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Delivering Superior Megaproject Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum

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Abstract

Civil Engineers represent a significant percentage of Project Managers, and Project Contributors, on the proliferation of transport infrastructure megaprojects. Whilst these megaprojects (>USD$1 billion) are now commonplace, colossal cost overruns, and schedule delays are the norm, not the exception. Transport infrastructure megaprojects have become a focus of public interest, due to the impact of the success of a project, particularly during times of political and economic uncertainty.

A review of megaproject performance propositioned the problem as behavioural, and 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. To understand these phenomena, a mixed-methods study was designed to gain insight into the decision-making behaviors 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 a pilot co-curricular intervention 'The Icarus Program', led to qualitative exploration of decision-making of second and fourth year civil engineering undergraduates. Motivation featured heavily, particularly a conflict between interest and enjoyment, and the reward structures of traditional education and industry. These 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.

Self-Determination Theory was used to illustrate the impact extrinsic motives of traditional education have on the intrinsic motivation of undergraduates. Results indicated the students participating in the Icarus Program scored higher levels of intrinsic motivation, specifically in terms of relatedness with peers and instructors. The Icarus Program also produced higher critical thinking scores, despite students having lower Grade Point Averages than the Non-Icarus group.

Despite the limitations of an exploratory study, findings from the educational environment had implications for industry and led to recommendations regarding the application of the contributing factors of the Icarus Program, to a megaproject environment. Implementing these recommendations has the potential to increase the ability to learn lessons, and moderate delusion. In parallel, recognising and removing the cognitive biases associated with incentives and rationalisation can also mitigate the opportunity for deception, leading to superior project performance outcomes on transport infrastructure megaprojects.

Declaration by Author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

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Professor Jose Torero was the principal supervisor throughout the thesis.

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Keywords

critical thinking, curriculum, decision-making, engineering education, infrastructure, megaprojects, pedagogy, project management, transport

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1 INTRODUCTION

1.1 PREFACE

The interest in this field of study was chosen by the author based on the personal and professional experiences encountered whilst working as a commercial manager on transport infrastructure megaprojects, where Civil Engineers comprised a significant percentage of Project Participants; and time spent in higher education, both as a student, and lecturer in the School of Civil Engineering, at the University of Queensland. In both industry, and academia, civil engineers are expected to comprehend the commercial consequences of the decisions they make, and the impact those decisions will have on a project, generally regarding the project budget and schedule. From the experiences of the author, the absence of understanding of the concepts of risk, uncertainty, and ambiguity led to graduates, and practicing civil engineers, being unable to identify the commercial consequences of the decisions they made. On a larger scale, the ability to identify the societal, and economic impact of commercial decisions made on the increasingly common large-scale transport infrastructure projects, or the 'megaproject' has greater implications, making cost overruns and schedule delays the norm, not the exception. Complex projects across all industries can fail for many reasons. Engineers Australia produced a Green Paper in 2014 citing reasons associated with project management, a discipline that remains fundamentally unchanged both in its existing frameworks and education delivery since its inception in the early 20th century (Morris, 2013). The rationale behind this thesis is ultimately based on the work of Bent Flyvbjerg. Flyvbjerg's work (2003a, 2003b, 2007, 2009, 2014) comprises a comprehensive review of the performance of megaprojects from a public interest point of view, citing human behaviour as an ultimate factor of poor project performance. The purpose of this thesis is to unpack the main findings of Flyvbjerg's work and gain insight into the core human behavioural traits, that he infers lead to the failure of megaprojects, and exploring the role education plays in influencing these behavioural traits. Whilst the author accepts that there are other methods of valuing and measuring megaproject performance (Love et al., 2012; Fahri et al., 2015; Takim et al., 2003; Lehtonen, 2014), understanding the behaviour and personalities of civil engineers, both throughout

their time at university and during their careers will give insight into many of the complex situations encountered by students and professional civil engineers throughout their careers.

1.2 INDUSTRY

1.2.1 MEGAPROJECTS – BIG BUSINESS AND EVEN BIGGER PROBLEMS

Megaprojects (>$1 billion USD) have rapidly become the preferred delivery model for many goods and services spanning a range of industry sectors including; infrastructure, industrial processing plants, mining, government administrative systems, and urban regeneration to name a few (Flyvbjerg, 2014). Major cities around the globe are experiencing increased demand for improved major urban transport infrastructure. These projects are not only getting larger but also more complex and they are attracting greater public interest. There appears to be no end in sight to the historical trend of increasing project scale. When the Chrysler Building opened in New York City in 1930 it was the tallest building in the world at 319 meters, a record that has been exceeded seven times. The tallest building in the world is now the Burj Khalifa, standing an impressive 828 meters. This represents a 160 percent increase in building height over 80 years. In infrastructure, projects have grown 1.5 to 2.5 percent annually (measured by value in real terms) over the last century, according to the megaproject database held by Flyvbjerg, this is equivalent to projects doubling in size three time per century (Flyvbjerg, 2014)

Such enormous sums of money ride on the success of megaprojects that company balance sheets and even government balance-of-payments accounts can be affected for years by the outcomes . . . The success of these projects is so important to their sponsors that firms and even governments can collapse when they fail. (Merrow, 1988)

It is not only the size and complexity that is increasing, the quantity and value of mega projects is also rapidly growing. The Economist (June 7, 2008:80) estimated infrastructure spending in emerging economies at USD$ 2.2 trillion annually 2009-2018. In Figure 1, The McKinsey Global Institute (2013) estimated global infrastructure spending at USD$ 3.4 trillion per year 2013-2030 (approx. four percent of total global GDP).

Between 2004-2008, China spent more on infrastructure in real terms than the rest of that century, an increase in spending rate of a factor of twenty (Flyvbjerg, 2014).

According to *The Economist* we are experiencing "the biggest investment boom in history" in infrastructure alone.

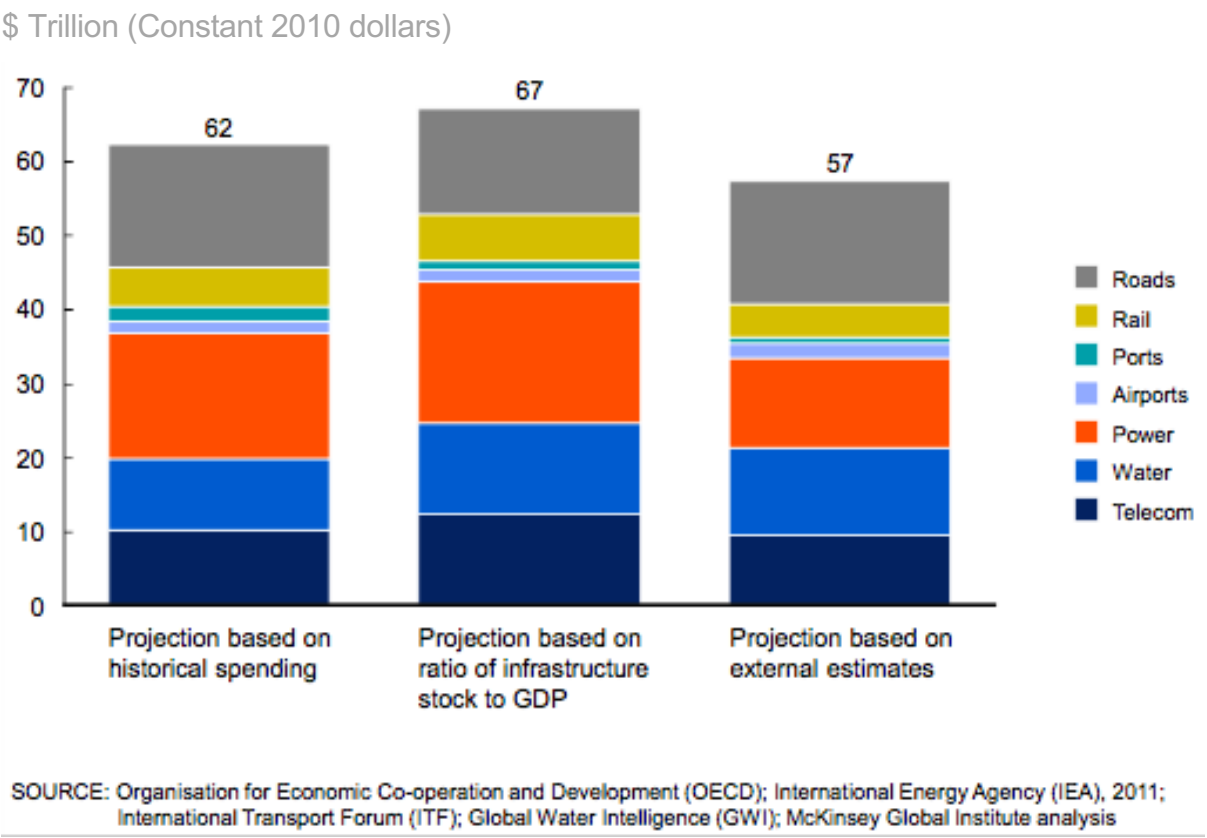


Figure 1: Estimates of needed infrastructure investments 2013 – 2030 (McKinsey Global Institute, 2013)

In addition to this, megaprojects have proven to be extremely recession proof. From the 2008 downturn stimulus spending, megaproject activity grew significantly. Megaprojects have transformed into a global multi-trillion-dollar business that affects all aspects of our lives, from our electricity bill to how we shop and what we do on the Internet to how we commute (Flyvbjerg, 2014).

1.2.2 MEGAPROJECT DRIVERS

To understand what drives megaprojects and why they are so attractive Flyvbjerg presents the "four sublimes" of megaproject management (Table 1). The term "technological sublime" is used to describe and explain the positive historical reception of technology in American culture (Marx, 1967; Miller, 1965). Frick (2008) was the first to use the term in relation to megaprojects in a case study of the multi-billion-dollar

New San Francisco to Oakland Bay Bridge. Frick described the technological sublime as *"The rapture engineers and technologists get from building large and innovative projects with their rich opportunities for pushing the boundaries for what technology can do, like building the tallest building, the longest bridge, the fastest aircraft, or the first of anything."* The case study concluded that the "technological sublime" dramatically influenced design, project outcomes, public debate and the lack of accountability for the projects excessive cost overruns. Three additional sublimes have been proposed by Flyvbjerg (2012, 2014). The first, the "political sublime" suggests politicians actively seek out megaprojects as monuments to themselves. Megaprojects are media magnates, garner attention, and lend an air of proactiveness to their promoters, the type of public exposure that helps get politicians re-elected (Flyvbjerg, 2014). The "economic sublime" is the potential to create jobs and make a lot of money for business and trade unions from megaprojects. Based on the 'mega budgets' made available for megaprojects the funds available to contractors, engineers, architects, consultants, construction and transport workers, bankers, investors, landowners, lawyers and developers are plentiful. The "aesthetic sublime" is a designer's desire to build and observe something iconic and stunning, and in most cases extremely large.

Table 1: The "Four Sublimes" of megaproject management (Flyvbjerg, 2014)

Type of Sublime	Characteristic
Technological (Frick, 2008)	*The excitement engineers and technologists get in pushing the envelope for what is possible in longest-tallest-fastest type of projects*
Political	*The rapture politicians get from building monuments to themselves and their causes, and from the visibility this generates with the public and media*
Economic	*The delight business people and trade unions get from making lots of money and jobs off megaprojects, including for contractors, workers in construction and transportation, consultants, bankers, investors, landowners, lawyers, and developers*
Aesthetic	*The pleasure designers and people who love good design get from building and using something very large that is also iconic and beautiful, like the Golden Gate bridge*

In understanding these drivers of frequency and scale of megaprojects, we can begin to appreciate the power that stakeholders who benefit from megaprojects can have. On the other hand, infrastructure projects if done right can create and sustain employment. They can also improve the environment when infrastructures that are environmentally sound replace infrastructures that are not (Helm, 2008: 1). However, this is not often the case and conventional infrastructure megaproject delivery is extremely challenging and to date has unsatisfactory performance outcome records in terms of actual cost and benefits.

Table 2 presents a list of megaproject characteristics, which are typically overlooked on large scale infrastructure projects, particularly in relation to the presence of the 'four sublimes' presented in Table 1 (Flyvbjerg, 2014).

Table 2: Megaproject characteristics affecting performance outcomes (Flyvbjerg, 2014)

Characteristic	Author
1. Megaprojects are inherently risky due to long planning horizons and complex interfaces	(Flyvbjerg, 2006)
2. Often projects are led by planners and managers without deep domain experience who keep changing throughout the long project cycles that apply to megaprojects, leaving leadership weak.	(Flyvbjerg, 2014)
3. Decision-making, planning, and management are typically multi-actor processes involving multiple stakeholders, public and private, with conflicting interests	(Aaltonen and Kujala, 2010)
4. Technology and designs are often non-standard, leading to **"uniqueness bias"** amongst planners and managers, who tend to see their projects as singular, which impedes learning from other projects.	(Budzier and Flyvbjerg, 2013)
5. Frequently there is overcommitment to a certain project concept at an early stage, resulting in "lock-in" or "capture," leaving alternatives analysis weak or absent, and leading to escalated commitment in later stages. "Fail fast" does not apply; "fail slow" does	(Cantarelli et al., 2010; Ross and Staw, 1993; Drummond, 1998).
6. Due to the large sums of money involved, principal-agent problems and rent-seeking behavior are common, as is optimism bias	(Eisenhardt, 1989; Stiglitz, 1989; Flyvbjerg el al., 2009)
7. The project scope or ambition level will typically change significantly over time.	(Flyvbjerg, 2014)
8. Delivery is a high-risk, stochastic activity, with overexposure to so-called "black swans," i.e., extreme events with massively negative outcomes. Managers tend to ignore this, treating projects as if they exist largely in a deterministic Newtonian world of cause, effect, and control.	(Taleb, 2010)
9. Statistical evidence shows that such complexity and unplanned events are often unaccounted for, leaving budget and time contingencies inadequate.	(Flyvbjerg, 2014)
10. As a consequence, misinformation about costs, schedules, benefits, and risks is the norm throughout project development and decision-making. The result is cost overruns, delays, and benefit shortfalls that undermine project viability during project implementation and operations.	(Flyvbjerg, 2014)

1.2.3 COST OVERRUNS, OVER AND OVER AGAIN

Cost overruns, delays and benefit shortfalls are as big as they are frequent in megaproject delivery. Overruns of over 50 percent are not uncommon and up to 50 percent even more so. Table 3 shows cost overrun results from megaprojects across the globe, across industries and over time. As with cost overruns, comparable levels of projects' benefit shortfall have been reported, again with no signs of improvement over time or geography (Flyvbjerg et al., 2002, 2005). Overruns and benefit deficits have remained high and consistent according to the 70-years for which megaproject performance data has been investigated, and the problem exists in private and public sectors alike.

These problems exist due to the influence of apparent lack of confidence coming from the core planning and decision-making stages of megaprojects. From the business cases through to the cost-benefit analyses through to the social and environmental impact assessments; the errors and biases are of such scale that they can be considered misleading. "Garbage in, garbage out" (Flyvbjerg, 2009). This is illustrated by Flyvbjerg (2003) in the largest study of megaprojects to date (258 transportation infrastructure projects). Rail projects showed an average cost overrun of 44.7 percent combined with an average demand shortfall of 51.4 percent, whilst road projects showed an average cost overrun of 20.4 percent combined with a '50/50' risk that demand was also wrong by over 20 percent.

Using the Channel Tunnel as an example of megaproject cost overrun, the private owner of the tunnel advised investors that a 10 percent allowance *"would be reasonable for the possible impact of unforeseen circumstances on construction costs"* (Under Water Over Budget, The Economist, 7 October 1989). Final costs for the project finished 80 percent overrun for construction and 140 percent for financing. With revenues since opening being half of those forecasted, the project proved non-viable and produced an internal rate of return of minus 14.5 percent with a total loss to the British economy of USD$17.8 billion. The Channel Tunnel is therefore considered a burden on the economy, not the benefit that was anticipated. Compare this to the speed, convenience and competitiveness with other modes of transport and the Channel Tunnel could well be considered a *'technological sublime'*, but at the price of an enormous financial failure.

Table 3: Megaproject history of cost overruns (Flyvbjerg, 2014)

Project	Cost Overrun (%)
Suez Canal, Egypt	1900
Scottish Parliament Building, Scotland	1600
Sydney Opera House, Australia	1400
Montreal Summer Olympics, Canada	1300
Concorde supersonic aeroplane, UK, France	1100
Troy and Greenfield railroad, USA	900
Excalibur Smart Projectile, USA, Sweden	650
Canadian Firearms Registry, Canada	590
Lake Placid Winter Olympics, USA	560
Medicare transaction system, USA	560
National Health Service IT system, UK	550
Bank of Norway headquarters, Norway	440
Furka base tunnel, Switzerland	300
Verrazano Narrow bridge, USA	280
Boston's Big Dig artery/tunnel project, USA	220
Denver international airport, USA	200
Panama canal, Panama	200
Minneapolis Hiawatha light rail line, USA	190
Humber bridge, UK	180
Dublin Port tunnel, Ireland	160
Montreal metro Laval extension, Canada	160
Copenhagen metro, Denmark	150
Boston-New York-Washington railway, USA	130
Great belt rail tunnel, Denmark	120
London Limehouse road tunnel, UK	110
Brooklyn bridge, USA	100
Shinkansen Joetsu high-speed rail line, Japan	100
Channel tunnel, UK, France	80
Karlsruhe-Bretten light rail, Germany	80
London Jubilee Line extension, UK	70
Bangkok metro, Thailand	60
Mexico City metroline, Mexico	60
High-speed Rail Line South, The Netherlands	50
Great Belt east bridge, Denmark	29

An economical and financial ex post evaluation of the Channel Tunnel concluded that "the British Economy would have been better off had the Tunnel never been

constructed" (Anguera, 2006). Other examples of significant cost overruns projects are presented in Table 3.

1.2.4 MEGAPROJECTS CAN BE A SUCCESS

It should be noted that not all megaprojects fail. Recent metro extensions in Madrid were built on time and to budget (Flyvbjerg, 2005) as were a number of industrial projects (Merrow, 2011). The ability to study such projects would be of significant benefit to understand the factors affecting project success. Flyvbjerg has endeavoured, but efforts so far have been futile due to the small-sample of projects available for research, concluding that megaproject success is rare.

If megaproject success is measured in terms of budget, time, and benefits; and approximately one in ten megaprojects is on budget, one in ten is on schedule and one in ten is on benefits, then approximately one in a thousand projects is a success (on target for all three). Suggestions have been made to address procedural changes to deliver successful megaprojects, but this has yet to be implemented and measured (Magnussen and Samset 2005).

Defining megaproject success is problematic. The traditional 'iron-triangle' of scope, schedule, and cost, are used to measure the success of most projects. However, there are other features that could be considered in determining whether a project is a success. Socioeconomic improvements, technological innovation, and improved environmental conditions could be part of the equation The Oakland Bay Bridge was deemed a project failure due to its excessive cost overruns, and delay in opening, yet, the bridge was built to last 150 years, significantly longer than the typical 50 years of expected service as it was built to withstand earthquakes and seismic activity of the highest magnitude (Greiman, 2015).

Understanding the larger benefits of a project, and including the impact of economic and social development in the final analysis would enable governments to communicate the overall success of a project to residents more successfully, whilst shifting the focus from the tangible matters of cost and time to the intangible bigger picture outcomes of a project.

In summary, if we consider all of these figures and contemplate the amount of resources tied up in these megaprojects, it is evident that the performance of these projects has never been more important. Never has it been more important to choose the most fitting projects and get their social, economic and environmental impacts right

(Flyvbjerg et al., 2003). Therefore, at no time has the understanding of megaproject drivers and participants been more important in the supremely costly industry of infrastructure.

1.3 EDUCATION

1.3.1 PROJECT MANAGEMENT IN ENGINEERING EDUCATION

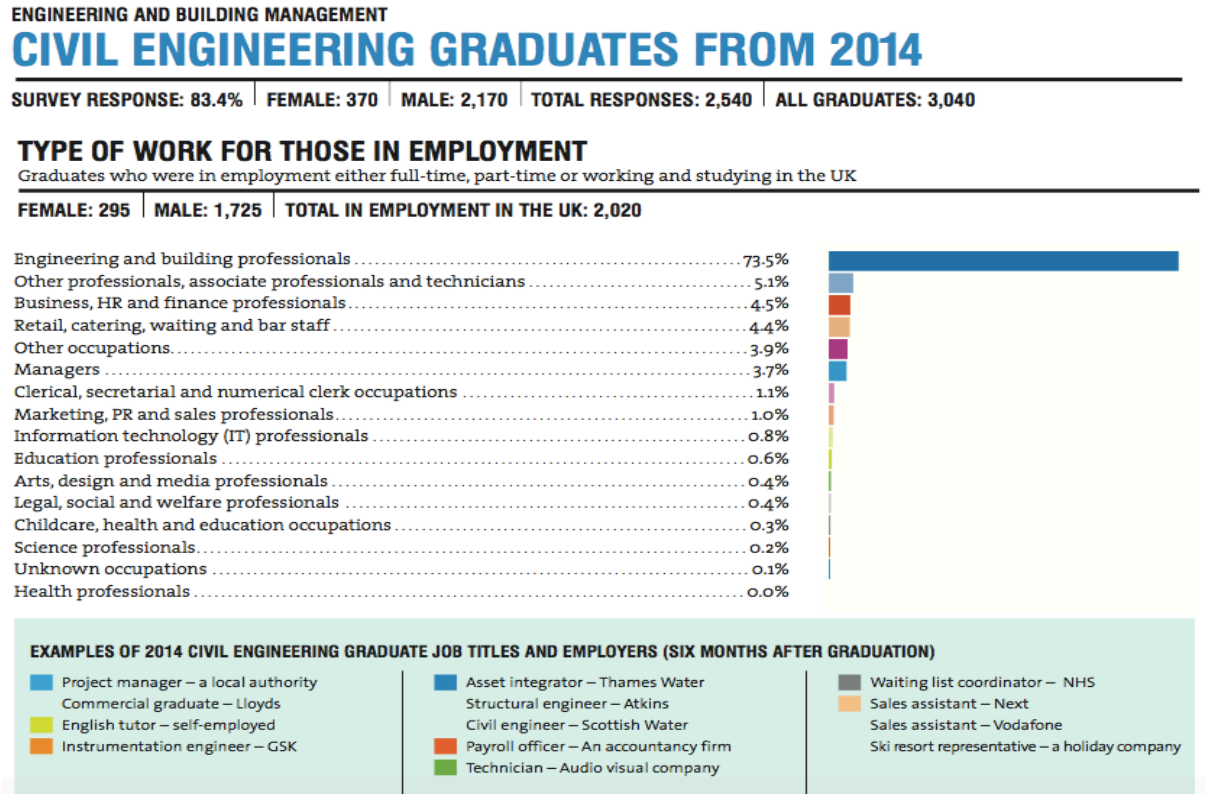
As we can see from the previous section, complex projects across all industries can fail for many reasons. Engineers Australia produced a Green Paper in 2014 citing reasons such as; lack of communication among stakeholders and participants; critical skills and knowledge gaps for key personnel; poor conceptual planning; insufficient implementation of project controls and risk management; and the ineffective transfer of lessons learnt between similar projects (Engineers Australia, 2014). These factors can be likened to the characteristics identified in table 2, and are associated with project management, a discipline that remains fundamentally unchanged both in its existing frameworks and education delivery since its inception in the early 20th century (Morris, 2013). But it is not just a lack of good project management skills driving megaprojects' failure to produce superior performance outcomes; the problem has been inferred as behavioural (Flyvbjerg, 2009). An ability to identify risk and uncertainty when operating in a complex project environment is crucial in a megaproject setting. Acting on that knowledge or understanding of risk is a separate challenge all together. Questionable decision-making associated with identifying, assessing and actioning risks has been linked to poor megaproject performance outcomes (Flyvbjerg, 2009). Questionable decision-making can arise from unchecked human biases, and delusion and deception have been cited as human factors affecting megaproject performance outcomes (Flyvbjerg, 2009).

In parallel 'non-technical' skills have been highlighted as increasingly important by engineering professionals, such as Engineers Australia (King, 2008), The National Academy of Engineering in the United States (NAE, 2004) and the Royal Academy of Engineering in the United Kingdom (Spinks et al., 2006). Each organisation independently published reports, identifying the qualities, skills and attributes required of the engineers of the future. The three reports were unanimous in identifying that principles of business, management, and leadership were equally as important during the undergraduate education of future engineers to that of in-depth technical and analytical skills. 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 2). 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.

Project management, business management, ethics, decision-making and managing risk and uncertainty play an insignificant role in current civil engineering curriculum globally (National Academy of Engineering, 2004; Spinks et al., 2006, King, 2008). But it is not simply the addition of content to existing programs that will address these underrepresented themes. Whilst 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 cited in the three unanimous reports. 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.

Figure 2: Career choice of Civil Engineering Graduates in the UK Six Months after Graduation (prospects.ac.uk)



1.4 RESEARCH PURPOSE

To distinguish and address this gap, this research seeks to understand the behavioural and environmental attributes contributing to decision-making, and the pedagogical requirements to educate civil engineers in ways that enhance the decision-making skills typically used in megaproject environments. The research focuses specifically on Civil Engineers due to the significant percentage of Civil Engineers that represent project participants on transport infrastructure megaprojects. Identifying, assessing and making decisions about risk, uncertainty and ambiguity are key determinants of megaproject outcomes, however these concepts are not explicitly taught, nor readily explored in research about current civil engineering curriculum.

This research aims to explore the role that education plays in influencing and moderating decision-making processes that can lead to behaviours affecting megaproject performance outcomes. As this study is exploratory, a study of the individual, and the situational factors affecting their decisions was proposed. In doing so, this thesis will identify and develop pedagogical techniques and educational recommendations for future leaders in engineering. Whilst a new graduate civil engineer is not expected to operate in an executive level decision-making role, critical thinking and decision-making behaviours learned both during their university program, and early career years have the potential to define them as a future leader of civil engineering. Early exposure to higher education plays a significant role in defining the permanent decision-making behaviours of graduates. The sequence in which fundamental concepts of motivation are addressed, will not only enhance decision-making behaviour, but if inappropriately applied can have a disadvantageous effect that becomes highly improbable to recover at a later stage (Woodrow, 2013). Therefore, the impact of enhancing decision-making behaviour through appropriate timely intervention in the curriculum will have a lasting effect throughout a civil engineer's career.

1.5 RESEARCH OBJECTIVE

The objective of this thesis is to examine how universities can better prepare Civil Engineering graduates by identifying and enhancing decision-making skills and

attributes relating to risk, uncertainty and ambiguity, in ways that minimise delusional and deceptive outcomes. By understanding the salient factors affecting sense-making and decision-making we can gain insight into the individual. From this we can develop pedagogy to enhance the decision-making skills required of the engineering leaders of the future, to deliver superior mega project performance outcomes.

1.5.1 RESEARCH QUESTION

To understand how engineering education affects student decision-making, and the implications for industry in a mega-project environment, the following research questions were developed:

RQ 1 - Which features and characteristics influence the decision-making of undergraduate civil engineers?

RQ 2 - How do the learning environment and incentives affect decision-making in an educational environment?

RQ 3 - How can engineering education enhance decision-making and moderate delusion and deception?

RQ 4 - What are the implications for industry?

In answering these questions, the thesis will answer the principal research question;

What role can Engineering Education play in moderating delusional and deceptive decision-making behaviours in graduate Civil Engineers?

1.6 CONTRIBUTION TO THEORY AND PRACTICE

By addressing current gaps in knowledge and practice this thesis will develop new methods to explore individual decision-making within a Civil Engineering undergraduate program. This study developed and assessed a research design for exploring individual factors that influence decision-making. In doing so, the thesis will address a gap in literature by making recommendations associated with research method as well as recommendations associated with changes to pedagogy.

1.7 SUMMARY OF REMAINING CHAPTERS

Chapter 2 provides a review of literature pertaining to the underlying issues relating to megaproject failure. Concentrating specifically on cost overruns, the review provides causes and explanations along with the theoretical embeddedness of such problems. This led to a review of decision-making behaviour on megaprojects and

focusses on delusion and deception as principle factors. Existing models of ethical and unethical decision-making were reviewed and after a further review of ethics in engineering education practice and theory, a theoretical framework was established based on the Future Self Theory.

Chapter 3 presents an overview of the underpinning philosophical foundations that led to the research design and resulting methodology, Interpretative Phenomenological Analysis. The chapter continues by presenting the methodology used in the development of interview structure and protocol, recruitment of participants and qualitative data collection and analysis. In presenting and discussing the findings of the qualitative data collection, a summary including the proposal for quantitative data collection carried out in chapter 4 concludes the chapter.

Chapter 4 introduces Self Determination Theory, and the concepts of Critical Thinking and Intellectual Development. The remainder of the chapter presents the methodology, choice of instrumentation, participant recruitment, data collection and analysis, and subsequent findings of the quantitative data collected to test levels of Critical Thinking and Intrinsic Motivation. The chapter concludes with an overview of findings from both chapters 3 & 4, leading to the discussion in chapter 5.

Chapter 5 discusses the limitations to this study, and provides a discussion and interpretation of the results of chapters 3 and 4 by answering each of the research questions, positioning the findings within existing research and theory. The chapter concludes with contributions to theory and practice, and recommendations for future work, including the areas of research that may be further explored beyond this thesis.

2 LITERATURE REVIEW

2.1 INTRODUCTION

To appreciate the phenomena of delusion and deception in decision-making behaviour, it is essential to understand the context in which these behaviours are being imputed. The ensuing literature review follows the progression of megaproject research, starting with early identification of poor performance outcomes, and the theory behind the technical, economical, psychological, and political explanations of megaproject performance outcomes. These explanations attribute project performance outcomes to the decision-making behaviour of individuals at all levels and stages of the project life-cycle, which led to a review of the phenomena of delusion and deception in decision-making, and the expectation of this behaviour occurring on megaprojects. The review then focused on the role of the individual in organisational decision-making, leading to the introduction of behavioural decision-theory and the concept of risk as it relates to future consequences. A review of future-self theory supported the link to engineering education to create a theoretical framework appropriate for the study of undergraduate civil engineers,. The supposition of the literature review was to focus on the decision-making behaviours of civil engineering undergraduates, and the factors affecting decision-making during the formative years of higher education.

The gap in research being addressed by this study is reflected by the sparsity of literature on the phenomena of delusion and deception, and the decision-making behaviours of civil engineers. This literature review leads to an exploration of phenomena, and provides an explanation based on the concepts and theories set forth herein.

2.2 A HISTORY OF COST OVERRUNS

Numerous quantitative studies exist of costs, benefits, and uncertainties in transport infrastructure have been carried out prior to the research carried out by Flyvbjerg. Examples of such studies can be found in Table 4. These studies were either case studies of individual projects or results from small samples of infrastructure projects that are too dissimilar to provide systematic statistical analysis. The first statistical analysis study to be carried out with a large number of sample transport projects was a comparison of cost overrun in urban rapid transport projects, with a specific focus on

the San Fransisco Bay Area Rapid Transport (BART) system (Merewitz, 1973a, b). The study compared 17 rapid transport projects and 49 road projects and was later replicated by Flyvbjerg (2003a, b), with some alterations based on the following issues;

1. The cost data in this study did not allow for inflation and used current prices rather than constant prices. This produces errors in results due to varying inflation rates between projects and varying construction durations.
2. In comparing the mean overrun of subgroups of projects e.g. rapid transit, with the grand mean of all projects, the statistical analysis is invalid due to the comparison of projects with themselves.
3. The studies (1973a, b) are inconsistent. 1973a calculates the grand mean of cost overruns as the average of means for sub groups. 1973b uses he weighted mean.

The objective of Flyvbjergs study (2003a) was to determine, in a statistically valid and reliable manner, whether forecast costs and benefits of transport infrastructure projects compared well with actual costs and benefits, or were costs and benefits highly uncertain phenomena along with the size and frequency of differences and the significance of these differences.

2.3 THE LARGEST STATISTICAL ANALYSIS OF COST OVERRUN & BENEFIT SHORTFALL

In 2003, Flyvbjerg published the results of a study stemming from 4 years of data collection of 258 land-based transport infrastructure projects (58 rail, 33 fixed link bridge and tunnel, and 167 road), located in 20 nations on five continents (181 Europe, 61 North America, 16 Other), taken from 70 years of projects, with a project portfolio worth approximately US$90 billion (constant 1995 prices) (Flyvbjerg, 2003a). The findings of this study concluded the following;

- Nine out of ten transport infrastructure projects exhibited cost escalation. (Range of projects - Rail projects 45%, fixed link projects 34%, roads 20%.)
- Cost escalation was clear across all nations but was more pronounced in developing countries.
- Cost escalation has not decreased over the past 70 years suggesting no learning is taking place.

Table 4: Examples of Studies of Costs, Benefits and Uncertainties in Transport Infrastructure Development

Author	Article	Overview
Fouracre et al. 1990	The Performance and Impact of Rail Mass Transit in Developing Countries	Findings of a world-wide study involving observations and data collected in 21 developing cities, and the analysis of that data using a strategic transport evaluation model.
Kain 1990	Deception in Dallas: Strategic Misrepresentation in Rail Transit Promotion and Evaluation	Description of the misuse of land-use and ridership forecasts by Dallas Area Rapid Transit (DART).
Pickrell 1990	Urban Rail Transit Projects: Forecast versus Actual Ridership and Cost	US Department of Transportation report comparing forecasts to actual costs and riderships of 10 rail transit projects constructed between 1970-1990. Identifies causes and provides recommendations to improve future planning.
Walmsley and Pickett 1992	The Costs and Patronage of Rapid Transit Systems compared with Forecasts	Research report by the UK Transport Research Laboratory of actual capital costs, operating costs and patronage levels of a number of existing rapid transit systems are compared with forecasts made when the systems were planned.
Szyliowicz and Goetz 1995	Getting realistic about megaproject planning: The case of the new Denver International Airport	The article addresses the reasons behind the planning, implementation and ultimate success of megaprojects becoming increasingly problematic.
Skamris and Flyvbjerg 1997	Inaccuracy of Traffic Forecasts and Cost Estimates on Large Transport Projects	The results of large transport infrastructure projects showed that cost overruns of 50–100% are common and overruns above 100% are not uncommon.
Nijkamp and Ubbels 1999	How Reliable Are Estimates of Infrastructure Costs? A Comparative Analysis	A comparative analysis of cost estimates of infrastructure projects in the Netherlands and Finland. The interesting conclusion is found that in general cost estimates tend to be rather reliable.
Richmond 2001	A Whole-System Approach to Evaluating Urban Transit Investments	An assessment of how new rail systems are fulfilling transportation goals

Flyvbjerg (2003b) was also able to suggest a cause of the cost overruns evaluated by focusing on three variables: 1) the length of the implementation phase of the project; 2) the size of the project; and 3) the type of ownership (Table 5).

Other methods of valuing and measuring megaproject performance use varying metrics and are largely and extension of Flyvbjergs work (Love et al., 2012; Fahri et al., 2015; Takim et al., 2003; Lehtonen, 2014).

Table 5: Flyvbjerg 2003b Comparison of Implementation Phase and Size of Project

Implementation Phase	Size of Project
• Cost escalation highly dependent on length of project.	• Fixed link bridge and tunnels had larger percentage cost escalations by size of project.
• Not statistically different for type of project.	• Risk of cost escalation is high for all project types.
• Average cost escalation of 4.64% year on year from decision to build until operational.	• Projects grow larger over time, significantly so for road projects.

Type of Ownership

The data did not show a difference between public and private ownership impact on cost overrun but did show that the issue of ownership is more complex than originally anticipated. Identifying the causes (variables or factors that influence costs overruns) has given rise to explanations of cost overruns which may encompass several causes and be more general.

2.4 An Explanation of Cost Overruns and the Theoretical Embeddedness

To understand planning failures, one has to look for a general explanation (Morris, 1990). In so much that the studies presented in Table 6 (excluding Nijkamp, 1999) provide evidence that cost overruns exist and aim to present causes for such overruns, a broader focus of project performance in general has given weight to explanations behind such cost overruns. Table 8 presents an overview of the studies providing a broader view of explanations

Flyvbjerg (2003b) distinguished four categories of explanation; technical, economical, psychological and political. Technical explanations include; inadequate data and lack of experience. Economical explanations portray cost underestimation as deliberate and economically rationale. Psychological explanations include; *optimism bias* and the planning fallacy. A political explanation is strategic misrepresentation. The four categories are described using supporting theory to provide clarification.

Table 6: Broad View Cost Overrun Studies Providing Explanations

Author	Article	Overview
Hall 1980	Great Planning Disasters	Historical and analytical look at seven different project plans.
Bruzelius et al. 1998	Big decisions, big risks: Improving accountability in Mega Projects	A case study of the decision to build a multi-billion dollar fixed link across the Baltic Sea connecting Scandinavia and Germany.
Mackie and Preston 1998	Twenty-One Sources of Error Bias in Transport Project Appraisal	Twenty-one sources of error and bias in the appraisal of transport projects are identified. Relating to objectives, definitions, data, models and evaluation conventions.
Altshuler and Luberoff 2003	Mega-Projects: The Changing Politics of Urban Public Investment	Review of research focusing on the new politics of infrastructure development.
Flyvbjerg et al. 2003b	How Common and How Large are Cost Overruns in Transport Infrastructure Projects	Four categories of cause, explanation provided based on statistical analysis of 258 land-based transport infrastructure projects.

2.4.1 Technical Explanations and Theories

Whilst price rises, poor project design and implementation, and incomplete cost estimates are examples of variables causing of cost overruns, they are more of an influence than an explanation. Scope changes, uncertainty and inadequate planning processes are considered explanations of these variables and mainly relate to difficulties in predicting the future and referred to as 'honest' errors (Flyvbjerg, 2010). Whilst scope changes represent changes in the design which may not have been predicted beforehand, inappropriate organisational structure, inadequate decision-making processes and an inadequate planning process are all evidence of inefficiency, which will understandably result in increased costs (Flyvbjerg, 2010). The theories used to support these explanations are; *forecasting theory* (Armstrong, 2001), *planning theory* (Faludi, 1973) and *decision-making theory* (Dunleavy, 1991). *Forecasting theory* suggests that estimating can be attributed to the cognitive mind and forecasting models have been used to gain insight into errors in forecasting techniques or inappropriate approaches that lead to poor cost estimates (Armstrong, 2001). *Planning theory* examines how projects and policy are established. Planning concepts can be used to refer to the inappropriate planning processes of projects and the poor design and implementation leading to cost overruns (Faludi, 1973). *Decision-making theory* is mainly used when referring to inappropriate institutional arrangements and considers government and politics as 'a series of decisions taken

by people and institutions that make rational decisions in the light of their interests and the circumstances under which they operate' (Dunleavy, 1991).

2.4.2 *Economical Explanations and Theories*

Incentives, resources, the selected funding process, and inefficient planning of public benefits are considered economic causes influencing cost overruns (Flyvbjerg, 2010). Due to a lack of resources, decision-makers inevitably must choose between projects, which can lead to project promoters deliberately underestimating costs to make their project attractive for selection. Inferior projects can be implemented because of this, resulting in insufficient funding and an inefficient use of resources (Flyvbjerg, 2010). Neoclassic economics and rational choice theory form the basis for the economic explanation.

Neoclassic economics is a framework for understanding the allocation of scarce resources among alternative ends, showing that incentives and costs play a significant role in decision-making. '*The dedicated funding causes little incentive to produce accurate figures because accurate figures decrease the chance of receiving part of the funding' (Pickrell, 1992)*. Neoclassical economics is also used to explain the tendency to deliberately misrepresent information due to a lack of incentive for planners in their role as 'advocates'. Rational choice theory is used to understand social and economic behavior and suggests that the actions of individuals are fundamentally rational and people calculate the costs and benefits of an action, recognising their preference functions and constraints facing them before making the decision (Arrow, 1987; Coleman, 1992). The theory supports the explanation that it is economically rational to underestimate costs because it will increase the likelihood of revenue and profit. Rational choice theory is also linked to psychological and political explanations.

2.4.3 *Psychological Explanations and Theories*

Peoples cognitive biases and cautious attitudes to risk when making decisions, can be linked to the concept of *planning fallacy* and *optimism bias*. People tend to be risk averse when making decisions with a risky prospect, are proportionally risk averse (have near proportional risk attitudes) and frame their decision problems narrowly i.e. people consider decision problems one at a time, often isolating the current problem

from other choices that may be pending, as well as from future opportunities to make similar decisions (Kahneman and Lovello, 1993).

Cognitive biases lead to optimistic forecasts, leading to cost overruns. *Planning fallacy, optimism bias, prospect theory* and *rational choice theory* address the psychological explanations. *Planning fallacy* is the tendency to underestimate time, costs and risks of future actions whilst at the same time overestimate the benefits of the same actions. The (universal) cognitive biases in scenario thinking, anchoring, and extrapolation of current trends, when applied by forecasters to an estimate, result in *optimism bias*. *Prospect theory* supports optimistic forecasts as a result of decision-making involving uncertainty and risk, and *rational choice theory* supports the consideration that people take risk into account in their goal of utility maximization (also an economic and political explanation. Flyvbjerg, 2010).

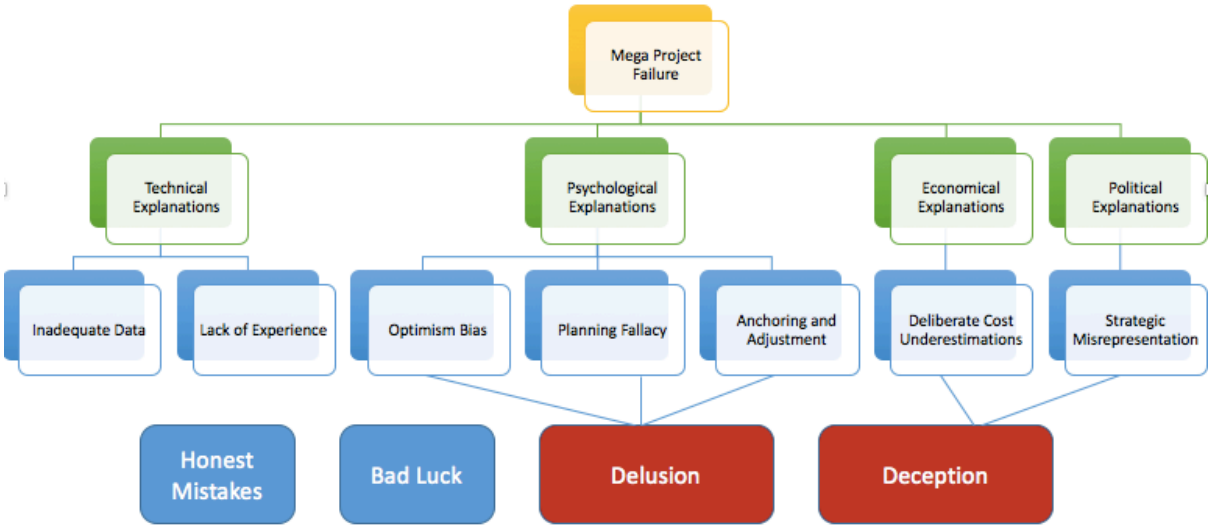
2.4.4 Political Explanations and Theories

Political advancement is considered the main explanation for cost overruns (agreed upon in the broad view cost overrun studies, Table 6), and offers an explanation for deliberate cost underestimation and forecast manipulation. Cost forecasts are manipulated because behaviour is determined on considerations of advocacy rather than objectivity (Wachs, 1989). Strategic behaviour in the misrepresentation of forecasts involves the awareness of managers and decision-makers that in order for a project to be selected, forecasts of outcomes must be highly favourable. Pressure from the organisation causes *strategic misrepresentation* as forecasts are adjusted to suit the most organisationally attractive outcomes. Theories that support these political explanations include; *Machiavellianism, agency theory* and *ethical theory*.

The core issue in political explanations is *strategic misrepresentation* and a feature of the concept of *Machiavellianism*, a person's tendency to deceive and manipulate others for personal gain (Byrne and Whiten, 1989: Christie and Geis, 1970). Strategic behaviour is enabled as a result of competition among parties for funding and project initiation because 'uncertainties are never bought to the attention of decision-makers' (Odeck, 2004). This also brings to light the notion of *ethical theory*, which studies the behaviour of people and groups and includes their values, customs and responsibility (Wach, 1982; LaFolette, 2000). *Agency theory* suggest that people act unconditionally in their own narrowly defined self-interest with, if necessary, guile and deceit (Noreen, 1999).

In summary, 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: 1) delusions or honest mistakes; 2) deceptions or strategic manipulation of information or processes or 3) bad luck (Figure 3). By exploring the concepts of delusion and deception we can begin to understand how influencing engineering education will encourage students to be more cognisant of their decision-making, and the consequences of those decisions.

Figure 3: A Summary of Cost Overrun Explanations and the Underlying Reasons (Lovallo and Kahneman, 2003)



2.5 Delusion and Deception in Megaprojects

Flyvbjerg et al. (2009) provide further explanations to the phenomena of delusion and deception in reference to infrastructure projects based on previous findings from megaproject research (Flyvbjerg 2003a, b).

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 (Kahneman and Tversky, 1986).

Delusional decision-making leads managers to pursue projects that are unlikely to produce the expected returns or come in on budget or on time. Decision-makers, particularly on infrastructure megaprojects have a strong inclination to consider the problem (the project) as unique, generating an *inside view* of forecasting.

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'. These misaligned incentives can be categorised as follows; *principal agent problems, asymmetric information, and asymmetric accountability.*

Principal agent problems are characterised by multiple and complex principal-agent contracts, most of which are resolved by the lowest bid. This incentivises actors (politicians, project champions, EPC firms and sub-contractors) to under estimate costs, only promote benefits and deliberately leave risk unacknowledged in order to ensure the project, or at least their part in it, proceeds over the competition. *Asymmetric information* occurs when the project champion has access to information that the principal decision maker does not which means the decision maker is more easily deceived. *Asymmetric accountability* arises when the agents responsible for cost overruns or schedule slippages may not be the ones held accountable, resulting in agents taking more risk than normal.

2.5.1 DELUSION

Throughout the forecasting that occurs on megaprojects, decision-makers often fall victim to *the planning fallacy* (Fyvbjerg et al. 2009), a well-established cognitive bias in experimental psychology literature (Kahneman and Tversky, 1979; Buehler et al. 1994; Lovallo and Kahneman, 2003). The *planning fallacy* is the tendency to underestimate completion times and costs, even with past evidence that similar

tasks have gone over time and budget, and prevents 'realistic' predictions from being made, creating an over optimism in project participants. *Overconfidence* is also linked to over optimism, and can be attributed to the behaviour of executives, entrepreneurs, and others e.g. young male drivers (Malmendier and Tate, 2003).

Little literature exists on the *overconfidence* of civil engineers, a significant participant in megaproject decision-making. *Overconfidence* in civil engineers has only been identified through assessment of technical decision-making skills when predicting the structural reliability of an embankment (Hynes and Vanmarcke, 1976). Overconfidence was the focus of the work done by Dunning and Kruger (1999) who found that those who exhibited overconfidence in their abilities were not only less skilled than they thought, but also unaware of their level of competency. Therefore, those who display overconfidence may have the dual burden of being ignorant to their own inabilities. This would suggest that those responsible for overoptimistic forecasts on megaprojects, may be completely ignorant to such errors and their own optimism bias.

Anchoring and adjustment is another result, but also a by-product, of optimistic forecasting. The 'anchor' is the first number considered possible to complete a project. This 'anchoring' makes movement from that number based on more accurate information very difficult, a double affliction when that number is insufficient. For example, in a study of experienced real estate agents who were all given information on a house, including a listing price which varied among the agents (Diekmann et al. 1996). Research found that the listing price had a significant impact on the agents 'true' pricing of the house, something the agents maintained had no effect.

In infrastructure planning, an 'anchor' is often seen as a best or most likely case and due to continuing optimism bias, it is unlikely that it will sufficiently adjust to the reality of the projects performance (Flyvbjerg, 2009).

2.5.2 *DECEPTION*

Large infrastructure projects are burdened by political and organisational pressures due to the complex principal-agent relationships that exist within them. Flyvbjerg (2009) illustrated the complexity of these relationships by using the example of a local government intending to build a new tunnel across the city for the benefit of the

local residents and state population (Figure 4). Using this example to describe the various tiers of relationship, the first tier shows the relationship between the taxpayer (principal) and the state government (agent). Taxpayers, as the end user of proposed infrastructure would expect big benefits for minimal cost within a short time frame.

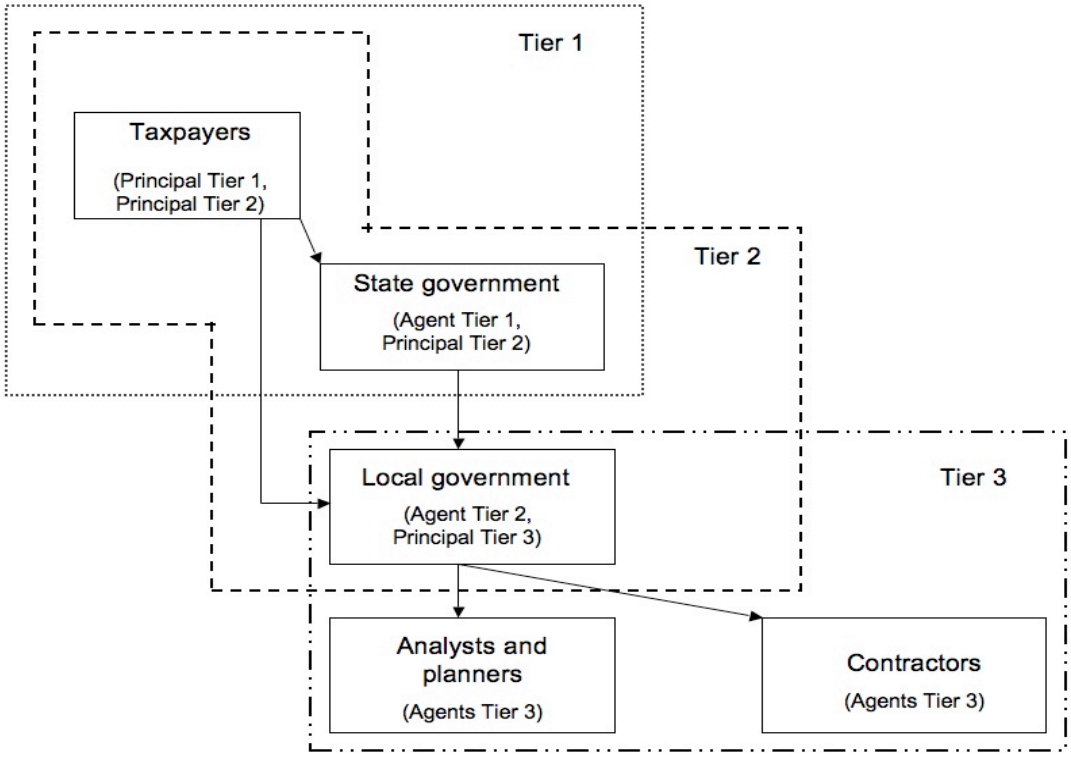


Figure 4: Illustration of Multi-Tier Principal Agent Relationships (Flyvbjerg, 2009)

The individuals making decisions within state government, who have been elected to do so, have their own interests, and are possibly motivated by one or more of the 'four sublimes' mentioned in Table 1 (Flyvbjerg, 2014). In the second tier the local government becomes the agent of the taxpayer and state government. Here local government seeks to gain approval of their project and therefore has an interest in providing overly optimistic estimates. The third tier shows the relationship between local government as the principal and the project planning and implementation teams. The project analysts, planners and contractors will all have an interest in providing favourable estimates to local government in an effort to; 1) assist local government in gaining approval, 2) win the contract to implement said project and 3) being re-engaged on future projects.

This relationship chart is simplified in order to illustrate a complex network of relationships. For example, if we consider the succeeding tiers of sub-contractors, consultants, etc., we can begin to visualise an incredibly complex network of relationships where the transparency, accountability and incentives influencing *strategic misrepresentation* can get lost in the relative mammoth beast of a megaproject.

2.5.3 Expectation of Delusion and Deception in Megaprojects

Delusion and/or deception is 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 5. Figure 5 was derived from research carried out into megaproject success and failure (Flyvbjerg, 2009).

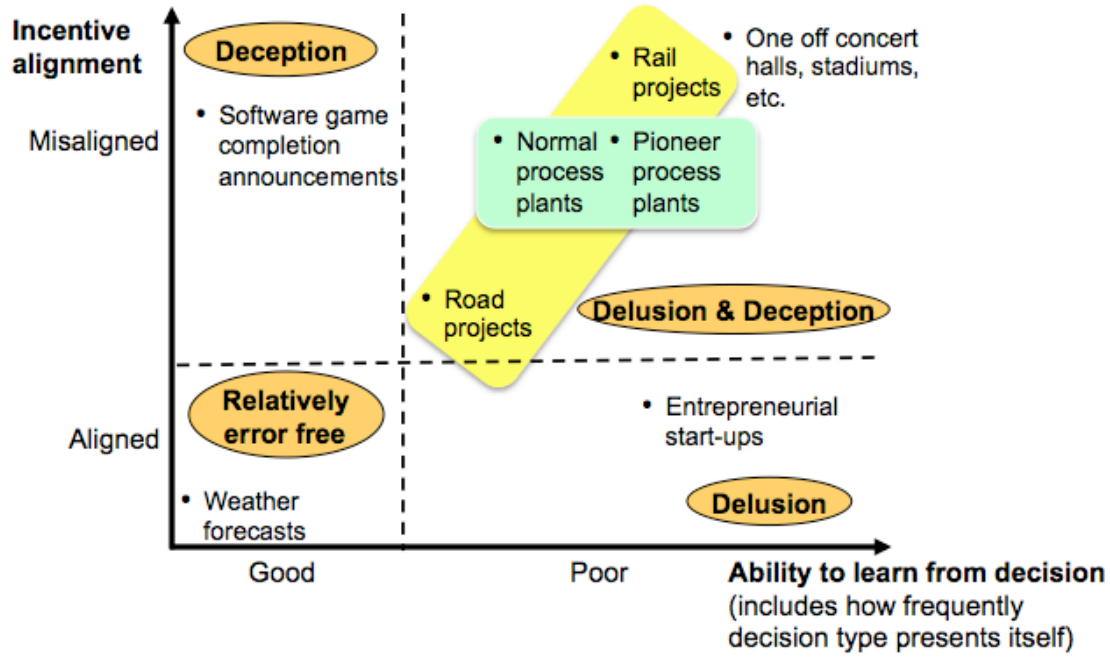


Figure 5: Likelihood of Delusion and Deception in Megaprojects (Flyvbjerg, 2009)

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). 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).

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. Entrepreneurial start-ups are an example where forecasts can be delusional. A study of entrepreneurs found that 33% of entrepreneurs perceived their chances of success to be certain, but these forecasts are clearly delusional because over 80% of entrepreneurial ventures fail (Cooper et al. 1988).

If the ability to learn is high but the incentives are mismatched, then deception can occur. For example, In the case of software gaming, whereby companies continuously state release dates of new games that they do not stick to, *‘cheap talk’* has been endorsed as the event of deception by trying to pre-empt sales of competitors’ products. (Farrell, 1987).

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).

Hence the ability to learn and the alignment of incentives impacts decision making in megaprojects. Investigating how the learning environment and the use of incentives in undergraduate education influences decision-making, could provide further insight into the contributing factors of delusional and deceptive behaviour in education, and offer insights into the identification and management of such behaviours.

2.5.4 Organisational Decision Making and the Individual

Organisations do not make decisions, people do (Carley and Behrens, 1999).

Organisational decision-making is a product of both the way individuals make decisions and the context in which these individuals make decisions (Carley and Behrens, 1999). An organisation is ‘an organised body of people with a particular purpose, especially a business, society, association’ (i.e. a megaproject or engineering cohort) and organisational decision-making is an area of work that

suggests that limits to cognition and rationality, and the structure of relations among individuals and organisations are equally important in determining what decisions are made. Organisations are shaped by individuals and are volatile or fluid constructs based on the dynamism of the rules, participants, and situations (Cohen, March and Olsen, 1972). Volatility can be attributed to the agents that comprise the organisations, and organisational performance is dependent on the individual experiences and histories of those agents, or individuals. In management decision-making, the strong interaction between cognition and task requires strategy to change not just the task, but the type of agents who engage in the task to achieve improved performance. Organisational performance is a function of both individual actions, and the context in which individuals act. The 'context' in which individuals make decisions is essentially the environment in which they are embedded, both physical and social, this includes the task being done, and the structure and culture of the organisation (Carley and Behrens, 1999).

2.5.5 BEHAVIOURAL DECISION THEORY

Behavioural Decision Theory (BDT) describes or predicts behaviour of an individual at various levels; in an organisation, in a group, or in a group within an organisation. BDT follows many behavioural fields of research and can be effectively categorised as 'psychological or descriptive' approaches and 'economic or normative' approaches. Both streams of research aim to explain fluctuations from rationality, with behavioural economists focusing on the rational decision maker, and psychologists centering on explaining consistent deviations from rationality.

Kahneman and Tversky (1979) produced ground breaking research with their Prospect theory, suggesting that individuals have a different perception when considering losses versus gains. The work of Kahneman and Tversky (1979) led to a wide range of research concerning departures from rationality and biases common to social judgement. The subsequent research included; *the framing effect*, people react to a particular choice in different ways depending on how it is presented; e.g. as a loss or as a gain. People tend to avoid risk when a positive frame is presented but seek risks when a negative frame is presented (Tversky and Kahneman, 1981); *false consensus effect*, people tend to overestimate the extent to which their opinions, beliefs, preferences, values, and habits are normal and typical of those of others (Dawes and Mulford, 1996; Dawes, 1989, 1990; Orbell and Dawes, 1993);

and *group think*, the tendency in groups for a convergence of ideas and approval of aberrant ideas to occur (Janis, 1982; Tetlock, 1979). These effects are the product of cognitive and perceptual biases, which create heuristics, the process or method enabling an individual to discover or learn something for themselves.

The *representative heuristic* suggests that individuals' base judgements on similarity of characteristics and attributes. People make judgements based on the degree to which A is representative of B, that is, by the degree to which A resembles B (Tversky and Kahneman, 1974). The *representative heuristic* can lead to the belief in 'the law of small numbers', that random samples of a population will resemble each other and the population more closely than statistical sampling theory would predict (Plous, 1993). The *representative heuristic* can also result in people ignoring base rate information (the frequency an occurrence is seen in the general population) and is closely linked to the *availability heuristic*.

The *availability heuristic* is a 'mental short cut' enabling individuals to "assess frequency of class or the probability of an event by the ease with which instances or occurrences can be bought to mind" (Tversky and Kahneman, 1974). *Availability bias* will not necessarily result in biased judgement, unless the most available information is not accurate. For example, the likelihood that your car is going to be stolen might very well be affected by the saliency of the information that your next door neighbour had their car broken into twice in the last two years. However, it is not anticipated that that we would go and ask our other neighbours how often their cars have been broken into, so that one neighbour's information is much more salient and is retrieved more readily when making the decision to purchase an anti-theft device.

Anchoring and adjustment heuristic, as mentioned in 2.4.1, can cause extreme variations among individuals. The *anchoring and adjustment heuristic* suggests that we take a piece of information and attempt to adjust our judgements around that one piece of information. For example, if an individual were asked to estimate the income from a new project and was told that a similar project last year earned $40,000, the estimate would be higher than if they were told last year's project had earned $4,000. Individual judgement of future consequences is strongly affected by the information individuals perceive and remember, and the degree to which we are willing to expend energy, and think critically, on the judgement process.

2.6 THE INDIVIDUAL AND FUTURE CONSEQUENCE

Most individuals recognise that their identity (personality, interests, values, goals and beliefs) changes over time. Some believe that this can happen only marginally and feel quite connected to their future self; these people represent a high level of psychological connectedness (Hershfield, Cohen & Thompson, 2012). Others who feel their identity will change dramatically over time represent low levels of psychological connectedness, or 'discontinuity' with their future self. (Parfit, 1984).

An individual's connectedness to their future self can impact many aspects of their lives, both personally and professionally. To establish the impact a level of connectedness to the future self can have it is important to recognise the affects low or high connectedness has to behaviours through previous research.

2.6.1 CONSEQUENCES AND CORRELATES OF CONTINUITY WITH FUTURE SELF

2.6.1.1 Unethical Behaviour

People who feel continuity with their future selves are more likely to behave in ethically responsible ways in comparison to those with low continuity (Hershfield, Cohen & Thompson, 2012). In a series of five (5) studies, Hershfield et.al found; 1) individual differences in perceived similarity to one's future self predicted tolerance of unethical business decisions, 2) low future continuity predicted unethical behaviour in the form of lies, false promises and cheating, 3 & 4) these relationships hold when controlling for general personality dimensions and trait levels of self-control, 5) a causal relationship was found between future self-continuity and ethical judgements by showing that when people are prompted to focus on their future self (as opposed to the future), they express more disapproval of unethical behaviour. Subjects were more inclined to lie when deception could benefit them immediately and were more likely to cheat. When asked to reflect upon their likely similarities to themselves now and their future selves in ten years' time, or reflect upon the world in ten years' time, the group reflecting on themselves were not as likely to endorse unethical behaviour. This would suggest that when putting oneself in to the picture when reflecting on the future impacts of business decisions, unethical decision-making could be reduced.

2.6.1.2 Temporal Discounting and Delayed Gratification

If psychological connectedness is high, individuals will tend to value their future needs. For example, if an individual was offered $100 now or $150 in one year, those with high psychological connectedness to their future self would more likely

choose $150 in one year as they know their motives now will apply in the future. Those with low connectedness would more likely choose the $100 now, prioritising their immediate need over their future goals, which is also known as temporal discounting (Bartels and Urminsky, 2011). In a series of studies undertaken by Bartels and Urminsky (2011), to verify the role of psychological connectedness in discounting future needs, subjects to whom it was implied had an unstable identity preferred to receive a sum of money now, over a significant amount more in one year. Those who were informed they had a stable connection to their identity chose the future, higher amount. Further studies by Bartels and Urminsky (2011) verified that psychological connectedness to the future self-affected the discount rate over time, and does not direct attention to the present instead of the future.

2.6.1.3 Consideration of Future Consequences

Hershfield, Cohen and Thompson (2012) also suggested that if people feel their self now and their future self in ten years' time overlap considerably, they are more likely to consider future outcomes when decision-making. This would suggest that if an individual had low self-continuity, the impact on their decision-making could prevent them from seeing the bigger picture of an engineering problem in the future (complete) and how their decision-making in the present could impact future tasks in the project.

2.6.2 Antecedents of Psychological Connectedness to Future Self

2.6.2.1 A Sense of Power

When an individual experiences a sense of power they feel they are not constrained by the whims of other individuals. This sense of power tends to make individuals feel high self-continuity, which can diminish the magnitude of temporal discounting. Joshi and Fast (2013) suggested that there are two mechanisms that underpin the association between a sense of power and connection to the future. Firstly, power provides a sense of control over an individual's environment, reducing vulnerability and uncertainty and the future seems more important. Consequently, if people feel a sense of power, their future image of themselves seems more certain, closer in time and therefore more connected to their current self. Secondly, when experiencing a sense of power, individuals adopt an abstract construal and in doing so they become sensitive to global patterns over specific details. As a need to focus on details

decreases, individuals are more inclined to consider their future self (Joshi and Fast, 2013).

In a series of studies by Joshi and Fast (2013), participants first completed a sequence of tasks (general knowledge tests) in groups. Some participants, not all, were assigned the role of manager, introducing a sense of power. Participants then completed a measure of temporal discounting. Temporal discounting was lessened in those given the managers role. In a second study participants were asked to recall a time in which they were granted power. In this case participants were more likely to feel a connection with their future self and correlated with reduced temporal discounting. A lack of autonomy, both in education and industry may be preventing individuals from feeling a higher level of self-continuity thus having an impact on an individual's ability to consider the future in their decision-making, resulting in unethical decisions.

2.6.3 Related Concepts

2.6.3.1 Expectation of Remaining in the Same Job

Expectation of staying in the same job is a recent concept that has links to psychological connectedness to the future. Rather than a connection to an individual's future self, this concept evaluates the degree to which people feel connected to their future job. Liebermann, Wegge and Muller (2012) evaluated the factors that are likely to promote or inhibit the expectation of remaining in the same job. Participants were asked to indicate the degree to which they could imagine themselves in the same job until their official retirement age. Options were "I cannot picture that", "I can picture that with restrictions" and "I can picture that". Participants also answered questions relating to resources at work, for example, social support, variety and appreciation from other people as well as the degree to which their job is demanding. Participants were also asked about their health and their age. In general, resources at work were positively associated and demands were negatively associated with expectation of remaining in the same job.

With the temporary, albeit often long term, nature of megaproject work, and the instability of the industry, the expectancy to remain in the same job can have an impact on self-continuity and is therefore a driver for the effects of low psychological connectedness to the future self.

2.6.3.2 Collective Futures Framework

The collective futures framework focuses on what could happen when individuals reflect on potential social changes. According to Bain, Hornsey, Bongiorno, Kashima & Crimston (2013), leaders often attempt to convey an inspiring vision of the future. Leaders can refer to a variety of changes; conditions that influence society, changes in the religious, ethnic or political groups, or changes in fiscal or social policies. After reflection on these possibilities, individuals assumed that features of society or people may differ and could therefore affect the behaviour or attitudes of individuals today. For example, if participants were given the picture of a more compassionate future, with the likelihood of the mitigation of climate control they were more inclined to support behaviours to expedite these changes. In comparison, individuals informed of a less compassionate future were less likely to support behaviours to facilitate the change.

2.6.4 Measuring Psychological Connectedness to the Future Self

2.6.4.1 The Future Self-Continuity Scale

The most common measure to gauge whether people do or do not feel self-continuity was developed by Ersner-Hershfield, Garton, Ballard, Samanez-Larkin and Knutson (2009). The Future Self-Continuity Scale (Figure 6) assesses the degree to which participants pick a pair of Euler circles (out of a possible seven pairs) that best represents how similar they feel to themselves in ten years' time.

As higher levels of self-continuity were found to have an impact on the decision-making behaviour used in critical decision-making then measures to influence self-continuity could be applied to the learning environment in both education and the megaproject environment, to enhance decision-making skills, resulting in the delivery of superior project performance outcomes.

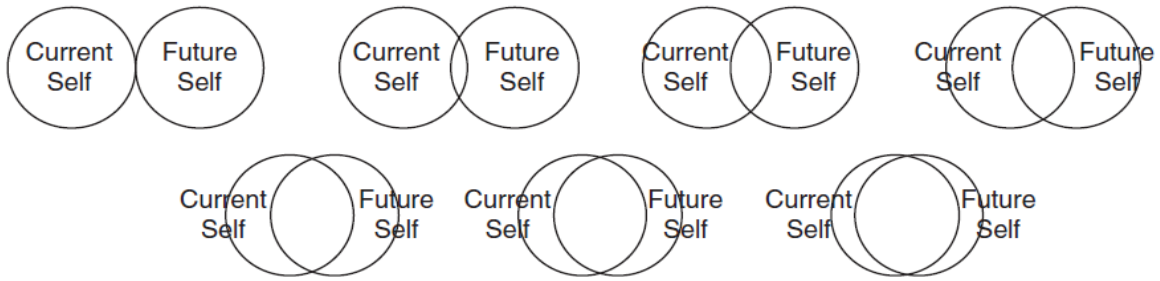


Figure 6: The Future Self Continuity Scale (Hershfield et al. 2009)

2.7 ENGINEERING EDUCATION

2.7.1 DECISION-MAKING AND ENGINEERING EDUCATION

The case of 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.

Values guide our action – what we choose and how we choose. Our values are the lens through which we view the world: they stem from our underlying beliefs and assumptions, which are generally neither articulated nor questioned (Mitchell and Baillie, 1998).

Baillie and Levine (2013) argue 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). An example of hegemonic culture and enculturation comes from the U.S. Military and is the result of cadets' "preferences" and "identities" to enable them to identify themselves 'above all else, as officers in the U.S. army' (Akerlof & Kranton, 2005). *Thought collectives* and *thought styles* (Fleck, 1979) 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 argues that stable thought collectives form organised 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 in order to reframe engineering practice, a critical repositioning of engineering itself is needed. Enlarging what it means to be an engineer is to understand the responsibility of a professional to see beyond what ethics means within the contemporary pressures and measures of success, and to know what the available choices are and which among them are morally justifiable before making a decision (Baillie and Levine, 2013). In Engineering & Social Justice

(2008) Donna Riley suggests engineers tend to abdicate responsibility for problem definitions to others, and state instead, that they are working on “given” problems, and yet autonomy and the ability to make independent ethical choices is an essential element of what defines professions in sociological terms (Riley, 2008).

The discussion of decision-making as it applies to ethics in engineering education is gaining more traction amongst academics and educators, but it is the behavioural traits developed during education that will enable an individual to reach the professional capacity required of a future leader of engineering. The missing link of the delivery of education, to cultivate the desired behavioural traits lacking in a megaproject environment, will afford significant contributions to theory and practice in decision-making behaviour.

2.7.2 The Role of Education in Engineering

The fundamental role of education is to teach people to think (Gagne, 1980; McMasters, 2004). In a world where information is more available, accessible, and in many cases biased, never has it been more critical to enable students to learn to differentiate between the good and the bad (Woodrow, 2013). *“What they [educators] are seeking to do is not only to help students to be equipped for the world of work but to develop criticality in those students”* (Savin-Baden, 2003). When considering the role of a ‘specialist’ versus a ‘generalist’ mindset in engineering, we can begin to appreciate the learning styles and environments that will enhance those types of mindset. ‘Specialists’ view knowledge as objective and separate from the situations in which it is applied (Felder, 1997). This assumes that the process is two-fold, to learn knowledge, and to learn how to apply it (Spinks, Silburn, & Birchall, 2006). The belief being that knowledge is transferrable and non-contextual (Harpaz, 2005). A ‘Generalist’ will think about a topic holistically, *before* breaking it down into smaller, separate components. Traditionally engineering education has been accredited by professional bodies (ABET, ICE, EA) and many faculty members feel pressure to cover large amounts of content (Litzinger et al. 2011). This type of learning environment encourages a ‘specialist’ mindset, creating barriers to developing a ‘generalist’ approach, and being able to view a problem holistically, and critically. *“It is more important for students to be able to learn quickly, effectively and independently when they need it, than it is for them to have assimilated (at graduation) all the information which their teachers believe is desirable”* (Boud &

Feletti, 1997) Generalist education encourages students in their personal growth and development (Fox, 1983). It is important that students develop their self-efficacy and an awareness of their own competence as this has been shown to be highly correlated with motivation and learning (Zimmerman, 2000). Alongside the generalist approach, creating an autonomous learning environment where students are more actively engaged, and self-directed has delivered far greater conceptual understanding amongst students (Hake, 1998). The findings of the study by Hake of 6500 students are supported by Glaser (1993), Redish et al. (1997), Felder et al. (1998), Black & Wiliam (1998a) and Laws et al. (1999). *"The ability to make connections among seemingly disparate discoveries, events, and trends, and to integrate them in ways that benefit the world community will be the hallmark of modern leaders"* (Bordogna, Fromm, & Ernst, 1993). By recognising the role that education plays in shaping the way in which students think, we can begin to comprehend the responsibility that education takes in enhancing the decision-making skills of graduate engineers.

2.8 SUMMARY

Figure 7 illustrates a summary of the literature review. In summary, poor megaproject performance outcomes are the norm, not the exception, and this has been the case since the beginning of megaproject delivery. By reviewing the technical, economical, psychological and political explanations of poor project performance outcomes (Canterelli et al., 2010), the phenomena of delusion and deception have been attributed as the human behaviours evident in megaproject delivery, and the ultimate factors leading to poor megaproject performance outcomes. By understanding Behavioural Decision Theory, we can gain insight in to the key indicators contributing to cognitive biases and heuristics used by individuals, that impact organisational decision-making that occurs in a megaproject environment. It is clear that there is a gap in research relating to decision-making in a megaproject environment and the role that education can play in improving the quality of decision-making, prior to entering, and once established in industry. Whilst 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. The definitive need for this research is two-fold, firstly to understand factors affecting

the development of decision-making skills during the undergraduate program, and secondly, to define the implications for industry, specifically enhancing decision-making quality in a megaproject environment. 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. By evaluating current education delivery and identifying the factors affecting undergraduate decision-making, appropriate timely intervention in the Civil Engineering curriculum will provide an opportunity to enhance decision-making skills and ultimately lead to delivery of superior megaproject performance outcomes.

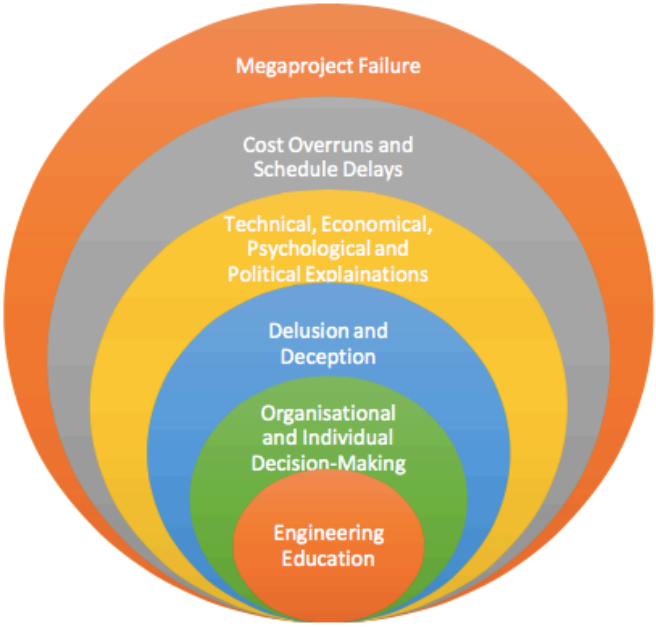


Figure 7: Summary of Literature Review

3 INTERVIEWING THE INDIVIDUAL

3.1 INTRODUCTION AND PURPOSE

The purpose of this study is to understand the role of education in the decision-making behaviour of civil engineers, and if and how this behaviour might be linked to delusion and deception.

This chapter describes the exploratory research conducted to explore the factors that influence decision-making behaviour of civil engineering students, gain insights into what drives their decision-making, and whether these factors are linked to delusion and deception. By interviewing students to identify what drives their decision-making, what they consider to be a difficult decision and how they deal with the complexity and ambiguity of decision-making, we seek to answer the following question.

RQ 1: ***Which features and characteristics influence the decision-making of undergraduate civil engineers?***

As this part of the research is based on individual interviews, Human Ethics Clearance approvals, and amendments to approvals were obtained from the University of Queensland prior to any contact with students.

3.2 RESEARCH DESIGN

The effectiveness in qualitative research methods has been proven in answering questions related to what is occurring, why it is occurring and how one phenomenon affects another (Borrego, Douglas and Amelink, 2009).

To answer the questions of what, why, and how, a phenomenon is occuring, semi-structured interviews were developed, conducted, and analysed using qualitative methodology. From the many qualitative research methodologies available, this study uses Interpretative Phenomenological Analysis (IPA) to investigate and understand how second year Civil Engineering students make decisions.

The decision to use IPA as a data analysis method was made after the development of semi-structured interviews, and data collection. The initial design of the interview questions and protocol was based on a review of Engineering Education research, and discussion with Engineering Education researchers. The decision to utilize IPA post-data collection is discussed further in section 3.2.5.

In using IPA we are assuming that our data can tell us something about people's involvement and orientation towards the world, and/or about how they make sense of this (Smith, Flowers and Larkin, 2010). The phenomena to be understood were the concepts of delusion and deception in a megaproject environment.

By gaining insight into how Civil Engineering students make sense of their decision-making we can gain a better understanding of what may affect the decisions they make on a daily basis. More specifically, understanding how students make sense of complexity and ambiguity when making decisions will offer insight into the phenomena of delusion and deception, identified as contributors to megaproject failure (Flyvbjerg, 2009). This will not only lead to development of pedagogical change, but will also convey awareness to industry about the individual factors affecting the decisions made in a megaproject environment.

For this research, volunteers were specifically sought from the second year civil engineering cohort due to the timing of the inaugural Icarus Program, and the opportunity to assess the impact of a co-curricular 'intervention' on decision-making.

3.2.1 THE ICARUS PROGRAM

The University of Queensland (UQ) offers a traditional BE Civil Engineering program, accredited by Engineers Australia, consisting of the courses shown in Table 7. 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 pilot 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 in CIVL2330 (structures), CIVL2130 (environmental), or CIVL2410 (transport). They 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.

Table 7: Current BE Civil Engineering Courses at the University of Queensland

			Part A - Compulsory
Year	**Semester**	**Course Code**	**Course Title**
1	1	ENGG1100	Engineering Design
1	1 or 2	ENGG1400	Engineering Mechanics: Statics & Dynamics
1	1 or 2	MATH1051	Calculus & Linear Algebra I [1]
1	2	ENGG1200	Engineering Modelling & Problem Solving
1	2	MATH1052	Multivariate Calculus & Ordinary Differential Equations
2	1	CIVL2130	Environmental Issues, Monitoring & Assessment
2	1	CIVL2330	Structural Mechanics
2	1	CIVL2410	Traffic Flow Theory & Analysis
2	1	MATH2000	Calculus & Linear Algebra II
2	1	STAT2201	Analysis of Engineering & Scientific Data
2	2	CIVL2131	Fluid Mechanics for Civil & Environmental Engineers
2	2	CIVL2210	Fundamentals of Soil Mechanics
2	2	CIVL2340	Introduction to Structural Design
2	2	CIVL2360	Reinforced Concrete Structures & Concrete Technology
3	1	CIVL3140	Catchment Hydraulics: Open Channel Flow & Design
3	1	CIVL3210	Geotechnical Engineering
3	1	CIVL3340	Structural Analysis
3	2	CIVL3141	Catchment Hydrology
3	2	CIVL3350	Structural Design
3	2	CIVL3420	Transportation Systems Engineering
3 or 4	*2*	*CIVL3510*	*Introduction to Project Management**
4	1	CIVL4514	Civil Design I
4	2	CIVL4515 or 6	Civil Design II or III

	Part B0 - Preparatory Mathematics & Science Electives		**Part B2 - Advanced Electives**
CHEM1090	Introductory Chemistry [4]	CHEE4012	Industrial Wastewater & Solid Waste Management
MATH1050	Mathematical Foundations	CIVL3150	Modelling of Environmental Systems
PHYS1171	Physical Basis of Biological Systems [6]	CIVL4110	Coastal & Estuarine Processes [7]
	Part B1 - Introductory Electives	CIVL4120	Advanced Open Channel Flow & Hydraulic Structures [8]
CHEM1100	Chemistry 1	CIVL4140	Ground Water & Surface Flow Modelling
CSSE1001	Introduction to Software Engineering	CIVL4160	Advanced Fluid Mechanics
ENGG1300	Introduction to Electrical Systems	CIVL4180	Sustainable Built Environment
ENGG1500	Engineering Thermodynamics	CIVL4230	Advanced Soil Mechanics
ENGG1600	Introduction to Research Practices - The Big Issues	CIVL4250	Numerical Methods in Engineering
ERTH1501	Earth Processes & Geological Materials for Engineers	CIVL4270	Geotechnical Investigation & Testing
MINE2105	Introduction to Mining	CIVL4280	Advanced Rock Mechanics
PHYS1002	Electromagnetism and Modern Physics	CIVL4320	Engineering of Small Buildings
REDE1300	Building Construction Management & Economics	CIVL4331	Advanced Structural Engineering
		CIVL4332	Advanced Structural Analysis
		CIVL4411	Advanced Transport Engineering
		CIVL4522	*Construction Engineering Management**
		CIVL4560	Project
		CIVL4580	Research Thesis [9]
		CIVL4582	Research Thesis [9]
		ENGG4900	Professional Practice and the Business Environment
		FIRE3700	Introduction to Fire Safety Engineering
		FIRE4610	Fire Engineering Design: Solutions for Implicit Safety
		MINE4000	Mine Waste Management & Landform Design

**Classes including Project Management material*

3.2.2 *Philosophical Foundation*

The methodological orientation of this study is based on the following ontological and epistemological viewpoint of the researcher. Based on the constructivism theory of Piaget, that humans generate knowledge and meaning from an interaction between their experiences and their ideas; and interpretivism theory (antipositivism), being the belief within social science that the social realm may not be subject to the same methods of investigation as the natural world, this study aims to explore the 'sense-making' taking place in the early career of a Civil Engineering undergraduate, through an interpretative phenomenological approach.

3.2.3 *Interpretative Phenomenological Analysis*

The primary goal of IPA research is to investigate how individuals make sense of their experiences. IPA draws upon the fundamental principles of phenomenology, hermeneutics, and idiography.

Phenomenology is concerned with the way things appear to individuals, in their experience. The goal of phenomenology is to understand how people perceive and talk about events, rather than describing phenomena according to a predetermined categorical system, conceptual and scientific criteria (Pietkiewicz and Smith, 2012).

Hermeneutics (from the Greek word *'to interpret'* or *'to make clear'*) requires the researcher to comprehend the mind-set of a person and language which mediates one's experiences of the world, in order to translate his or her message (Freeman, 2008). This process makes IPA a dynamic process, with an active role taken by the researcher, through their interpretative activity, creating a double hermeneutic (Smith and Osborn, 2008).

Idiography refers to the in-depth analysis of single cases, and the examination of study participants, in their unique contexts. IPA relies on ideography, meaning that researchers focus on the particular, rather than the universal (Smith, Harre and Van Langenhove, 1995).

IPA combines phenomenology, hermeneutics and idiography resulting in a descriptive interpretation of the individual lived experience. IPA has not prescribed a single 'method' for working with data. As with many other approaches in qualitative research, the essence of IPA lies in its analytical focus.

Figure 8 presents the overview of underpinning philosophical foundations that led to the utilization of IPA.

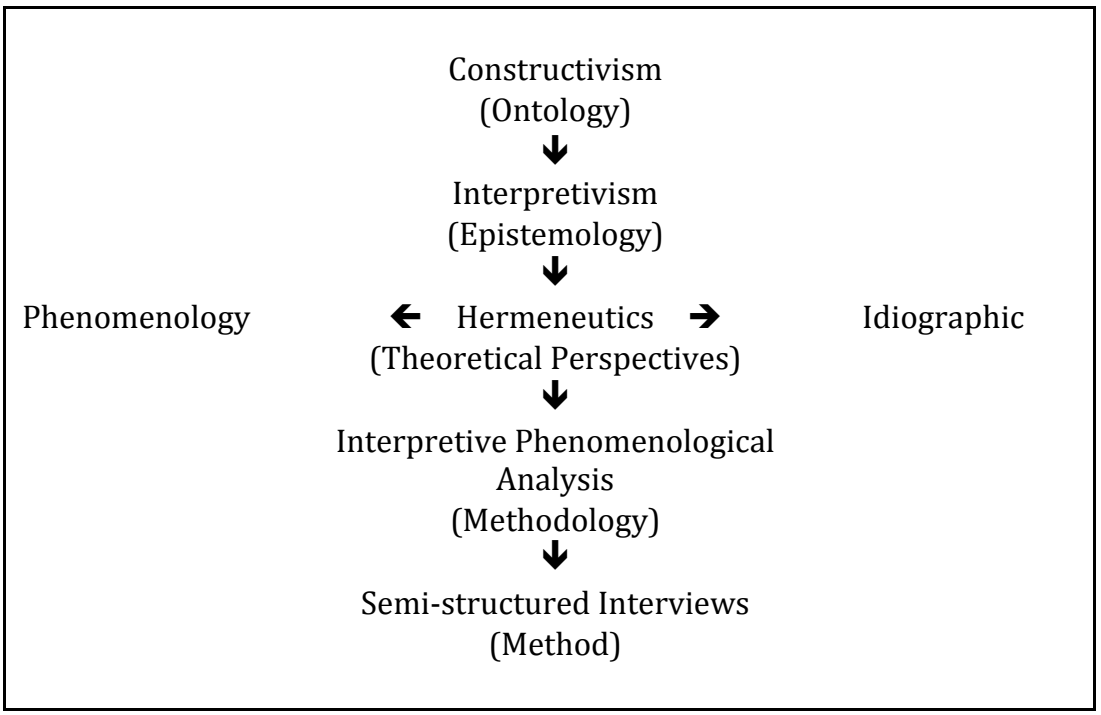


Figure 8: Overview of Underpinning Philosophical Foundations

After reviewing alternative traditional methods of qualitative research, and to gain a true insight in to the individual lived experience of decision-making by the participants, it was decided that an idiographic and hermeneutic approach was most suited to this exploratory study. Although the primary concern with IPA is the lived experience, the end result is always an account of how the analyst thinks the participant is thinking – a double hermeneutic, making the analysis subjective.

Table 8 presents alternative research questions that could have resulted from using alternate methodological approaches. IPA will facilitate understanding the phenomena of delusion and deception in decision-making at a purely idiographic level, and recognise the role of the researcher, having declared their own experiences. How that could influence their interpretation of the participants' sense-making, provides a double hermeneutic, allowing the researcher to gain a unique introspective insight in to the interpretation of the interviewer as well as the student.

Table 8: Alternative Qualitative Research Questions and Suited Approach (Smith, Flowers, Larkin 2010)

Question	Key Feature	Suitable Approach
How do people who enrolled in a Civil Engineering program make sense of their decision-making?	**Focus on personal meaning and sense-making in a particular context, for people who share a particular experience**	**Interpretative Phenomenological Analysis**
What are the main experiential features of decision-making?	Focus on the common structure of 'decision-making' as an experience.	Phenomenology
What sorts of story structures do people use to describe events, which made them make a decision?	Focus on how narrative relates to sense-making (e.g. via genre or structure)	Narrative Psychology
What factors influence how people make decisions?	Willingness to develop an exploratory level account (factors, impacts, influence)	Grounded Theory
How do people talk about 'decision-making' in Civil Engineering programs?	Focus on interaction over and above content, and caution about inferring anything about anger itself.	Discursive Psychology
How is 'decision-making' constructed in experiential reports from a Civil Engineering Student?	Willingness to use a range of data sources, and the focus on how things 'must be understood' according to the conventions of a particular setting.	Foucauldian Discourse Analysis

3.2.4 *Role of the Researcher and Researcher Bias*

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.

As a former Commercial Manager on transport infrastructure megaprojects, my position as a researcher is biased by my own prior experiences. Although these prior experiences and biases are what has driven the purpose of this thesis, these biases had the potential to impact data analysis in a way that represented my personal views on the phenomena being investigated.

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 would place the researcher in a prime position for interviewing potential graduate engineers for roles within a megaproject team.

3.2.5 PARTICIPANTS

The participants of this study were all second or fourth year students enrolled in the Civil Engineering program at The University of Queensland (UQ is situated in Brisbane, Queensland Australia) Brisbane has been involved in a resources and construction boom since 2007 with significant federal and state funds being invested in the development of the city. Brisbane has played host to a significant number of transport infrastructure megaprojects during the last decade and is continuing to grow with further infrastructure developments being planned and implemented during the composition of this thesis.

Students were recruited through an email invitation sent via the lecturer of the four courses in which students were enrolled for semester one of 2015 (Appendix A). The researcher also attended lectures and early Icarus Program sessions to recruit students from both groups. Fourth year students were also recruited using the same methods. Table 9 presents the demographic data of the participants involved in the qualitative section of this study.

Table 9: Demographic of Participants taking part in Qualitative Study

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)

3.2.6 *Interview Development and Protocol*

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 an outside of an educational context. The questions would allow insight into the hermeneutics of the participants for decisions that specifically relate to them and their development as an individual, and would provide further insight in to their interpretation of significance and consequence within the responses to the questions. For the majority of the participants this would be their first experience of participating in an interview, therefore a relaxed, semi-formal approach was developed to encourage full and open answers to the questions. The style of questions was designed to loosely simulate a recruitment interview, to allow the researcher the opportunity to identify whether decision-making behavioural traits could be identified in an interview style typical to industry.

Despite the interview questions and protocol being developed prior to the decision to use IPA as a method of data analysis, the style of interview and questions are considered appropriate to the decision, and corresponded with methodological framework for the design of IPA research. 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, 2008). Questions suitable for IPA studies concentrate on exploring sensory perceptions, mental phenomena (thoughts, memories, associations, fantasies), and specifically

individual interpretations (Pietkiewicz and Smith, 2012). Notwithstanding the suitability of the interviews, this process of research design is discussed further in research limitations, section 3.5.3.

As mentioned in section 3.2.3, the researcher plays a central role in the inquiry of IPA, providing the researcher with the unique opportunity of designing an interview to encourage a narrative from the participant, without imposing their understanding of the phenomena. Whilst the interview was 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).

It was important to give the participants only a brief explanation of the overall objective of the questions, rather than potentially encouraging any preconceptions and biases pertaining to the phenomena being studied (Smith et al., 2010). This was considered a fundamental requirement of qualitative research methodology as predetermined by the researcher, further supporting the post-interview choice of analysis method.

Questions were also developed based on the theoretical framework discussed in chapter 2 with the intention of providing an insight into the participants' current self-continuity (Table 12). Beginning with simple, general questions to put the student at ease, followed by increasingly probing questions with a purposeful focus on what each participant thought was the reason behind the decision they had made. Table 9 presents the semi-structured interview protocol used during the interviews, including the purpose of each question.

Pilot interviews were conducted with students from the final year cohort resulting in interviews being adapted 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 in return for their time.

3.2.7 SAMPLE SIZE

At an early stage, the researcher must decide whether he or she wants to give a comprehensive and in-depth analysis about a particular participant's experiences or present a more general account on a group or specific population (Pietkiewicz and Smith, 2012).

In IPA studies there is no rule regarding how many participants should be included. Total number of participants depends on the following criteria:

1. The depth of analysis of a single case study,
2. The richness of the individual cases,
3. How the researcher wants to compare or contrast single cases,
4. The pragmatic restrictions that the researcher is working under.

(Pietkiewicz and Smith, 2012).

A total of 17 students were interviewed. Smith (2008) suggested a sample size of three was sufficient for an IPA sample size, and clinical psychology programs in the UK recommend six to eight participants (Turpin et al., 2006). IPA studies have been published with sample sizes ranging from one to fifteen participants (Pietkiewicz and Smith, 2012).

17 students exceeded the recommended size, although not significantly. This was identified after data collection as IPA was selected as a method of analysis post-interview, and discussed further in research limitations section 3.5.3. Interviewees were initially second year civil engineering undergraduates, 10 ‘Icarus Program’ students and 7 general cohort students (6 Female, 11 Male). A smaller sample of fourth year students were also asked to volunteer for the same semi-structured interview. All interviews were audio recorded and later transcribed, with the consent of the participants. Participants were also given the option to later withdraw their data from the study at any time.

3.3 METHOD

3.3.1 DATA COLLECTION

Interviews were scheduled at a time convenient for the student, in the Civil Engineering Meeting Room, a venue free from interruption and distraction. At each interview participants were invited into the room and whilst getting settled were asked to read and complete the Participant Information and Consent Form (Appendix B). During the review of the consent form, notes were made in a research diary on the first impression of the participant i.e. mood, composure, time of day; alongside a reflection of the researcher’s own current mood and composure for

Table 10: Semi-Structured Interview Protocol

Question Category	Questions	Purpose of Question
Choice of program and university	1. What made you choose Civil Engineering as a program? 2. What made you choose UQ as a University? 3. Is the course fulfilling your expectations? 4. What aspect of your education is the most relevant to your future career expectations?	Recent Decision
Future career expectations	5. What is most important to you when considering future employment? 6. Where do you see yourself in 10 years' time? 7. Identify current/future self on Future Self Scale. 8. Can you explain to me what you do at the beginning of each semester in preparation for your classes?	Future Self Identification
Decisions about education	9. Do you spend much time planning your assessments? 10. How important are these decisions? 11. What are the main reasons for making the decisions you do regarding your courses? 12. What role do your peers, family, friends, partners etc. play in your decisions? 13. Do you go to class? 14. What makes you go/not go to class?	Current Decision
Hypothetical Questions	15. If you were given to option of a class that you knew was an easy 7 or a class that was extremely difficult, yet relevant to your future career aspirations, which one would you choose and why? I. Can you explain your decision-making? 16. If you were offered a role as an intern with a weekly salary of $500 a week or $400 a week and a bonus upon completion of the vacation work, which one would you choose and why? I. Can you explain your decision-making?	Future Self Identification
General decision-making	17. Can you give me an example of a time when you've had to make a difficult decision? I. What made the decision difficult? 18. Have you ever been in a situation where your own ethical standards have been breached by someone else? II. Can you explain what happened? What did you do?	Past Decision

future reference. Once the consent form was signed and the participant indicated they were ready to start, the audio recorder was started and the interview began. Interviews were recorded to allow the researcher to listen and fully engage in the conversation whilst making minimal notes. Interviews were intended to go for no longer than one hour and varied in length from 30 to 55 minutes depending on participant responses.

Once the interview had begun, the researcher followed the structure in Table 12 including probing questions where the researcher considered relevant, at all times allowing the student to make their point and feel that they had fully answered the question.

Following the completion of all interviews, each audio file was transcribed and de-identified. Each interview was given a code with no descriptors identifying the participant in order to maintain confidentiality (Groenewald, 2004) Interviews were transcribed verbatim to capture all parts of the conversation to aid in the quality of analysis.

3.3.2 DATA ANALYSIS

The researcher who is engaging in a phenomenological inquiry is central to the IPA research. The assumption in IPA is that the analyst is interested in learning something about the respondent's psychological world (Smith, 2008).

Interview data was reviewed and each interview was analysed on an individual basis and categorised based on the emanating themes. In this study, the focus directs 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 (Smith, Flowers and Larkin, 2010). A set of simple steps is laid out by Smith, Flowers and Larkin (2010);

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

An excel spreadsheet was used to record the constructs and emergent themes (Figure 9)

3.3.2.1 Stage 1 – Immersion

The first stage of the analysis was to read the individual transcripts multiple times whilst listening to the audio. By fully immersing oneself back into the interview it was possible to note the important points being made and the initial sense of the interview. During this process of immersion, a 'free textual analysis' (Smith and Osborn, 2008) was performed, where potentially significant excerpts were highlighted, and a general theme for the complete interview was identified. A total of four main categories were initially identified; contradictory (students who had strong views, which were contradicted with equally strong views), big picture (students who had a world view, and/or strong feelings about their impact on the environment, and society), impressionable (students who appeared anxious, wanting direction, and supervision with all decisions) and drifter (students who appeared nonchalant, but had a desire to achieve something on a personal level).

3.3.2.2 Stage 2 – Understanding

'Units of meaning' (Hycner, 1985) were identified for each transcript from the highlighted excerpts (i.e. regret, anxiety, low motivation, needs structure, conscientious), and each excerpt of narrative that had a 'unit of meaning' linked to it was listed in a table. Commonalities were identified to consolidate a list of 138 units to a list of 90, referred to as the 'master-theme list' (Smith et al., 1999).

3.3.2.3 Stage 3 - Abstraction

Units of meaning were clustered, counted and sorted in a table to identify the most common units across the interviews. A total of 36 units were used more than once. Linking the holistic reflective analysis (stage 1) with the units of meaning (stage 2) led to the emergence of themes that appeared to be salient to each of the general themes identified in stage 1.

3.3.2.4 Stage 4 - Synthesis

With stages 1-3 completed for all interviewees, a meta-level analysis across the cases was conducted. The most commonly used units of meaning were identified. Both positive and negative forms of units were identified, suggesting a clear difference between two of the general themes identified in stage 1 (contradictory and big picture). The similarities between the remaining general themes were less clear,

resulting in a consolidation of the 2 themes, retitled ‘unclear’. This exercise ensured that only themes with strong representation throughout the texts were supported and included in the final list. The initial general themes of ‘contradictory’, ‘big picture’, and ‘unclear’ were substituted for ‘extrinsic’, ‘intrinsic’, and ‘conflicted’, based on the most commonly used units of meaning within each of these general themes.

3.3.2.5 Stage 5 – Illumination

Relationships between heavily represented themes were identified, creating 'links' between interviews (Easterby-Smith et al., 2002). This included both general and unique themes for all the interviews (Hycner, 1985). This stage of analysis involved a formal process of writing up a 'narrative account of the interplay between the interpretative activity of the researcher and the participant's account of their experience in their own words' (Smith and Eatough, 2006). Although the emphasis was on conveying shared experience, this process allows the unique nature of each participant's experience to re-emerge (Smith et al., 1999).

3.3.2.6 Stage 6 – Integration

To allow the data to ‘speak for itself’ (Cope, 2005b), salient themes were selected using the narrative representation presented in the results and findings section. This was done without the use of any academic literature, to maintain the phenomenological approach to the interpretative analysis.

Stage	2	3	4									5	6
	Understanding	**Abstraction**	**Synthesis**									**Illumination**	**Integration**
Interview	**1st Construct**	**2nd Construct/Similarities**	**Contradiction**	**Qty**	**Impressionable**	**Qty**	**Drifter**	**Qty**	**Big Picture**	**Qty**		Relationships	Themes List/Critique
A	Contradiction	Lack of Patience	Extrinsic Motivation	12	Anxiety	4	Creative	1	Appreciates Value	1	Extrinsic Motivation	Intrinsic Motivation	Motivation
A		Stubbornness	Lack of Empathy	2	Comparison to Others	1	Critical	1	Confident with Future	3	Lack of Empathy	Empathy	Empathy
A		Rebellious	Lack of Patience	2	Craves Direction/Advice	1	Easily Influenced	2	Conscientious	3	Lack of Patience	Conscientious	Patience
A		Needs Challenge	Needs Challenge	1	Intrinsic Motivation	4	Extrinsic Motivation	12	Dislikes Constraints/Standards	1	Self Absorption	Holistic View	Self/Others
A		Wants Autonomy	Over Confidence	2	Low Motivation	2	Indecisive	1	Empathy	5	Short Term Goals	Long Term Goals	Short/Long term Goals
A		Lack of Empathy	Rebellious/Stubborness	1	Low Self Efficacy	5	Lack of Focus	1	Focused	1	Over Confidence	Reflective	Confidence
A		Extrinsic Motivation	Self Absorption	2	Needs Feedback	2	Low Motivation	2	Holistic View	5			
A		Short Term Goals	Short Term Goals	1	Needs Structure	3	Low Self Efficacy	5	Long Term Goals	2			
A		Self Absorption	Skeptical	1	Overwhelmed	1	Prefers Absolutes	1	Reflective	5			
A		Over Confidence	Takes Leadership Role	2	Regret	1	Requires Support	1	Respects Leadership/Authority	4			
A		Extrinsic Motivation	Wants Autonomy	3	Values Security	5	Self Absorption	2	Responsible	3			
A		Takes Leadership Role											
B	Impressionable	Regret											
B		Anxiety											
B		Overwhelmed											
B		Comparison to Others											
B		Craves Direction/Advice											
B		Low Motivation											
B		Intrinsic Motivation											
B		Needs Structure											
B		Values Security											
B		Needs Feedback											
B		Low Self Efficacy											
C	Contradiction	Takes Leadership Role											
C		Lack of Patience											
C		Extrinsic Motivation											
C		Over Confidence											
C		Recognises Own Optimism											
C		Lack of Empathy											
C		Skeptical											
C		Status Driven											
D	Big Picture	Holistic View											
D		Empathy											
D		Respects Leadership/Authority											
D		Dislikes Constraints/Standards											
D		Desires Innovation											
D		World View											
D		Self Efficacy											
D		Content/Settled											
D		Thorough											
D		Relaxed											
D		Focused											
D		Long Term Goals											
D		Appreciates Value											
D		Good Time Management											
D		Responsible											

Figure 9: Example of IPA Process using interviews A - D

3.4 RESULTS

3.4.1 PRESENTATION OF RESULTS

This section reflects on the experiences and sense-making of the participants interviewed. Figure 9 provides an example of the IPA process using interview A to interview D. The table of second constructs, including all sub-themes and final themes derived from Figure 9 is available in Appendix C. Main findings and final themes are presented in a narrative form intended to give life to participants' stories. The final section of IPA is *"concerned with moving from the final themes to a write up and final statement outlining the meanings inherent in the participants' experience"* (Smith, 2008). Each theme is introduced and discussed, followed by quotes from the participants to support the themes. The results were then supported with the table of themes and their relationships. It is important to be clear about the distinction between participants' comments and the researcher's experience of the phenomenon under investigation (Willig, 2001). The description of themes using quotes gave insights into the rich findings of the initial set of data. Using interviewees' own words to illustrate themes has two functions, it enables the reader to assess the pertinence of the interpretations, and retains the voice of the participants (Pietkiewicz and Smith, 2012).

3.4.2 INTERPRETATIVE PHENOMENOLOGICAL ANALYSIS OF INTERVIEWS

The findings are presented in five themes: (1) Patience, (2) Empathy, (3) Confidence, (4) Egocentrism, and (5) Goals. The responses and resulting themes are presented as excerpts from throughout the interview, as a general theme was more prevalent than focusing on specific answers to specific questions. An overarching theme of motivation was identified as the main factor contributing to the decision-making of the undergraduates and is discussed further after presentation of the initial themes. 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 realising there may be a trade-off with extrinsic values to be a successful engineer).

Each theme generated extreme opposites as responses in most cases, and excepting the question specifically relating to ethical breaches and morals (Q18), narrative supporting each theme is presented hereafter.

3.4.2.1 Patience

***Patience - the capacity to accept or tolerate delay, problems, or suffering without becoming annoyed or anxious*.**

Pressure is identified as a leading contributor to creating an environment where deception may occur (Heuer, 1981). Students at any stage of their degree programs are subject to far greater time constraints and deadlines that they may have ever experienced prior to their enrolment as an undergraduate. Time or lack of it, and the different ways in which students choose to deal with pressure was evident throughout the interviews when it came to making decisions. There were no specific questions which heralded greater responses, however, an apparent 'feeling' of having little time, or regard for subject matters that did not concern them was distinct. The most significant difference was between the students identified as having strong extrinsic motives and strong intrinsic motives. Responses are labelled by de-identified interview labels.

3.4.2.1.1 Extrinsic Students Responses

'I realised that wasn't going to be a good career for me because I didn't have the patience to deal with children that perhaps didn't have the abilities that I did…'[A]

'It's all about now, what do I do next, what do I have to do now… I don't really have time to think about who influenced me…'[C]

3.4.2.1.2 Intrinsic Student Responses

'I think you've got to factor in that you'll have problems. You've got to spend time on certain things and they're not going to go the way you want them to go… "nature does not hurry, yet everything is accomplished" – Lao Tzu, this is my favourite quote…'[D]

'I find myself without thinking or being told that I'm in a position of leadership, it may just be the person I am but I find the management skills I have, I can apply to help other people complete a project to a certain quality or efficiency…'[F]

3.4.2.2 Empathy

Empathy - the ability to understand and share the feelings of another.

The ability to understand and appreciate the impact of your decision, and the consequences it may have on those other than yourself is critical in management, particularly in an environment of pressure and incentives. As Flyvbjerg (2009) suggested, deception is more likely to occur when incentives are misaligned. The ability to make a decision based on the consequence of others, in an environment of pressure is also a skill that is rarely practiced during an undergraduates' degree program. Creating a suitable culture within a team, to enhance the quality of decision making can often result on superior outcomes. The questions that resulted in the following responses were related to why *'they'* had chosen Civil Engineering as a course of study, and experiences they had with other students and peers which led them to the make the decisions they did about their education. Again, there were significant differences with students identified as having extrinsic and intrinsic motives throughout their entire interview.

3.4.2.2.1 Extrinsic Students Responses

'I've always wanted more, I don't like staying stagnant, and I don't like people who stay stagnant, it really bothers me…' [C]

'I'd never struggled academically so for them [the students] to suddenly not be able to, after doing something maybe 10 times, and still not be able to pick it up… I'd never experienced that myself…' [A]

3.4.2.2.2 Intrinsic Student Responses

'It isn't all about knowing the technical, sometimes it's just agreeing and knowing what decisions to make…' [Q]

'Imagine having engineers like that where you have people who really want to go outside of just the general engineering profession to try and grow… I feel like it

shouldn't be just through courses, like if you interacted with people like that you automatically grow an affinity towards those kinds of things… I think everyone in the [Icarus] program really wants to know more…' [D]

3.4.2.3 Confidence

Confidence - generally described as a state of being certain either that a hypothesis or prediction is correct or that a chosen course of action is the best or most effective. Self-confidence is having confidence in one's self.

Confidence levels varied amongst students in all three categories of extrinsic, intrinsic and unclear motives. Again, extreme opposite levels of confidence were identified, students either appeared to have a high level of confidence in their own abilities, or a distinct lack of confidence in their decisions and choices. Confidence levels are discussed further in the following section relating to the Future Self Scale. Over confidence, and low self-efficacy can both have detrimental effects on the quality of decisions made and must be addressed to allow lessons to be learned from experience, both in education and industry. The inability to learn lessons between projects creates a greater chance of delusion leading to project failure (Flyvbjerg, 2009). Again, these responses were identified throughout interviews, with no specific questions garnering specific responses.

3.4.2.3.1 Student Responses

'I've never struggled academically…' [A]

'I know where I am, I know what skills I've learned, I know what skills I've got…' [C]

'I go to one [lecture] and I just feel so lost and so overwhelmed that I decide not to go to the rest…' [B]

3.4.2.4 Egocentrism

Egocentrism - having or regarding the self or the individual as the center of all things: an egocentric philosophy that ignores social causes and having little or no regard for interests, beliefs, or attitudes other than one's own; self-centred: an egocentric person; egocentric demands upon the time and patience of others.

Whilst similar to empathy, and linked to time and patience, egocentrism is identified as an inhibitor to critical thinking development (Paul and Elder, 2005). Remarkably, the key responses identified as being linked to egocentrism were positive, and suggested a positive link to social identity as 'being an engineer'.

3.4.2.4.1 Extrinsic Students Responses

'People just don't have the same goals; I found there was a massive discrepancy between where people wanted to be… I get frustrated with people who've had a month to do one task which would take about 30 mins… I give them a final warning and then do the work for them and penalise them in their PAF' [A]

3.4.2.4.2 Intrinsic Student Responses

'I was interested to see what we could do in Civil Engineering that really makes a difference… in civil you can work on something big enough to make an impact…' [C]

'I want to be someone who can offer something to the profession rather than being someone who just follows the profession, who just follows the guidelines and the rules…' [C]

'It [group work] gives me a different perspective I guess like we're only students now but we still have ideas so having different team mates opens you up to their ideas…' [K]

3.4.2.5 Goals

Goal - the object of a person's ambition or effort; an aim or desired result.

'*My short term 5 year goal is set financially because that is what drives me and I find it's a good way to gauge success…' [C]*

'The goal at the moment is to get through the next course, and the next course. There's only so much you can make yourself learn…' [A]

'I realised that networking would probably help more than anything. If I get to know people that I can do jobs for, I could develop other skills afterwards…' [D]

'Because it's better in the long run, you have to think about the long run. You may get a crappy GPA but at least you'll have the knowledge about it…' [Q]

'The most useful thing for me would probably be learning for life…' [R]

3.4.2.6 Fourth Years' Responses

Based on the initial findings from the second Years' interviews, it was decided that fourth year students should also be interviewed to see if the themes identified above were any stronger or weaker by the time they were approaching the end of their program. Whilst the overarching themes were still apparent, they appeared more diluted and almost 'laid back' in their responses. The biggest finding from the fourth years' interviews was the following quote when asked to identify a moral issue. As with the second years, all students were able to identify a moral issue, but followed it with the excerpt below.

'Yes it's a problem… but it's not a big deal…' [ALL]

This was of particular interest to the researcher, based on the fact that they had not been prompted for their opinion, but were merely asked to identify an issue.

3.5 Discussion

3.5.1 Qualitative Findings

3.5.1.1 Interpretative Phenomenological Analysis

The responses from the second-year Icarus and Non-Icarus students would suggest that their decisions are driven by motivation. There was no notable difference between the responses of Icarus and Non-Icarus students in terms of more, or less, intrinsically or extrinsically driven 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 (chapter 4).

It was a consideration of the researcher that the responses of the fourth-year students, that the ethical dilemmas and moral issues identified during the interview we're *'not a big deal'* due to the dominant discourse identified throughout their

program of study. As identified whilst the researcher delivered the Project Management module CIVL3510, the subject of ethics is considered supplementary, and best placed as a module on a Project Management course. If the educators are uninformed of the concept and underlying values of ethical decision-making, then through dominant discourse, this message can form an availability bias amongst a thought-collective such as a group of engineering students. This notion is discussed further in chapter 5.

3.5.1.2 Future Self Analysis

In order to gain insight into the students' psychological connectedness to their future selves, a number of questions were included in the interview (Table 11) to establish a greater understanding.

Table 11: Questions related to Future Self Theory

1. *What aspect of your education is the most relevant to your future career expectations?*
2. *What is most important to you when considering future employment?*
3. *Where do you see yourself in 10 years' time?*
4. *If you were given to option of a class that you knew was an easy 7 or a class that was extremely difficult, yet relevant to your future career aspirations, which one would you choose and why?*
5. *If you were offered a role as an intern with a weekly salary of $500 a week or $400 a week and a bonus upon completion of the vacation work, which one would you choose and why?*

To accompany these questions, a set of Euler Circles (Figure 7) was used to assess the degree to which participants considered best represented how they felt about their future selves.

On a scale of 1-7; 1 being no connection with future self, and 7 being complete connection with future self, the first set of participants (second year Icarus and Non-Icarus participants) gave scores between 3 and 6. The average scores for both groups were 4.8 (n = 10) and 4.0 (n = 6) respectively, showing that Icarus students felt a greater psychological connectedness to their future selves. Answers to the Future Self questions substantiated these findings, showing a greater level of confidence (over confidence in the case of the 'contradictory' or 'extrinsically' motivated participants).

It was during the collection of this data that the researcher felt that the scores appeared high for a group of students in their second year of study on the Civil Engineering program. Based on the researcher's previous experience of high confidence, and low competency levels faced in industry, and during the delivery of the Project Management course (CIVL3510), a decision was made to interview students in their final semester to compare scores and interview responses.

The final year students who participated were recruited in the same manner as the initial group of participants; however, they had all previously enrolled and completed the Project Management course (CIVL3510) delivered by the researcher. Participant scores from final year students (n = 9) ranged from 2-7, with an average of 4.44. As with the second-year students, final year students' answers to the Future Self questions substantiated the scores. Whilst not displaying the same type of candid confidence, the high scoring group of 'extrinsically' motivated participants displayed a very laid back approach to their future and competency, which when coupled with their responses to moral and ethical dilemmas as *'not being a big deal'* gave the researcher some concern and led to a further review of literature focusing on motivation theories (chapter 4).

3.5.2 RESEARCH QUALITY

To ensure the quality and rigour of this qualitative research, broad principles were followed to address the validity and reliability with the same rigour applied to quantitative research.

Yardley (2008) presents four broad principles for assessing the quality of qualitative research to which this thesis adheres to by the methods presented below.

1. Sensitivity to Context
2. Commitment and Rigour
3. Transparency and Coherence
4. Impact and Importance

Because IPA recruits purposive samples of participants who share a particular lived experience, they can be more difficult to access than other kinds of samples and sustained engagement, in terms of establishing access or rapport, and is central to the very validity of an IPA project from the outset.

3.5.2.1 Sensitivity to Context

Sensitivity of context is demonstrated through an appreciation of the interactional nature of data collection within the interview situation (Yardley, 2008). This was achieved by the development of a robust interview protocol where the interviewer showed empathy and put the participant at ease to soften interactional difficulties. A good IPA study will always have a considerable number of verbatim extracts from the participants' material to support the argument being made, thus giving participants a voice in the project and allowing the reader to check the interpretations being made (Yardley, 2008). Sensitivity of context is also shown through the thoroughness of the literature review leading to the underpinning philosophical foundations and theoretical framework forming the basis for this research.

3.5.2.2 Commitment and Rigour

Commitment and rigour was confirmed by ensuring the participants were comfortable and attending closely to what the participant was saying, synonymous with a demonstration of sensitivity of context. This was was also achieved by drawing participants from an appropriate sample, developing the interview protocol to ensure quality questions, and following methodology guidelines provided by experienced IPA researchers Smith, Flowers and Larkin (2010). The sample was chosen carefully to match the research question and to be reasonably homogenous. A good IPA study tells the reader something important about the particular individual participants as well as something important about the themes they share (Yardley, 2008).

3.5.2.3 Transparency and Coherence

Transparency and coherence is validated by the presentation of the thesis. By providing a coherent and logical argument in the literature review, the methodology was able to be developed consistently with the underlying principles of IPA. Transparency was provided by presenting a detailed description of how participants were selected, how the interview schedule was constructed and the interview conducted, and what steps were used in analysis.

3.5.2.4 Impact and Importance

Finally, the impact and importance of the research is validated by the recognition of the work being a unique piece of research, as required for fulfilment of a Doctor of Philosophy degree.

3.5.2.5 Independent Audit

Yin (1989) suggests that one way of checking the validity of one's research report is to file all the data in such a way that somebody could follow the chain of evidence that leads from initial documentation through to the final report for example, an independent audit. An independent audit is required to ensure that the account produced is a credible one. The aim of the audit is not to produce a single report that claims to represent 'the truth', nor necessarily to reach a consensus. Instead the independent audit allows for the possibility of a number of legitimate accounts and the concern therefore is with how systematically and transparently this particular account has been produced (Yin, 1989). This is also achieved by the fulfilment of a Doctor of Philosophy degree.

3.5.3 RESEARCH LIMITATIONS

The study contains a number of limitations which should be acknowledged when considering the report's findings. Specific limitations linked to the use of IPA are the role of language, suitability of accounts and explanation versus description (Willig, 2001). As language is the means by which data is collected, a criticism of IPA is that 'language does not constitute the means by which we can express something we think or feel; rather language prescribes what we can think and feel' (Willig, 2001). It is therefore noted that the language does not always describe the entire experience. The suitability of the accounts denotes the ability to which a participant is able to provide a rich account of an experience.

A significant limitation of this study was the decision to use Interpretative Phenomenological Analysis (IPA) as a method of data analysis, after the collection of data. Whilst the method on which the interviews were designed, and protocol delivered, adhere to the practical guidelines of IPA, the order of which these steps took place should be acknowledged when considering the results of this study.

Other limitations associated with qualitative data collected are more general to

qualitative data collection. Firstly, all data was collected from a single institution. The effect of using only a single context is that there are several contextually specific variables and biases that limit the extent to which transfer to a broader audience are viable. These variables and biases, and their impacts are discussed further in chapters 4 and 5. Another limitation of this study was that participants self-selected to be part of the study. As a result, the participants in this study may not have been representative of the entire cohort or wider civil engineering community. In addition, participants in this section of the study were paid $5 for their time. While historically payment has not been the driving factor in student participants' decisions to take part in a study, it does need to be noted.

3.6 SUMMARY

This chapter has in the opinion of the researcher answered the following research question:

- ✓ ***RQ 1 - Which features and characteristics influence the decision-making of undergraduate civil engineers?***

Motivation; extrinsic, intrinsic, and a conflict between the two has been identified as the main theme impacting undergraduate decision-making. Themes of (1) Patience, (2) Empathy, (3) Confidence, (4) Egocentrism, and (5) Goals were identified as main contributors to undergraduate decision-making.

Chapter 4 introduces Self Determination Theory, a 'Meta-Theory' considering the interplay between extrinsic forces and intrinsic motives, and critical thinking, the process of analysing and assessing thinking with a view to improving it. This led to an investigation in to the intrinsic motivation levels of students, and how they are impacted by the extrinsic motives of traditional education. Levels of intrinsic motivation and critical thinking were then examined to understand the association and impact they can have on one another, and is the focus of chapter 4 which aimed to answer the following question:

RQ 2 - How do the learning environment and incentives affect decision-making in an educational environment?

4 IDENTIFYING THE IMPACT OF THE ENVIRONMENT

4.1 INTRODUCTION AND PURPOSE

This chapter introduces Self Determination Theory, a 'Meta-Theory' considering the interplay between extrinsic forces and intrinsic motives, and Critical Thinking, the process of analysing and assessing thinking with a view to improving it. In reviewing these concepts, the methodology for the second phase of the study was developed. The quantitative methodology involved the assessment of critical thinking levels, and survey of the intrinsic motivation levels of undergraduate students to gain insight in to the impact that extrinsic motives have on their motivation, and whether this impacted critical thinking ability.

The research design section defines the type of design, recruitment, and instrumentation used to collect the data. The subsequent sections describe the data collection, analysis, limitations, findings and validity. The successive chapter will combine and discuss findings and implications of both the qualitative and quantitative data, along with a summary of the mixed methods methodologies used in this exploratory research.

4.1.1 SELF DETERMINATION THEORY – A META THEORY

To be motivated means to *be moved* to do something (Ryan and Deci, 2000). Self Determination Theory (SDT) is a 'Meta-Theory' representing a broad framework of the study of human motivation and personality. People may appear to *be moved* by external (extrinsic) factors; for example, grades, evaluations, or even the opinions other people may have of them. It is less obvious, without probing, further evaluation, and the removal of existing subjective biases, to identify the internal intrinsic) motivators; for example, interest, curiosity, care and values. Self Determination Theory considers the interplay between extrinsic forces and intrinsic motives, and was therefore deemed the most appropriate theory for further investigation in this study. The fundamental premise of SDT is a focus on how social and cultural factors facilitate or undermine an individual's sense of choice and initiative (Ryan and Deci, 2000). Autonomy (self-directing freedom, and moral independence), Competence (the quality or state of being competent), and Relatedness (connected by reason of an established or discoverable relation), are considered central to high quality forms of motivation, including enhanced performance, persistence, and creativity.

Furthermore, SDT indicates a detrimental impact on wellness should any of these three psychological needs remain unsupported within a social context (Deci and Ryan, 2000).

SDT encompasses six 'mini-theories', which were individually developed to explain phenomena related to motivation. Each theory address one feature of motivation, or personality characteristic.

1. **Cognitive Evaluation Theory (CET)** – addresses the effects of social contexts on intrinsic motivation. (Deci, 1975)
2. **Organismic Integration Theory (OIT)** – addresses extrinsic motivation in its various *instrumental* forms; external regulation, identification, introjection, and integration; producing a continuum of *internalization.* The more internalized the extrinsic motivation, the more autonomous the behaviour of the individual. OIT suggests support for autonomy and relatedness are critical to internalization. (Deci and Ryan, 1985)
3. **Causality Orientations Theory (COT)** – describes differences in individuals' tendencies to regulate behaviour and lean towards specific environments. COT focuses on three types of causality: autonomy, control; and amotivated orientation, or the anxiety concerning competence. (Deci and Ryan, 1985)
4. **Basic Psychological Needs Theory (BPNT)** – argues that psychological well-being and optimal functioning is centered on autonomy, competency, and relatedness. BPNT also argues that all three needs are essential and if any are obstructed, optimal functioning will be in inhibited. (Deci and Ryan, 2000)
5. **Goal Contents Theory (GCT)** – addresses the distinction between intrinsic and extrinsic goals and their impact on motivation and wellness. Extrinsic goals are more likely associated with lower wellness and greater ill-being, and intrinsic goals are differentially associated with well-being. (Sheldon et al., 2004)
6. **Relationships Motivation Theory (RMT)** – concerns *relatedness,* the development and maintenance of close personal relationships, such as belonging to a group. Some amount of interaction is not only desirable, but in fact essential for well-being and adjustment. (Deci and Ryan, 2014).

4.1.2 CRITICAL THINKING

Critical thinking is being progressively cogitated in education due to the accelerating change and intensifying complexity of the world we live in. Students need to take charge of their own minds, to recognize their own deepest values, and to take action that contributes to the good of others (Paul and Elder, 2005).

Educators have long noted that school attendance and even academic success are no guarantee that a student will be an effective thinker in all situations (Willingham, 2008). Students who are able to think critically in one situation may not be able to apply the same type of thinking in another situation. Willingham (2008) argues that thought processes are intertwined with what is being thought about, for example, a student may have learned to estimate the answer to a math problem before beginning calculations as a way of checking the accuracy of their answer, but in a chemistry lab, the same student calculates the components of a compound without noticing that their estimates sum to more than 100 percent. Taken from the Critical Thinking Competency Standards Guide (Paul and Elder, 2005), Critical Thinking is defined as follows: *Critical thinking is the process of analysing and assessing thinking with a view to improving it. Critical thinking presupposes knowledge of the most basic structures in thinking (the elements of thought) and the most basic intellectual standards (universal intellectual standards). The key to the creative side of critical thinking (the actual improvement of thought) is in restructuring thinking as a result of analysing and effectively assessing it. (Paul and Elder, 2005)*

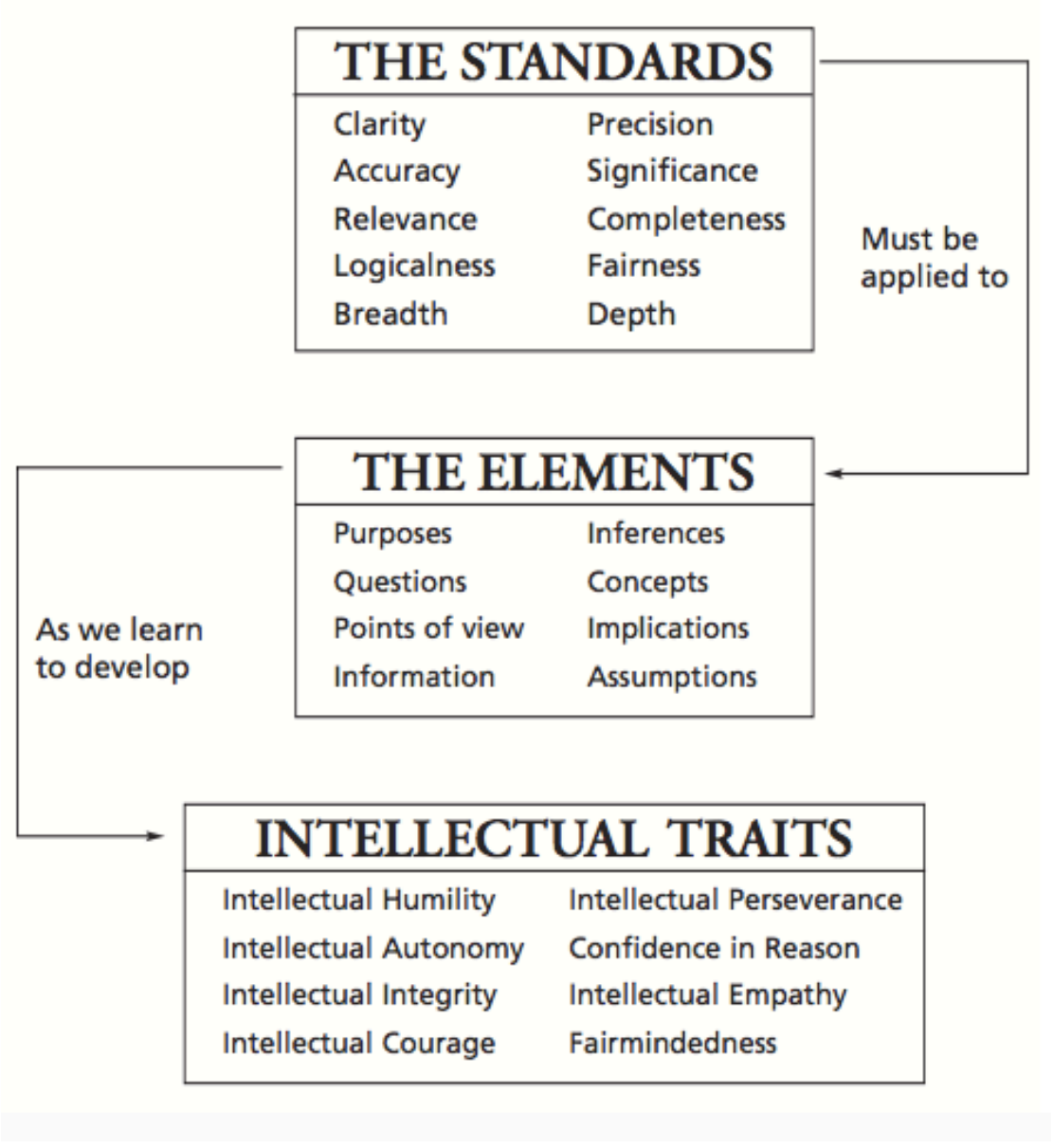
Paul and Elder (2005) also argue that it is possible to develop critical thinking skills within one or more content areas without developing critical thinking skills in general. They argue that critical thinking is a set of intellectual skills, abilities and dispositions, which leads to content mastery and deep learning whilst developing appreciation for reason and evidence. In developing a master rubric for critical thinking assessment in education, Paul and Elder (2005) presented three foundational sets of concepts to foster critical thinking (Figure 10):

1. All thinking can be analysed by identifying its *eight elements*
2. Thinking should be assessed for quality using *universal intellectual standards*
3. The ultimate goal of critical thinking is to foster the development of *intellectual traits or dipositions*

Paul and Elder (2005) also identified two overlapping and interrelated barriers to the development of thought, Egocentrism and Sociocentrism, defined as follows:

- **Egocentrism**, the natural tendancy to view everything within the world in relationship to oneself, to be self-centred (Webster's New World Dictionary).
- **Sociocentrism**, group egocentricity.

Figure 10: Foundational Sets of Concepts to Develop Critical Thinking



If students are to develop as thinkers, both students and educators must understand the barriers to the development of thinking embodied in egocentric and sociocentric thought, particularly where it relates to thought collectives and thought styles (Fleck, 1979) provided by the dominant discourse of engineering education.

4.1.3 INTELLECTUAL DEVELOPMENT

In the 1960's, an educational psychologist at Harvard University, William Perry, observed that students' attitudes toward the learning process varied considerably. In response, he developed the Perry Model of Intellectual Development (1970), consisting of a hierarchy of nine levels of intellectual development, grouped into four categories. Felder (1997) summarises the levels as follows:

1. **Dualism** *(Levels 1 & 2)* Knowledge is black and white and the authority is expected to have all the answers. Students at Level 1 believe their role is to memorise and repeat the correct solutions. Students at Level 2 begin to see that some questions may have multiple answers but they still believe one of them must be right.
2. **Multiplicity** *(Levels 3 & 4)* The questions may not have the answers now but the answers will eventually be known (Level 3) or responses to some (or most) questions may remain a matter of opinion (Level 4). Individuals at Levels 1 – 4 perceive knowledge to be externally and objectively based and perform tasks that are expected of them by authority (e.g. lecturer, tutor, examiner)
3. **Relativism** *(Levels 5 & 6)* Knowledge and values depend on context and individual perspective. Students use real evidence to reach and support their conclusions independently (Level 5). Students may feel inclined to use critical judgement to make and support their own decisions on a course of action, despite a lack of certainty (Level 6)
4. **Commitment within Relativism** *(Levels 7 – 9)* Individuals start to make actual commitments in personal direction and values (Level 7), evaluate the consequences and implications of their commitments and attempt to resolve conflicts (Level 8), and finally acknowledge that the conflicts may never be fully resolved and come to terms with the continuing struggle (Level 9).

Whilst comparisons can be drawn with Kohlberg's model of moral development (1958), Perry's model relates more to decision-making as opposed to Kohlberg's

model based on understanding. In both cases, levels of development relative to undergraduate students and beyond, form a basis by which to asses and gauge levels of moral and intellectual development in individuals.

Perry's model (1970) has been used to measure intellectual development in university students considering a number of variables; time at university, level of academic achievement, gender, and teacher expectations (Bateman and Donald, 1987); and the effects of a first-year engineering design course (Marra et. al., 2000). Both studies found that time at university, academic achievement, and gender were not significantly related to the Perry ratings. Marra et. al. (2000) qualitatively measured the intellectual development of students participating in a project-focused, active-learning course (ED&G 100) to those in the same cohort who did not take the class. Students spent time during class working in teams, interacting with their instructors in a student-coach type relationship. Students' semi-structured interviews were rated by an expert from the Center for the Study of Intellectual Development (CSID). Results showed that students who had taken the course showed higher levels of intellectual development after completing the course, compared to those who did not. Instructional methods used during the class included; emphasis on hands-on design activities, oral and written forms of communication, team work, in-class discussions, and solving ill-structured problems. Similar methods were applied during the development of the Icarus Program at the University of Queensland.

4.1.4 SUMMARY

Self Determination Theory (Ryan and Deci, 2000), Critical Thinking (Paul and Elder 2005; Halpern, 2010), and Intellectual Development (Perry, 1970), although complex and contested constructs within education, were considered an appropriate foundation framework upon which to develop the quantitative portion of this thesis. Based on the quantitative measures that already exist within each theory, the use of previously validated instrumentation provides quality and rigour to the exploratory study of this thesis.

4.2 RESEARCH DESIGN

A validated Critical Thinking test was chosen to investigate the levels of Critical Thinking ability in the two groups of participants. There are currently only two validated tests available to assess levels of Critical Thinking; The Watson Glaser

Critical Thinking Test (WGCT: Watson and Glaser, 1991), and the Halpern Critical Thinking Assessment (HCTA: Halpern, 2010). The HCTA was the chosen test for this study, and is further explained in section 4.2.3.1 under Instrumentation. As discussed in the previous chapter, Self Determination Theory (SDT) formed the basis for the selection of validated tests to be used to assess the impact of the environment on students' decision-making. A combination of existing surveys including; the Intrinsic Motivation Inventory (IMI: Ryan, 1982), and the Learning Climate Questionnaire (LCQ: Williams et al., 1994) were used to develop the final instrument used for data collection and is also explained in further detail in 4.2.3.3.

4.2.1 PARTICIPANTS

The participants in this section of the study were recruited from the original second year cohort who participated in the interview section of research in chapter 3. These participants had all been given the option of applying to participate in the inaugural Icarus Program. The control group for the study were recruited from a group of students who had participated in all 3 semesters of the Icarus program up to the point of testing. The comparable group were recruited from the remaining cohort and had no experience on the Icarus Program. Table 12 presents the demographic data for the participants involved in the quantitative section of the study.

Table 12: Demographic of Participants taking part in Quantitative Study

CT Test/IMI Survey	Total (n)	M (n)	F (n)	M (%)	F (%)
Cohort Total	261	198	63	76	24
Icarus*	64	33	31	52	48
Non Icarus*	197	165	32	84	16
Research Participants**	19	14	5	73	27
Total - Icarus	12	8	4	67	33
Total - Non Icarus	7	6	1	86	14
Previously Interviewed*** - Icarus	5	2	3	12	18
Previously Interviewed*** - Non Icarus	1	1	0	6	0
New Participants - Icarus*	6	5	1	8	2
New Participants - Non Icarus*	6	5	1	25	0.5

* % Group (Icarus/Non Icarus)

** % Participants (n=19)

*** % Previously Interviewed (n=17)

The male to female ratio of overall research participants is representative of the wider cohorts demographic. The Icarus Program attracted a higher number of female students, but Icarus Program interviewees were representative of the wider cohort. Non Icarus interviewees, whilst being lower in total, also had a much lower female representation. The original Icarus group (n = 64) was 25% of the wider cohort, showing that more Icarus students volunteered to participate in this study, which is reflected in the recruitment section (4.2.2), and further discussed in chapter 5.

4.2.2 RECRUITMENT

Due to the need to test the impact of the Icarus Program (for the purpose of this section is further referred to as the 'intervention') against the wider cohort, recruitment was conducted in two formats.

4.2.2.1 Recruiting Icarus Students

1) Students who had volunteered to be interviewed for the first stage of the study were approached first and asked to volunteer, as the opportunity to revisit their qualitative data and compare it to their test and survey results would provide the highest quality of data, and allow a thorough and robust investigation by the researcher. Students were not offered any compensation for participation at this stage. 5 of the original 17 students were available and volunteered to participate.
2) Icarus students who had not volunteered for an interview, but had participated in all three semesters of the program were approached next. 6 students volunteered to participate. Students had still not been offered any compensation for participation at this stage of recruitment.

4.2.2.2 Recruiting Non-Icarus Students

1) Students from the wider cohort were invited to volunteer to participate via an email (Appendix D) sent through the university's student/instructor communication portal 'Blackboard', by one of the timetabled lecturers. No volunteers came forward from this format. A different lecturer was approached and the researcher was invited to attend a lecture to carry out a brief presentation, explaining in the same amount of detail (as the Icarus volunteers, and subsequent email), the requirements and anticipated implications of the study. This also garnered no interest from students.

2) On a second visit to the same class during the same week, the researcher asked the students (a class of approx. 200) for suggestions as to what they would consider a reasonable reimbursement for an hour of their time to participate in the test and accompanying survey. Suggestions included $30, or a free meal/student union voucher to spend on campus. There were still no wider cohort volunteers at this stage.
3) After seeking ethics approval to provide financial compensation for their participation, a $20 student union voucher was offered during a third and final visit to the same class. The researcher also distributed volunteer forms, asking for the names of those who would be interested to know more about the study, but would prefer to speak with the researcher in person. From this effort, 15 students submitted their names and contact details, all of whom were subsequently contacted with details of the test date and conditions.
4) All participating Icarus students already recruited were offered the same financial compensation as the Non-Icarus students.

4.2.3 INSTRUMENTATION

The instrumentation used for this data collection was designed by the researcher based on the concepts discussed in the review of Critical Thinking literature (section 2.7.2), and Self Determination Theory (section 3.4). The full test and survey can be found in Appendix E.

4.2.3.1 Critical Thinking Assessment

Two validated measures of Critical Thinking (CT) Assessment were chosen as appropriate for testing levels within undergraduate students. Despite widespread agreement in higher education that critical thinking ability is required yet lacking, an agreement of existing definitions is also required. Two main deliberations exist: (1) CT is considered discipline specific and/or discipline general, and (2) CT is a set of skills, or a combination of skills resulting in a 'critical thinker'. To select the most appropriate method of testing for this study, a review of the Watson Glaser Critical Thinking Appraisal, and Halpern Critical Thinking Assessment (HCTA) was carried out based on the availability of test due to licensing agreements. The HCTA was chosen based on the availability of an online test, which was purchased and marked online, providing further validity and removing researcher bias from the scoring of the tests. It was also decided that a total critical thinking score would be given, as

opposed to a breakdown of scores within constructs, as an overall score would be sufficient and further research could evaluate constructs dependent on results. The HCTA tests ability in the following constructs; verbal reasoning, argument analysis, hypothesis testing, likelihood and uncertainty, and decision-making and problem solving. These five categories of the HCTA showed good correspondence with the second definition of critical thinking, most closely linked with the research objective of this study. The test consists of 20 descriptions of daily-life situations. Each situation has multiple questions, with multiple choice responses, relating to the amount of, and quality of information given in the statement. Pilot tests were carried out by the researcher and another academic to establish time taken to complete, and appropriateness of questions.

4.2.3.2 Measure of 'Delusion' or 'Optimism Bias'

To gain additional insight in to the phenomena of delusion, questions were developed by the researcher, and included both before, and after the critical thinking test to gain insight in to the participants' ability to; predict self-competency, and time taken to complete the test, and then estimate achieved competency and estimate the actual time taken to complete the test. Participants were asked to follow the instructions of the test and only turn the page when instructed to do so, by the text on each page, in order to gain true and insightful data. Below are examples of the questions developed to assess levels of 'delusion'.

Page 3 - QUESTION A

i. *How long do you think this test will take you to complete?*

ii. *What do you think your score will be:*

   a) *Below Average*

   b) *Average*

   c) *Above Average*

PLEASE COMPLETE THE ONLINE CRITICAL THINKING TEST (Turn page once test is complete)

Page 4 - QUESTION B

i. *How long did you take to complete the test?*

ii. *What do you think your score will be:*

a) *Below Average*

b) *Average*

c) *Above Average*

PLEASE GO TO THE NEXT PAGE AND COMPLETE THE SURVEY.

4.2.3.3 Intrinsic Motivation Inventory

The Intrinsic Motivation Inventory (IMI) is a validated multidimensional measurement device intended to assess participants' subjective experience related to a target activity in laboratory experiments. In this case the inventory was used to assess participants' experience in taking the Critical Thinking Test. The IMI has been used in several experiments related to intrinsic motivation and self-regulation (e.g., Ryan, 1982; Ryan, Mims & Koestner, 1983; Plant & Ryan, 1985; Ryan, Connell, & Plant, 1990; Ryan, Koestner & Deci, 1991; Deci, Eghrari, Patrick, & Leone, 1994). The instrument assesses participants' interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice while performing a given activity, thus yielding six subscale scores. A seventh subscale has recently been added to explore the experiences of relatedness, although the validity of this subscale has yet to be established. The tests used a Likert scale to establish students level of agreement with various statements relating to the constructs mentioned above.

4.2.3.4 Pilot Study

In order to test the appropriateness of the critical thinking test, and the time taken to complete the test and survey in its entirety, the researcher and another academic carried out the test and survey. It was concluded that one hour was sufficient time to complete the test and survey without causing undue pressure on the participants.

4.3 METHOD

4.3.1 DATA COLLECTION

Tests were conducted during week 12 of a 13-week semester, in order to gather responses during a similar time to interviews being conducted. As with the interviews, participants were briefed pre-test and asked to read and complete the 'Participant Information and Consent Form' if they were happy to proceed (Appendix F). All participants were happy to continue. A 'Research Participant Withdrawal of Consent Form' was also provided at this time, along with instructions on how to submit and withdraw their data from the study. 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 $20 voucher, were thanked for their time, and informed that a full debriefing session would be available 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.

4.3.2 DATA ANALYSIS

The data analysis methodology selected for this section of the study was determined once the data had been collected. Based on the exploratory nature of the research, it was suggested that the data be subject to multiple levels of analysis to determine its accuracy and statistical significance.

4.3.2.1 Measures

Table 11 contains the measures used in this study. The IMI assesses participants' interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice, and relatedness, while performing a given activity (in this study, the critical thinking test). The interest/enjoyment subscale is considered the self-report measure of intrinsic motivation; although the overall questionnaire is called the Intrinsic Motivation Inventory, it is only the one subscale that assesses intrinsic motivation. As a result, the interest/enjoyment construct has more items on it than the other constructs. The perceived choice and perceived competence concepts are positive predictors of both self-report and behavioral measures of intrinsic motivation, and pressure/tension is a negative predictor of

intrinsic motivation. Effort is a separate construct that is relevant to motivation, and the value/usefulness construct is used in internalisation studies (e.g., Deci et al, 1994), the idea being that people internalise and become self-regulating with respect to activities that they experience as useful or valuable for themselves. Finally, the relatedness subscale is used in studies having to do with interpersonal interactions, friendship formation.

The questionnaire for this part of the study was produced by consolidating existing surveys suggested by SDT for testing participants' constructs covering the last four constructs; subject impressions: describes thoughts and feelings you may have had regarding another person (Icarus mentor/Instructor/peers), text material: how you felt about the text, activity perception: participants experience with the task, and task evaluation: how you felt you performed on the task.

4.3.2.2 Mean and Statistical Analysis

The purpose of this study was to assess the level of critical thinking ability amongst Icarus and Non-Icarus students, and to identify measures of intrinsic motivation that are impacted or have an impact on critical thinking ability.

The quantitative data was analysed primarily using basic methods of means analysis to identify initial differences between overall scores of CT, IM, and DSO in the control group (Icarus) and uncontrolled group (wider cohort). The data was then processed through the Statistical Package for the Social Sciences (SPSS) to determine if there was any statistically significance in the results, and is discussed further in 4.6.5.

Table 13: Quantitative Instrumentation Measures

Test Scores	**Code**	**Intrinsic Motivation Constructs**	**Code**
Critical Thinking Ability	(CT)	Overall Intrinsic Motivation	(IM)
Delusion Score (Ability)	(DSA)	Interest and Enjoyment	(I/E)
Delusion Score (Time)	(DST)	Effort	(E)
Delusion Score (Overall)	(DSO)	Choice	(C)
		Competence	(Cm)
		Pressure and Tension	(P/T)
		Relatedness	(R)
		Value and Usefulness	(V/U)
		**Subject Impression*	*(SI)*
		**Task Evaluation*	*(TE)*
		**Text Material*	*(TM)*
		**Activity Perception*	*(AP)*

**Specific Questionnaires within the inventory suggested by SDT*

4.4 RESULTS

4.4.1 MEAN DIFFERENCES

Table 14 presents all mean differences measured during the study.

4.4.1.1 Critical Thinking Score and GPA

The Critical Thinking (CT) test was scored out of 100. The Icarus groups' mean CT score (m = 67.58, SD = 24.22) was higher than that of the Non-Icarus group (m = 61, SD = 27.82).

Table 14: Mean Differences from Main Scores (CT, IMI, DSO)

	Icarus (n = 12)		Non-Icarus (n = 7)	
Measure	Mean	SD	Mean	SD
GPA – Semester 1	4.80	0.92	5.15	1.42
GPA – Semester 2	4.94	1.18	5.05	0.96
GPA – Semester 3	5.03	1.04	5.41	1.05
GPA – Semester 4*	4.82	1.74	5.22	1.41
CT Score	67.58	24.22	61	27.82
IMI Score	264.6	24.12	245	48.91
Delusion Score Overall	0.294	1.64	-0.009	1.51
Delusion Score Ability	0.007	1.41	-0.013	1.10
Delusion Score Time	0.290	0.89	0.000	0.57

**Post-Intervention*

GPA for both groups was taken, per semester, from the beginning of program through to post-intervention (end of semester 4, completion of first full semester of Icarus Program). The Icarus group started with, and maintained a lower GPA before and after the intervention, despite having scored higher on the CT test (Figure 11).

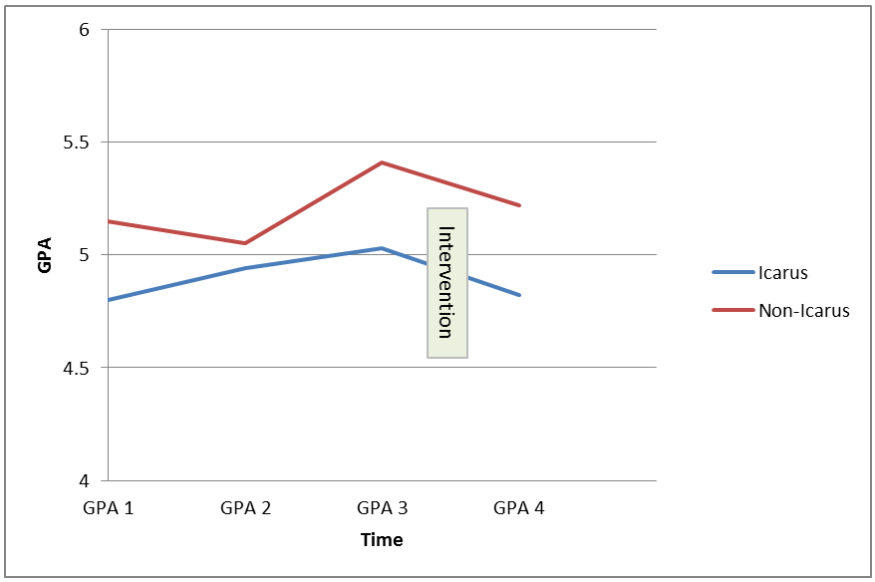


Figure 11: Mean GPAs for Icarus and Non-Icarus Groups from Start of BE Program

A drop in GPA was identified in both groups post-intervention meaning it was highly unlikely the intervention was the reason behind the lower GPA for the Icarus group.

4.4.1.2 Intrinsic Motivation Score

The Intrinsic Motivation Inventory (IMI) was scored using a Likert scale from 1 – 7, for a total of 72 statements, allowing a maximum score of 504. The IMI mean was also higher for the Icarus group (m = 264.6, SD = 24.12) in comparison to the Non-Icarus group (m = 245, SD = 48.91).

4.4.1.3 'Delusion' Score

The 'Delusion' score was determined by establishing the individual, overall scores' variance from 0. (>0 = overestimate ability and time, <0 = under estimate ability and time). The Icarus groups mean was higher (m = 0.294, SD = 1.64) than the Non-Icarus group (m = -0.009, SD = 1.51).

These scores alone were not considered significant when processed using SPSS. Table 16 presents a comparison of the main scores and their mean differences.

4.4.2 Descriptive Statistics

4.4.2.1 Critical Thinking Score

For both groups (Icarus and Non-Icarus) the critical thinking score was strongly and negatively correlated with 'delusion' scores independent of group. Pearson product-moment correlations were calculated to determine if associations existed between students' mean critical thinking scores and their mean delusional ability and mean

overall delusional overall scores. This was done separately for the Icarus and Non-icarus groups. As shown in Tables 15, for both student groups large-sized significant negative correlations existed between critical thinking and delusional ability scores (Icarus: r = -.94, p<.001; Non Icarus: r = -.95, p<.001) and critical thinking and overall delusional scores (Icarus: r = -.81, p<.01; Non Icarus: r = -.86, p<.05).

Table 15: Strong and Negative Correlation of 'Delusion' Score and Critical Thinking Score

Delusion and Critical Thinking Scores	***Icarus***	***Non-Icarus***	***All***
Ability	0.94, *p<.001*	0.95, *p<.001*	0.92, *p<.001*
Overall	0.81, *p<0.1*	0.86, *p<.05*	0.80, *p<.001*

4.4.2.2 Intrinsic Motivation Constructs

Although IMI scores were higher overall, and across constructs, only one measure produced a significant result. Paired samples t-tests were conducted to determine if there were any significant differences between the mean scores for the Icarus and non-icarus groups for 12 motivation measurements (as shown in Table 16). None of the motivation mean scores were found to be significantly different across groups at p<.05. Statements relating to Subject Impression (how they viewed their relationship with their mentor/instructor) showed a statistically significant difference in the Icarus group compared to those in the Non-Icarus group at p<.07. The score that was close to being statistically significant was relatedness, the construct linked to interpersonal interactions, friendship formation, and can be linked to the feelings of working with peers in a group environment. These two constructs are directly linked to relational activity, both within groups/teams, and the relationship with an instructor/mentor.

Table 16: Descriptive Statistics of Constructs within IMI

		Icarus (n = 12)		Non-Icarus (n = 7)	
Construct	Code	Mean	SD	Mean	SD
Interest & Enjoyment	(I/E)	51.42	12.738	48.00	15.078
Effort	(E)	19.75	6.703	17.14	3.761
Choice	(C)	75.08	5.977	73.43	5.740
Competence	(Cm)	20.83	4.589	19.71	6.576
Pressure & Tension	(P/T)	15.25	6.690	19.71	6.969
Relatedness	(R)	43.33	9.764	33.71	12.672
Value and Usefulness	(V/U)	38.92	4.814	33.29	14.162
***Subject Impression**	*(SI) p=.07*	63.08	12.588	50.86	14.542
***Task Evaluation**	*(TE)*	80.67	8.038	80.00	13.429
***Text Material**	*(TM)*	35.25	5.065	34.29	8.789
***Activity Perception**	*(AP)*	85.58	7.366	79.86	16.737

**Specific Questionnaires within the inventory*

Pearson product-moment correlations were calculated to determine if associations existed between all students' (collapsed across groups) mean relatedness, subject impressions and intrinsic motivation scores. There was a strong positive correlation of participants who thought highly of their mentor/instructor, and also related well with their peers; and vice versa, people who thought poorly of their mentor/instructor did not relate well to their peers (Figure 12). It is also important to note that the six respondents with the highest relatedness and subject impression scores are from the Icarus group, and had the most positive relationship (characterised by feelings of relatedness and positive impressions) with their mentor, suggesting that there was an overall more positive experience being had by students in the Icarus Program.

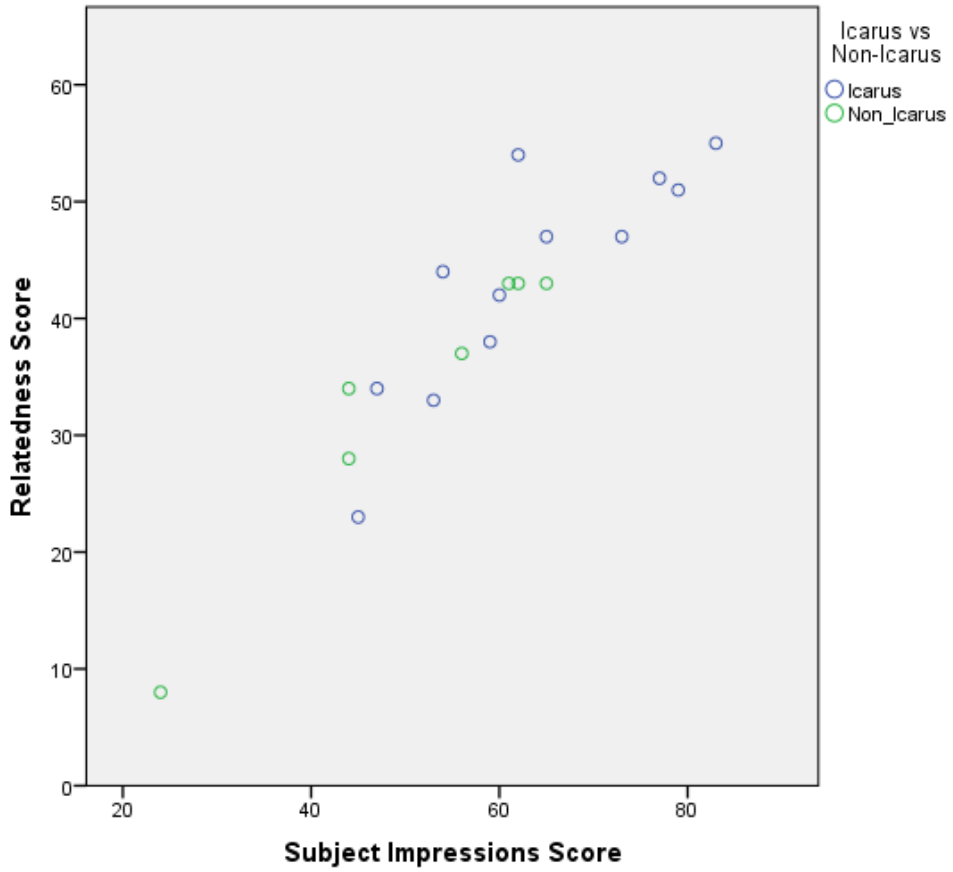


Figure 12: Scatterplot: Relatedness x Subject Impression Scores (r = .92) x Group

4.5 Discussion

4.5.1 Quantitative 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.

4.5.2 RESEARCH QUALITY

4.5.2.1 Internal and External Validity

To ensure the validity and reliability of the assessment instrumentation, the Critical Thinking Test (HCTA), and Intrinsic Motivation Inventory (IMI) were both selected based on their previous validation (4.2.3.1 and 4.2.3.3).

Due to the exploratory approach of this research, it was imperative to address the quality and rigour of the research design to both understand the results, and for future replication. Based on the work of McCall (1923), Campbell and Stanley (1963) examined the validity of a variety of experimental and quasi experimental designs, specifically focusing on education research, resulting in a list of 'threats' to the *internal* and *external validity* of experimental design in education research. *Internal validity* is the basic minimum without which any experiment is uninterpretable. *External validity* concerns the question of generalisability. Whilst alternatives to the nomenclature have been proposed; and further categorisation of the 'threats', including expansion of the framework exists (Mcmillan, 2000; Onwuegbuzie, 2000), the original list can be applied to this study to address the quality of research undertaken. Table 17 presents the 'threats' to any quantitative research design in the field of education.

The work of Campbell and Stanley (1963) was intended to address and suppress the sensed disillusionment with experimentation in education historically. Table 18 provides the methods of research design intended to address internal and external threats, with varying levels of control over the extraneous variables identified in table 17 (Campbell and Stanley, 1963). The quantitative research conducted in this thesis is identified as a Post-Test-Only Control group. A pre-test was considered unacceptable due to time constraints, and inappropriate at the time of commencing the Icarus Program in order to prevent participant bias.

Table 17: Internal and External Threats to Quantitative Research Design

Internal Threat	***Description***	***Control***
History	The specific events which occur between first and second measurement (in addition to experimental variable).	Both experienced the same current events.
Maturation	The processes within subjects which act as a function of the passage of time (not specific to particular events).	Both groups experienced the same developmental process.
Testing	The effects of taking a test on the outcomes of taking a second test.	N/A
Instrumentation	Changes in the instrument, observers, or scorers which may produce changes in outcomes.	N/A
Statistical Regression	The selection of subjects based on extreme scores or characteristics.	Subjects were generally equivalent at the beginning of the research.
Selection of Subjects	A bias which may result in the differential selection for the comparison of groups.	**^Subjects self-selected, which could affect validity.**
Experimental Mortality	Differential loss of respondents from the comparison group.	N/A
Selection-Maturation Interaction	The selection of comparison groups and maturation interacting, possibly leading to confounding outcomes, and erroneous interpretation that treatment caused effect.	N/A
External Threat	***Description***	
Reactive or Interaction Effect	A pre-test may increase/decrease a subjects' sensitivity or responsiveness to the experimental variable.	No pre-testing.
Interaction Effects of Selection Biases	The interaction effect of selection bias and the experimental variable.	**^Subjects self-selected, which could affect validity.**
Reactive Effects of Experimental Arrangements	Difficulty to generalise to non-experimental settings if the effect was attributable to the experimental arrangement of the research.	**^Would require main features of Icarus Program to be identified and replicated in other Schools of Engineering.**
Multiple Treatment Interference	Difficulty in controlling effects of prior treatments when multiple treatments given to same subjects.	N/A

^Discussed further in chapter 5 – Research Limitations

Table 18: Examples of Experimental Design in Education

Experimental Design	*Quasi Experimental Design*
One Shot Case Study	Time-Series Experiment
One Group Pre-Test/Post-Test	Equivalent Time-Samples
Static Group Comparison	Equivalent Materials
Pre-Test/Post-Test Control Group	Non-Equivalent Control Group
Solomon Four-Group	
Post-Test-Only Control Group	

The Post-Test-Only Group design compares the findings of a group in which a treatment was presented, to a group in which no treatment was presented. Unlike the Pre and Post Test Group Design, the Post-Test-Only Group does not *measure* the difference between the groups. In the case of this intervention (the Icarus Program), the Post-Test-Only Group design was appropriate for gaging *whether* there was an effect. A further critique of these threats, and experimental design is discussed in chapter 5.

4.5.2.2 Triangulation

"By combining multiple observers, theories, methods, and empirical materials, researchers can hope to overcome the weakness or implicit biases and the problems that come from the single-method, single-observer, single-theory studies. Often the purpose of triangulation in specific contexts is to obtain confirmation of findings through convergence of different perspectives. The point at which the perspectives converge is seen to be reality" – (Jakob, 2001)

Denzin (1978) defined methodological triangulation as *"the combination of methodologies in the study of the same phenomenon"*. Campbell and Fiske (1959) developed the idea of 'multi operationism' (the use of two or more measures to represent a construct), and argued that more than one method should be used in the validation process to ensure that the variance reflected that of the trait and not of the method. Therefore, the convergence or agreement between two methods *"enhances our belief that the results are valid and not a methodological artifiact"* (Bouchard, 1976).

Triangulation of the results from both the interviews and test/survey followed the initial analysis of data. By applying the main themes, and significant excerpts of the interviews, to the main findings (statistically significant, and noteworthy) of the test/survey, the process of triangulation allowed the researcher to capture a more

complete, holistic, and contextual portrayal of the participants experience throughout the study. By examining the phenomena from multiple perspectives, the researcher was able to enrich their own understanding, allowing a new, deeper dimension to develop from the data.

4.5.3 RESEARCH LIMITATIONS

4.5.3.1 Small Sample Sizes

Reliability of the data is also vulnerable due to the small sample sizes of the groups. The sample size and low response rate can result in response bias where “the responses do not accurately reflect the views of the sample and population” (Cresswell, 2005). This may limit the generalisability of the results. As the researcher was known to the group of participants from the previous data collection for this study, this may have influenced the decisions to participate in the second phase of data collection, through either a positive or negative experience from the initial data collection, and word of mouth within the cohort.

Quantitative research presumes a positivist world view, and emphasises the importance of generalisability and reliability. The aim of sample selection is to apply the relationship obtained amongst variables to the general population, which is why a selection of a sample representative of the population is essential (Karasar, 1999). Based on the exploratory nature of the research, and the difficulties experienced in recruiting participants, the reliability of the results put forward in this section of the thesis should be viewed alongside those qualitative results obtained in the previous section. A full discussion of the triangulation of results is given in chapter 5.

4.5.3.2 Recruitment and Self-Selection Issues

As with the interviews discussed in chapter 3, participants self-selected to be part of these tests. As a result, the participants in this study may not have been representative of the entire cohort or wider civil engineering community. It should be noted that both the enthusiasm and interest of the Icarus group to participate was in stark contrast to the issues faced during recruitment of the wider cohort (4.3.2). Whilst the recruitment process itself was an unofficially observed measure of intrinsic motivation by the researcher, the familiarity of the Icarus students with the researcher may also have encouraged participation in the test and survey. The overall impact of the Icarus Program on the students is discussed in chapter 5

In addition, participants in this section of the study were paid $20 for their time. While historically payment has not been the driving factor in student participants' decisions to take part in a study, it does need to be noted.

4.6 SUMMARY

This chapter has presented the quantitative results of the exploratory research carried out to contribute to the main research question:

What role can Engineering Education play in moderating delusional and deceptive decision-making behaviours in graduate Civil Engineers?

- ✓ ***RQ 2 - How do the learning environment and incentives affect decision-making in an educational environment?***

In chapter 3 motivation was identified as the main driving force behind the decision-making of undergraduate engineers. Further quantitative exploration has provided evidence that the Icarus program participants have a higher critical thinking ability, lower GPA, higher 'delusion score', and more positive relationships with their mentor/instructors and their peers. Further interpretation, a discussion of the theory explaining these results, and the implications this has for education and industry, is presented in the next chapter.

Chapter 5 answers the remaining research questions.

RQ 3 - How can engineering education enhance decision-making and moderate delusion and deception?

RQ 4 - What are the implications for industry?

5 DISCUSSION

5.1 INTRODUCTION

This research was motivated by the observations and experiences of the researcher whilst working on transport infrastructure megaprojects, and the comprehensive analysis of megaprojects by Bent Flyvbjerg (2003, 2007, 2009, 2014). Flyvbjerg inferred that the ultimate cause of megaproject failure is human behaviour, specifically delusion and deception (Flyvbjerg, 2009). Using the results presented in Chapter 3 and Chapter 4, this discussion chapter poses answers to the research questions underpinning this thesis to address the role that engineering education can play in moderating delusional and deceptive decision-making behaviours in graduate civil engineers, and the implications this has for industry:

RQ 1 - Which features and characteristics influence the decision-making of undergraduate civil engineers?

RQ 2 - How do the learning environment and incentives affect decision-making in an educational environment?

RQ 3 - How can engineering education enhance decision-making and moderate delusion and deception?

RQ 4 - What are the implications for industry?

These questions were raised to help inform engineering educators and engineering organisations, not only to raise awareness of the human behaviour that leads to delusion and deception, but also gain insight in to the environmental factors influencing quality decision-making, and to make recommendations for practical applications to enhance decision-making behaviour. Answers to RQ 1 were presented in Chapter 3 and gave insight in to fundamental decision-making behaviours, and sense-making of undergraduate civil engineers. By selecting Interpretative Phenomenological Analysis as the qualitative methodology, it was expected the interviews would deliver a sufficient quality of data, to allow further

investigation using quantitative methodology. The results of the interviews led to the development of a survey instrument to measure and validate the findings of the qualitative data source with quantitative analysis. A deliberate selection of validated instruments was used to put quantitative figures and findings to the exploratory qualitative data. The development of the survey instrument was central to answering RQ 2, and gave insight into the impact of the environment on an individual's decision making, the results of which were presented in Chapter 4. The remaining sections of this chapter discuss and interpret the results of Chapters 3 and 4 and provide further theoretical explanations of the most significant findings of this study. Understanding behavioural theory that elucidates the findings of RQ 1 and RQ 2 provides answers to RQ 3, and by translating these answers in to a megaproject environment, I develop a proposition in response to RQ 4.

5.2 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.

5.2.1 QUALITATIVE DATA ANALYSIS METHOD CHOICE POST-DATA COLLECTION

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. As mentioned in the limitations of chapter 3 (section 3.5.3) whilst the method on which the interviews were designed, and protocol delivered, adhere to the practical guidelines of IPA, the order of which these steps took place should be acknowledged when considering the results of this study.

5.2.2 THE POST-TEST-ONLY GROUP DESIGN

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 pretest 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). The same issue of sensitivity would have arisen if opting for pre-test/post-test interviews, and would have led to the use of an alternative qualitative methodology, thereby negating the quality and rigour achieved when using IPA. A pretest could have provided a *measure* of the variances found between groups and constructs, but the exploratory nature of the research meant that primarily the focus on *whether* variances existed was fundamental to the research design, and development of the instrumentation for this study and future work. The conditions under which this study was conducted were unique due to the concurrence of the research with the inauguration of the Icarus Program. The generalisability of this study would require the main features of the Icarus Program to be applied to other engineering schools, other disciplines, different environments (i.e. megaprojects), and geographical locations, to validate the instrumentation prior to developing a pre-test/post-test group design to *measure* variances in decision-making.

5.2.3 THE STUDY OF STUDENTS ONLY

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. Revisiting these students as working graduates, 5 and 10 years out from graduation, would be of enormous value, but would require a study that is not within the scope of this project.

The generalisability of this current study amongst individuals at varying levels, and with varying degrees of experience in megaprojects would create a different dataset with another set of extraneous variables requiring control and validity. As with the

longitudinal study, a study outside of the controls of an educational setting is not within the scope of this project, and is discussed further in section 5.4.

5.2.4 *Recruitment and Self-Selection*

Another limitation to this study occurred during the recruitment of participants, during both phases of data collection. The disproportionately low number of volunteers from the wider cohort should be noted. Whilst the low number of participants from the wider cohort can be interpreted as lower levels of intrinsic motivation amongst the group, a larger sample size would have been ideal, and may have contributed to greater statistical significance in the results. Self-selection bias was identified as a limitation, but also considered a finding and is discussed further in section 5.3. All participants were volunteers to both the interviews and the test/survey, and despite the Icarus Program having an application process, the self-selection of the students to apply for the Icarus Program, and/or volunteer to participate in the study, would differentiate them from the wider cohort, also implying the presence of non-response bias. An additional limitation during the recruitment of participants was the compensation for their participation. Whilst compensation did not appear to be a motivator for participation, the $5 payment for the interview, and $20 payment for completion of the test/survey was advertised upfront as part of the recruitment process. The impact of payment was not directly measured but should be noted.

Despite these limitations, the remainder of this chapter interprets the findings of the research conducted, to answer the questions set out at the inception of this study.

5.3 Answering the Research Questions

5.3.1 *Research Question 1: The Individual*

Which features and characteristics influence the decision-making of undergraduate civil engineers?

Participant responses to a range of questions both in and out of an educational context provided a source of decision-making data. As the interviews progressed, rapport with the interviewer and reflection on their answers allowed many of the participants to begin to make sense of their sense-making relating to the decisions they had made, and were going to make. This not only provided the researcher with

data about the decisions faced by civil engineering undergraduates, but also a deeper understanding of why they think they made/make the decisions they do.

5.3.1.1 Motivation

Chapter 3 presents the main themes emanating from participants' interviews and proposes that motivation is the main driver behind participants' decision-making. The main themes that contributed to this proposal were; patience, empathy, confidence, egocentrism, and goals. Participants were either extrinsically motivated, intrinsically motivated, or conflicted between intrinsic motivation and the extrinsic motives of traditional education and industry. The responses from both second and fourth year students suggested that their decisions are driven by both their internal motivation, and the impact of their learning environment, including incentives. This finding is consistent with achievement motivation theory (McClelland, 1961; Atkinson, 1968; Elliot, 1996). Achievement motivation can be defined as; *the need for success or the attainment of excellence. Individuals will satisfy their needs through different means, and are driven to succeed for varying reasons both internal and external (Rabideau, 2005)*.

The effect of *achievement motivation* on decision-making behaviour is an interaction between situational variables and the individual subject's motivation to achieve. Implicit and explicit motives will directly affect behaviour, and both are stimulated by incentives. Implicit motives induce a spontaneous impulse to act, generally aroused by incentives inherent to the task, whilst explicit motives are deliberate choices driven by extrinsic reason (Rabideau, 2005). Individuals with strong implicit needs to achieve goals set higher internal standards, whereas others tend to follow societal norms. These two motives often work together to determine the behaviour of the individual in direction and passion (Brunstein & Maier, 2005).

When asked to describe why they had chosen a Civil Engineering Program at the University of Queensland, all students responded with *'because it's the best…'* and/or *'I got a high OP and the other universities OP requirements were lower'* (OP – Overall Position, a tertiary education entrance rank awarded by the Queensland Education System for selection in to Universities). The need to achieve was consistent throughout the participant responses, regardless of the type of motivation identified during data analysis. The variation between participants' responses did emerge when questioned about future achievements i.e. goals. These questions

provided the researcher with a deeper understanding of drivers of decisions with future consequences.

Achievement goals affect achievement related attitudes and behaviour consistent with the other themes identified during analysis of the interviews (patience, empathy, confidence, and egocentrism). Achievement-related attitude can be described as task-involvement or ego-involvement; task-involvement being a desire to acquire skills or understanding, and ego-involvement being the need to demonstrate superior ability. Both can affect the way an individual performs a task and represent a desire to show competence in the classroom (Butler, 1999; Harackiewicz et al.,1997).

5.3.1.2 Representative and Availability Heuristic

Both second year and fourth year students were able to identify a moral issue, when asked to do so. Fourth year participants consistently followed their responses with, '*but it's not a big deal'*. The traditional civil engineering program at the University of Queensland (UQ) provides limited opportunities for students to explore the concepts of risk, uncertainty, and ambiguity, and the societal and economic consequences of decision-making. The addition of further technical courses has resulted in a lack of opportunity for dialogue around these concepts throughout the program, and provides a barrier to students' intellectual development. By ignoring these concepts, the program is reinforcing both representative and availability heuristics in graduating civil engineers. Consequently, upon reaching the end of the program, a graduating civil engineer, supported by the dominant discourse of peers and faculty, has developed heuristics confirming that society and the economy do not form part of their responsibility. By focusing heavily on technical competence, students are less able to develop critical thinking skills concerning future societal and economic consequences of their decision-making.

5.3.1.3 Summary

In conclusion, 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.

Flyvbjerg (2009) suggested delusion occurs on megaprojects due to an inability to learn lessons. 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. The conclusions drawn from the qualitative data resulted in further investigation to determine the impact that incentives (Flyvbjerg's main contributing factor to deception) had on participants' motivation.

5.3.2 RESEARCH QUESTION 2: THE ENVIRONMENT

How do the learning environment and incentives affect decision-making in an educational environment?

The validated instrumentation used to measure the influence of the Icarus Program was selected purposely, to substantiate, and quantify the findings of the previous interviews. The test and survey were designed to assess individual levels of; critical thinking, 'delusion', and intrinsic motivation, and identify any relationships, within, and between the constructs. For the purpose of this study the Icarus Program was considered an intervention, providing a change in learning environment, whilst removing incentives. The program was co-curricular and offered no academic credit.

Measuring critical thinking ability in participants was an important part of the research, to gain insight into how participants responded to complexity and ambiguity when faced with information of varying detail and quality whilst being required to make a decision based on the information available. A 'delusion' score was devised to measure the participants' accuracy in their perceived level of competence, and their awareness of duration and time taken to complete a task. Measuring levels of intrinsic motivation and associated constructs, made it possible to assess whether the intervention of the Icarus Program was having an impact on participants' motivation. Three main relationships; motivation and recruitment, critical thinking/grade point average (GPA)/'delusion' score, and relational constructs, are identified within the results, each of which is discussed on its own merits, leading to an overall conclusion.

Triangulation of both data sets enriched the most significant findings of the study, and provided a holistic interpretation, and contextual description of the overall findings.

5.3.2.1 Intrinsic Motivation and Recruitment of Participants

The first relationship identified is between intrinsic motivation levels and recruitment. Whilst the interviews did not suggest a difference between the Icarus Program and

wider cohort in respect to the spread of extrinsic, intrinsic, and conflicted participants, survey results did show a higher average mean intrinsic score for the treatment group (The Icarus Program Intervention).

Although this result was not statistically significant, when combining this with the issues faced during recruitment throughout the study, it was clear that the treatment group had a greater interest in taking part. For both the interviews and the test/survey the researcher had to cap the number of Icarus students wanting to volunteer to participate in the study. Though an extrinsic reward was offered for both, in the case of the test/survey the reward was offered after recruitment of the control group participants had closed, and required negotiation with those interested in participating from the wider cohort. Even then, the number of students offering to participate was far less than the treatment group, and was further reduced on the actual day of data collection with many of the students who had signed up from the wider cohort, deciding (without informing the researcher) not to attend the test/survey. This suggested that students from the wider cohort were less willing to participate in something if there was no need for them to do so, regardless of a monetary incentive or personal benefit. Whilst the reward of money was not a motivator, the lack of a more relative reward (academic credit) could be viewed as a possible deterrent to both volunteering to participate in the study, and enrolling in the Icarus Program.

These findings are consistent with Cognitive Evaluation Theory (CET), a sub-theory of Self Determination Theory (Deci and Ryan, 1985). CET focuses specifically on the external consequences of internal motivation. Deci and Ryan (1985) argued that the following three key points would impact an individuals intrinsic motivation;

1. *The notion that an event (participation in an experiment) could enhance or diminish perceived competence, will increase or decrease intrinsic motivation respectively.*
2. *Events initiating and regulating behaviour each have features, with a function affecting intrinsic motivation;*
    i. *Information enables an internal perceived locus of causality (a person's perception of the cause of success or failure) and perceived competence, positively influencing intrinsic motivation.*

ii. *Controlling enables an external perceived locus of causality, negatively influencing intrinsic motivation and increasing extrinsic compliance or defiance.*

iii. *Apathy enables perceived incompetence, undermining intrinsic motivation while promoting disinterest in the task.*

(Note - The relative prominence and strength of these three aspects to a person determines the functional significance of the event.)

3. *Personal events and external events are alike insofar as they both have differing functions. Information enables self-determined functioning, and maintains or enhances intrinsic motivation. Control creates pressure, therefore undermining intrinsic motivation. Apathy promotes incompetence, also undermining intrinsic motivation.*

During recruitment for both the interviews and the test/survey, not only was the premise for both volunteer opportunities unrelated to a familiar course of study within the engineering degree program, but the students were also given a very brief description of the intended research, to control participant bias. It is therefore suggested that students felt diminished perceived competence with the event, resulting in an absence of intrinsic motivation, and apathy towards participation in the study. Students may have also felt that they had nothing to contribute, particularly if their level of intellectual development was not advanced, resulting in an absence of agency, which would not be unusual in a group of second year students.

5.3.2.2 Critical Thinking Score/GPA/'Delusion' Score

Alongside having a higher intrinsic motivation score, the Icarus participants had a higher average mean critical thinking score, whilst showing a consistently lower GPA before, during, and after the intervention. There were no correlations with critical thinking score and GPA, either positive or negative, suggesting that critical thinking ability is not linked to GPA within this group of students. This is inconsistent with the *belief* that higher GPA results in higher levels of critical thinking ability, but is supported by the results of Gadzella et al. (2002), and Schwanz and McIlreacy (2015). Both studies found no relationship between GPA and Critical Thinking scores.

Another relationship with critical thinking that produced a strong negative correlation, independent of group, was the 'delusion' score. The 'delusion' score was designed to measure variance between the participants anticipated critical thinking score, their

actual score, and their perceived performance after taking the test. Independently, the groups scores produced vastly different findings. The Icarus groups 'delusion' scores were considerably varied, suggesting that the students were unsure of their abilities, both before and after the test. In stark contrast, the wider cohort group showed no variance at all, despite a wide range of actual critical thinking scores. All wider cohort students (except one), anticipated and perceived their ability as being average (the one student went from average to below average). This would suggest that the Icarus group not only had a higher mean average critical thinking score, but also demonstrated critical thinking about their own abilities. Whether the students were correct or incorrect in their perceptions, they were reflecting and thinking about themselves, in comparison to the wider cohort group who demonstrated no sign of reflection. It is for this reason that the 'delusion' score is quoted, as the researcher considers the 'delusion' score is in fact an additional measure of critical thinking.

This finding is consistent with outcomes of Krebber (1998), who found a relationship between critical thinking ability and self-directed learning. *Individuation* is the process of becoming aware of oneself (Jung, 1971). It was argued by Jung (1971) that functions that are not developed consciously through daily usage 'remain in a more-or-less primitive infantile state, often only half conscious, or even quite unconscious'. The process of *individuation* suggests that formerly unconscious psychological functions i.e. reflection, intuition, and logical reasoning, are further developed and differentiated by self-directed learning. The result of *individuation* is a more complete, and more mature personality, and an increase in personal effectiveness. It is suggested that *individuation* led to the greater variance in 'delusion' scores in the Icarus Program participants, as a result of the self-directed and experiential learning of the program.

5.3.2.3 Relational Constructs

The only construct within the Intrinsic Motivation Inventory that produced statistically significant results was 'Relatedness' (feelings of interpersonal interactions, friendship formation, and working with peers in a group environment). 'Subject Impressions' (how participants viewed their relationship with their mentor/instructor) showed a stronger variance than other intrinsic constructs, and scores for these relational constructs were also strongly, positively correlated. These scores suggest that the Icarus group were having a more positive experience with their mentor/instructor, and peers, than the wider cohort. It is not clear from these results which construct is

responsible for the other, but the results are consistent with the overall higher level of Intrinsic Motivation. It should be noted that the relatedness construct is the only construct within the inventory that has not been validated.

The degree of cohesion between these three relationships has educational significance, however, it is not clear from the results that the Icarus Program has had an impact on critical thinking scores, delusion, or intrinsic motivation. For this reason, it is suggested that the Icarus program appears to have brought together a group of students seeking, and benefiting from specific leadership (Subject Impression) and culture (Relatedness) qualities from their education experience, who have higher critical thinking ability, and intrinsic motivation. These findings are consistent with Self Determination Theory (Ryan and Deci, 2000), and supported by Beachboard and Beachboard (2010) who found an increase in educational outcomes, including literacy, critical thinking, and job preparation, in learning communities similar to that of the Icarus Program within higher education. In the case of the Icarus Program intervention, the social and cultural factors of the Program have supported the individuals' intrinsic motivation, and critical thinking skills, resulting in 'higher order' decision-making skills.

5.3.2.4 Summary

In conclusion, 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. By creating opportunities to enhance intuition and logical reasoning, providing a learning environment comparable to the Icarus Program will moderate delusional decision-making behaviour, and reduce the likelihood of vulnerability to deceptive decision-making behaviour.

5.3.3 Research Question 3: The Future for Education

How can engineering education enhance decision-making and moderate delusion and deception?

From the answers to RQ 1 and RQ2 we can deduce the following two statements;

1) *The traditional civil engineering curriculum creates barriers to intellectual development and critical thinking.*

2) *The Icarus Program provides a space for higher level critical thinking, and intrinsic motivation.*

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. By presenting the individual factors fundamental to the Icarus Program, it is possible to evaluate the effects of the distinctive elements contributing to the outcomes of RQ1 and RQ2.

5.3.3.1 Traditional Education and Extrinsic Motivation

Traditional learning settings provide an environment of; external controls, close supervision, monitoring, and evaluations, accompanied by rewards or punishments, to ensure that learning occurs. Under such controlling conditions, the feelings of joy, enthusiasm, and interest that once accompanied learning are frequently replaced by experiences of anxiety, boredom, or alienation (Niemiec et al., 2009). Intrinsically motivated individuals explore, and engage, in activities for the inherent challenge, and excitement of doing the activity. These behaviours have an *internal perceived locus of causality*, meaning the behaviours are experienced as originating from the self as opposed to external sources (DeCharms, 1968). An *internal perceived locus of causality* is supplemented by feelings of curiosity and interest, making it a paradigm of autonomous functioning, and crucial to an individual's inherent tendencies to learn and develop (Deci and Ryan, 1985; Flavell, 1999). Decreasing levels of autonomy can lead to externalisation of *perceived locus of causality*. Eliminating autonomy, and externalising a *perceived locus of causality* therefore contributes to the inability to relate the consequence of a decision to oneself, removing implied responsibility and potential accountability especially if the decision is affiliated with an extrinsic reward. Intellectual autonomy is required to develop the

traits and disposition required to think critically (Paul and Elder, 2005). A lack of autonomy in traditional education delivery is obstructing critical thinking development, and if critical thinking is inhibited amongst a thought collective such as a civil engineering cohort (inclusive of faculty) then the dominant discourse can only reinforce the level of thinking achieved and in turn becomes self-fulfilling.

It is important to note that higher education teaching practices have become controlling, rather than autonomy supportive, due to the external pressures placed on educators. Educators experiencing control by extrinsic rewards structures are less likely to support autonomous teaching practice, as their own levels of autonomy are compromised.

5.3.3.2 The Icarus Program and Intrinsic Motivation

The most significant finding of the study was the impact of the Icarus Program on participants' feelings of relatedness to their peers, which was both strongly and positively correlated with the relationship they had with their mentor/instructor. Self Determination Theory (SDT) suggests that relatedness facilitates the process of internalisation. Relatedness is deeply associated with students feeling that their instructor genuinely likes, respects, and values them, and students who report such relatedness are more likely to identify and integrate the regulation involved in learning (Niemiec et al., 2009).

Autonomy and relatedness were the two main features of the Icarus Program. Students arranged themselves in to self-selecting groups, and were presented with the research objectives of the mentors. From this group development, students worked to determine the methodologies used to deliver the outcomes imagined by the mentors. This autonomous approach, and the relatedness that ensued are believed to be the main contributing factors to increased levels of intrinsic motivation amongst the Icarus Participants. Relatedness, and the experiential learning of applied research methodology, are also believed to be a contributing factor to the higher levels of critical thinking achieved within the group.

Competence is the final construct SDT considers crucial to the psychological needs of students for their internalisation of academic motivation. Whilst the results from the Icarus group were so varied that they did not confirm a consistent high level of perceived competence, they did suggest that students had internalised their response through individuation, as opposed to the wider cohort group who did not demonstrate this behaviour.

5.3.3.3 Recommendations

The fundamental principles of the Icarus Program have created an intrinsically motivated environment, enhancing the internalisation 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.

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. Table 19 presents examples of the fundamental

features of purpose, autonomy, and relatedness, that can be introduced to a course or program to increase intrinsic motivation in students.

Table 19: Examples of Strategy to Increase Intrinsic Motivation in Students

Key Feature	Examples to Increase Intrinsic Motivation
Purpose	▪ Asking students why they are taking a course, and what they expect to achieve from the course. ▪ Revisiting the above question throughout the course. ▪ Provide rationale behind the value of learning objectives.
Autonomy	▪ Offer elective subjects. ▪ Articulate fewer directives and fewer solutions. ▪ Ask students how they are going to learn the material. ▪ Ask students how they are going to demonstrate that they have learnt the material.
Relatedness	▪ Small group work. ▪ Self-selected groups. ▪ Option to self-select group or randomised/purposeful selection by instructor.

Ongoing monitoring of intrinsic motivation levels and critical thinking ability, will allow academics to evaluate, and measure the impact of changes made to their courses, whilst providing feedback to students about the development of their decision-making skills.

5.3.4 *Research Question 4: The Future for Industry*

What are the implications for industry?

Flyvbjerg (2009) inferred that the likelihood of delusion and deception occurring in a megaproject environment can be attributed to; the learning environment (the ability to learn lessons based on the frequency of its occurrence), and incentives (the [mis]alignment of incentives and principal-agent relationships). By applying the main findings of this study to a megaproject environment, recommendations can be made to deliver superior megaproject performance outcomes.

Flyvbjerg (2014) suggested that the scale and frequency of megaprojects is driven by the Four Sublimes; technological, political, economic, and aesthetic (Table 1). Whilst Flyvbjerg suggests that these 'sublimes' negatively impact the delivery of megaprojects, focusing on the primary motivators behind each 'sublime' provides opportunities to make fundamental changes to enhance decision-making. Flyvbjerg (2003b) gave suggested explanations to the cost overruns experienced on megaprojects; technical, political, economic, and psychological. Linking these

explanations to the drivers of megaprojects, and their motivations will provide further opportunity to harness the motivation of engineers, and moderate the external motives contemporaneous with megaproject delivery.

5.3.4.1 The Ability to Learn Lessons

The technological and aesthetic sublimes described by Flyvbjerg (2014) are consistent with intrinsic motivation. The 'excitement' engineers experience, and the 'pleasure' designers, and those appreciative of good design experience from megaprojects throughout the lifecycle, are essential to the psychological needs of the individuals involved in, and end-users of the infrastructure. The technical and psychological explanations suggested by Flyvbjerg (2003b) focus on inflexibility, accountability, and control. These explanations are consistent with the cognitive biases posited by Behavioural Decision Theory, however, the 'human nature' aspect of cognitive biases makes mitigation techniques onerous. Self-awareness is a method of detection of cognitive biases, and this would require education, training and monitoring by an expert. In parallel, enhancing intrinsic motivation will also provide a prime environment to develop critical thinking. Purpose, autonomy, relatedness and competence are fundamental to intrinsic motivation, and the internalisation of education and learning (Niemiec et al., 2009). Leadership and culture are critical factors in cultivating an environment that will enhance all three of these psychological needs. Providing an intrinsically motivated work environment will ultimately lead to individual psychological well-being, and internalisation during decision-making, resulting in greater reflection and an ability to learn from previous experiences. Providing a culture of autonomy and relatedness may not appear of importance to a technically focused individual; and suitable education, training, and supervision may be necessary to enhance the emotional intelligence of suitable managers. Developing the intrinsic motivation of project participants by creating and maintaining a culture of inclusion and reflection will not only increase the quality of decision-making, but regular reflection and feedback will improve the ability to learn lessons from recent behaviours.

5.3.4.2 Incentives and the Metrics of Success

The political and economic sublimes described by Flyvbjerg (2014) are consistent with extrinsic motivation. The 'visibility' generated by megaprojects for politicians, to the public and media results in the 'reward' (or 'punishment') of support (or disapproval) and can impact the future success of politicians and their parties.

‘Making lots of money’ is a measure of success for individual stakeholders, whereas ‘cost overruns’ are associated with project failure. The political and economic explanations given by Flyvbjerg (2003b), of personal gain, bureaucracy, principal/agent relationships, and rational choice theory, are consistent with the Fraud Triangle Theory (Cressey, 1973). Cressey argued that three factors must be present for fraud to take place; pressure, opportunity, and rationalisation. Whilst fraud may be considered a strong term, and implies a level of legal obligation, it can be substituted for the term ‘strategic misrepresentation’ which also suggests deliberate behaviour. Pressure is experienced through the budget and time constraints placed on project stakeholders during the planning and delivery of megaprojects. Opportunity is created by the complexity and misalignment of principal-agent relationships, and can often be concealed and even stimulated by bureaucracy. Rationalisation is a fundamental cognitive bias, and will ultimately influence the behaviour that ensues. As mentioned previously, mitigating cognitive bias can only be achieved through detection, reflection, and self-awareness. To mitigate the effects of pressure and opportunity, the metrics used to determine levels of success, and the organisational structure can be reformed to transfer extrinsic motives to a more intrinsic environment. Forming a relational procurement and contracting method is more proactive and collaborative and will create an environment of autonomy and relatedness. In turn a relational environment will develop intrinsic motivation amongst project participants, resulting in critical thinking development, internalisation, and the self-awareness, detection and reflection required to enhance quality decision-making.

5.3.4.3 Recommendations

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.

Table 20: The Role of a Behavioural Economist on Megaprojects

Key Responsibilities of a Behavioural Economist on Megaprojects
▪ Advocate for the needs of the individuals involved in a megaproject, identifying and monitoring levels of motivation across project participants, and stakeholders; identifying, promoting, and evaluating initiatives to foster intrinsic motivation.
▪ Collect and analyse data and intelligence on project progress, and present to the project leadership team on a regular basis to create a loop of cognisance.
▪ Assess levels of critical thinking and cognitive biases, and recommend and provide suitable programs to promote self-awareness, and professional and intellectual development.
▪ Provide a bias check, by introducing a polemicist role minimising susceptibility to delusion and deception.

5.4 Contribution and Future Work

5.4.1 Contribution to Theory and Practice

5.4.1.1 Theory

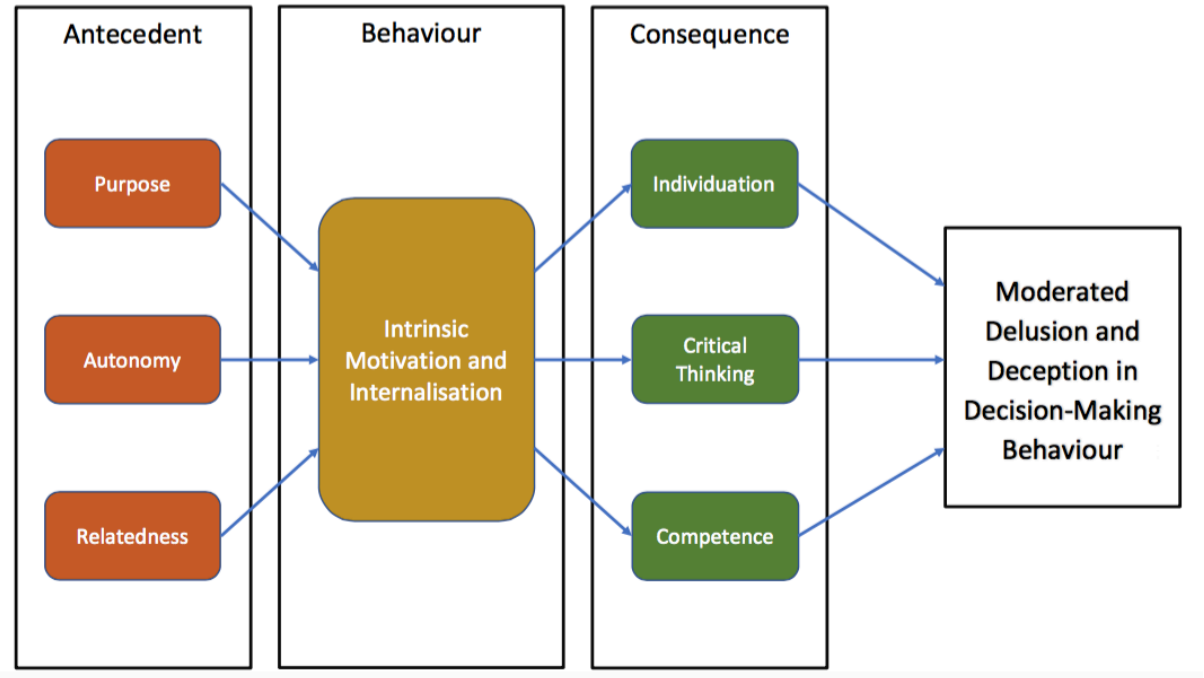
The theoretical contributions of this research are linked to Self-Determination Theory, concerning the interplay between extrinsic forces, and intrinsic motivation;

and Behavioural Decision Theory, predicting the behaviour of an individual at various levels, in an organisation, group, or group within and organisation.

By using the Antecedent-Behaviour-Consequence (ABC) model from the work of Skinner (1938) on operant conditioning, it is possible to illustrate the integration of the two theories. A model of Self-Determined Decision-Making Behaviour can be used to diagrammatically explain the interaction between the learning environment, and the impact it can have on an individual's decision-making behaviour.

Whilst figure 13 captures the findings of this study, further research is required to understand the specific relationships between antecedent, behaviour, and consequence to deliver a more well-rounded approach to creating an environment capable of enhancing levels of intrinsic motivation.

Figure 13: ABC Model of Moderated Delusion and Deception in Decision-Making Behaviour



5.4.1.2 Practice

The contribution to practice from this research, in both academia and industry, is the development of a tool to assess factors impacting delusion and deception in decision-making. Though validation and further modifications will be required, this research has taken great steps in providing a means by which to identify, monitor, and address the phenomena of delusion and deception in decision-making.

The research has also made a contribution to applied behavioural economics, and presents a good argument for the need for behavioural economic assessment and evaluation to be conducted in industry, to create superior performance outcomes in megaprojects, and other industries.

5.4.2 *Future Work*

This study was exploratory, and only possible due to the timing of the conception of the research being concurrent with the inaugural Icarus Program intake. The sample size of participants for interview was sufficient for qualitative analysis and provided a foundation on which to base the quantitative analysis. Further interview data could be collected and analysed, focusing on the conflicts between intrinsic motives and extrinsic forces experienced by students during their education, and the specific impact it has on their decision-making. These further interviews should also be carried out with professional civil engineers, at varying stages of their careers to understand the stages at which an individual's decision-making behaviour is most vulnerable, and how professionals view their own, and each other's decision-making ability and professional competence.

Due to the timeframe constraints, and recruitment difficulties experienced by the researcher, a consideration for future work should be a replication of the quantitative data collection with increased sample size, and test-taking both pre-intervention and post-intervention. This will allow further insight in to the explicit impact of the intervention, providing a measure of variance. By developing the Icarus Program to include all engineering disciplines, interviews could be carried out to establish decision-making differences across the various engineering disciplines. Analysis of this data could provide further insight which may allow development of the critical thinking test and intrinsic motivation survey instrument used in this study. Revised instrumentation could provide an 'engineering specific' critical thinking test that focusses explicitly on the type of questions experienced by professional engineers in a megaproject environment.

As mentioned in the limitations section, a longitudinal study, revisiting the students, 5 and 10 years out of university would provide validation, and further insight in to the impact education has and had on future decision-making behaviour, and factors affecting that behaviour. A longitudinal study would also allow ongoing monitoring of

decision-making behaviour, throughout education and industry, offering further insight into the phenomena of delusion and deception.

5.4.3 CONCLUSION

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.

5.4.4 SUMMARY

In summary, this study, and the potential for future work was designed to create solutions to the problems associated with megaprojects identified by Bent Flyvbjerg, with the ultimate goal being the enhancement of decision-making skills in civil engineers in a megaproject environment. It is hoped that this research, and future work emerging from this exploration, will not only generate awareness for the need to further explore behavioural economics in engineering, but also develop the overall intrinsic motivation and critical thinking of engineers to deal with the ever-increasing complexities of the modern world.

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APPENDIX A: PARTICIPANT RECRUITMENT EMAIL (PART I)

Dear Students

As I mentioned in your lecture on Monday, I am looking for volunteers to participate in my PhD study looking at ways of improving Civil Engineering Education. I am interested to know more about the choices you have made and the decision-making involved in those choices that have got you to where you are today, the Civil Engineering program at UQ.

The interview will last **no longer than 1 hour** and can take place in **Week 12 or Week 13.** Depending on the number of volunteers and your availability I may also be able to interview during SWOT VAC and Exam Period (and beyond if any of you are around). As I also mentioned, there will be a small incentive for participating in the way of a food or drink voucher.

Your participation in this study would be greatly appreciated and will have a great impact on the way education is delivered here at UQ so if you'd like to make a difference then please get in touch.

danielle.lester@uq.edu.au

Many thanks in advance!

Danielle.

APPENDIX B: PARTICIPANT INFORMATION AND CONSENT FORM (PART I)

Research Participant (Student/Icarus)

Information Statement

Research Study Title: Delivering Superior Mega Project Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum

Researcher's Name: Danielle Lester – RHD Student, School of Civil Engineering at University of Queensland

(1)What is the study about?

You, the research participant, are invited to participate in this research study looking at the relationship between social identity and mega project performance outcomes. I, Danielle Lester, the researcher, hope to learn what impact social identity has on a student's decision-making. You were selected as a possible participant in this study because you applied to participate in the **Icarus Program**

(2)What does the study involve?

If you decide to participate, I will ask you to participate in a semi-structured interview lasting approx. 60 minutes, which will be recorded on an audio recording device.

As a participant in this study, you may be involved in activities such as audio/video taping, questionnaires, surveys, focus groups, interviews.

(3)How much time will the study take?

Approx. 60 minutes

(4)Confidentiality and disclosure of information

Any information that is obtained in connection with this study able to be identified as in connection with you will remain confidential and will be disclosed only with your permission, except as required by law. If you consent to participating in this study, I plan to discuss/publish the results. In any publication, information will be provided in such a way that you cannot be identified.

(5)Can I withdraw from the study?

Participation in this study is **voluntary** - you are not under any obligation to consent and - if you do consent - you can withdraw at any stage without affecting your participation in the Icarus Program. You can withdraw your consent by advising the researcher either verbally, via email, or by completing and returning the 'Participant Withdrawal of Consent Form' (attached).

Interviews
You may stop the interview at any time if you do not wish to continue. The audio recording will be erased and the information provided will not be included in the study.

Focus Groups
If you take part in a focus group and wish to withdraw. As this is a focus group it will not be possible to exclude individual data once the session has commenced.

Surveys
Being in this study is voluntary and you are not under any obligation to consent to complete the survey. Submitting a completed survey is an indication of your consent to participate in the study. You can withdraw any time prior to submitting your completed survey.

(6) Will I receive the results of the study?

A summary of research findings will be offered to research participants at the completion of the study. All participants will be offered a debriefing session once the study is complete.

(7) How can I obtain further information?

When you have read this information, Danielle Lester, will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact either the researcher.

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research. Whilst you are free to discuss your participation in this study with project staff (contactable on 3365 3698), if you would like to speak to an officer of the University not involved in the study, you may contact the Ethics Coordinator on 3365 3924.

This information sheet is for you to keep.

Research Participant Consent Form

Research Study Title: Delivering Superior Mega Project Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum

Researcher's Name: Danielle Lester – RHD Student, School of Civil Engineering at University of Queensland

Participant Consent

I _____, agree to participate in this research study. I have read the Research Participant Information Statement and had any question I have about the research answered for me by the researcher.

Any information that is obtained in connection with this study able to be identified as in connection with you will remain confidential and will be disclosed only with your permission, except as required by law. If you consent to participating in this study, I plan to discuss/publish the results. In any publication, information will be provided in such a way that you cannot be identified.

Please complete, placing a ✓ in applicable boxes

_____

Name of Research Participant *(First name and Surname)(Print)*

Are you 18 years of age or older? ☐ Yes
☐ No - A parental consent form is required to be completed.

_____ _____

Research Participant Signature Date

_____ _____

Name of Witness Relationship of Witness to Research Participant *(e.g., friend, sibling, parent, partner)*

_____ _____

Witness Signature Date

_____ _____

Researcher's Signature Date

Research Participant
Withdrawal of Consent Form

You can withdraw your participation consent by advising the researcher verbally, via email to danielle.lester@uq.edu.au or by returning this completed form to 78-219 (GP South Room 219)

Research Study Title: Delivering Superior Mega Project Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum

Researcher's Name: Danielle Lester – RHD Student, School of Civil Engineering at University of Queensland

I hereby wish to **WITHDRAW** my consent to participate in the research proposal described above and understand that such withdrawal **WILL NOT** jeopardise any participation I have in the Icarus Program.

_____

Research Participant Name *(Print)*

_____ _____

Research Participant Signature Date

APPENDIX C: TABLE OF SECOND CONSTRUCTS

2nd Construct	Qty
Extrinsic Motivation	12
Values Experience	8
Empathy	5
Low Self Efficacy	5
Reflective	5
Values Security	5
Holistic View	5
Intrinsic Motivation	4
Respects Authority	4
Anxiety	4
Confident with Future	3
Conscientious	3
Needs Context	3
Needs Structure	3
Organised	3
Responsible	3
Wants Autonomy	3
Confident	2
Considers Future	2
Content/Settled	2
Easily Influenced	2
Embraces Change	2
Flexible	2
Independent	2
Lack of Empathy	2

Contradiction	Qty
Extrinsic Motivation	12
Lack of Empathy	2
Lack of Patience	2
Needs Challenge	1
Over Confidence	2
Stubbornnes	1
Self Absorption	2
Short Term Goals	1
Skeptical	1
Takes Leadership Role	2
Wants Autonomy	3

Impressionable	Qty
Anxiety	4
Comparison to Others	1
Craves Direction	1
Intrinsic Motivation	4
Low Motivation	2
Low Self Efficacy	5
Needs Feedback	2
Needs Structure	3
Overwhelmed	1
Regret	1
Values Security	5

Drifter	Qty
Creative	1
Critical	1
Easily Influenced	2
Extrinsic Motivation	12
Indecisive	1
Lack of Focus	1
Low Motivation	2
Low Self Efficacy	5
Prefers Absolutes	1
Requires Support	1
Self Absorption	2

Big Picture	Qty
Appreciates Value	1
Confident with Future	3
Conscientious	3
Dislikes Constraints	1
Empathy	5
Focused	1
Holistic View	5
Long Term Goals	2
Reflective	5
Respects Authority	4
Responsible	3

Extrinsic Motivation
Lack of Empathy
Lack of Patience
Self Absorption
Short Term Goals
Over Confidence

Intrinsic Motivation
Empathy
Conscientious
Holistic View
Long Term Goals
Reflective

Lack of Patience	2	Lack of Focus	1	Skeptical	1
Long term Goals	2	Lack of Independence	1	Surface Learner	1
Low Motivation	2	Likes Context	1	Takes Easy Option	1
Needs Feedback	2	Low Expectations	1	Team Player	1
Over Confidence	2	Needs Challenge	1	Tempted	1
Recognises Limitations	2	Needs Interaction	1	Thorough	1
Respectful	2	Needs to Prepare	1	Unconscious Decisions	1
Seeks Motivation	2	No Future Awareness	1	Unsure	1
Self Absorption	2	No Planning	1	Values Feedback	1
Takes Leadership Role	2	Not Flexible	1	Values Relationships	1
Abstraction	1	Not Understanding	1		
Appreciates Value	1	Overwhelmed	1		
Comparison to Others	1	Pefers Specifics	1		
Craves Direction	1	Prefers Absolutes	1		
Creative	1	Proud	1		
Critical	1	Quick to Answer	1		
Critical Thinking	1	Rebellious/Stubornness	1		
Desires Innovation	1	Recognises Optimism	1		
Dislikes Constraints	1	Regret	1		
Driven	1	Relaxed	1		
Intrinsic Motivation	1	Requires Support	1		
Fear of Failure	1	Reserved	1		
Focused	1	Self-Critical	1		
Follows Authority	1	Self-Efficacy	1		
Time Management	1	Self-Conscious	1		
Honest	1	Short Term Goals	1		
Indecisive	1	Single tasking	1		

APPENDIX D: PARTICIPANT RECRUITMENT EMAIL (PART II)

Dear Students

I am again looking for volunteers to participate in my PhD study in which I am looking at ways of improving Civil Engineering Education.

I am specifically looking for volunteers who **have not** participated in the Icarus Program.

The test and survey will last **no more than 2 hours** and can take place in **Week 12/13.**

In return for your time and participation I will be providing lunch.
Your participation in this study would be greatly appreciated and will have a great impact on the way education is delivered here at UQ so if you'd like to be involved then please get in touch.

danielle.lester@uq.edu.au

Many thanks in advance!

Danielle.

APPENDIX E: TEST/SURVEY INSTRUMENTATION

Please enter the code in your email in this box

HCTA	**S2/I**	**0**	**0**	**0**		

Participant Information Sheet

Welcome and thank you for volunteering to participate in this study. There are 3 parts to this study. An online test and a paper copy survey with 2 sections.

Part 1 of the study is an online test and will take approx. 30 mins

PLEASE ANSWER QUESTION (A) BEFORE STARTING THE TEST

Please make sure that no other browsers are open during the test.

Please complete the test as per the instructions on the screen.

Some questions have multiple parts to them. The question, and question part, can be found in the top left hand corner of the screen.

PLEASE ANSWER QUESTION (B) ONCE YOU HAVE COMPLETED THE TEST

Part 2 of the test is a list of questions about the activity you have just completed. (Approx. 10 mins)

Part 3 of the test is a list of questions about your Instructor. (Approx. 5 mins)

PLEASE FOLLOW THE INSTRUCTIONS ON THE FOLLOWING SHEETS.

THIS IS NOT AN EXAM. IF YOU HAVE QUESTIONS PLEASE RAISE YOUR HAND AND I WILL COME OVER.

MANY THANKS!

DANIELLE.

This page is intentionally left blank.

PLEASE COMPLETE THIS PAGE BEFORE TURNING TO THE NEXT PAGE

Part 1 is an online test of 20 multiple choice questions about your level of critical thinking

Critical thinking is the intellectually disciplined process of actively and skillfully conceptualizing, applying, analysing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action.

QUESTION A

iii. How long do you think this test will take you to complete?

iv. What do you think your score will be:

d) Below Average

e) Average

f) Above Average

PLEASE COMPLETE THE ONLINE TEST

QUESTION B

iii. How long did you take to complete the test?

iv. What do you think your score will be:

d) Below Average

e) Average

f) Above Average

PLEASE GO TO THE NEXT PAGE AND COMPLETE THE SURVEY

	PLEASE CIRCLE YOUR ANSWER		Not at all true			Somewhat			Very true
1	While I was reading this material, I was thinking about how much I enjoyed it.		1	2	3	4	5	6	7
2	I did not feel at all nervous while reading.		1	2	3	4	5	6	7
3	This material did not hold my attention at all.		1	2	3	4	5	6	7
4	I think I understood this material pretty well.		1	2	3	4	5	6	7
5	I would describe this material as very interesting.		1	2	3	4	5	6	7
6	I think I understood this material very well, compared to other students.		1	2	3	4	5	6	7
7	I enjoyed reading this material very much.		1	2	3	4	5	6	7
8	I felt very tense while reading this material.		1	2	3	4	5	6	7
9	This material was fun to read.		1	2	3	4	5	6	7
10	I believe that doing this activity could be of some value for me.		1	2	3	4	5	6	7
11	I believe I had some choice about doing this activity.		1	2	3	4	5	6	7
12	I believe that doing this activity is useful for improved concentration.		1	2	3	4	5	6	7
13	This activity was fun to do.		1	2	3	4	5	6	7
14	I think this activity is important for my improvement.		1	2	3	4	5	6	7
15	I really did not have a choice about doing this activity.		1	2	3	4	5	6	7
16	I did this activity because I wanted to.		1	2	3	4	5	6	7
17	I think this is an important activity.		1	2	3	4	5	6	7
18	I felt like I was enjoying the activity while I was doing it.		1	2	3	4	5	6	7
19	It is possible that this activity could improve my studying habits.		1	2	3	4	5	6	7
20	I am willing to do this activity again because I think it is somewhat useful.		1	2	3	4	5	6	7

21	I believe doing this activity could be somewhat beneficial for me.		1	2	3	4	5	6	7
22	I believe doing this activity could help me do better in school.		1	2	3	4	5	6	7
23	While doing this activity I felt like I had a choice.		1	2	3	4	5	6	7
24	I would describe this activity as very fun.		1	2	3	4	5	6	7
25	I felt like it was not my own choice to do this activity.		1	2	3	4	5	6	7
26	I would be willing to do this activity again because it has some value for me.		1	2	3	4	5	6	7
27	While I was working on the activity I was thinking about how much I enjoyed it.		1	2	3	4	5	6	7
28	I did not feel at all nervous about doing the activity.		1	2	3	4	5	6	7
29	I felt that it was my choice to do the activity.		1	2	3	4	5	6	7
30	I think I am pretty good at this activity.		1	2	3	4	5	6	7
31	I found the activity very interesting.		1	2	3	4	5	6	7
32	I felt tense while doing the activity.		1	2	3	4	5	6	7
33	I think I did pretty well at this activity, compared to other students.		1	2	3	4	5	6	7
34	I felt relaxed while doing the activity.		1	2	3	4	5	6	7
35	I didn't really have a choice about doing the activity.		1	2	3	4	5	6	7
36	I am satisfied with my performance at this activity.		1	2	3	4	5	6	7
37	I was anxious while doing the activity.		1	2	3	4	5	6	7
38	I thought the activity was very boring.		1	2	3	4	5	6	7
39	I felt like I was doing what I wanted to do while I was working on the activity.		1	2	3	4	5	6	7
40	I felt pretty skilled at this activity.		1	2	3	4	5	6	7
41	I felt pressured while doing the activity.		1	2	3	4	5	6	7
42	I felt like I had to do the activity.		1	2	3	4	5	6	7

43	I would describe the activity as very enjoyable.		1	2	3	4	5	6	7
44	I did the activity because I had no choice.		1	2	3	4	5	6	7
45	After working at this activity for a while, I felt pretty competent.		1	2	3	4	5	6	7

PLEASE CONTINUE TO THE NEXT PAGE TO COMPLETE THE NEXT SURVEY

ICARUS ONLY
If you are in the Icarus Program, your **current** Instructor is the academic running your project.

Please also identify previous Icarus Instructors……...

	PLEASE ANSWER THE FOLLOWING QUESTIONS IN RELATION TO THE INSTRUCTOR YOU HAVE IDENTIFIED	**Strongly Disagree**			**Neutral**			**Strongly Agree**
1	I feel that my instructor provides me choices and options.	1	2	3	4	5	6	7
2	I feel understood by my instructor.	1	2	3	4	5	6	7
3	I am able to be open with my instructor during class.	1	2	3	4	5	6	7
4	My instructor conveyed confidence in my ability to do well in the course.	1	2	3	4	5	6	7
5	I feel that my instructor accepts me.	1	2	3	4	5	6	7
6	My instructor made sure I really understood the goals of the course and what I need to do.	1	2	3	4	5	6	7
7	My instructor encouraged me to ask questions.	1	2	3	4	5	6	7
8	I feel a lot of trust in my instructor.	1	2	3	4	5	6	7
9	My instructor answers my questions fully and carefully.	1	2	3	4	5	6	7
10	My instructor listens to how I would like to do things.	1	2	3	4	5	6	7
11	My instructor handle's peoples emotions very well.	1	2	3	4	5	6	7
12	I feel that my instructor cares about me as a person.	1	2	3	4	5	6	7
13	I don't feel very good about the way my instructor talks to me.	1	2	3	4	5	6	7
14	My instructor tries to understand how I see things before sugggesting a new way to do things.	1	2	3	4	5	6	7
15	I feel able to share my feelings with my instructor.	1	2	3	4	5	6	7
16	I felt really distant to this person.	1	2	3	4	5	6	7
17	I really doubt that this person and I would ever become friends.	1	2	3	4	5	6	7

18	I really feel like I could trust this person.	1	2	3	4	5	6	7
19	I'd like a chance to interact more with this person.	1	2	3	4	5	6	7
20	I'd really prefer not to interact with this person in the future.	1	2	3	4	5	6	7
21	I don't feel like I could really trust this person.	1	2	3	4	5	6	7
22	I think it's likely that this person and I could become friends.	1	2	3	4	5	6	7
23	I feel really close to this person.	1	2	3	4	5	6	7
24	I tried hard to have a good interaction with this person.	1	2	3	4	5	6	7
25	I tried very hard while interacting with this person.	1	2	3	4	5	6	7
26	I didn't put much energy into interacting with this person.	1	2	3	4	5	6	7
27	I put some effort into interacting with this person.	1	2	3	4	5	6	7

THANK YOU FOR PARTICIPATING IN THE STUDY!

PLEASE COMMENT BELOW IF YOU WOULD LIKE TO GIVE THE RESEARCHER ANY FEEDBACK (OPTIONAL)

APPENDIX F: PARTICIPANT INFORMATION AND CONSENT FORM (PART II)

Research Participant (Student/Icarus)

Information Statement

Research Study Title: Delivering Superior Mega Project Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum: Part II

Researcher's Name: Danielle Lester – RHD Student, School of Civil Engineering at University of Queensland

(8)What is the study about?

You, the research participant, are invited to participate in this research study looking at the relationship between critical thinking and mega project performance outcomes. I, Danielle Lester, the researcher, hope to learn what impact critical thinking has on a student's decision-making. You were selected as a possible participant in this study because you applied to participate in the **Icarus Program**

(9)What does the study involve?

If you decide to participate, I will ask you to participate in a critical thinking test lasting approx. 60 minutes, and an accompanying survey. The test and survey will be scored confidentially and only made available to the principal researcher.

(10) How much time will the study take?

Approx. 60 minutes. You will be reimbursed with a $20 UQ Union Voucher for your time.

(11) Confidentiality and disclosure of information

Any information that is obtained in connection with this study able to be identified as in connection with you will remain confidential and will be disclosed only with your permission, except as required by law. If you consent to participating in this study, I plan to discuss/publish the results. In any publication, information will be provided in such a way that you cannot be identified.

(12) Can I withdraw from the study?

Participation in this study is **voluntary** - you are not under any obligation to consent and - if you do consent - you can withdraw at any stage without affecting your participation in the Icarus Program. You can withdraw your consent by advising the researcher either verbally, via email, or by completing and returning the 'Participant Withdrawal of Consent Form' (attached).

Surveys

Being in this study is voluntary and you are not under any obligation to consent to complete the survey. Submitting a completed survey is an indication of your consent to participate in the study. You can withdraw any time prior to submitting your completed survey.

(13) Will I receive the results of the study?

A summary of research findings will be offered to research participants at the completion of the study. All participants will be offered a debriefing session once the study is complete.

(14) How can I obtain further information?

When you have read this information, Danielle Lester, will discuss it with you further and answer any questions you may have. If you would like to know more at any stage, please feel free to contact either the researcher.

This study adheres to the Guidelines of the ethical review process of The University of Queensland and the National Statement on Ethical Conduct in Human Research. Whilst you are free to discuss your participation in this study with project staff (contactable on 3365 3698), if you would like to speak to an officer of the University not involved in the study, you may contact the Ethics Coordinator on 3365 3924.

This information sheet is for you to keep.

Research Participant
Consent Form

Research Study Title: Delivering Superior Mega Project Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum: Part II

Researcher's Name: Danielle Lester – RHD Student, School of Civil Engineering at University of Queensland

Participant Consent

I _____, agree to participate in this research study. I have read the Research Participant Information Statement and had any question I have about the research answered for me by the researcher. I have accepted a $20 UQ Student Voucher for participating in this study.

Any information that is obtained in connection with this study able to be identified as in connection with you will remain confidential and will be disclosed only with your permission, except as required by law. If you consent to participating in this study, I plan to discuss/publish the results. In any publication, information will be provided in such a way that you cannot be identified.

Please complete, placing a ✓ in applicable boxes

_____
Name of Research Participant *(First name and Surname)(Print)*

_____ _____
Research Participant Signature Date

_____
Voucher numbers (please initial receipt of vouchers)

Research Participant
Withdrawal of Consent Form

You can withdraw your participation consent by advising the researcher verbally, via email to danielle.lester@uq.edu.au or by returning this completed form to 78-219 (GP South Room 219)

Research Study Title: Delivering Superior Mega Project Performance Outcomes Through Timely Intervention in the Civil Engineering Curriculum: Part II

Researcher's Name: Danielle Lester – RHD Student, School of Civil Engineering at University of Queensland

I hereby wish to **WITHDRAW** my consent to participate in the research proposal described above and understand that such withdrawal **WILL NOT** jeopardise any participation I have in the Icarus Program.

_____

Research Participant Name *(Print)*

_____ _____

Research Participant Signature Date