Student design teams: how are teamwork and leadership negotiated?

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Structured abstract

BACKGROUND
The importance of interpersonal and teamwork skills within the engineering profession has been long acknowledged by various accrediting bodies around the world. To provide students with the opportunity to develop these skills, project-based and team-based learning is often implemented, however there is still little empirical data on how such learning activities enhance individual students' generic skills or how leadership is developed and negotiated within student teams.

PURPOSE
To be able to describe the interpersonal skills developed in first year student design teams and to determine how leadership naturally occurs and develops within these teams.

DESIGN/METHOD
Students were surveyed to determine cohort psychometric data relating to their Trait Emotional Intelligence, General Self-Efficacy and their levels of Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism as measured by the Australian Personality Inventory.
After specific content and learning activities relating to teamwork and leadership were completed, student teams were observed on a volunteer basis during a team meeting. Team behaviours were described in terms of the level of engagement with each other and with the task at hand, verbal and non-verbal interactions, content of discussions (task versus process) and "other" observations such as the physical layout of the team.
Analysis of the perceptions of students in relation to teamwork and leadership will be achieved by analysing reflection tasks for common themes.

INTERIM RESULTS
Student profiles indicate that the engineering cohort examined varies by a small, but significant amount compared to a general Australian University population.
Within a highly scaffolded learning environment, first year students work collaboratively and demonstrate on-task behaviour. Leadership was generally observed to follow a distributed model, although there were a significant minority of teams which had coordinators. Student perceptions of teamwork and leadership remain at a fairly superficial level.

CONCLUSIONS
In a structured team learning environment, students naturally exhibited a distributed leadership model, even though the same cohort of students demonstrated lower levels of Openness, Extraversion, Conscientiousness and Neuroticism compared to a broader group of Australian University students.

KEYWORDS

Design teams, teamwork behaviours, leadership development

Background

Teamwork and Leadership Skill in Engineering Design Teams

Engineering design commonly occurs in teams in industry (Taguas et al, 2012), yet engineering graduates often don't have expertise in shared creativity nor the ability to move between leadership and team support roles as the situation demands (Tzouanas & Campbell, 2011). It is arguable that these shortcomings limit the ability of engineers to fully utilise their technical knowledge (Prakash & Nagash, 2012). The importance of these skills in developing engineers has long been recognised by Engineers Australia (EA), and other accrediting bodies around the world such as ABET in the United States and The Engineering Council in the United Kingdom. (e.g. Engineers Australia, 2011; Accreditation Board for Engineering and Technology, 2013-2014; The Engineering Council, 2013).

Transferable Skill Development within Engineering Bachelor Qualifications

It is common practice therefore to embed teamwork and leadership skills within an engineering qualification: typically through the use of project-based learning. This is certainly the approach taken within the School of Aerospace, Mechanical and Manufacturing Engineering at RMIT University, where a series of project-based learning courses has been implemented within each Bachelors qualification to strengthen the students' transferable skill development.

The first year course within this project-based series of courses uses the EWB Challenge as the context within which students have their first experience of teamwork and leadership within an engineering design situation. In the initial implementations of this course, students were asked to reflect on their teamwork skills and provide assessment of their peers, however these learning activities did not provide the program team with a clear picture of the types of interactions which were occurring within the EWB student teams. There was also concern as to whether the project-based learning course provided sufficient opportunities for individuals to display and develop leadership skills. In addition, student reflections are, of course, limited and subjective, and to have a more precise understanding of student interactions, the program team needed some objective measures of student behaviour.

Examination of the relevant literature revealed that there is still little empirical data which describes the teamwork processes which occur within engineering student teams and that even in project-based learning courses, much of the focus is still on the acquisition of technical knowledge with (at best) some peer and/or self reflection on the development of transferable skills (e.g. Salleh et al, 2009; Wildermoth & Rolands, 2012). Furthermore, where interpersonal skills are addressed directly, only in a few noteworthy cases are students given tools to assess and moderate their own behaviours for the benefit of the team (e.g. Ogot & Okudan, 2006). Further, although there is evidence that personality traits are related to leadership (e.g. Zaccaro, 2007), there has been little research into the relationship between personality traits and skill development in student populations (Fini & Mellat-Parast, 2012; Närhi et al, 2012; Seat et al, 2001; Tzouanas & Campbell, 2011). Despite Zaccaro's (2007) claim that trait attributes such as personality are immutable, and hence leadership roles should be allocated based on existing personality, a recent study found that a leadership development program could affect key personality factors in young adults (Edwards-Hart, 2012).

Purpose

The current research project was therefore developed to:

- Qualitatively describe the teamwork and leadership styles demonstrated by first year engineering students;
- Quantitatively measure the personality factors of a first year engineering cohort, as described by the Australian Personality Inventory (API); General Self-Efficacy (GSES)

and Trait-Emotional Intelligence (TEI) and compare these metrics to those of a general Australian University population;
- Qualitatively describe the students' own perceptions of teamwork and leadership.

A comparison between the metrics determined and the behaviours, both observed and self-reported, will then provide vital information which can be used to ensure that the teamwork and leadership opportunities provided are recognised and utilised by the students.

Design

Learning and Teaching Intervention Implemented for 2012

For the 2012 offering of the first year course, the learning activities relating to teamwork were:

1. During a traditional lecture, students were exposed to the Myers-Briggs approach to Jungian Type and a simple model of team behaviours;
2. Students were then required to complete a Jungian Type inventory and reflect on their profile and whether they believed it was accurate;
3. During formal tutorial time, the teams were asked to list all the Types which existed in their team. Each team then workshopped potential strengths and weaknesses according to the types of personalities which made up the team (under the supervision of the tutor);
4. During the semester students were asked to reflect on the progress of the EWB Design; the interactions of their team; and the development of their own behaviours within the teams.

Psychometrics measured to gain cohort data

For the purposes of learning, Jungian Type Indicators of personality are easy to administer and relatively simple to explain to students. However, since current personality theory describes personality in terms of the well-validated 5-factor model (e.g. McCrae & John, 1992), for the purposes of research, a more robust personality measure using the 5-factor model approach was warranted. In terms of an individual's approach to leadership and teamwork, recent research (Edwards-Hart, 2012) has indicated that the Australian Personality Inventory (API) measures key psychometrics which are sensitive to skill development in this area. The API is based on the lexical work by Goldberg (1999).

In addition, other researchers have suggested that where leadership effectiveness is described in terms of devising solutions to novel situations (e.g. Connelly et al., 2000), general self-efficacy (GSE) in relation to problem solving is likely to be a necessary but insufficient condition for successful team leadership and has been shown to be linked to leadership development in young adults (Edwards-Hart, 2012).

Another attribute relevant to leadership effectiveness, is trait emotional intelligence (TEI). Consistent with the theoretical work of Zaccaro (2007) and the empirical work of Edwards-Hart (2012), aspects of EI such as emotional regulation, awareness of others and effective assertiveness may all be related to leadership effectiveness. These attributes fit well within accepted models of teamwork such as the "people versus production grid" model proposed by Blake and Mouton (1964) and the later, more nuanced, model of Ames and Flynn (2007). The Trait Emotional Intelligence Questionnaire (TEIQ) has also been used recently to examine student behaviour (Sanchez-Ruiz et al, 2010) and the "short form" (TEIQ-SF) of this survey instrument was used in this research project.

Hence, for this research, the first year cohort was examined in terms of API, GSE and TEI.

Methodology

The base skill level of first year students was quantitatively measured by:

- the Australian Personality Inventory (API); General Self-Efficacy (GSE) and Trait Emotional Intelligence (TEI) as quantitative measures of the cohort.

  The Australian Personality Inventory (Murray et al., 2009) is based on the lexical work of Goldberg (1999) and measures the attributes of individuals in terms of neuroticism, openness, conscientiousness, agreeableness and extraversion.

  General Self-Efficacy can be measured using the Schwarzer and Jerusalem (1995) General Self-Efficacy scale and compared with data from similar cohorts which have been published in the literature (Cohen & Cairns, 2011).

  The Trait Emotional Intelligence of the first year cohort was determined using the Trait Emotional Intelligence Questionnaire-Short Form (TEIQue-SF), as reported by Petrides and Furnham (2006).

  Data was collected from the first year student cohort using paper-based survey instruments and, out of a total cohort of 322, over 200 students agreed to participate. Standard tests for significance compared with other data previously published for a general Australian University population was then performed (Murray et al., 2009).

The team behaviours exhibited by first year design teams were described by:
- The team behaviours that were observed during student team meetings;
- The leadership styles which were exhibited during student team meetings;
- Summary of the common themes relating to team work and leadership, as identified by the students in their reflection tasks.

Students were observed during their formal tutorial time, during which specific teamwork activities were undertaken. Students were asked to consent to being observed before the observations commenced and the observations were categorised according to:
- the levels of student engagement with each other and with the task at hand;
- whether the engagement was task-focussed (specific to activity content) or processed-focussed (focussed on team processes and communication);
- what style of verbal and non-verbal interactions occurred (friendly/formal/hostile);
- whether one or several team members appeared to be directing the discussions or leading the team.

Initially, the researchers performed observations of the same teams at different times during the same tutorial session, to ensure that they were recording the same quality and type of information. Thereafter, the researchers observed teams individually to cover as many teams as possible within the same week. Seventeen teams, out of a cohort of 60 teams volunteered to be observed. Team membership during observations ranged from four team members to a maximum of six team members being present.

Students were also asked to allow their individual reflections to be used as part of this research. Only cohort concerns will be reported here.

Interim Results

Quantitative Data

Independent sample *t* tests were performed on the chosen psychometrics. The tests were done on the data collected in this study against data published in the literature for similar cohorts. Table 1 therefore lists the mean (M) and standard deviation (SD) for both the data previously reported and the data from the current study. Also listed are the values of n for each dataset: the number of data points obtained.

The *t*-distribution assumes a normal distribution, with a scaling factor and *t*(n) is the test statistic used to determine whether the difference between the two population means is significant or not. The p-value is the probability that the difference between the two means

can occur by chance and is compared with the significance level, which in this case was taken as $\alpha = 0.05$. A significant difference between two means is found therefore when $p<\alpha$.

Table 1: Analysis of the Psychometric measures of a first year engineering cohort

Variable (Instrument)	RMIT *M* (SD), n	Comparison *M* (SD), n	*t*-test	Source of comparison data
General Self-Efficacy (GSES)	30.77 (3.57), 213	30.90 (5.00), 500	*t*(711) = -0.34 *p* = 0.73, *d* = -0.03	Cohen & Cairns, 2011 (Australian data)
Openness (API)	34.34 (5.76), 208	36.40 (5.90), 270	*t*(476) = -3.87 *p* < 0.001, *d* = -0.36	Murray et al., 2009 (University sample)
Conscientiousness (API)	34.03 (5.85), 208	36.10 (6.10), 270	*t*(476) = -3.74 *p* < 0.001, *d* = -0. 35	Murray et al., 2009 (University sample)
Extraversion (API)	32.28 (7.13), 208	34.30 (6.20), 270	*t*(476) = -3.29 *p* = 0.001, *d* = -0.30	Murray et al., 2009 (University sample)
Agreeableness (API)	36.76 (4.51), 209	37.70 (5.40), 270	*t*(477) = -2.04 *p* = 0.042, *d* = -0.19	Murray et al., 2009 (University sample)
Neuroticism (API)	24.20 (6.17), 206	25.70 (7.20), 270	*t*(474) = -2.38 *p* = 0.017, *d* = -0.22	Murray et al., 2009 (University sample)
Trait Emotional Intelligence (TEIQ-SF)	4.86 (0.65), 203	4.99 (0.69), 886	*t*(1087) = -2.37 *p* = 0.018, *d* = -0.19	Zampetakis, 2011 (Community sample, nation unknown)

It can thus be seen that in terms of General Self-Efficacy, there was no significant difference between the first year cohort and the comparison group. (Table 1).

However, there were significant differences between the first year engineering cohort and comparison groups in measures of Neuroticism, Openness, Conscientiousness, Agreeableness and Extraversion. This indicates that the first year students are more introverted than the reference population, less conscientious, less open to experience, less agreeable and more emotionally stable (less neurotic). The magnitude of these differences, are reflected in the Cohen's *d* values in Table 1. Cohen's *d* is an indication of population effect size, expressed in units of within-group standard deviation. This is meant to provide an indication of the level of difference that would be noticeable to an observer, with small, medium and large effect sizes corresponding to *d* = 0.2, 0.5 and 0.8 respectively (see Cohen, 1992).and thus the differences shown here are significant but small.

Similarly, the first year student cohort results averaged slightly lower on the TEIQue-SF compared to a reference sample, suggesting that the students perceived their own emotional skills and social skills to be slightly lower than members of the general community. This result is consistent with other studies of similar students (e.g. Sanchez-Ruiz, 2010; Perez-Gonzales & Petrides, 2010), indicating that even the students themselves recognise they may have deficiencies and difficulties within this subset of transferable skills.

Observed Team Behaviours

All the student teams observed were engaged with each other during the time of the observations, with the vast majority of teams also demonstrating that they were engaged with the task at hand as well.
In terms of the content of the team discussions, there was an even split between task-focussed and process-focussed discussions, even though the observations were performed in the latter half of the semester when it would be expected that students would be concentrating on the completion of assessment (i.e. task-focussed).

Approximately half of the groups had one or two dominating members, out of a team size of five or six. In particular, up to half of the teams appeared to have a designated coordinator who controlled the team discussions and who collated all the technical information. However this team role appeared only for as long as it was necessary: once the “debrief” was completed a distributed model of leadership was evidenced. During the debriefing phase of the team meeting the leadership shown by the coordinator was directive in terms of the process and progress of the design task, and consultative when it came to considering the technical content relating to the design project.

The interactions between team members were classified as either “friendly”, “friendly-professional” or “polite-professional” and all interactions were very natural. None of the interactions appeared to be forced or overly formalised.

A side observation was that technology was used in several teams as a focal point for discussion and it was used to involve all team members. There were instances where individual members were observed using technology alone, on occasion to look up information and then report back to the group, but there may have been instances when technology also provided a distraction. It was difficult at times to determine when this occurred as some groups used social media platforms as their online team communication tool in preference to the online system provided by RMIT University.

In terms of the physical arrangement of the teams, most groups organised their space so that they were sitting “ in the round” rather sitting in a single row.

Analysis of Student Reflections: Work in Progress

Initial analysis of the student reflections demonstrate that while the students were able to reflect on their own individual personality profile, further reflections relating to the progress of their team in terms of teamwork skills was very superficial. Most students tended to focus on the progress of the technical aspects and difficulties of their project work, rather than reflecting on the progress and difficulties relating to the human dimension of their project.

Current and Future Research Directions:

It is planned to continue measuring the psychometrics for this cohort of students throughout their four/five year degree. Changes within the psychometrics of the cohort will then allow the program team to determine whether the project-based learning courses provide additional developmental benefits in terms of transferable skills over and above what might be expected from maturation effects alone.

It is also vital to determine how much scaffolding is required in later years to still ensure there are opportunities for the students to experience teamwork and to develop leadership skills within their project-based learning. Part of this research is currently underway where a second year project-based learning course is under examination. This course provides much

less scaffolding compared to the EWB course and observations relating to this second year course will be reported in a later publication.

In terms of the first year course, it would appear that students require more direction in their reflection activities to ensure that they encompass both transferable and technical skill development.

Conclusions

First year engineering students, even though they exhibited more introverted behaviours than the broader University population and perceived themselves as less capable in terms of their own social and emotional skills, generally exhibited a distributed form of leadership in well-scaffolded learning situations.

Team interactions were evenly split between task and process focussed and all interactions observed were friendly and unforced. Team leadership occurred naturally within teams, with many teams having a “gatekeeper” who directed the tasks but demonstrated consultative skills in discussing the design project. The gatekeepers appeared to only operate when needed and when there was a general discussion, a distributed model of leadership was observed.

Student reflections relating to their own teamwork skills and leadership potential was observed to still remain at a rudimentary level, even when specific reflection and tutorial activities were implemented.

References

Accreditation Board for Engineering and Technology (ABET). (2013-2014). Criteria for Accrediting Engineering Programs. Retrieved August 28, 2013, from http://www.abet.org/DisplayTemplates/DocsHandbook.aspx?id=3149

Ames, D.R., & Flynn, F.J. (2007). What breaks a leader: The curvilinear relation between assertiveness and leadership. *Journal of Personality and Social Psychology, 92*(2) 307–324.

Blake, R.R., & Mouton, J.S., (1978). *The new managerial grid: strategic new insights into a proven system for increasing organization productivity and individual effectiveness, plus a revealing examination of how your managerial style can affect your mental and physical health.* Houston: Gulf Pub. Co., Book Division.

Cohen, J. (1992). A power primer.*Psychological bulletin*. *112*(1), 155–159.

Cohen, K., & Cairns, D. (2011). Is searching for meaning in life associated with reduced subjective well-being? Confirmation and possible moderators. *Journal of Happiness Studies*. Advance online publication. doi:10.1007/s10902-011-9265-7

Connelly, M. S., et al. (2000). Exploring the relationship of leadership skills and knowledge to leader performance. *The Leadership Quarterly, 11*(1), 65-86.

Edwards-Hart, T. (2012), *Evaluation of the psychological outcomes of a residential youth leadership program*. Unpublished doctoral dissertation, RMIT University, Australia.

Engineers Australia. (2011). Engineers Australia National Generic Competency Standards – Stage 1 Competency Standard for Professional Engineers. Retrieved August 28, 2013 from http://www.engineersaustralia.org.au/sites/default/files/shado/Education/Program%20Accreditation/110318%20Stage%201%20Professional%20Engineer.pdf

The Engineering Council. (2013). The UK Standard for Professional Engineering Competence (UK-SPEC). Retrieved August, 28, 2013 from http://www.engc.org.uk/ecukdocuments/internet/document%20library/UK-SPEC.pdf

Fini E.H., & Mellat-Parast, M. (2012). Empirical Analysis Effect of Project-based Learning on Student Learning in Transportation Engineering, *Transportation Research Record: Journal of the Transportation Research Board, 2285,* 167-172

Goldberg, L. R. (1999). A broad-bandwidth, public-domain, personality inventory measuring the lower-level facets of several five-factor models. In I. Mervielde, I. Deary, F. De Fruyt, & F. Ostendorf

(Eds.), *Personality psychology in Europe* (Vol. 7, pp. 7–28). Tilburg, The Netherlands: Tilburg University Press.

McCrae, R. R., & John, O. P. (1992). An introduction to the five-factor model and its applications. Journal of Personality, 60(2), 175-215. doi:10.1111/j.1467-6494.1992.tb00970.x

Murray, G., et al. (2009). Personality for free: Psychometric properties of a public domain Australian measure of the five-factor model. *Australian Journal of Psychology, 61*(3), 167-174.

Närhi, et al. (2012). *Project-based Learning for a Biosciences laboratory in an Engineering Curriculum.* Paper presented at the SEFI 40th Annual Conference, Thessaloniki, Greece.

Ogot, M., Okudan G.E., (2006). The Five-Factor Model of personality assessment for improved student design team performance. *Journal of Engineering Education, 31*(5), 517-529.

Petrides, K. V., & Furnham, A. (2006). The Role of Trait Emotional Intelligence in a Gender-Specific Model of Organizational Variables. *Journal of Applied Social Psychology, 36*(2), 552-569.

Prakash, & Nagesh. (2012). *A Study on Shaping Engineers to be Effective Project Managers: Teaching Models*. Paper presented at the National Conference on Rousing Enterprises in a Declining Global Economy: Opportunities and Challenges, Bangalore, India.

Salleh, N., et al. (2009). *An Empirical Study of the Effects of Personality in Pair Programming using the Five-Factor Model*. Paper presented at the Third International Symposium on empirical software engineering and measurement, Washington DC, USA.

Sanchez-Ruiz, M. J., et al. (2010). Trait emotional intelligence profiles of students from different university faculties. *Australian Journal of Psychology, 62*(1), 51–57.

Seat, E., et al. (2001). Enabling Engineering Performance Skills: A Program to teach Communication, Leadership and Teamwork, *Journal of Engineering Education*, *14*(1) pp 7-12

Schwarzer, R., & Jerusalem, M. (1995). Generalized self-efficacy scale. In J. Weinman, S. Wright & M. Johnston (Eds.), *Measures in health psychology: A user's portfolio. Causal and control beliefs* (pp. 35-37). Windsor, UK: NFER-NELSON.

Taguas, E.V et al, 2012, Group dynamics for the acquisition of competences in Project Management, *Geophysical Research Abstracts*, *14*, EGU2012-10444, 1 page.

Tzouanas & Campbell. (2011). *Team work Conundrum: What should be taught and how can we assess team learning in Engineering Technology*. Paper presented at the 2011 ACEE (The American Society for Engineering Education) Conference, Vancouver, Canada.

Wildermoth, B.R., & Rowlands, D.D. (2012). *Project Based Learning in Embedded Systems: a Case Study*. Paper presented at the Australasian Association for Engineering Education Annual Conference, Melbourne, Australia.

Zaccaro, S. J. (2007). Trait-based perspectives of leadership. American Psychologist, 62(1), 6–16–discussion 43–7. doi:10.1037/0003-066X.62.1.6

Zampetakis, L. (2011). The Measurement of Trait Emotional Intelligence with TEIQue-SF: An Analysis Based on Unfolding Item Response Theory Models. in C.E.J. Härtel, N.M. Ashkanasy, W.J. Zerbe (Eds.), *What Have We Learned? Ten Years On (Research on Emotion in Organizations, Volume 7)* (pp.289-315). UK: Emerald Group Publishing Limited.

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