Key factors that influence engineering students' academic success: A longitudinal study

Lorelle J. Burton
Department of Psychology, Faculty of Sciences, University of Southern Queensland, Australia
burtonl@usq.edu.au

David G. Dowling
Faculty of Engineering and Surveying, University of Southern Queensland, Australia
dowling@usq.edu.au

***Abstract**: The aim of this longitudinal research was to identify the key predictors of academic success for 66 on-campus students enrolled in first-year engineering programs at USQ in 2004. In this paper, the relationships between cognitive abilities, personality, and previous educational experience, and academic success are examined. Other variables measured in the test battery are not analysed here. The initial findings as reported in Burton and Dowling (2005) and Dowling and Burton (2005) indicated that the Queensland Tertiary Admissions Centre (QTAC) rank was the most significant factor in predicting academic success for engineering students in their first year of study. Interestingly, the Extroversion personality trait also proved to be important. This paper will report on the results of the longitudinal study which concluded when the students had completed four years of study in 2007. It will also briefly outline other longitudinal research currently underway with a cohort of distance students.*

Introduction

Many engineering schools in Australia have experienced increased diversity in the characteristics of their commencing cohorts with many factors influencing their success in first year studies. McInnis, James, and Hartley (2000) found that a large proportion of first-year on-campus students in Australia were not fully prepared for tertiary education, were uncertain about what was expected of them, and were not motivated to achieve in their studies. In engineering programs in particular, spatial abilities are also seen to be critical for success, particularly in graphics courses (see Magin & Churches, 1996). Other factors also recognised as relevant to academic success include previous academic achievement (McKenzie, Gow, & Schweitzer, 2004), personality, and learning approaches (see Burton & Dowling, 2005; Burton, Taylor, Dowling, & Lawrence, 2009), among others. Venter (2003) suggested that teachers must respond to student diversity so they can enable each student to become a confident, self-directed, and independent learner. An inclusive learning environment that caters for the increasing diversity among commencing student cohorts may make the difference between success and failure. The challenge, then, is how to better understand the characteristics of the students in the commencing cohort and in so doing, provide a nurturing educational climate in which the prime goals are quality learning and academic success.

To achieve this goal, educators need to better understand those individual differences factors that impact on student learning. This study extends previous work by tracking a sample of first-year on-campus engineering students through to completion of their degrees. The aim of this paper was to examine the key individual differences (e.g., cognitive abilities and personality) and socio-cultural factors (e.g., previous educational experience) that influence the academic achievement of first-year engineering students over time. A key research question was to determine whether personality, cognitive abilities, including verbal and spatial abilities, and prior educational experience each predict grade point average (GPA) both at the end of first-year and again at the completion of their fourth year studies. By identifying the key factors that impact on student learning, adjustments to the teaching and learning environments can be made to ensure a smooth and successful transition to university for all students.

Methodology

A battery of tests was developed to create a "learning profile" for each student by identifying students' learning preferences, cognitive abilities (e.g., general reasoning, verbal, and spatial abilities), and major personality traits. The battery was developed for use in a longitudinal study of individual differences in student achievement. However, only those measures relevant to the current research aims are discussed here.

In 2004, the battery was administered via paper-and-pencil, however, from 2006, a refined battery was administered online, providing a more efficient data collection process and enabling distance education students to also participate in the project. This data is under analysis and will inform the current findings based on the 2004 on-campus cohort.

Individual feedback is provided to each participant summarising their learning preferences, cognitive strengths, and weaknesses and outlining strategies for optimising their learning environments. Further detail is provided below.

Participants

A total of 132 commencing on-campus students (17 females and 115 males) initially participated in the study in 2004. Complete data, however, were obtained from 66 students (13 females and 53 males), with a mean age of 20.15 years (*SD* = 4.99*)*. The mean age of the females was 18.15 years (*SD* = 2.51), and the males had a mean age of 21.96 years (*SD* = 6.51). Most had not previously studied engineering or surveying. All but five students spoke English as their first language, with six other languages spoken across the sample. At the end of fourth year, 61 of the original 66 students had successfully completed their engineering degrees.

Eight of the 132 students in the 2004 sample did university preparatory studies prior to commencing their engineering degrees. Four students cancelled their enrolment during or at the end of their first year of study in 2004 and another four students remained enrolled in their program but did not study in Semester 2, 2004. Six students chose to transfer to another degree at the end of their first year of study. Interestingly, five of these students were female. This is of concern for the Faculty as the female participation rate in engineering programs is already less than 12%.

Cognitive ability tests

General reasoning, verbal, and spatial abilities are cognitive abilities often shown to predict academic achievement (Rothstein & Paunonen, 1994). All three cognitive abilities are clearly relevant to success in the engineering profession, especially spatial ability (Strong & Smith, 2002). Each of the following reference tests were from the Ekstrom, French, Harman, and Dermen (1976) kit of factor-referenced cognitive tests, except where otherwise indicated. These tests are recognised as standard measures of cognitive abilities in the field of individual differences. The dependent variable for each reference test was the total number correct. These descriptive statistics are shown in Table 1.

General reasoning ability (the ability to reason, form concepts, and problem solve with novel information) was measured by the following three tests: (a) Letter Series (20 items; Thurstone & Thurstone, 1965), (b) Number Series (20 items; Thurstone & Thurstone), and (c) Matrices test (10 items; Cattell & Cattell, 1965). Verbal ability (the ability to process information presented as words) was measured by summing performance across three tests: (a) Scrambled Words (25 items), (b) Hidden Words (56 items), and (c) Incomplete Words (18 items).

A total of nine marker tests were included to measure three major spatial factors: Spatial Relations, Visualisation, and Spatial Scanning. The Spatial Relations factor reflects the ability to perceive an object from different positions. Spatial Relations ability was computed by summing performance on the following tests: (a) Card Rotations (80 items), (b) Cube Comparisons (21 items), and (c) Spatial Relations (70 items; Thurstone & Thurstone, 1965). The Visualisation factor reflects the ability to apprehend a spatial form and rotate it in two or three dimensions before matching it with another spatial form. Visualisation ability was computed by summing performance on each of the following tests: (a) Paper Form Board (120 items), (b) Paper Folding (10 items), and (c) Surface Development (30 items). The Spatial Scanning factor reflects the speed with which you can mentally scan a map or object and find a path or connection between two points. Spatial Scanning ability was computed by three mental scanning tests: (a) Maze Tracing Speed (4 items), (b) Choosing a Path (16 items), and (c) Map Planning (20 items).

Self-report survey

The self-report survey asked for demographic information on variables including gender, age, language, nation of origin, field of study, and experience. Additionally, data on student Queensland Tertiary Admission Centre (QTAC) rank and year 12 subject results were obtained. Self-report measures of preferred learning styles and general self-efficacy were also included in the survey (unreported).

The Big Five factors of personality were measured using the short version of the International Personality Item Pool questionnaire (Goldberg, 1999). For each major personality trait, 10 items were rated using a 5-point Likert scale and a total score computed, as follows (see Table 1):

- Extroversion – a person's interest in interactions with others and levels of sociability.
- Agreeableness – a tendency to cooperate and trust others.
- Conscientiousness – self-discipline, reliability and persistence.
- Emotional stability – self-reliance and the ability to deal with anxiety.
- Openness to Experience – creativity and a preference for novel experiences.

Performance outcomes

The GPAs the students achieved for both their first year (GPAY1; $M = 4.53$, $SD = 1.20$) and their final year of study (GPAY4; $M = 4.73$, $SD = 1.13$) were used as measures of academic success. The students were, on average, successful in their studies.

Procedure

The total testing time was about 2.5 to 3 hours, broken into two, 1-hour test sessions and a take-home self-report survey. The first session involved the timed general reasoning and verbal ability tests and the first half of the spatial ability tests. The second session included the second half of the spatial ability tests. A maximum of 25 people were present in either test session as students completed these tests during weekly tutorials. At the end of the second test session, students were each given the self-report survey to complete in their own time. They were required to return the completed survey in a sealed envelope within one week. Testing was carried out over a 4-week period. Students who completed the full battery of tests received personal feedback on their learning profiles.

Key findings

The following analyses examine the nature of the relationship between cognitive abilities, personality traits, prior academic achievement and academic success.

Correlations

Table 1 presents the key variables correlated against academic success (GPAY1 and GPAY4). QTAC rank is the main factor used to allocate university places once other entry requirements have been satisfied. It is a measure of previous academic achievement and, as expected, it showed a strong positive correlation with both GPA variables.

The correlation results in Table 1 show that both verbal and spatial abilities were related to success in students' first year of tertiary study. While all spatial abilities were to some extent associated with academic achievement, Spatial Relations ability, in particular, appeared especially relevant to success in first year and again in final year studies.

Of the Big Five personality measures, the on-campus cohort scored highest on the Agreeableness personality trait ($M = 38.21$, $SD = 5.64$) – being sympathetic, trusting, co-operative, modest and straightforward – although this trait was not significantly related to overall academic success. Interestingly, although the student sample scored lowest on the Extroversion personality trait ($M =$

30.97, *SD* = 7.77), this personality variable correlated most highly with academic success for both Year 1 and Year 4.

Table 1: Cognitive abilities, personality and QTAC rank correlated against academic success

Variables	Mean	*SD*	No. items	Correlation Matrix	
				GPAY1	GPAY4
Cognitive Abilities					
General Reasoning	32.46	5.85	50	.23*	.26*
Verbal	64.54	16.45	99	.34*	.35**
Spatial Relations	98.86	37.57	171	.36**	.40**
Visualisation	100.51	28.42	160	.21*	.20*
Spatial Scanning	32.97	8.96	40	.27*	.34*
Personality Traits					
Extroversion	30.97	7.77	50	.35**	.38**
Agreeableness	38.21	5.64	50	.24*	.19
Conscientiousness	35.62	5.42	50	.24*	.16
Emotional Stability	31.38	6.86	50	.20*	.10
Openness to Experience	34.35	5.95	50	-.11	.15
Other Indicator Variables					
QTAC Rank	81.53	11.68	-	.66**	.68**

Note. GPAY1 is the grade point average for end of first year of study in 2004; GPAY4 is the grade point average for end of final year of study in 2007; QTAC rank is calculated from the year 12 subjects by the Queensland Tertiary Admission Centre. $^*p < .05$. $^{**}p < .01$.

Regression analysis

An overall regression analysis was not appropriate due to the small sample size. Given that QTAC rank is strongly correlated with GPAY4, this variable was controlled to better establish the contribution of the remaining variables in the battery. QTAC rank was entered at step one of the regression analyses. In order to establish the relative predictive value of the various cognitive abilities, the spatial variables were regressed second onto the GPAY4 variable, followed by the Extroversion personality trait, the only personality trait that significantly related with academic achievement. Step one of the analysis revealed that QTAC rank was a significant predictor ($\beta = .72$, $t = 4.47$, $p < .01$), explaining 51% of variance in GPAY4 ($F_{(1,20)} = 20.00$, $p < .01$). When the cognitive abilities were entered at step two, only Visualisation ($\beta = .32$, $t = 2.01$, $p < .01$) showed a unique contribution to the prediction of GPAY4, explaining an additional 18% of the variance. When the personality trait

Extroversion was entered at step three, R^2 increased to .77 ($F_{(6,20)} = 5.33$, $p < .01$), with Extroversion contributing an additional 8% of the variance in GPAY4 ($\beta = .42$, $t = 2.11$, $p < .05$).

Implications and future research directions

Many engineering schools in Australia have experienced increased diversity in the characteristics of their commencing cohorts with many factors influencing their success in first year studies. The results concur with those of McKenzie and Schweitzer (2001) who found that previous academic performance (e.g., QTAC Rank) was the most significant predictor of engineering students' overall university performance (GPAY4).

The implications of the key findings that emerged from this longitudinal study are discussed in the following sections.

Cognitive abilities

Consistent with previous research (Strong & Smith, 2002), spatial ability is relevant to success for on-campus engineering students. Spatial abilities, in particular, Visualisation skills that enable individuals to mentally manipulate and rotate objects predict academic success in engineering programs. Thus, students deficient in these skills should be given the earliest opportunity to acquire these spatial skills that facilitate academic success.

Personality

The on-campus student sample scored highest on the Agreeableness personality trait, although Extroverted students were more likely to be successful, both in first-year and again in final year. This finding is in contrast to previous research that found Introverted and Agreeable students more likely to be successful in their studies (McKenzie et al., 2004). This finding may be due to changes in the curriculum brought about by an increasing emphasis on generic attributes and capabilities, such as communication skills and teamwork, by both the University and Engineers Australia, the accrediting institution. A greater emphasis is now placed on these skills in the curriculum and assessment. For example, a number of the core problem solving courses involve a substantial amount of team work and a considerable component of the assessment is based on team processes and outcomes. Additionally, the students must report verbally on the results of their work in a number of courses. It is therefore understandable that Extroverted students, who feel confident and comfortable consulting and collaborating with others, socialising, and working in teams, are more likely to be successful in assessments measuring these capabilities than their more Introverted peers.

The implication is that the problem based learning curriculum appears to be rewarding Extroverted students in their assessment practices. Extroverts are expected to succeed in a relaxed, group learning environment in contrast to introverts who are more likely to be attracted to a highly organised and independent learning environment (Eysenck, 1996). If the current findings are replicated in further datasets with distance students, then the Faculty will need to consider strategies to engage the more introverted students in learning, especially during their first year of studies. This will provide such students with more time to become familiar with the learning and teaching environment and facilitate a smoother transition to the university.

Conclusion

This longitudinal research based on a cohort of on-campus engineering students showed that prior educational experiences are relevant to students' academic success in their final year of study. As expected, Visualisation ability, the ability to apprehend a spatial form and mentally rotate it in two dimensions before matching it with another form, also predicts academic success beyond that already accounted for by prior knowledge. An unexpected finding was that Extroversion, rather than Introversion, also contributed to the prediction of academic success in engineering programs. The problem based learning curriculum therefore appears to provide an optimal learning environment for extroverts who enjoy learning in social contexts. Thus, knowledge of student learning profiles can enable educators to better design teaching environments that facilitate learning and help all students to achieve success. These initial results are being used to inform a review of the engineering programs at USQ to help facilitate the transition of a diverse group of students into their first year of tertiary study.

For example, the results are being used to inform a proposal to introduce an enabling skills course that may in future be undertaken by all commencing students. Longitudinal data from a large scale study including distance students and on-campus students from the 2006 cohort is under analysis to determine if the current key findings can be replicated in other cohorts.

References

Burton, L. J., & Dowling, D. G. (2005). In search of the key factors that influence student success at university. *Higher Education in a Changing World, Proceedings of the 2005 Higher Education Research & Development Association Conference, 28*, 68-78. Sydney, Australia.

Burton, L. J., Taylor, J. A., Dowling, D. G., & Lawrence, J. (2009). Learning approaches, personality and concepts of knowledge of first-year students: Mature-age versus school leaver. *Studies in Learning, Evaluation, Innovation and Development, 6*(1), 65-81. Retrieved May 28, 2009, from http://sleid.cqu.edu.au

Cattell, R. B., & Cattell, A. K. S. (1965). *Manual for the culture fair intelligence test, scale 2.* Champaign, IL: Institute for Personality and Ability Testing.

Dowling, D. G., & Burton, L. J. (2005). The End of the Pipeline: Profiling Commencing Students To Ease Their Transition into an Engineering School, *Proceedings of the 4th ASEE/AaeE Global Colloquium on Engineering Education,* Sydney, Australia.

Ekstrom, R. B., French, J. W., & Harman, H. H., & Dermen, D. (1976). *Manual for kit of factor-referenced cognitive tests.* Princeton, NJ: Educational Testing Service.

Eysenck, H. J. (1996). Personality and the experimental study of education. *European Journal of Personality, 10,* 427-439.

Magin, D., & Churches, A. (1996). *Gender differences in spatial abilities of entering first year students: What should be done?* Paper presented at the 8th AAEE Annual Convention and Conference, Sydney, Australia.

McInnis, C., James, R., & Hartley, R. M. (2000). *Trends in the first year experience in Australian universities.* Canberra, Australia: Australian Government Publishing Service.

McKenzie, K., Gow, K., & Schweitzer, R. (2004). Exploring first-year academic achievement through structural equation modelling. *Higher Education Research & Development, 23,* 95-112.

Rothstein, M. G., & Paunonen, S. V. (1994). Personality and cognitive ability predictors of performance in graduate school. *Journal of Educational Psychologist, 86,* 516-531.

Strong, S., & Smith, R. (2002). Spatial visualisation: Fundamentals and trends in engineering graphics. *Journal of Industrial Technology, 18,* 1-6.

Thurstone, L. L., & Thurstone, T. G. (1965). *Primary mental abilities.* Chicago, IL: Science Research Associates.

Venter, K. (2003). Coping with isolation: The role of culture in adult distance learners' use of surrogates. *Open Learning, 18,* 271-287.

Acknowledgements

The authors acknowledge the seed funding provided by USQ and the Faculty of Engineering and Surveying to support this research.

Copyright statement