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RESEARCH ARTICLE

Using megaproject performance outcomes to enhance decision-making behaviours in civil engineering graduates

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Abstract

A comprehensive review of megaproject performance propositioned the issues leading to project failure as behavioural. Project failure linked cost overruns and schedule delays to acts of delusion and deception, citing the ability to learn lessons, and the misalignment of incentives as influencing factors. A mixed-methods study was designed to gain insight into the decision-making behaviours of undergraduate civil engineers, and the role that education could play in enhancing decision-making. A co-curricular intervention led to qualitative exploration of decision-making in civil engineering undergraduates. Motivation featured heavily, particularly a conflict between interest and enjoyment, and the reward structures of traditional education and industry. Results led to a quantitative measure of intrinsic motivation and critical thinking ability. Findings from the educational environment have implications for industry and led to recommendations regarding the importance of autonomy and relatedness, to a megaproject environment.

Keywords

Co-curricular Design, Decision-Making, Delusion, Deception, Megaprojects

Introduction

While transport infrastructure megaprojects (>US\$1 billion) are now commonplace, colossal cost overruns and schedule delays are the norm, not the exception, and typical of these large-scale projects (Flyvbjerg, 2014). Megaprojects have now become a focus of public interest, due to the impact of the success of a project, particularly during times of political and economic uncertainty. Flyvbjerg, Nils and Rothengatter (2003), Flyvbjerg, Skamris Holm and Buhl (2003), and Flyvbjerg (2007; 2009; 2014) attributed project failure to acts of delusion and deception, citing the ability to learn lessons, and the misalignment of incentives as factors influencing this behaviour. As most Civil Engineering graduates go into engineering and building professional roles, the likelihood of a Civil Engineer becoming part of a project team on a transport infrastructure megaproject is high (Figure 1). Civil Engineers represent a significant percentage of Project Managers, and Project Contributors on the proliferation of transport infrastructure megaprojects.

Type of work	Percentage
Engineering and building	74.8
Technicians and other professionals	5.6
Managers	4.2
Retail, catering and bar work	4.2
Other	11.2

Exhibit 1 Type of work for graduating Civil Engineers in UK in 2018 (prospects.ac.uk)

Civil engineering higher education is primarily focused on achieving mastery of technical knowledge. Project management, business management, ethics, decision-making and managing risk and uncertainty have played an insignificant role in current civil engineering curriculum globally, however, it is not simply the addition of content to existing programs that will address these underrepresented themes. While teaching an Introduction to Project Management course to third year undergraduate Civil Engineers at the University of Queensland the author found that many students were unable to see the relevance of the non-technical skills and were unable to apply technical concepts, in context, to the non-technical skills. This suggests that there is a gap in Civil Engineering programs that if addressed through content and appropriate pedagogy could help improve the performance outcomes of future megaprojects. When considering the role that education plays in shaping the way in which students think and make decisions, we can appreciate the responsibility that education takes, and the impact it could have in enhancing the decision-making skills of graduate engineers. As cohorts increase in size and the quantity of information students are expected to retain during their engineering programs increases in line with new technologies and practices, we are failing to address the fundamental issues of risk, uncertainty, and ambiguity, and in turn inhibiting the development of critical decision-making skills.

'Non-technical' skills have been highlighted as increasingly important by engineering professionals, such as Engineers Australia, The National Academy of Engineering in the United States, and the Royal Academy of Engineering in the United Kingdom (National Academy of Engineering, 2004; Spinks, Silburn and Burchall, 2006; King, 2008). 'Enhancing employability skills' was identified as a key requirement, and while project and business management skills are being incorporated into global engineering curriculum, addressing the psychology of decision making, specific to engineers, lacks supporting research and requires further study. The case for quality decision-making in engineering education has become more common in recent years, but despite being placed under the theme of engineering ethics, the discussion of underlying values and the influence these have on decisions made in a current context has been less so. Baillie and Levine (2013) stated that the values underlying the [ethical] decision-making process can develop very different responses to the same issue. These underlying values, defined by political, social and cultural influences are often socially constructed and based on dominant discourse. Values evolve from human interactions with the external world and are related to, but more abstract, than norms (Santrock, 2007). In any society and culture there are ways of thinking that are common sense or 'hegemonic' that result from norms and turn in to values (Gramsci, 1971). Thought collectives and thought styles refer to the systems of thought (composed of ideas, attitudes, courses of action, beliefs and practices) that systematically construct our understanding of the world we live in (Fleck, 1979). Fleck maintains that stable thought collectives form organized social groups i.e. professional engineers and can become fixed and formal in structure if a large group exists for long enough. The longer a thought exists within a collective, the more certain it appears (Fleck, 1979). If engineering is considered a community of practice, with an associated common sense and thought style, then to reframe engineering practice, a critical repositioning of engineering itself is needed Baillie and Levine (2013).

While we can retrospectively address the issue of poor decisions made on megaprojects, an evaluation of what can be done in education would be less accusatory and focus more on the impact of individual and situational factors affecting decision-making. Existing studies on early intervention focus mainly on K-12 students (Torgesen, 2004; Ramey and Ramey, 2004), but Zhang et al. (2014) examined the effectiveness of early intervention on academic success for at-risk undergraduate business students and found that students' academic performance was enhanced with an early intervention advising program. As a response to these findings an exploratory mixed-methods study was designed to gain insight into the decision-making behaviours of undergraduate civil engineers, and the role that education could play in enhancing decision-making to moderate delusion and deception in graduates and practicing civil engineers. An opportunity to measure the effect of an inaugural co-curricular intervention 'The Icarus Program', led to qualitative exploration of decision-making of second- and fourth-year civil engineering undergraduates. Results led to a post-intervention quantitative measure of intrinsic motivation and critical thinking ability; and further investigation into nuances between the Icarus and Non-Icarus group. The study was conducted using a theoretical framework drawing from future-self theory (Parfit, 1984), self-determination theory (Deci and Ryan, 1985), and behavioural decision theory (Kahneman and Tversky, 1979). Finally, this paper addresses the issues faced during the study and highlights the difficulties experienced when attempting to measure the impact of a co-curricular intervention.

Background

AN EXPLANATION OF COST OVERRUNS IN MEGAPROJECTS

While the subject of poor decision making could be applied to all types of project, the focus of this research is large scale transport infrastructure megaprojects. The comprehensive analysis carried out to date by Flyvbjerg, Nils and Rothengatter (2003), Flyvbjerg, Skamris Holm and Buhl (2003), and Flyvbjerg (2007; 2009; 2014) provides clear context and purpose to the research by identifying ultimate factors specific to megaprojects. Flyvbjerg, Skamris Holm and Buhl (2003) distinguished four categories of explanation of cost overruns on megaprojects; technical, economical, psychological and political. Technical explanations include; inadequate data and lack of experience, or honest mistakes and bad luck. Economical explanations portray cost underestimation as deliberate and economically rationale. Psychological explanations include; optimism bias, the planning fallacy, and anchoring and adjustment. A political explanation is strategic misrepresentation. All four ‘explanations’ can be attributed either individually or collectively to decision-makers and their respective behaviour during various phases of project development and implementation. Lovallo and Kahneman (2003) suggested that the underlying reasons for all forecasting errors can be grouped in to three categories (Figure 2): 1. delusion, 2. deception, or 3. bad luck or honest mistakes.



Exhibit 2 Explanations of Megaproject Failure and the Underlying Reasons

DELUSION AND DECEPTION IN MEGAPROJECTS

Poor megaproject performance outcomes are the norm, not the exception, and this has been the case since the beginning of megaproject delivery (Flyvbjerg, Nils and Rothengatter, 2003). Flyvbjerg (2009) provides explanations to the phenomena of delusion and deception in reference to infrastructure projects based on previous findings from megaproject research (Flyvbjerg, Nils and Rothengatter, 2003; Flyvbjerg, Skamris Holm and Buhl, 2003).

Delusion in megaproject environments is defined as the demonstrated systematic tendency for people to be overly optimistic about the outcome of planned actions. This includes over-estimating the likelihood of positive events and under-estimating the likelihood of negative events. Delusion can be attributed to optimism bias, resulting from the psychological theory of the planning fallacy, the tendency to underestimate the time taken to complete a task

(Kahneman and Tversky, 1977), and anchoring and adjustment, the tendency to allow the first number considered to act as an anchor around which estimates are developed, regardless of whether it is explicitly known (Tversky and Kahneman, 1986).

Deception in megaproject environments is defined as the planned, systematic distortion or misstatement of fact (lying) in response to incentives in the budget process. Deception is evident when decision-makers deliver strategic misrepresentation and can be attributed to the different preferences and incentives of the project participants.

Exploring the phenomena of delusion and deception creates opportunity to investigate the influence engineering education can have to encourage students to be more cognisant of their decision-making, and the consequences of those decisions.

Methodology

QUALITATIVE EXPLORATION

To answer the questions of what, why, and how, a phenomenon is occurring, semi-structured interviews were developed, conducted, and analysed using Interpretative Phenomenological Analysis (IPA). The researcher's role in this study was to identify the features and characteristics most salient in the undergraduates' decision-making. By using IPA as a methodology, the researcher's aim was to 'make sense' of the 'sense-making' taking place in a student's decision-making. The ultimate goal was to understand the main driving forces behind a student's decision-making in a variety of situations; to capture themes, experiences, and feelings that transpire during a semi-structured interview, about decisions they have made and are yet to make. IPA was chosen as a methodology for this very reason as the researcher who is engaging in a phenomenological inquiry is central to the IPA research. Research in the qualitative tradition has often been characterized and motivated by the author's commitment to facilitating change (Kidder and Fine, 1997), and by their willingness to reflect upon the consequences of this commitment (Finlay, 2002). It was proposed that being involved in a Commercial Management role on transport infrastructure megaprojects would place the researcher in a prime position for interviewing potential graduate engineers for roles within a megaproject team.

PARTICIPANTS

The participants of this phase of the study were second year Civil Engineering students at The University of Queensland, Australia. Students had either successfully applied to participate in a co-curricular intervention during their degree program or were from the wider cohort following the traditional program. Students were recruited through an email invitation sent via the lecturer of the four courses in which students were enrolled for the first semester of 2015. Table 1 presents the demographic data of the participants involved in the qualitative section of this study.

THE ICARUS PROGRAM

The University of Queensland (UQ) offers a traditional BE Civil Engineering program, accredited by Engineers Australia. In Semester 1 of 2015, The BE Civil Engineering program at the UQ offered second year students the opportunity to participate in the inaugural Icarus

Program, a co-curricular program offering students small group experience in applied research, with academics acting as mentors within their active research projects.

The program had two goals:

1. To develop a university environment that blurs the lines between an academic's 'teaching' and 'research' time and a student's 'curricular' and 'extracurricular' time.
2. To leverage this engagement to diversify and elevate student learning paths, and student career outcomes.

This was achieved by supplementing core civil learning material with civil research and non-civil extended learning material in a co-curricular program. The 2015 program had four projects across structural, environmental, and transport civil engineering streams. Students commencing their second year in the civil engineering program applied to participate in a single project and completed project-specific activities which complemented their learning progress. Icarus participants were also given the opportunity to participate in cross-project activities to develop interdisciplinary technical skills and professional skills. This intervention in the program offered the researcher the opportunity to explore and evaluate any differences in decision-making behaviour between two groups of students; those participating in the Icarus Program, and those in the wider cohort.

DATA COLLECTION

The interview was developed based on questions that the researcher considered to reflect past, present, and future decisions that would resonate with the participant both in and outside of an educational context. The style of question was designed to loosely simulate a recruitment interview, allowing the researcher the opportunity to identify whether decision-making behavioural traits could be identified in an interview style typical to that used in industry. Semi-structured, in-depth, one-on-one interviews are the most popular method to elicit rich, detailed, and first-person accounts of experiences and phenomena under investigation (Smith, Flowers and Larkin, 2009). Despite the interview being designed prior to the decision to use IPA, the role of the researcher and their own experiences were considered appropriate post-design according to IPA methodological framework guidelines (Pietkiewicz and Smith, 2012).

Pilot interviews were conducted with students from the final year cohort resulting in interviews being revised to encourage deeper insight. Students were asked to volunteer for up to one hour for a semi-structured interview about the decisions they make regarding their education and were offered a \$5 student union voucher for their time. Interviews were conducted during week 12 of the semester before classes ended and final assessments were due. A total of 17 students were interviewed. Smith, Flowers and Larkin (2009) suggested a sample size of three was sufficient for an IPA sample size, clinical psychology programs in the UK recommend six to eight participants (Turpin et al., 1997). IPA studies have been published with sample sizes ranging from one to fifteen participants (Pietkiewicz and Smith, 2012).

Data analysis

Interview data was reviewed, and each interview was analysed on an individual basis and categorized based on the emanating themes. In this study, the focus directed the analytical attention towards our participants' attempts to make sense of their experiences and reflecting

on their decision-making. The process of analysis in IPA is an iterative and inductive cycle, and a set of simple steps is provided by Smith, Flowers and Larkin (2009);

1. Immersion - Reading and re-reading
2. Understanding - Initial Noting
3. Abstraction - Developing Emergent Themes
4. Synthesis - Searching for Connections Across Emergent Themes
5. Illumination - Moving to the Next Case
6. Integration - Looking for Patterns Across Cases

Exhibit 3 Participant Demographics

Interviews	Total (n)	M (n)	F (n)	M (%)	F (%)
Cohort	261	198	63	76	24
Icarus*	64	33	31	52	48
Non-Icarus*	197	165	32	84	16
Research Participants** - Second Year Students	17	12	5	71	29
Research Participants** - Fourth Year Students	9	6	3	67	33
Participant - Icarus* (Second Years Only)	12	8	4	13	6
Participant - Non-Icarus* (Second Years Only)	5	4	1	2	0.5

* % Group (Icarus/Non-Icarus)

** % Participants

(Second Years, n=17)

(Fourth Years, n=9)

Interview analysis resulted five themes: (1) Patience, (2) Empathy, (3) Confidence, (4) Egocentrism, and (5) Goals. An overarching theme of motivation was identified as the main factor contributing to the decision-making of the undergraduates. Students were initially identified as being; extrinsically motivated (driven by grades, salary, rewards and/or punishment), intrinsically motivated (driven by interest, enjoyment, and a desire to make good in society), or showing signs of conflict between intrinsic motivation and extrinsic motives (wanting to enjoy and provide for society, but realizing, and displaying uncomfortableness that there may be a trade-off with extrinsic values to be a successful engineer).

There was no notable difference between the responses of Icarus and Non-Icarus students in terms of more, or less, intrinsically or extrinsically motivated students. Both groups showed an equal spread of individuals with extrinsic, intrinsic and conflicted motivation. It was therefore deemed necessary to conduct quantitative data collection and analysis to assess the levels of motivation within the individual, and the impact the environment has on that individual to be able to triangulate the qualitative data with quantitative results.

Self Determination Theory (Ryan and Deci, 2000), Critical Thinking (Paul and Elder 2005; Halpern, 2014), and Intellectual Development (Perry, 1970), although complex and

contested constructs within education, were considered an appropriate foundation framework upon which to develop the quantitative triangulation of this mixed method study. Based on the quantitative measures that already exist within each theory, the use of previously validated instrumentation provided quality and rigor to this explorative study.

The Halpern Critical Thinking Assessment [HCTA] was selected for this study to investigate the level of Critical Thinking ability in the two groups of participants (Icarus and Non-Icarus). Self Determination Theory (SDT) formed the basis for the selection of validated tests to be used to assess the impact of the environment (Icarus or Non-Icarus) on students' decision-making. A combination of existing surveys including; the Intrinsic Motivation Inventory (IMI: Ryan, Mims and Koestner, 1983), and the Learning Climate Questionnaire (LCQ; Williams et al., 1994) were used to develop the final instrument used for data collection.

Tests were conducted during week 12 of the 13-week semester in order to gather responses during a similar time to the interviews previously conducted. Participants were asked to read the introduction to the study and to login and begin the test. In addition to the researcher another academic was present to both invigilate and offer assistance to students if they were unsure on the instructions. As participants completed the test and survey, they left the test area, submitted their surveys and collected their compensation, were thanked for their time and informed that a full debriefing session would take place once their upcoming exam period was over. It was decided that this was the most appropriate time to debrief so as not to cause any undue stress to students who may not have scored as well as they hoped on the critical thinking test.

The quantitative data was analysed primarily using basic methods of means analysis to identify initial differences between overall scores of Critical Thinking, Intrinsic Motivation, and 'Delusion Scores Overall' in the control group (Icarus) and uncontrolled group (wider cohort).

FINDINGS

The main findings deduced from this section of the research were as follows:

- ◆ Icarus Program participants scored higher on the Critical Thinking test than participants from the wider cohort.
- ◆ Icarus participants had a consistently lower GPA throughout their participation in the Icarus program.
- ◆ Icarus participants had a higher 'Delusion' score (both in ability and overall), which had a strong negative correlation with their Critical Thinking score.
- ◆ Icarus Program participants scored higher on the Intrinsic Motivation Inventory.
- ◆ Icarus Participants reported (statistically significant) more positive relationships with their peers and mentors/instructors.

Discussion

EXPECTATION OF DELUSION AND DECEPTION IN MEGAPROJECTS

Delusion and/or deception are more likely to occur in mega projects where incentives are misaligned and there is not the opportunity to learn from decisions as illustrated in Figure 3 (Flyvbjerg, 2009).

Learning occurs “when closely similar problems are frequently encountered, especially if the outcomes of decisions are quickly known and provide unequivocal feedback” (Kahneman and Lovallo, 1993), this definition of learning occurrence is more readily apparent in fields such as music training or sport, where the consequence of one’s decision making is almost immediate, but is not often considered in engineering education. Environments that promote learning are less likely to be subjected to delusion. Similarly, environments where incentives are aligned are less likely to encourage deceptive behaviour. The primary causes of incentive misalignment are differences in preferences, time horizons, financial incentives and information between principals and agents (Flyvbjerg, 2014).

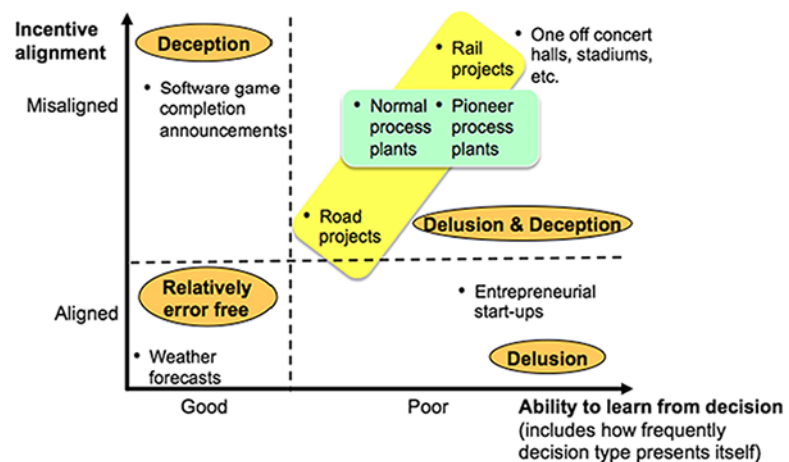


Exhibit 4 Likelihood of Delusion and Deception (Flyvbjerg, 2009)

When the learning environment is good and incentives are well-aligned, forecasts tend to be “relatively error free” with minimal opportunity for delusion or deception. For example, weather forecasting provides good opportunities to learn from decisions as their predictions are frequent and feedback is received within a short period of time. In addition, forecast decisions are more likely to be unbiased if meteorologists have no incentive to give incorrect forecasts. If the incentives are aligned but the opportunity to learn does not exist, then delusion can occur. If the ability to learn is high but the incentives are mismatched, then deception can occur. The impact of both delusion and deception occurring together is greater depending on the frequency of project type (ability to learn lessons) and project incentives (structure and alignment). The lower the frequency of a project type and ability to learn lessons, and the higher the incentive misalignment, the more likely errors will occur due to the manifestation of delusion and deception (Chen, 2007). This led to an opportunity to investigate how the learning environment and the use of incentives in undergraduate education influence decision-making, to provide further insight into the contributing factors of delusional and deceptive behaviour in education, and the management of such behaviours.

BEHAVIOURAL DECISION THEORY

The impact of cognitive and perceptual biases that create heuristics led to a broad range of research concerning departures from rationality and biases common to social judgement. The process or method enabling an individual to discover or learn something for themselves

is dependent on the heuristics created prior to that event. The framing effect, (Tversky and Kahneman, 1981); false consensus effect, (Dawes and Mulford, 1996; Dawes, 1989, 1990; Orbell and Dawes, 1993); group think, (Janis, 1982; Tetlock, 1979); representative heuristic (Tversky and Kahneman, 1974); and the availability heuristic (Tversky and Kahneman, 1974), all have an impact on decision-making, and can influence an individual's ability to learn.

IMPACTS OF THE ICARUS PROGRAM

Participants' decision-making was driven by achievement motivation, and although students were not necessarily aware of the type of motivation driving their decisions, they showed consistency with either extrinsic, intrinsic, or conflicted motivation throughout their interviews. Participants also displayed decision-making behaviour consistent with representative and availability heuristics, providing a barrier to intellectual development and critical thinking. The explicit theme of motivation emerging from the interviews, combined with the implicit biases demonstrated by the participants, particularly by the fourth year of their studies, revealed that the concept of delusional decision-making behaviour was evident.

It was also concluded that the main features of the Icarus Program; autonomy, competence, interest, and relatedness, are crucial to intrinsic motivation. Individuation, and an internal perceived locus of control as a result of increased intrinsic motivation, are essential for intellectual development, resulting in increased levels of critical thinking. Creating opportunities to enhance intuition and logical reasoning by providing a learning environment comparable to the Icarus Program will moderate delusional decision-making and reduce the vulnerability to deceptive decision-making behaviour. The outcomes of the Icarus Program intervention allude to the value of providing a non-traditional learning environment, exclusive of incentives, to enhance critical thinking skills within undergraduate civil engineers. The intervention also provides students with an intrinsic environment in which they can explore applied concepts in a contextual situation offering autonomy and relatedness, features relatively inaccessible to the wider cohort. It could also be argued that traditional methods of assessment are creating misleading levels of competence in students, as the concepts of risk, uncertainty, and ambiguity are not assessed, yet form a fundamental part of a graduating engineers' decision-making. Instead the traditional programs focus heavily on technical aspects of civil engineering. The fundamental principles of the Icarus Program have created an intrinsically motivated environment, enhancing the internalization of undergraduates' decision-making, and providing an opportunity for individuation. From this, students can increase self-awareness, resulting in moderation of 'delusional' decision-making. Simulating or creating a learning environment that encourages intellectual development, and critical thinking, will reduce a student's vulnerability to 'deceptive' decision-making behaviour by themselves and others.

LIMITATIONS

Due to the exploratory approach, and timing of this study, several limitations emerged throughout the design and implementation of the methodology. These limitations are presented and discussed further in this section.

1. Due to the timing of this research, and the opportunity to study the impact of the co-curricular intervention, the ability to research appropriate qualitative methodology was impacted as time was limited. The decision to move forward with semi-structured

interviews, with the intention of researching the most appropriate method of analysis post-data collection was made by the researcher, including full declaration that this decision be acknowledged as a limitation of the study.

2. The design of this study was possible due to the inaugural offering of a co-curricular program (the 'intervention' - the Icarus Program) occurring concurrently with the development of the research. The opportunity to measure variances in critical thinking, and intrinsic motivation using a Pre-Test/Post-Test Group design was not possible due to the time constraints associated with the delivery of this thesis. The pre-test was also considered inappropriate by the creators of the Icarus Program as there was a concern the students may have felt that the program was purely experimental, which may have impacted the students' sensitivity to the experimental variable, the learning environment (Wilson and Putnam, 1982); Lana, 1959).
3. The purposive study of students only was a decision made during the research design and implementation. Though an interest in understanding the role of the formative years of higher education, on the development of decision-making behaviours in undergraduates was considered the ultimate goal of this research, it was also crucial to the control and validity of the experimental design. The exploratory focus of this research required a rigorous approach to quality and validity of research design. Whilst a longitudinal study is suggested in the succeeding future work section, it should also be noted as a limitation to this study.

Recommendations

EDUCATION

There are several potential ways to apply the findings from the Icarus Program to pedagogy, curriculum, and educators, to identify, interrupt, and monitor the likelihood of delusional and deceptive decision-making behaviour in undergraduate civil engineers. When introducing change to pedagogy, it is essential to consider the role of the educator in creating change. As previously mentioned, there are issues in creating an autonomous learning environment when the educators themselves function within a controlled extrinsic reward structure. Furthermore, the time required to educate and train educators, and develop essential materials to support the change, would require significant investment. The success of the Icarus Program is largely attributable to the mentors. Comprising post-doctoral research fellows, and early career lecturers purposely selected to support the established academic staff, this not only provided an opportunity for new academics to learn and prepare for future teaching assignments, but also lessened the burden on established academic staff to produce new learning material and course structures. The benefits of this process are two-fold; 1) established academic staff have to do very little (if nothing) to create this learning environment, 2) once established (and often sceptical) academic staff saw the change in interest and enjoyment being experienced by students and mentors, interest to participate as a mentor in the Icarus Program increased. The inaugural Icarus Program provided four applied research projects, by its third semester offering, the Icarus Program provided 19 options to participate in existing applied research projects from the academic staff within the School of Civil Engineering.

Whether autonomous supportive pedagogy is applied to an Icarus Program style co-curricular program, or to a traditional course structure, the key features to increase intrinsic

motivation; purpose, autonomy, and relatedness, can be introduced using simple, yet effective strategy.

INDUSTRY

To allow accurate and meaningful recommendations to employers and employees, the first step would be to conduct this research in industry. Identifying indicators of intrinsic motivation and critical thinking ability outside of an educational context may require modification, based on the broader scope of motivators, and other influences, outside of higher education.

Applying the features of the Icarus Program to a megaproject environment requires context. The features of purpose and autonomy can translate to leadership; and relatedness can translate to culture. Though project teams often vary in size, and can sometimes have high turnover of staff, the basic needs of purpose, autonomy, and relatedness are fundamental to the well-being and performance of individuals. Creating an intrinsic environment around the ultimate drivers of delusion and deception in decision-making, focusing on the factors that create that behaviour (the ability to learn lessons and incentives respectively) will improve decision-making quality in individuals. Applying these principles to a megaproject environment would have a significant impact on project performance outcomes, creating superior data for future projects to learn from, and employ when considering future infrastructure needs.

Megaproject performance outcomes would benefit immensely from having a dedicated, impartial team of behavioural economics professionals working with the project team throughout the project lifecycle. These recommendations are purposely non-specific, as providing more specific initiatives would negate the role of autonomy in fostering intrinsic motivation. These recommendations should be considered as a basic requirement, as more specific recommendations and initiatives would arise throughout the project, based on project needs.

Contribution and future work

Despite the limitations of this research, this study makes important contributions to the future of engineering education and megaproject delivery, including; the measurement of efficacy in education interventions, and the assessment of quality of decision-making behaviours in project participants.

This research has explored the individual and environmental factors that impact the decision-making behaviour of undergraduate civil engineers. The intervention has indicated that providing an environment of autonomy and relatedness in an educational setting allows students to exploit their intrinsic motivation and develop their critical thinking skills. Whilst this study identified a trend, it is unclear whether the program developed the critical thinking skills of the students, or whether a specific type of student was drawn to this type of learning environment.

The elimination of incentives by way of a non-credit co-curricular program provided an opportunity to examine the influence of motivation on critical thinking, and ultimately decision-making. Quality decision-making relies heavily on self-awareness, particularly awareness of cognitive biases, and the ability to acknowledge, accept, and preferably neutralise those biases. Metacognition is fundamental to the process of quality decision-making. Having identified higher levels of critical thinking ability amongst intervention participants, the next

step should involve providing participants with the purpose of this information for them to further understand the consequences of their decision-making.

Offering students and employees the opportunity to test their own levels of intrinsic motivation and critical thinking, with full disclosure of the purpose of the test, will allow individuals to explore their own biases, and provide further awareness of one's own competence, also providing an autonomous opportunity to develop in those areas. Whilst making the tests mandatory in schools, universities, and industry would provide significant data, it would also eliminate autonomy, a fundamental factor of motivation.

The work conducted within this thesis also take steps towards providing a tool for ongoing monitoring of decision-making quality, enabling a greater understanding of factors throughout life that may impact an individual's decision-making quality.

This research is the first step in understanding the human behaviour traits that are associated with the phenomena of delusion and deception, and the impact that the environment can have on an individual's decision-making in a megaproject situation.

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