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Three dimensions of learning: Experiential activity for engineering innovation education and research

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ABSTRACT

This paper outlines a novel approach to engineering education research that provides three dimensions of learning through an experiential class activity. A simulated decision activity brought current research into the classroom, explored the effect of experiential activity on learning outcomes, and contributed to the research on innovation decision making. The ‘decision task’ was undertaken by more than 480 engineering students. It increased their reported measures of learning and retention by an average of 0.66 on a 5-point Likert scale, and revealed positive correlations between attention, enjoyment, ongoing interest and learning and retention. The study also contributed to innovation management research by revealing the influence of different data visualization methods on decision quality, providing an example of research-integrated education that forms part of the research process. Such a dovetailing of different research studies demonstrates how engineering educators can enhance educational impact while multiplying the outcomes from their research efforts.

Keywords: learning, retention, experiential learning, engineering innovation, decision simulation

Introduction

Engineering education is a dynamic endeavour where the engineering content, societal context, and teaching pedagogies are continually evolving. This dynamism has resulted in new cross-disciplinary fields of engineering; increased attention to contextual factors such as sustainability, finance or legal considerations; and the application of a plethora of new teaching approaches in engineering education. In addition to the need to adapt to these changes, engineering educators are under increasing pressure to conduct and publish research. This challenging environment calls for innovative approaches to engineering education and research.

This paper details the engineering education research findings from an experiential class activity that delivered three types of learning. The activity was designed to meet the needs of a relatively new and growing theme within engineering education: the management of engineering innovation. The three types of learning are: (1) students' learning about decision-making frameworks for managing engineering innovation and about the research process; (2) learning about learning – through engineering education research on the effects of experiential activity on learning and retention; and (3) learning from innovation decision research on the effectiveness of the methods used in the activity.

The design of the study, combining three types of learning into one experiential activity, offers a revolutionary approach that can assist engineering educators address current challenges. It builds on the ongoing evolutions in engineering education such as increasing experiential and active learning and the use of students to test methods during educational sessions (Carver et al. 2003).

The background for this paper is provided in an overview of the trends in expanding 'innovation' content in engineering education, followed by a brief discussion of the innovative approaches to education and the work being done to support innovation education with innovative teaching methods. The paper then focuses on experiential learning and proposes four hypotheses to examine the relationships between experiential activity and learning. The following section explains the context for the study as part of an 'innovation engineering' educational module. An overview of the research design, highlighting the experimental approach and the design's novel aspects, is followed by a detailed description of the experiential session at the centre of the study. Subsequent sections present the data collection and analysis, findings and analysis, discussion and, finally, the conclusions and implications.

Innovation content in engineering education – a growing trend

A 'paradigm shift' in engineering education is underway in response to increasing demands for engineers with the ability to manage technological innovation (Creed, Suuberg, and Crawford 2002). This shift has been underway for decades, first influencing postgraduate engineering management education and increasingly prompting a redefinition of engineering curricula to embrace the development of innovation abilities in undergraduate engineers. Accreditation bodies, government reports, and industry input are primary motivators of the ongoing process that aims to keep engineering education aligned with trends in technological development and application. For example, the influential ‘Karpin Report’ commissioned by the Australian Government (Karpin 1995) highlighted the need to improve innovation management and entrepreneurship abilities, and prompted a series of further actions to encourage and support the development of innovation abilities in undergraduate engineers and scientists (Killen and Ford 2005). The first of a three-part series, ‘The future of engineering education I: a vision for a new century’ (Rugarcia et al. 2000), highlighted trends affecting the future of engineering education. These trends recognized the need for engineers with interdisciplinary problem-solving abilities and increased involvement in resource allocation decisions, change management, and participation in management decisions. Steiner (1998, 1) highlighted management and innovation skills as central to preparing engineers for work in the ‘global marketplace’ and boldly claimed that ‘engineering curriculum that does not address innovation and high-level technical management is depriving its students of essential competencies for engineering success in the global marketplace’.

While engineering masters-level programs started introducing innovation themes during the 1980s and 1990s, undergraduate offerings in ‘innovation’ have appeared more recently. The trend is taking hold across the globe in accredited undergraduate engineering institutions. For example, Brown University (USA) developed a technology entrepreneurship module for undergraduate engineering education that highlights working across disciplines (Creed, Suuberg, and Crawford 2002), the MINES ParisTech (France) engineering school introduced a technology innovation specialty in 2007 (Mustar 2009), and the National University of Singapore (NUS) added an undergraduate technology management specialty for undergraduate engineers in 2005, building on the well-established postgraduate program (Hang et al. 2009). Some of the many other institutions that now offer undergraduate engineering programs for ‘innovation’ include the University of Maine’s minor in ‘Innovation Engineering’, the University of Southern Denmark’s ‘product development and innovation engineering’ degree (offered at both bachelor and masters levels), and the undergraduate engineering ‘Innovation Major’ introduced in 2005 at the University of Technology, Sydney (UTS) following the introduction of a ‘Technology and Innovation Management’ option at the masters level in 2002 (Killen and Ford 2005).

Including ‘innovation’ content in engineering curriculum is an ongoing evolution. The curricula details vary across offerings and change over time; however, almost all offerings include some balance of topics on technology and innovation management, product development, and entrepreneurship. For the purposes of this paper, this theme of engineering educational content will be referred to as ‘engineering innovation’ content. The research cited in this paper was conducted in both postgraduate and undergraduate UTS engineering innovation programs.

Innovative educational approaches for engineering innovation education

In parallel with the increased engineering innovation content, the pedagogies for engineering education are being transformed by multiple calls for new ways to improve the educational experience. In addition to increasing educational research into the value of experiential learning and the development of new educational technologies, other strong drivers for change are financial pressures and increased competition; universities across the globe are under increasing pressure to do 'more with less' while maintaining standards, and engineering educators are expected to produce an ever-growing quantity of high-quality research outputs. To meet these conflicting goals, many of the new approaches to engineering education are designed for effectiveness (improvement of learning outcomes) as well as efficiencies (reduction in required resources).

The long-established lecture format for delivering engineering education is rapidly being replaced. Active and experiential learning is linked with improved engagement and learning, influencing radical changes for education through new teaching philosophies such as flipped learning, service learning, and problem-based learning (Fernandes et al. 2013; Carberry, Lee, and Swan 2013; Bishop and Verleger 2013). In addition, the advent of new technologies has enabled totally new approaches for engineering education such as remote and/or virtual laboratory work (Nickerson et al. 2007; Lowe et al. 2009; Restivo et al. 2009), online interactive formats, and the development of smart classrooms that facilitate interaction and the creation, analysis, and sharing information in real time (Laurillard 2002; Resta and Laferrière 2007; Sharples, Taylor, and Vavoula 2007; Suo et al. 2009). It is an exciting and challenging time for engineering educators who must keep abreast of new teaching approaches and technologies and tailor their application to meet the needs of their evolving disciplines.

The inclusion of engineering innovation content within engineering education calls for the adoption of innovative educational practices and the modelling of a new mindset. While including such content in undergraduate programs is proving to be popular with students and well supported by industry, it creates additional challenges for educators. Radcliffe (2005) suggests that how the engineering innovation content is taught has a strong influence on the development of graduate attributes in engineers and that the attitude of the educators and the culture of the institution need to support the 'innovation' agenda.

Engineering innovation courses embrace experiential approaches for developing the desired learning in students. Active learning involving the application of knowledge is required to meet the accreditation boards' calls for graduates with improved problem-solving, communication, real-world knowledge, and abilities to work across disciplines (Felder et al. 2000). Learning by experience is found to be appropriate for education on the management of innovation (Jørgensen and Busk Kofoed 2007; Pittaway and Cope 2007) and simulations are effective for teaching students how to make decisions and to organize and assess information quickly (Teach and Govahi 1993). Such approaches are consistently employed in engineering innovation education. For example, the engineering innovation specialty at MINES ParisTech has an experiential learning focus (Mustar 2009), the engineering innovation institute at the

University of Florida emphasizes the use of experiential education to develop a culture of innovation and entrepreneurship, and students at the National University of Singapore experience the innovation process through a semester-long collaborative project (Hang et al. 2009).

Experiential learning is also embedded in the UTS innovation engineering units through classroom-based role plays, games, case analysis, collaborative projects and in-class simulations, such as the one detailed in this paper. The simulated decision task was conducted in the undergraduate ‘Introduction to Innovation’ unit and the postgraduate ‘Technology and Innovation Management’ unit as part of a common module on ‘innovation decisions’.

Learning about learning: Hypothesis development

Of the three types of learning, this section focuses on the development of the education-based aspects of the study; the ‘learning about learning’. Although the experiential task employed in this study was conducted to develop a specific aspect of engineering innovation ability, the hypotheses focus on the experiential nature of the task and are posed in general educational terms. Additional hypotheses were generated for the ‘learning from innovation decision research’ aspect of the study to explore the influence of the three different methods employed in the study on the decision making process and the decision quality. These additional hypotheses were tested in a parallel analysis and are reported in detail in Killen (2013a; 2013b).

Experiential learning activities are recognized for their contribution to student learning, and research highlights benefits such as the ability to cater for different learning styles, and to contribute to improved knowledge acquisition and increased retention of learning over time (Ruben 1999; Kolb and Kolb 2005; Snider and Eliasson 2013). Findings on learning from experiential activity are mixed. For example, one study showed no difference in the initial level of learning through an experiential activity; however, the effect on retention of learning over time was significant (Specht and Sandlin 1991). A review of the scholarship on the effectiveness of experiential learning (Gosen and Washbush 2004) cautions that some studies may be skewed due to the ‘halo effect’ from students’ enjoyment of experiential activities; if they enjoy an activity they may be more likely to report perceptions of higher levels of learning. Despite medical students reporting higher enjoyment and educational value from an experiential learning session than from a video-based one, the halo effect may explain why there was no significant difference in the learning achieved (Morgan et al. 2002). Although it is generally accepted that experiential activity increases learning and retention, further understanding of the relationship is warranted, leading to the first set of hypotheses:

H1a – experiential learning activity corresponds with an increased degree of learning from the activity

H1b – experiential learning activity corresponds with increased retention of the learning from the activity

Proponents of experiential learning assert that active learning by its nature improves student engagement – for example, a study of an experiential gaming activity showed that it increased engagement (Snider and Eliasson 2013). Engagement is also thought to contribute to student learning, and the creation of activities to engage students is strongly promoted in engineering education and tertiary education literature in order to maximize student learning (Smith et al. 2005; Zepke and Leach 2010). However, learning outcomes are not measured in some studies of student engagement, such as the US National Survey of Student Engagement (NSSE). In a study of learning in an online unit, Arbaugh (2000) found that engagement through interactivity was the only significant factor affecting student learning while aspects such as ease of use and time spent online had no effect. Carini, Kuh, and Klein's (2006) findings show that student engagement correlates with most measures of student learning, although some of the correlations are not strong. Many studies evaluate learning through student grades or test scores; however, such studies do not provide insight into the effect of specific activities on the resultant learning. It is hypothesized that:

H2 – higher levels of engagement during an experiential task are correlated with higher levels of learning from that task.

The development of interest in the topic is thought to be an effect of experiential activity that will improve learning outcomes by increasing motivation. One study found that incorporating an experiential game activity during the introduction to a topic increased students' interest in learning more about the topic and improved the levels of learning reported (Snider and Eliasson 2013). Studies in the workplace (Reio and Wiswell 2000) and in university settings (Reio 2004) provide further empirical evidence of the positive influence of curiosity, the desire to know more about a topic, on learning. However, Reio (2004) notes that curiosity is often seen as a transient state and suggests that better understanding of the relationship between curiosity and learning will require further research. Hypothesis 3 is:

H3 – higher levels of ongoing interest in the topic after an experiential task is correlated with higher levels of retention of the learning over time.

Enjoyment of educational experiences is thought to be associated with increased learning, and several studies report enjoyment from experiential activities. For example, students reported strong levels of enjoyment and perceptions of high educational value following a hands-on experiential activity (Dalrymple, Sears, and Evangelou 2011). However, as mentioned earlier, the 'halo effect' can increase the positive estimation of the reported level of learning from the activity (Gosen and Washbush 2004). Therefore further study is recommended, preferably through a design that avoids the halo effect. Hypothesis 4 is:

H4 – Higher levels of enjoyment reported after an experiential task is correlated with perceptions of higher educational value from the task.

Context for the study: Innovation engineering education and decision making

Decision making on resource allocation is a central theme in the emerging curricula on 'engineering innovation'. Such decisions are crucial to the management of engineering innovation and require consideration of multiple criteria; however, humans are subject to 'bounded rationality', which limits their ability to interpret data and make appropriate decisions (Simon 1955). Complex and critical decisions are particularly affected by these constraints in the ability to evaluate information (Foreman and Selly 2002). Visual methods of displaying and evaluating data are often useful in management environments as they enable decision makers to harness their cognitive capacities by providing an efficient alternative approach for analyzing complex data (Mikkola 2001; Tergan and Keller 2005). Graphical forms of communication can illustrate complex multi-dimensional aspects of organizations in a simple and powerful manner (Meyer 1991). Therefore, information and exercises on the use of visual displays to support innovation decisions are often included in educational modules for the development of engineering innovation capabilities.

The experiential exercise developed for this study was part of an educational module on 'innovation decisions' that introduced project portfolio management (PPM) frameworks for decision making about resource allocation in complex interdependent project portfolios. PPM is a set of organizational activities that provides a holistic framework for the management of the project portfolio. The literature highlights that PPM is primarily a strategic decision-making process which involves identifying, minimizing, and diversifying risk, identifying and responding to changes, and understanding, accepting, and making trade-offs (Kester, Hultink, and Lauche 2009; Kester et al. 2011; Levine 2005). The power of visualizations to support strategic decision making is only beginning to be exploited, and there is a need for more research in this area (Warglien and Jacobides 2010). Research to evaluate a new network mapping approach for visualizing project interdependencies to support PPM decision making was initiated at the UTS in 2009 (Killen et al. 2009).

An introduction to project portfolio decision frameworks is increasingly included as part of courses on engineering innovation (see, for example, recent textbooks: Schilling 2013; Swink et al. 2011; Tidd and Bessant 2011). Education on PPM often includes an explanation of the benefits of a portfolio framework for innovation decision making and an overview of the common approaches. In addition to the introductory content, a simulated decision task has been included in the undergraduate 'Introduction to Innovation' unit and the postgraduate 'Technology and Innovation Management' unit at the UTS since 2007 to provide students with a deeper understanding of the complex decision challenges and the methods commonly used to address these challenges. In 2011, the 'decision task' reported in this paper was introduced to measure the effect of experiential learning and to expose students to leading-edge research on the management of project interdependencies while testing the new network mapping approach.

Experimental research design

The simulated decision task was designed to provide students with experience in analyzing visual representations of data to support portfolio decision making, collect data on the decisions made using each of the three data visualization methods, and test four hypotheses on the effect of the experiential task on learning and retention. The experiential experimental session, referred to here as 'the decision task', was conducted in a controlled classroom setting and embedded in a longer educational module as described in detail in the following section. The chosen experimental design offers benefits for both educational research and the parallel research on methods for visualizing data to support project portfolio decision making.

New processes, tools, and techniques are regularly proposed to enhance organizational results from project portfolio management. However, each organizational environment is different and many uncontrollable factors can influence project performance. Organizational environments do not facilitate repeatable trials and it can be difficult to obtain generalizable findings. Despite these drawbacks, the evaluation of new PPM methods in organizational settings provides valuable insights and experimental studies are not proposed to replace such evaluations. Instead, experimental studies are best used to complement organization-based research by testing the effects of changes in a systematic manner. The use of an experimental approach is quite novel for PPM research; only a few studies have employed experimental approaches to simulate resource allocation decisions in a project environment (Bendoly and Swink 2007) and to understand decision-making processes and learning effects in the project and portfolio management domain (Arlt 2011). Students are often used as research subjects in experimental research and can provide relevant input when they have an appropriate background (Arlt 2011; Bendoly and Swink 2007; Dull and Tegarden 1999).

New educational approaches are also regularly trialled in the classroom with the intention of enhancing student learning and academic success. Experimental research can be appropriate for testing hypotheses, and such studies often use measures of knowledge acquisition and retention to compare the effect of new teaching initiatives on an experimental group with a control group (Cohen, Manion, and Morrison 2007; Smith et al. 2005; Borrego, Douglas, and Amelink 2009). However, the use of a control group can be difficult. Groups of students are often taught separately, requiring additional resources and introducing other factors that may influence outcomes. In addition, the educational imbalance between the experimental and control groups could disadvantage one of the groups.

Considerations from both aspects of this research, the innovation decision aspect and the research on learning and retention, contributed to the final research design. The experiential learning approach was carefully designed to provide a session that was realistic enough to be useful, but simple enough to be practical, following the principles summarized by Grossklags (2007) and aligned with guidelines for experimenting with students to ensure the educational, ethical, and practical aspects of the session (Carver et al. 2010). In software engineering students are often used to test new methods in an experimental session that is also educational (Carver et al. 2003); however, such studies are not designed to evaluate the learning effects of the experiential activity. The design of the 'decision task' is unique in combining education, method testing, and research of the learning effects.

Three types of methods for representing data were evaluated in the decision task. Two of the methods are already in use in some organizations as part of their PPM process: The 'Tabular list' display presents project interdependencies in a single column as part of a spreadsheet, and the 'Dependency matrix' display highlights dependency relationships in the cell corresponding to the pair of interdependent projects (in the row and column). The third method is a newly proposed method under investigation. The 'Visual project map' (VPM) displays each project as a node in the network and uses arrows to identify relationships or interdependencies between nodes.

Figure 1 provides an example of the three types of visual representation of project interdependency data that were compared in the decision task. Each of the methods of displaying the data provided the same information, and each has been colour coded in an identical manner to highlight the strategic importance of the projects in the portfolio. In addition to strategic importance and dependency data, the scenario also included financial information (investment and projected return on investment).

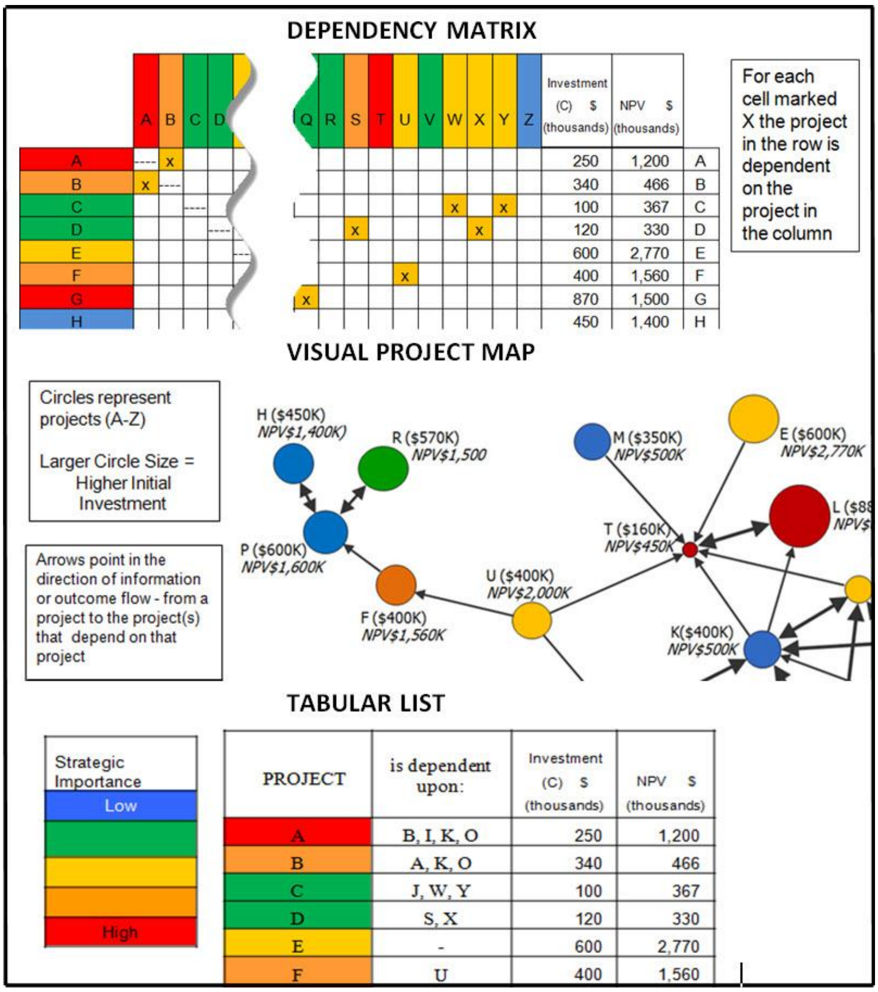

Figure 1: Three methods for displaying project interdependency data in the decision task. Portions of each of the three displays with examples of instructions.

Before applying the methods displayed in Figure 1 in the decision task, the students received instruction on all three specific methods and the wider framework for the decision. The two units 'Introduction to innovation' and 'Technology and Innovation management' provided a strong background for the decision task through earlier modules on strategy, financial estimation, and project portfolio management frameworks.

Benefits and novelty of the research design

Embedded in an educational session, the decision task was designed to reveal the potential influence of the type of data representation on the resulting decision, and to collect data on how the use of a method affected the students learning and retention of the learning about the method. The experimental research design has the following four benefits, and offers a novel approach to experiential education and research design:

(1) Three types of learning. The decision task was designed to educate students and collect data on the educational impact of experimental activity, while also collecting data for a separate research study. This approach has resulted in the efficient collection of research data, allowing the researcher to report on two sets of findings and ensuring that the students' education was also enhanced by the study. A central aspect of the research design is that, although all students learned about three methods for representing data visually to support decision making, each student applied only one of the three methods during the decision task. Each student was randomly assigned to one of the methods, and the results from the three different groups of students were compared. The goals of two research studies were dovetailed into this single study in order to collect data for educational research (focusing on the hypotheses outlined above) and a separate discipline-based study on innovation decisions (evaluating the impact of three different visual representations of data on the resulting decision). It is common in software engineering to conduct an educational session where data are collected to evaluate the use of new methods (Carver et al. 2003; Carver et al. 2010); however, such studies have not been designed to also evaluate the influence of the experiential sessions on learning and retention.

(2) Benefits for all students. The decision task was designed so that all students benefit from the educational initiative; rather than assign some students to a 'control group', all students participated in the experiential activity. The use of a control group can be useful for making comparisons and measuring the effect of a new teaching initiative (Borrego, Douglas, and Amelink 2009). However, ethical considerations are an important part of the design of research employing students (Carver et al. 2010), so that no group of students should be disadvantaged by the research design. As the task was designed as a summative exercise that formed an important part of the learning, the use of a 'control group' that did not participate in the experiential exercise was felt to provide disadvantage. We decided not to deny some of the students the opportunity to learn from the decision task simply so that the effect of learning through the task could be compared with the control group. Instead, the effect of experience with the specific methods used within the task was measured – and the three groups were compared based on which method they used, and how well they understood all three methods.

(3) Addressing the 'halo' effect. Gosen and Washbush (2004) point out the potential bias from the 'halo' effect, where enjoyment from participating in an experiential study can influence students' perception of learning. In this study, all students participated in the experiential learning activity. All students received close-to-identical experiences in the same environment, with the only variable being the assigned method for visualizing project interdependencies. Therefore the results will not be biased by differences in students' access to the experiential activity producing different levels of enjoyment.

(4) Research exposure and participation. In addition to enhancing education on the core topic (innovation decisions), the task was also designed to educate students about the research process and introduce them to engineering innovation management research. As research is an important part of all engineering students' education, research exposure is felt to help students understand research and learn how to become researchers. Healey and Jenkins (2009) identify four ways of engaging students in research and inquiry through the two axis quadrant model. One axis evaluates whether students are primarily an audience or participants, the other evaluates the emphasis based on content or process focus. The research design for this study exposed students to all four quadrants. In the lead-up to the classroom task, students learn about the research process, the ethics requirements and the content aspects such as rationale and goals for the research outcomes. During the task students become participants and engage with both the content and the process of research. In addition to the educational nature of the task, the inclusion of current research into the classroom is also argued to engage students and increase learning overall (Healey and Jenkins 2009).

Research design and decision task session detail

The experimental research design for this study represents a novel approach to engineering education research. In brief, more than 480 students have participated in a classroom-based simulated decision task. The three goals for the decision task provided the basis for the research design: (1) the task formed an important part of the education for the students; it enabled them to experience a complex decision-making challenge and to understand and participate in research; (2) the educational research aspect of the study was designed to explore the relationships between the experiential activity and learning and retention; and (3) in parallel, an 'innovation management' aspect of the study compared three different methods of visually representing data to support decision making.

The research design and the conduct of the experiential class session are outlined in Figure 2. The 'decision task' was conducted late in the semester in the two units: the undergraduate 'Introduction to Innovation' unit and the postgraduate 'Technology and Innovation Management' unit. The class session built upon earlier modules in the two units and drew upon students' understanding of the use of strategy to drive decisions, the nature of financial estimations, and the use of portfolio frameworks to support decision making.

The research design included the design of the decision task within an 80-minute class session, and the development of two research instruments to collect data: an initial survey collected data immediately after the decision task in the classroom, and a follow-up survey conducted online six weeks later. It was important to keep both surveys short in order to avoid overload during the classroom session, and in order to improve response rates during the follow-up survey.

Survey and item development

Respondents identified which method they used in the task in each survey through the item METHOD; results are reported in Table A1 in the Appendix. Tables A2 and A3 in the Appendix list the items on learning, retention, engagement, curiosity, and enjoyment from both surveys. Items from the follow-up survey are identified with '_F' appended to the item label. The items employed 5-point Likert scales to collect perception-based responses from the participants. Scales were anchored at the end- and mid-points as shown in the examples in the Appendix.

The survey responses were anonymous to avoid any student concern that their performance may affect their grades. This was particularly important as the students were asked to learn new methods and complete a challenging task that was designed to be difficult to complete in the time allowed in order to allow differences between the methods to be revealed. Due to the anonymity, the before and after survey data could not be pair matched, and the analysis relied on the mean differences between the samples.

Items on learning and retention of learning were included in both the initial and follow-up survey to test hypotheses 1a and 1b. Respondents were asked to rate their degree of learning for each of the three methods, although they applied only one method during the decision task. Two items explored the degree of learning – APP (the student's ability to recall enough to apply the method) and EXP (the ability to explain the method). Further detail is included in the Appendix.

Two items were included in the initial survey to capture the respondents' feedback on their engagement with the decision task in order to test Hypothesis 2 on the relationship between levels of engagement and higher levels of learning from an experiential task. ATT measured the degree of focus on the task, and THINK measured how much the decision task caused the student to think.

Hypothesis 3, examining the relationship between higher levels of ongoing interest in the topic after an experiential task and the retention of the learning over time, was evaluated through the follow-up survey. Ongoing interest in the topic was measured through THOT_F, how much students had thought about the task, and WTKM_F, the degree to which students wanted to know more about the topic after the decision task (following Reio's (2004) example of operationalizing curiosity).

Finally, Hypothesis 4 proposed that higher levels of enjoyment reported after an experiential task is correlated with perceptions of higher educational value from the task. Two items, ENJY_F and EDUC_F, were measured during the follow-up survey to capture student reflections on how much they enjoyed the task and whether they thought it was educational.

The initial survey also contained several additional items as part of the parallel research study on the three methods for visualizing interdependencies. Correlations were tested between the items developed for the two studies, and two items from the parallel study provided insights for hypotheses 1a and 2. These items are included in Table A3 in the appendix: the quality of the actual decision made by the student (DRATE) and the student's confidence with the decision (CONF). The remainder of the findings from the parallel study did not lend insight to this study and are not discussed in this paper.

Class session design

As shown in Figure 2, the class session was designed to include education and explanations before students participated in the experiential decision task and completed the survey. Through this approach, students had the opportunity to learn about all three methods, learn about and experience decision making in a simulated scenario based on real-life challenges, and apply one of the three methods.

The research was approved by the university ethics committee and was conducted in a way that ensured that student participation was voluntary and confidential. The research design was pilot tested twice, first with seven participants and then with twelve. Following feedback from the pilot testing, the session was refined with improved explanations and warm-up tasks, and 15 minutes was confirmed as the right amount of time to allocate to the decision task.

During the week before the decision task class session, students were informed in person and by email about the purpose of the research, the initial and follow-up surveys, and the voluntary nature of the task, and were assured of confidentiality. An alternative task was offered if students elected not to participate; however, all students decided to participate in the decision task experiment.

During the main decision task, students evaluated identical data on the 26 projects in a generic project portfolio. The following information was provided for each project: investment and net present value projections, a rating for degree of strategic fit, and information on project interdependencies. Students were randomly assigned one of the three methods for their decision task; the set of materials they received contained a visual data representation that was created using one of the three data display formats. Students were given 15 minutes to complete the decision task. In this time, they were required to review the information provided and decide which project or projects to cancel to trim the portfolio budget by 10%. During the decision process, students were asked to balance strategic, financial, and project efficiency goals.

Although simplified for the purposes of this experiment, this scenario required multiple types of data to be balanced in several dimensions and it reflects the challenges faced by PPM decision makers. Through the decision task, students gained experience in this type of decision challenge as well as specific experience with one of the methods for visualizing project interdependencies.

Approximately six weeks after the class session, students were sent an email and asked to complete the follow-up survey. The data from both surveys were then analyzed, and findings were discussed in presentations and publications in innovation management (Killen 2013a; Killen 2013b) and education (this publication).

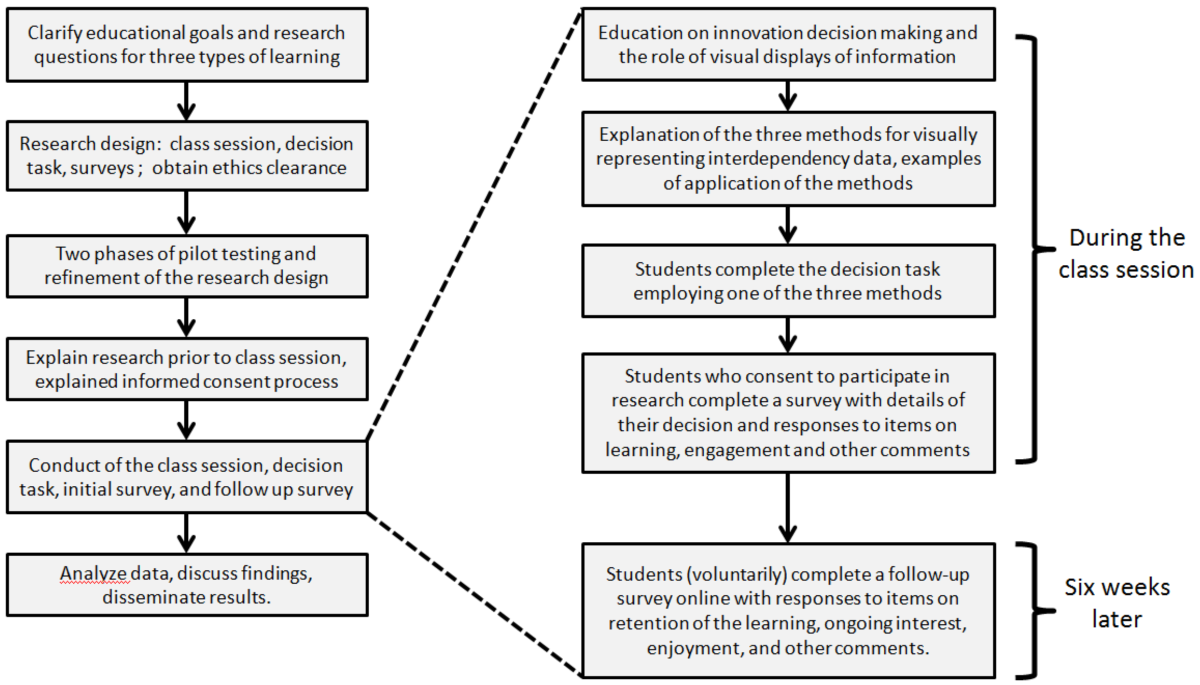

Figure 2: Process for research design and conduct

Data collection and analysis

A total of 480 valid responses were obtained from 487 engineering students who participated in this experiential activity at the UTS over five semesters from 2011 to 2013. About one-quarter of the valid responses (*n*=116) were from undergraduate students in 'Introduction to Innovation', an engineering unit for the Bachelor of Science Engineering Major in Innovation. The remainder were from postgraduate students (*n*=364) in the unit 'Technology and Innovation Management', an option for students in the Master of Engineering Management or the Master of Engineering Studies, two coursework-based masters programs. The activity was conducted in classes of 30–50 students in 12 different classes. Three were undergraduate classes (one class each spring semester 2011–2013) and eight were postgraduate (large enrolments with two or three parallel classes each semester during 2012 and Autumn 2013).

Responses were considered invalid if participants did not identify which method they used during the experiment or selected more than one method; these invalid responses were ignored during the data analysis. The valid responses (N=480) represented a random allocation of the item METHOD across the class sections; n=162 used the Dependency matrix, n=166 the Visual project map, and n=152 for the Tabular list. Although the experiment was designed to allocate the methods equally across the sample, the resultant numbers were not fully balanced between the methods due to the use of multiple class sections where class numbers were not always divisible by three, the random nature of distributing the surveys in the classes, and removal of some invalid surveys.

The follow-up survey was conducted online six weeks after the initial survey, which was timed to be right after the final exam period. Responses were encouraged by explanations of the purpose of the follow-up survey, follow-up reminders, and the chance to win a gift voucher from the university book shop. The resulting response rate for the follow-up survey (N=192) was 40% of the total number of participants. The breakdown of the METHOD reported in the follow-up survey was n=63 for the Dependency matrix, n=70 for the Visual project map and n=59 for the Tabular list.

Tables A2 and A3 in the Appendix provide summary statistics for all items from the two surveys. Table A1 summarizes the frequency of the three METHODs for both surveys.

Several variables were calculated to assist with the analysis. The variables APP, EXP, APP_F, and EXP_F are each based on the three separate items (one for each method). The variable APP is detailed here; the others follow the same format. The column for 'mean of all data' is the mean value for APP across the sample (the mean value across all survey responses of the mean value for the three APP items APP.D, APP.V, and APP.T). The column for 'mean for users of the method' shows the mean value across the sample of APP.D where METHOD = Dependency matrix; APP.V where METHOD = Visual project map, and APP.T where METHOD = Tabular list. This column reveals the mean level of learning about a method that has been used during the decision task. The column for 'mean for non-users of the method' is the reverse: the mean value across the sample of APP.D where METHOD ≠ Dependency matrix, and so on. This column shows the mean level of learning about a method that has NOT been used during the decision task.

The final column in Table A2 reveals the influence of the experiential task on the measures of learning and retention. The student's t-test for independent samples (referred to here as the t-test) was used to evaluate responses for APP, EXP, APP_F, and EXP_F between groups of respondents based on the method used during the experiment. Groupings were set up for users (1) and non-users (0) for each method. Levene's test for equality of variance was used to determine the applicability to the 'equal variance assumed' or the 'equal variance not assumed' t-test values (Collis and Hussey 2003; Garson 2012). As shown in the final column of Table A2, the differences between the means of the two groups (users and non-users of each method) for each item are significant at .001 or better. The values in the three final columns of A2 were used to evaluate hypotheses 1a and 1b.

The student's t-test was also used to check for any significant differences in responses based on the unit or the class session. Independent sample t-tests did not reveal significant differences between item responses based on the unit or the class attended, therefore the findings are able to be reported for the full set of data combined from all classes.

Bivariate Pearson correlations were used to test relationships between items to test hypotheses 2, 3, and 4. Tests for normal distribution revealed acceptable kurtosis of the data; however, data for a few of the items were negatively skewed, and so nonparametric analyses were also conducted using Kendall's tau and Spearman test. These tests confirmed the significant relationships identified using Pearson's Chi squared tests with only minor differences between the Pearson results. Therefore, for simplicity the data have been reported using the Pearson format. All statistical results represent two-tailed analysis. Significance levels are reported for each correlation.

Findings

Learning dimension 1: Student learning

Student learning has been enhanced through participation in the decision task. In addition to learning about the decision-making frameworks and challenges in innovation management, students also learned about the research process. The educational research on the effects of experiential task presented in the next section provides evidence of the student learning achieved through the experiential task. In short, the evidence shows how the experiential task enhanced learning and retention and contributed to enhanced abilities to make decisions. Student feedback, such as the open responses reported in Table 3, further affirms that the decision task has had a positive effect on student learning.

Learning dimension 2: Learning about learning

The educational research aspect of this study has contributed to 'learning about learning'. The data collected during and after the decision task supports the four hypotheses in varying degrees. Hypotheses 1a and 1b are convincingly supported by the study, while the other hypotheses are supported by mild to moderate correlations. The design of the study allowed a detailed and fine-grained analysis of the effect on the learning of using a method in a decision task. This effect was measured by comparing the findings students who used each of the three methods with those who did not use that method. Learning was evaluated through responses about how well the student could recall the method in order to apply it to a similar task and whether the student could explain the method, with the same questions repeated six weeks later to evaluate retention.

The results of the study strongly support H1a and H1b and provide evidence of the influence of experiential activity on learning and retention. Figure 3 illustrates the influence:

when a student used a particular method during the decision task, they reported significantly stronger levels of learning about that method (the light bar in each pair) than students who did not use the method during the task (the dark bar in each pair). The overall mean difference of all responses between users of the method (4.08) compared with non-users (3.42) is 0.66 on a 5-point Likert scale.

The improved learning hypothesized in H1a is evidenced by the experiential activity corresponding to an increase of 0.72 on a 5-point Likert scale on the reported level of ability to apply the method to a similar task, and a difference of 0.54 in the reported ability to explain the method. Additional support for H1a can be inferred from the correlations between the learning measures and two items from the parallel study, DRATE and CONF. The decision rating (DRATE) measures the quality of the actual decision made in the decision task. The item CONF measures the level of confidence in the decision quality in the parallel study. The correlations in Table 1 suggest that when a method is applied the increased learning is translated to better decision quality and higher reported confidence in the decision.

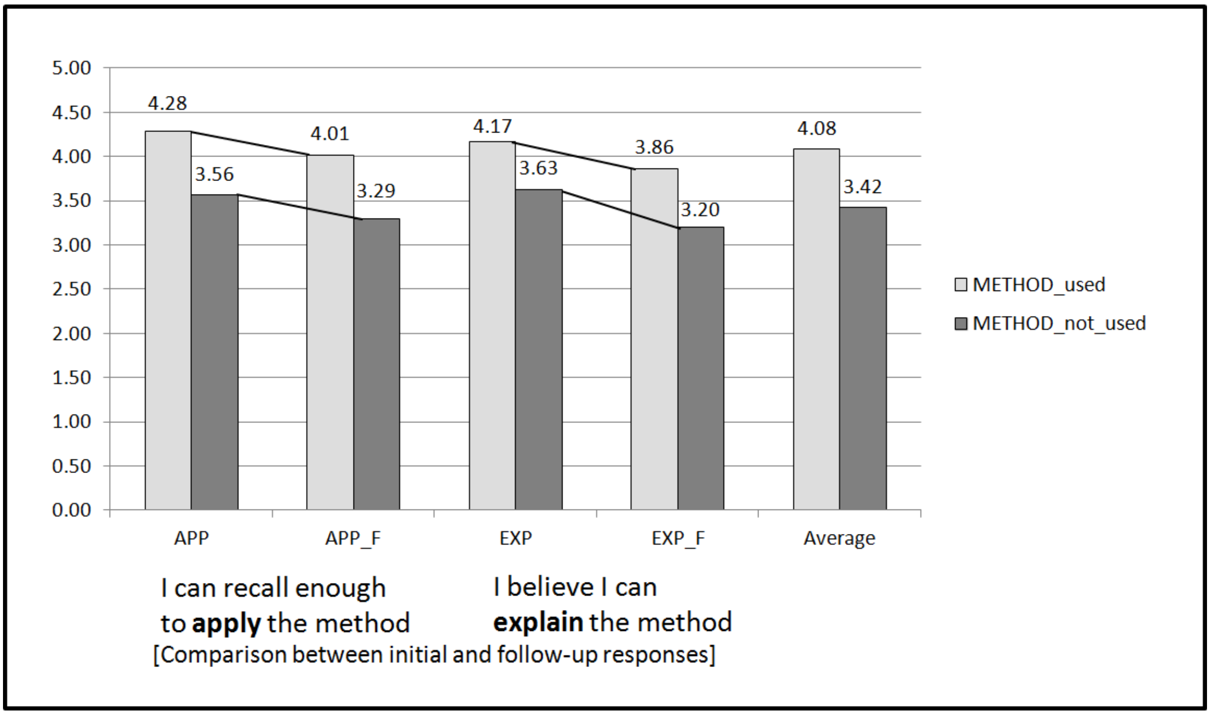

Figure 3: Effect of experiential activity on learning and retention

Responses on a 5-point Likert scale, comparison of responses between those who applied the method in the activity, and those who did not, data is compiled from users of all three methods. Differences between users and non-users of methods are all significant to at the 0.001 level or better. The lines link responses from the initial survey and the follow-up survey. Bold values in Table A2 in the appendix are displayed in this figure. See Table A2 for further detail of the data.

To address H2, student engagement was assessed through the two measures ATT and THINK in the initial survey. As shown in Table 1, Correlation with the overall responses about the levels of learning (APP and EXP) for all three methods shows a significant but mild relationship with ATT, but not with THINK; however correlation with the responses about the level of learning about the method applied in the task show stronger relationships. Although still moderate, the relationships provide solid support for H2, and show that higher levels of engagement during an experiential task are correlated with higher levels of learning from that task.

Additional insight and validation for Hypothesis 2 is found by comparing responses across the two studies. The correlations in Table 1 show relationships between the engagement measures ATT and THINK and their actual performance in applying the method (DRATE) and their confidence in their performance on the decision task (CONF). These relationships align with the findings on engagement and learning and provide further confidence in the findings in support of H2.

Table 1: Initial survey correlations between engagement, learning and decision quality.

		Measures of learning – Mean of responses		Measures of learning – Values for the method that was used in the task		Decision rating	Confidence in decision
		APP	EXP	APP (method_used)	EXP (method_used)	DRATE	CONF
Engagement	ATT	**0.228 *****	**0.172 *****	**.284 *****	**.255 *****	**0.192 *****	**0.265*****
	THINK	0.092	0.091	**.207 *****	**.186 *****	**0.106 ***	**.098 ***
Deci-sion rating	DRATE	.029	.090	**.238 *****	**.239 *****	–	**.303*****
Confi-dence	CONF	**.267 *****	**.264 *****	**..396 *****	**.397 *****	**.303*****	–

Pearson's Chi-square correlations; data from initial survey; bold figures are significant at the .001 level (***); and the 0.05 level (*).

Hypothesis 3 is supported through mild to moderate correlations, as shown in

Table 2. Ongoing interest in the topic was evaluated in the follow-up survey through measures of how much the student had thought about the task (THOT_F) and whether they want to know more after the task (WTKM_F). Both measures reveal significant mild to moderate correlations, with stronger correlation between THOT_F and learning than WTKM_F and learning. The analysis using the overall responses about the levels of learning

(APP_F and EXP_F) show slightly stronger correlations with THOT_F and WTKM_F than the analysis that used the responses about the level of learning about the method applied in the task. This difference in correlation does not follow the pattern identified in the evaluation of H2 on engagement and learning.

Table 2: Follow-up survey correlations between ongoing interest, enjoyment and retention of learning.

		Measures of learning		Measures of learning – Values for the method that was used in the task	
		APP_F	EXP_F	APP_F (method_used)	EXP_F (method_used)
Ongoing interest	THOT_F	**.238 ****	**.343 *****	**.178 ***	**.269 *****
	WTKM_F	**.209 ****	**.261 *****	**.200 ****	**.247 *****
Enjoyment and education	ENJY_F	**.193 ****	**.219 ****	**.235 *****	**.214 ****
	EDUC_F	**.270 *****	**.316 *****	**.199 ****	**.274 *****

Pearson's Chi-square correlations; data from follow-up survey collected six weeks after the task; bold figures significant at the .001 level (***) or .01 level (**).

Finally, Hypothesis 4, that enjoyment is correlated with perceptions of better educational value, is supported by the findings. High levels of enjoyment (4.09 on a 5-point scale) were reported in the follow-up survey, and these levels of enjoyment showed a fairly strong correlation (Pearson's chi = 0.484, sig 0.000) with perceptions of higher educational value from the task (mean 4.11 on the 5-point scale). This strong correlation is also supported by free (un-prompted) responses, such as those shown in Table 3. The task has also aided students in understanding research and has inspired a few students to consider conducting experimental studies of this nature as part of their research projects.

Table 3: Sample of free responses on enjoyment and learning

Selection of responses to 'Optional: Please use this space to record your comments about the decision task or the dependency evaluation methods.'
I liked the decision task best of everything we did in this subject – it was challenging and made me think of how to solve the problem
I really enjoyed the session, and I found it very useful.
I actually enjoyed the decision making activity. It was something that I have learned extra. I hope I can use this knowledge somewhere in my career.
Helps to reinforce concepts previously discussed. More memorable than lectures.
It was a great task and it was fun participating in the survey.
This was one of the activities I enjoyed most in the subject. Working out problems and looking at possible solutions and weighing them up is something I find interesting.

Learning dimension 3: Learning from innovation decision research

Findings from the parallel study on methods used to visualize interdependencies have provided valuable insights. The primary hypothesis proposed that the visualization method would affect the decision quality, and that due to a higher degree of cognitive fit with the problem being analyzed, the network mapping visualization (the VPM display) would contribute to better decision quality. The findings confirmed that the three methods influenced the decision quality in different ways, and statistically significant improvements in decision quality correlated with the use of VPM displays. A range of other findings on the levels of understanding of project interdependencies afforded by the three methods, the influence on perceptions of time adequacy and other factors were studied. These findings and details of all hypotheses from the parallel research on innovation decision making methods are included in other publications (Killen 2013a; Killen 2013b). In addition, the findings on decision quality and the respondents' confidence in their decisions have contributed to the analysis of hypotheses 1a and 2 as discussed above.

Discussion

A primary contribution of this study is illustrating how a novel experiential activity has been designed to meet the challenges for engineering education and research to do 'more with less'. The design of the 'decision task' as an educational and dual-purpose research session has provided multiple benefits and enhanced learning in three dimensions. Careful design has created a task that aligns with the 'engineering innovation' educational context, is supported by the students' preparedness for the task, and enables students to engage in a challenging activity based on real-world challenges.

Student learning is highlighted by the 'learning about learning' produced through the study. The effect of experiential learning is evident, even from a relatively short class activity. Retention of learning appears to be supported particularly well by the experiential activity. It is not surprising that the degree of learning reported reduced during the six-week gap between the initial and follow-up survey (as indicated by the downward sloping lines between the initial and follow-up responses for the variables in Figure 3). However, the interesting finding is that the learning advantage from experience with a method was retained and even slightly extended over time. These findings suggest that experiential learning may be especially important for retention of learning, as suggested by earlier work by Specht and Sandlin (1991).

The support for hypotheses 1a and 1b, showing the positive effect of the experiential activity on learning and retention, is encouraging. However, student learning about a method offers no particular benefit in itself; it is the application of this knowledge that is of particular interest. For this reason, the correlation of the findings on learning with findings on decision quality from the parallel study are especially valuable because the increased learning is shown to be related to better innovation decision-making abilities. These findings provide measurable outcomes to confirm that the learning from experiential activity can lead to the development of practical abilities. This is an important finding that shows how the inclusion of experiential activities in engineering education can contribute to the development of engineering competencies.

In line with earlier research, the correlations between engagement and learning were significant but not very strong (Smith et al. 2005; Carini, Kuh, and Klein 2006). Correlations were more evident with the learning responses for the method that was applied than with the overall responses on learning. This supports expectations; the effect of the use of a method on learning should more accurately measure the relationship. The mild to moderate relationships provide some support for Hypothesis 2 and suggest that, while engagement is valuable for learning, it is only a part of the picture. The finding has also been reinforced by the correlation between the attention to the task and the resulting decision quality and confidence with the decision.

An unexpected finding was the difference between results for the item THINK (how much the task made the student think) and ATT (how much attention was focused on the decision task). The mean values for THINK were only slightly higher; however, the correlations were much weaker or non-existent. While the two items were intended to measure the degree of engagement with the task, the results suggest that the items have measured aspects that are quite different. The decision task was designed to be difficult and to require a high learning curve on the application of a new method. Given the level of challenge in the task, it is not surprising that students were required to think – but for some students a higher level of 'thinking' did not lead to either better learning in the overall analysis or better decisions. At the same time, those that were able to maintain focus on the task consistently achieved better learning and better decisions. The results suggest that further investigation is required to increase understanding of this unexpected finding.

Analysis of the relationship between ongoing interest and learning provides mild support for Hypothesis 3; however, the differences in strength of correlation between the average learning and the learning measures for the specific method are counterintuitive. Although the relationships with learning measures for the applied method would be expected to be stronger, as in the analysis of engagement and learning from the initial survey, they are in fact slightly weaker. It is possible that the measures of ongoing interest have a broad effect on retention. At a mild to moderate level of correlation, the students who thought about the task and those who wanted to know more after the task have better retention of their learning about all methods, not just the one they used. This situation warrants further study on how ongoing interest, curiosity and motivation to learn about a topic influence learning and retention.

While the correlation between perception measures of enjoyment and educational value was quite strong, it may be affected by the 'halo effect' that tends to influence students who enjoyed the activity to also feel it is of better educational value (Gosen and Washbush 2004). Therefore these findings should not be taken at face value, and the level of support for Hypothesis 4 needs to be considered in the context of the wider study. The mild correlation between reported levels of enjoyment and the measures of learning (the ability to apply or explain each method) may provide a better indication of the relationship than the perception of educational value.

The findings provide a unique look at learning and retention by providing an experimental research design that enabled a detailed analysis of the effect of an experiential activity on learning. The experimental approach also produced detailed findings on the effect of different methods for visualizing data on project interdependencies on the resulting decision quality. The dual-purpose research design has provided the ability to corroborate the findings on reported measures of learning with the demonstrated ability to make quality decisions. In this way, the study has shown how experience can enhance learning that can be applied to enable engineers to solve problems. This provides an additional layer of support for the inclusion of carefully designed experiential activities to enhance engineering education.

Limitations and future research

This study provides an example of an experiential experiment-based decision task that was used to support two parallel research studies while enhancing students' educational outcomes. The ability to successfully combine the three goals will depend upon the discipline areas and the types of research studies, and may not be practical in some other areas of engineering education. Future research may seek to follow this type of model and explore the breadth of applicability for successful implementation of this type of approach.

The findings on learning and engagement have been generated by a short decision task during one class session, and the retention findings were based on the follow-up survey six weeks later. Further studies from more lengthy experiential activities, or on the cumulative effect of multiple experiential activities, could provide valuable insights into the relationships. In addition, studies with a longer duration between initial and follow-up surveys, or those that are able to collect matched pairs of initial and follow-up data, could provide a deeper level of understanding of the effect of experience on retention.

The results of the study may be influenced by bias from the single informant nature of the study; however, the study has been designed to reduce the ‘halo effect’ and correlations with data on decision results from the parallel study have provided additional support for the perception-based findings.

Conclusions and implications

The decision task, implemented as part of the experiential engineering approaches to engineering innovation education at UTS, has been a triple success. First and foremost, student learning has been enhanced. Several measures of learning confirm that students have benefitted from the experiential activity. Enjoyment of the activity was high and student perceptions of educational value are statistically supported by the educational research study. In addition, students received an additional layer of learning about the nature of research and the research process. The second success from the decision task is the strength of findings from the educational research study. The study has provided clear correlations between experience and increased learning and retention of learning, and provides additional insights on the influence of engagement and interest in a topic. The third success is from the parallel study. The decision task has further developed the understanding of methods for visualizing data to support project portfolio decision making. This parallel study has produced a series of findings that are reported in other publications and has also provided insights to support the educational study.

These three areas of success, and the corresponding three dimensions of learning from the decision task, are a result of a novel educational research design that merges three goals into one activity. The study was designed so that all students were able to learn from the decision task; there was no control group that did not have the opportunity to participate. The approach allowed the comparison of findings on three methods in a design that minimized ‘halo effect’ bias by ensuring that all students had the chance to enjoy the experiential exercise. By employing an experimental research design in a controlled setting, the study isolated differences stemming from experience. It dovetailed two research studies into the one activity, producing ‘learning about learning’, and ‘learning from innovation decision research’ while enhancing student learning. In addition, the correlation of findings from the two parallel studies provided a deeper layer of understanding: student learning from the decision task correlated with an ability to make better decisions, underscoring the effect of the experiential activity on the development of practical real-world abilities

The study has implications for engineering education and research. The findings demonstrate the influence of experiential activity on learning and provide support for further inclusion of experiential activity in engineering education. In particular this research illustrates how experiential activity can assist engineering educators meet the growing need to develop engineering students’ ability to manage technological innovation. Engineering educators and researchers may find inspiration from this example and design a multi-dimensional study using a similar approach. Future research directions have been suggested that may help adapt this type of approach to other environments and extend the findings from such studies. The decision task study provides a richly detailed example of experimentation in the classroom and illustrates how it can be designed to be educational and engaging and to collect data for multiple purposes. The study demonstrates how this type of approach can help to address challenges in engineering education by doing ‘more with less’: it provides an experiential learning task that is tailored for innovation engineering education, generates insights through a simulated experience based on a real-world scenario, engages and educates students, and enables researchers to perform research and generate results for multiple studies at once.

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APPENDIX

Table A1: Numbers of responses in each category. The item 'METHOD' was included on each survey to determine which method was applied in the decision task.

	Initial Survey	Follow-up Survey
Total number of responses	480	192
METHOD = Dependency matrix	162	63
METHOD = Visual project map	166	70
METHOD = Tabular list	152	59

Table A2: Results summary for survey items on learning and retention

Item number (survey items)	Label (survey items and variables)	Item statement for 5-point scale Likert response	Mean of all data	Mean for users of the method	Mean for non-users of the method	Mean diff users and non-users ***
1 2 3	APP.D APP.V APP.T	I can recall enough about the different methods to **apply** them to a similar problem	3.85 3.92 3.70	4.17 4.45 4.21	3.66 3.61 3.42	.51 .84 .78
	APP	Average values for the above three items across the sample	3.83	**4.28**	**3.56**	**0.72**
4 5 6	EXP.D EXP.V EXP.T	I believe I could **explain** the different methods to others	3.86 3.92 3.70	4.14 4.28 4.09	3.70 3.71 3.48	.44 .57 .61
	EXP	Average values for the above three items across the sample	3.83	**4.17**	**3.63**	**0.54**
7 8 9	APP.D_F APP.V_F APP.T_F	I can recall enough about the different methods to **apply** them to a similar problem	3.40 3.74 3.46	3.83 4.13 4.05	3.19 3.51 3.16	.64 .62 .89
	APP_F	Average values for the above three items across the sample	3.55	**4.01**	**3.29**	**.72**
10 11 12	EXP.D_F EXP.V_F EXP.T_F	I believe I could **explain** the different methods to others	3.34 3.58 3.37	3.77 4.05 3.81	3.19 3.33 3.15	.58 .72 .66
	EXP_F	Average values for the above three items across the sample	3.43	**3.86**	**3.20**	**.66**
	OVERALL	Mean response	3.72	4.08	3.42	.66

(Labels with .D refer to responses related to the Dependency Matrix, .V for the Visual project map, and .T for the Tabular display; Labels with _F appended are from the follow up survey six weeks later. Standard deviations for mean data range from 0.8 to 1.1; Numbers of responses were guided by the breakdown in Table A1; *** Mean difference values all significant at .001 or better; Bold data are displayed in the graph in Figure 3).

Participants were presented with item scales anchored at the end- and mid-points for each of the items listed in Table A2. The following example illustrates the style of anchoring used in the data collection survey for the item:

"I can recall enough about the different methods to apply them to a similar problem"

	1	2	3	4	5
APP.D Dependency Matrix	I have no recall of the method and I could not repeat the task now		I may need some prompts, but I could repeat the task		I am confident that I could repeat the task without further prompting

< in a similar fashion one row was used to collect responses for each method in the initial and follow up survey>

Table A3: Descriptive statistics for other survey items

Item Label	Item statement for 5-point scale Likert response	Mean	Std. Deviation
ATT	My attention was focused on the decision task	3.96	.927
THINK	The decision task caused me to think	4.13	.897
CONF	I am confident I have selected the best projects to eliminate	3.61	1.044
^ DRATE	Rated variable on decision quality (5 is the best decision quality)	2.84	1.499
ENJY_F	I enjoyed the decision task	4.09	.855
EDUC_F	The decision task session was educational	4.11	.861
THOT_F	I have thought about the decision task since the class session	3.21	1.194
WTKM_F	The decision task session has made me want to know more about the topic	3.47	.992

(ATT, THINK and CONF are items from the initial survey (*N*=480), ^ DRATE is a rated variable based on the initial survey (*N*=480), and the remaining items with _F appended to the label are from the follow up survey six weeks later (*N*=192). CONF and DRATE were developed for the parallel study on innovation decisions and found to provide additional insights for H1 and H2.

Participants were presented with item scales anchored at the end- and mid-points for each of the items listed in Table A3 except for DRATE. The following example illustrates the style of anchoring used for the item:

ATT: "My attention was focused on the decision task"

1	2	3	4	5
Not at all, it was uninteresting and I could not focus		It held my attention enough of the time		I was deeply engrossed in the task and did not notice the time passing

^ The decision quality rating DRATE was developed by rating the decision on how well it balanced the required criteria and how closely it represents an optimal decision. To reduce the potential bias from the use of judgment in the rating process, two researchers separately developed the ratings with no knowledge of the method used or class session of the participant. The ratings were then discussed and final ratings agreed.