that work for standardized groups but are rarely modified for individual students. This can become a concern with larger class sizes where lecture-style teaching methods are prevalent and remain unchanged from year to year. At the end of first year only a fraction of the students remain. Attrition rates for degree completion in engineering have been reported to be between 40-60%[1-3]. At our institution the attrition rates for transfer to second year from our first-year program fall within this same range. Efforts to maximize retention have been reported through modifications of curriculum[4] and teaching methods[5] (for example) with varying success.

Studies done almost two decades ago found a strong link between personality type and academic success[6-9]. In particular, these studies used Myer's Briggs typing as the method of analysis in an attempt to direct teaching practices. To date, an entire body of literature has now been devoted to engineering education with the pursuit of enhancing the education of first-year engineers. The need for engineers in our increasingly complex world as the baby boomers retire has never been more apparent. It is necessary to minimize attrition rates to satisfy this need.

Risk assessment models can be created which use student identifiers to predict the probability of student success. The hypothesis tested in this study is that attrition rates can be correlated with learning styles, which in turn can be correlated with strength typing. In order to test this hypothesis, we begin by studying the traits of first-year engineering students using the Clifton StrengthsFinder® assessment tool[10] which is a combined strengths/leadership/team building tool that has been used to categorize areas of strength for individuals. Previous research[9, 10] has postulated a connection between personality typing and strengths profiling. It was found that first-year engineering students at MacEwan University had a somewhat definitive strengths signature using data obtained from an ongoing longitudinal study[11, 12].

More recently in 2011, Paretti & Cross[13] provided a synopsis of the literature that has been devoted to assessing first-year programs and summarized the issues facing these educators: in particular, the need to examine outcomes surrounding retention and success as well the rubrics that would help verify that these outcomes have been realized. It is clear that there have been

many different strategies used to quantify and understand the phenomenon of "success" in engineering education. Veenstra et al.[2] have summarized the different approaches and have gone even further to define a "model for freshman engineering retention"[14], suggesting that understanding pre-college characteristics of students is important for student success and retention.

The research agenda for engineering education in the US in the past several years is linked to the National Academy for Engineering's report published in 2009 entitled "Educating the Engineer of 2020: Adapting Engineering Education to the New Century" [15].This report has set guidelines for research in engineering education by providing several recommendations, as well as listing many of the attributes of the "model engineer" including: analytical skills, creativity, ingenuity, learning focused, professionalism, leadership, teamwork, communication skills, work ethics, ethical reasoning, and societal and global contextual analysis skills.

The vision for the Engineer of 2020 paper is used in setting the goals of our current research which is devoted to the exploration of the characteristics of first-year engineering students at MacEwan University using the Clifton StrengthsFinder® survey and the examination of quantitative trends in data collected over a five year longitudinal study.

Methods

Participants:

The data for this study were collected over a five year period starting in 2009. The program is a first year engineering transfer program with an intake of ~200 students in each first-year class. Table 1 summarizes the number of students that participated in the survey during the longitudinal study.

Table 1: Sample Size Strengths Data from Longitudinal Study

Year	**2009**	**2010**	**2011**	**2012**	**2013**
Sample Size	156	156	117	187	192

Entrance statistics from High School into the transfer program show an overall average that varies yearly but has typically been ~80%. Data for age and sex were not recorded during the study but the percentage of males is typically between 80%-90% with at least 90% of the incoming students being less than 20 years of age. Participation rates in the study averages at 77% of the total engineering class. More recently, participation has increased as the use of this tool has become a part of the regular first-year curriculum. The strengths profile data analyzed in this paper span the full five year period, while the data pertaining to high school marks and first-year GPA were a bit more sporadic since these data were more difficult to acquire. The data that were analyzed with respect to academic quantifiers was from 2009, 2011 and 2013.

Procedure:

At the beginning of each year the incoming first-year students are requested to take the CliftonStrengthsFinder® survey. The test is a part of the curriculum of an engineering

professionalism course but the students receive no credit or rewards for taking it and is strictly interest based for the students. Participation in the research study is voluntary. The survey is a web based survey which asks the user 177 questions; each question allowing the user 20 seconds to respond. Self-descriptive questions are asked which read, for example: "I read instructions carefully" and "I like to jump right into things" allowing the students to choose the option which best describes them[10].

Measures:

Clifton's StrengthsFinder® is a proprietary online survey tool[16] that is used to determine the top 5 strengths of individuals from a list of 34 potential strengths. Clifton's StrengthsFinder has been tied to leadership attributes by Rath & Conchie[17], who postulated that successful teams possess broader strengths groupings according to four leadership domains: Executing, Relationship Building, Influencing, and Strategic Thinking. They have also postulated that the strengths identified in the Clifton's StrengthsFinder® can be categorized in terms of these four domains as shown in Table 2. Reliability of the survey has been previously checked, using Cronbach's alpha which has reported to be in the range of 0.54-0.79 depending on the strength[19].

Table 2: Categorization of Strengths in terms of Leadership Domains

Executing (E)	**Influencing (I)**	**Relationship Building (R)**	**Strategic Thinking (S)**
Achiever	Activator	**Adaptability**	**Analytical**
Arranger	Command	Developer	Context
Belief	Communication	Connectedness	**Futuristic**
Consistency	**Competition**	Empathy	Ideation
Deliberative	Maximizer	Harmony	Input
Discipline	Self-Assurance	Includer	Intellection
Focus	Significance	Individualization	**Learner**
Responsibility	Woo	Positivity	**Strategic**
Restorative		Relator	

Results

The data collected for this study come from the online survey Clifton's StrengthsFinder®. The top five strengths out of 34 possible strengths are provided for each student according to their survey responses. A detailed discussion of the 34 themes in light of engineering attributes was provided in earlier papers[11, 12] with theme descriptions available on the StrengthsQuest™ website[16].

Table 3 shows the cumulative strengths results for the period 2009 – 2013 for just over 800 first-year engineering students. There is no distinction made between those students that later transfer to second year programs, and those that do not. The analysis of the data was performed by considering the top five strengths for each participant, and then counting the frequency of these strengths in each of the samples. For example, for the "competitive" strength 237/808 students or 29% have this attribute in their top five strengths.

Table 3: Strengths of First-Year Engineering Students

Cumulative Results (2009 - 2013)					
Strength	#	%	Strength	#	%
Competition	237	29	Focus	97	12
Restorative	219	27	Input	95	12
Learner	210	26	Significance	89	11
Achiever	209	26	Intellection	87	11
Futuristic	196	24	Command	85	11
Analytical	191	24	Context	84	10
Adaptability	181	22	Maximizer	78	10
Harmony	150	19	Positivity	76	9
Deliberative	145	18	Communication	66	8
Relator	136	17	Discipline	65	8
Strategic	136	17	Developer	60	7
Responsibility	133	16	Woo	59	7
Consistency	131	16	Self-Assurance	55	7
Individualization	122	15	Activator	49	6
Ideation	120	15	Belief	47	6
Empathy	118	15	Arranger	42	5
Includer	110	14	Connectedness	37	5

The strengths shaded in Table 3 are attributes that are the most common amongst the group and have percentages > 20%. These were “competition”, “restorative”, “learner”, “achiever”, “futuristic”, “analytical”, and “adaptability”. A detailed breakdown of the strengths typing for the entire longitudinal study to date is attached in Appendix 1. Qualitative results from an earlier study[12] which focused on whether or not first-year engineering students at MacEwan University had a distinct strengths signature were identified and are described as follows using standard definitions[17].

- **Competition** – strive to gain something by establishing superiority over others
- **Restorative** – problem solving
- **Learner** – someone who gains knowledge/understanding by study, instruction or experience
- **Achiever** – goal driven; motivation drive and determination
- **Futuristic** – dreamer, visionary
- **Analytical** – to break down problems into components to understand
- **Adaptability** – flexibility, able to respond to changes

These strengths were most common in the first-year engineering students studied to date and are relatively consistent from year to year (see Appendix 1). In fact, it has been proposed that these first-year engineering students have an identifiable strengths signature that is qualitatively similar to characteristics that are often attributed to engineers[12]. Other studies that examined personality types of first-year engineering students, almost two decades ago[6-8], found a strong link between personality type and academic success. For the purpose of this study, Strengths

from Clifton's StrengthsFinder® were mapped with the desirable attributes for the "model engineer" and are shown in Table 4.

This table was used to group the strengths traits together as "engineering strengths" and further used to conduct a more detailed analysis on a subset of the data that tied high school marks and first year GPAs to the strengths profiles. Since strengths are qualitative and academic performance is quantitative, it was quite difficult to examine correlations of the data. Correlations of high school average and first-year GPA with the number of "engineering strengths" were found to be r = 0.034 and r = 0.141, respectively and are considered to be weak.

Table 4: Mapping of Strengths onto Engineering Attributes

Engineer 2020 Attributes	Strengths
Analytical Skills	Analytical (S), Restorative (E)
Creativity	Futuristic (S)
Ingenuity	Strategic (S), Futuristic (S)
Lifetime learner	Learner (S)
Group Work	Adaptability (R), Includer (R), Achiever (E)
Work strategies	Competition(I), Arranger (E), Consistency (E)
Leadership	Command (I), Activator (I), Positivity(I)
Communication	Communication (I)
Professionalism	Discipline(E), Responsibility(E)
Ethical Reasoning	Belief (E)
Societal/Global Analysis Skills	Connectedness(R), Context(S)

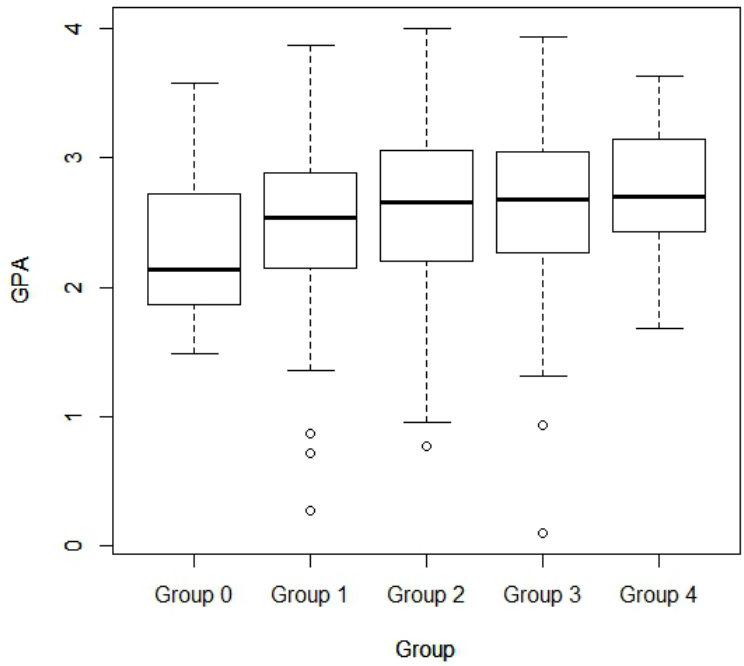
Although the preliminary analyses showed a weak correlation for academic indicators, the data were further examined by grouping students into the number of "engineering strengths" present (0-5) and comparing it with the first year GPA. These numbers are presented in Table 5. The results for the group of students that had five "engineering strengths" in their top five is not shown because there were no students in this category. The average GPA for students in each of the groups (0-4) was then calculated. The results in Table 5 show the average GPA increasing with increasing number of "engineering strengths". The percentage of students that achieved a grade of 2.5/4.0 or greater also increases with engineering strengths. This data suggest that for the students considered in this study, a higher percentage of students with a larger number of "engineering strengths" achieved GPAs greater than 2.5 (success) than those with fewer "engineering strengths".

A box plot of the means shown in Figure 1, illustrate the differences in the means of the five groups. A one-way ANOVA was performed on the same data showing the results $F(3.464) > 2.46$ and $p = 0.00843$. From this we conclude that within a 95% confidence level, the means are statistically different for the Groups, selected according to the number of engineering strengths. To further investigate the importance of these differences, and determine where the variations in mean occurred, a Tukey multiple comparison of means was used. This analysis showed significant differences in the means between Group 0 and Groups 2, 3 and 4, where the p values were all less than 0.05 in all cases. For all of the other cases there were no significant differences.

Table 5: Comparison of Strength Categories to Engineering Success

# Engineering Strengths	#Students GPA>=2.5	#Students GPA<2.5	Average GPA	Standard Deviation	Success Ratio
0	8	21	2.24	0.51	0.27
1	79	65	2.50	0.59	0.55
2	86	65	2.60	0.64	0.57
3	49	31	2.70	0.49	0.61
4	30	9	2.70	0.55	0.77

Figure 1: Box Plot of Engineering Strength Groups



The data were also examined in light of a "success ratio". The success ratio was defined as the ratio of students in a group that achieved a GPA > 2.5 relative to the total number of students in the group. This threshold is based on our transfer student's current 2nd year entrance requirement based on a GPA scale of 4.0.

It should be noted that the data analyzed in this paper were a subset of an ongoing longitudinal study. The samples sizes may not be large enough to make conclusions that would useful to the general first-year engineering education audience. A more in-depth analysis of the data that were not considered in this study might provide additional insight. A breakdown of high school marks by subject, and first-year GPAs according to term, and perhaps other indicators. It might also be useful to conduct the surveys at the beginning of the year, and again at the end of the year to determine the validity of the instrument that we are using.

Discussion

The engineering strengths shaded in Table 3 are consistent with the desirable engineering attributes associated with the "Engineer of 2020"[13] as shown in Table 4. The "restorative" and "analytical" strengths fit well with the analytical skill attribute. The "learner" strength is consistent with a learning focus and lifelong learning. The "futuristic" strength fits with ingenuity and creativity. The adaptability, achiever, and competition strength fit within group work and work strategies attributes. The remaining attributes of leadership, communication, professionalism, ethical, and social/global skills are not found to be strong strengths of incoming students.

Four of the "engineering strengths" identified in this study come from the strategic thinking domain, two from the executing domain, and one from each of relationship building and influencing domains, respectively. Clearly the strengths signature identified for this group of first-year engineering students is dominated by strategic thinking. The shortfall in strengths for this group is in the relationship and influencing domains. Rath & Conchie[16] suggest that successful teams are created with individuals that have strengths contributions from all domains. Again, the data would suggest that it might be quite difficult to build strong teams as many of the strengths with relationship building and influencing have very low percentages in this group.

Agoki et. al[20] suggested that this shortfall can be addressed by creating group activities that focus on building communication skills in the first-year engineering curriculum. There is a course offered each term at our institution that focusses on engineering professionalism using this team approach. It is quite possible that this course could provide a mechanism for enhancing these skills. Rath & Conchie[17] also indicate that the StrengthsFinder assessments can be used to build strong teams.

Furthermore, the results obtained in this study suggest that the approach taken by Felder et al.[22], with a move to teaching practices that utilize open-ended questions, co-operative learning and multi-disciplinary problem formulation and solution, might be prove beneficial at the first-year level. This approach speaks to the strengths of students through the use of problem solving, yet addresses the lack of societal/global analysis skills through the use of multi-disciplinary approach. With the data that have been already collected in this study, it might be possible to examine the impact of making these changes comparing data collected before and after these changes have been incorporated. Additionally, if these teaching practices could be adopted across the entire first-year engineering curriculum, including mathematics, physics, chemistry and English courses, it would be likely that the impact would be substantial.

Use of the StrengthsFinder® assessment has an inherent benefit in that the students become more self-aware of their strengths through the use of this tool. Bernold et al[21] have suggested that one of the challenges faced by engineering educators is to understand the learning process that students engage in while nurturing strengths and addressing weaknesses of the students. Use of a tool that can help identify strengths is definitely a step in the right direction to foster the learning process.

The quantitative analysis that was performed, examining the number of engineering strengths in light of first-year GPA provided positive results. The results indicate that students with some "engineering strengths" have a significantly higher first-year GPA than those with none, and have a better chance of success in first-year. Since this data is a subset of all of the data in the ongoing longitudinal study, the fact that these results connect success in first year with engineering attributes, it would be worthwhile to continue the research in this area. It will be interesting to see if the consistency in the strengths profile continues.

Summary

The longitudinal study qualitatively shows consistency in the core strengths profiles for the first-year engineering students being competition, restorative, learner, achiever, futuristic, analytic, and adaptability. An attempt at correlating academic indicators with student strength show a weak correlation ($0.034 < r < 0.141$), however, it was found that students with more of the core engineering strengths had a better chance of successfully completing first year. It is possible, then that the existing teaching methods are not satisfying the needs of the students that have strengths that are different than the "engineering strengths". If we are trying to improve retention, it would be worthwhile to explore the use of teaching practices that would address the challenges faced by the group with zero engineering strengths. It will be necessary, then to identify teaching practices that will enhance the success of the predominant strengths of that group. On a more positive note, since the results here suggest that the success rate for students that have four engineering strengths is 0.77, it is plausible that the teaching methods, to some extent, satisfy the needs of those students.

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Appendix 1 – Strengths Typing Data for First-Year Engineering Students – 2009 – 2013

2009	%	2010	%	2011	%	2012	%	2013	%
Competition	35	Competition	32	Competition	32	Restorative	37	Restorative	36
Achiever	33	Adaptability	27	Analytical	27	Learner	30	Futuristic	30
Adaptability	27	Analytical	26	Achiever	26	Competition	27	Learner	29
Learner	23	Achiever	24	Futuristic	26	Achiever	27	Competition	27
Restorative	23	Learner	24	Learner	25	Analytical	25	Achiever	23
Analytical	22	Futuristic	24	Adaptability	23	Harmony	25	Responsibility	23
Futuristic	21	Deliberative	21	Deliberative	20	Futuristic	24	Analytical	22
Harmony	21	Relator	19	Strategic	20	Relator	24	Harmony	21
Deliberative	19	Restorative	19	Command	18	Adaptability	23	Includer	20
Consistency	18	Strategic	19	Ideation	18	Deliberative	17	Strategic	18
Empathy	18	Ideation	18	Maximizer	18	Responsibility	17	Adaptability	17
Strategic	18	Command	18	Relator	18	Consistency	16	Consistency	17
Individualization	17	Individualization	18	Consistency	17	Includer	16	Deliberative	17
Ideation	17	Maximizer	18	Individualization	17	Empathy	15	Relator	15
Focus	14	Consistency	16	Restorative	17	Individualization	15	Empathy	14
Responsibility	14	Significance	16	Significance	15	Strategic	14	Positivity	14
Includer	12	Empathy	15	Responsibility	15	Focus	12	Ideation	14
Context	11	Input	15	Empathy	14	Ideation	12	Input	14
Developer	11	Harmony	13	Input	13	Communication	11	Context	13
Discipline	11	Responsibility	13	Focus	12	Significance	11	Intellection	13
Command	10	Context	11	Harmony	12	Input	11	Focus	13
Maximizer	10	Focus	11	Intellection	11	Intellection	11	Individualization	13
Positivity	10	Intellection	11	Context	10	Woo	9	Discipline	10
Relator	10	Includer	10	Self-Assurance	10	Context	9	Arranger	8
Input	10	Self-Assurance	10	Includer	9	Positivity	9	Self-Assurance	8
Intellection	10	Activator	8	Activator	9	Activator	7	Command	8
Significance	10	Discipline	8	Discipline	9	Developer	7	Communication	8
Communication	9	Belief	7	Belief	7	Belief	7	Significance	7
Connectedness	7	Developer	7	Communication	7	Arranger	6	Woo	7
Arranger	6	Positivity	7	Developer	7	Maximizer	6	Developer	6
Belief	4	Communication	6	Positivity	7	Command	5	Activator	5
Activator	3	Connectedness	5	Connectedness	5	Connectedness	5	Belief	5
Self-Assurance	3	Woo	5	Woo	5	Discipline	5	Maximizer	4
Woo	1	Arranger	2	Arranger	2	Self-Assurance	5	Connectedness	3