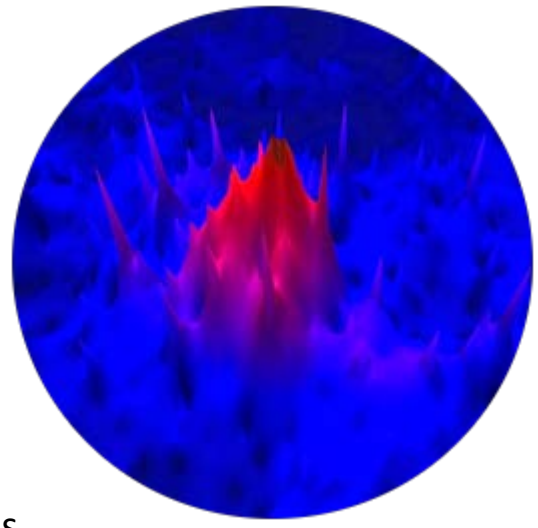
Australian Government | Office for Learning & Teaching

# Enhancing collaborative learning in information systems business analytics using data visualisation and manipulation techniques

Final report 2015



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visanalytics.org

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# List of acronyms used

| | |
|---|---|
| ADDIE | Analyse, design, develop, implement and evaluate |
| BA | Business analytics |
| CME | Cooperative and mutual enterprises |
| IS | Information systems |
| IVA | Interactive visual analytics |
| OLT | Office for Learning and Teaching<br>see http://www.olt.gov.au/ |
| SAS | Statistical Analysis System,<br>see http://www.sas.com |
| TUN | Teradata University Network,<br>see http://www.teradatauniversitynetwork.com/ |
| VA | Visual analytics |

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# Executive summary

Technological advances combined with the mass adoption of social media and digital devices have changed the role of information in our economy. This is truly the 'Information Age' with individuals and organisations creating, capturing and consuming data like never before: IBM[1] estimates that the world creates 2.5 quintillion bytes of data each day. Apart from the sheer volume, modern-day data also has velocity, variety, veracity, and is now associated with the buzz phrase 'big data'. Organisations that have the skills and technological tools to capture and use this deluge of information strategically are gaining a competitive advantage, and business analytics professionals who have the skill set to make this possible are highly valued.

While the industry has been quick to leverage advances in technology to develop tools that are able to capture, store, manipulate and process complex data, the development of analytics skills and expertise has lagged. One of the difficulties in building skills in this field is that analytics, rather than being a discipline of its own, is multidisciplinary. It requires both technical and domain expertise and the ability to grasp complex, abstract business problems. Hence, teaching business analytics, especially to undergraduate business students, is particularly challenging. The project team set out to address this challenge through the use of visual analytics, where visual metaphors provide an effective vehicle for capturing complex, multifaceted problems. The selected approach is especially well suited to the present generation of students, who are accustomed to engaging with interactive visualisations in their day-to-day use of consumer electronics such as smart TVs, tablets, mobile phones and video game consoles.

The aim of this project was to develop effective methods and tools for teaching analytics by visual interaction with data, as informed by industry practices and founded in educational research. The project team set out to achieve this by creating the *Visual Analytics Collaboratory* – a place (labs at Deakin University and The University of Sydney), a space (on the web) and a community (of students, teachers and researchers) to enable co-development and sharing of technical and educational resources to support teaching and learning of visual analytics.

The successful development of different aspects of the *Collaboratory* included a conceptual framework of the ways thinking and working together could be accomplished, patterns of collaboration and co-design of innovative teaching activities among academics, the language for expressing these activities in a systematic and consistent way, learning designs, software tools for educational activities, as well as shared repositories of resources and ideas for teachers and researchers. The project team wrote 11 papers to disseminate the learnings through the life of the project, and contributed new knowledge in the use of business intelligence for decision-making, the design and use of visual analytics and visual metaphors, and teaching and learning methods in business analytics. In addition, the project provided a pathway of thinking about visual analytics deployment in education and industry that goes well beyond the current standards and practices, and which is technology independent.

[1] https://www-01.ibm.com/software/data/bigdata/what-is-big-data.html

The learning designs, methodologies and curriculum, included in this *Collaboratory* were trialled across the partner institutions, and the visual analytics tools and teaching resources used were found to be capable of improving learning of the fundamental concepts of business analytics. The team developed a theoretical framework of primary metaphors for the design of visual forms for interactive visual analytics and developed guidelines for the development of data visualisation tools that are cognitively acceptable to students undertaking study in business analytics. The project evaluated multidimensional educational data terrain environments that facilitate learning through visual analytics and adopted gamification to create a new generation of data visualisation tools that are engaging, interactive and immersive for individual and collaborative exploration of data.

The learning outcomes of this research project extend beyond academia: the project developed deeper understandings of the organisational context in which business analytics plays a pivotal role, supporting management decision-making, and how information visualisation – and visual analytics in particular – can assist creative problem-solving in a data-driven organisation.

The project provided many new opportunities for its members and their partner institutions to establish research and industry links and initiate new ventures in this project area. The research program was very successful in securing industry collaboration, and helped build many linkages across academia and industry, as well as a diverse community of practice.

The resources made available through the *Visual Analytics Collaboratory* and the Teradata University Network (TUN) will entice others to join a growing community of academics teaching visual analytics. This community will continue to share and exchange their field experience to contribute to the further evolution of this very exciting field.

This research project has demonstrated the role of visualisation in teaching and learning, particularly in fields such as business analytics that draw on multiple skill sets and perspectives. Visualisations and visual metaphors helped students conceptualise complex, dynamic business problems and understand the value of information. The visualisation tools proved to be a very effective medium to integrate multi-disciplinary knowledge and approaches, while keeping the focus on the business problem. Above all, visual analytics taught students to work collaboratively to draw on the range of skills, expertise and perspectives around the table to learn from each other. This way they incrementally build their understanding of a problem to develop insights, explore a range of possible solutions and come to a consensus on the best way forward – invaluable for both work and life.

# Project context

**Business analytics and big data:** In today's business world organisations face constant environmental volatility and change, which are responsible for the creation of an enormous amount of corporate data. To master this change and turn it to business advantage, many organisations strive to transform the huge volume of available data into a genuine understanding of business. Consequently, such organisations are able to base their decisions on insights derived from facts – a process called business analytics (BA) (Shanks and Bekmamedova, 2012).

**Need for BA education:** A recent study by the McKinsey Global Institute predicts that by 2018 the US market alone will face a shortage of 140,000 to 190,000 people with strong analytical skills, and 1.5 million managers and analysts to work in the big data space (Manyika, Chui, Brown, Bughin, Dobbs, Roxburgh & Byers, 2011). In order to cater for future demand of BA graduates, higher education institutions are designing new BA curricula, combining materials from many different disciplines such as statistics, operations research, information management, information systems, business, computer science and artificial intelligence.

**Challenges of BA education:** The effective delivery of new university BA courses faces numerous challenges (Wixom, Ariyachandra & Mooney, 2013). These include unavailability of suitable teaching tools and resources, rapid rate of technology and curriculum obsolescence, and shortage of academic staff able to teach multidisciplinary content (Wixom et al., 2013). Furthermore, BA curriculum includes complex and abstract subject matter that has been traditionally challenging to students with little mathematical knowledge (Prabhakar, 2008) and no prior exposure to the business world (especially in their first year of study) (Harmer, 2009).

**Solution to BA challenges: visual analytics in BA curriculum:** As a solution to the challenges of BA education, the project team suggested introducing BA curriculum where difficult analytics concepts could be introduced gradually with exercises and learning accomplished by interaction with the familiar visual metaphors of business problems – the approach known in BA as visual analytics (VA) (Ham, 2010). In this way, the gap between the knowledge and experience of learners and the abstract concepts and methods of BA could be reduced. The visual metaphors may incorporate interactive 2D and 3D forms, commonly encountered in consumer electronics products (such as smart TVs, tablets, mobile phones and video game consoles), which are very familiar to the present generation of students, and thus the future generation of business decision-makers.

**Project aim: development of the *Visual Analytics Collaboratory*:** The project's main aim was to establish a facility called the *Visual Analytics Collaboratory*, serving academics at partner institutions, but also nationally and internationally. The *Collaboratory* would provide access to a shared repository of tools, data sets, methods and educational materials to support teaching and learning of BA by means of visual interaction with data. The project research results would subsequently be disseminated via the *Collaboratory*, but also at workshops, conferences and in academic journals.

# Project approach

## Approach

The design of the project tools and resources was informed by the constructivist view of learning and the principles of instructional systems design, where learning is seen as a sensemaking activity to construct and integrate new understandings into learners' existing knowledge frameworks (Wittrock, 1989), often undertaken collaboratively. Project activities were guided by Driscoll's (1994, pp. 359–377) five constructivist conditions for learning. The constructivist view of learning is particularly suited to educational approaches that rely on technologically enabled environments, simulations and serious games (Aldrich, 2009); in other words, a setting similar to the proposed *Collaboratory* environment.

Table 1 explains how these constructivist conditions were applied to the visual learning of BA concepts.

**Table 1: Constructivist conditions of learning vs project design**

| Constructivist conditions of learning | Design of the project tools and resources |
|---|---|
| Provide complex learning environments that incorporate authentic activity. | Students are challenged to solve complex business problems (using real data) that require exploration and intuition in authentic business decision-making. |
| Provide for social negotiation as an integral part of learning, providing learners with the opportunity to share understandings and perspectives, leading to deeper understanding and knowledge construction. | Students are encouraged to solve business problems collaboratively in teams, thus exploring different viewpoints, discussing options, making group decisions and debating impacts of actions based on such decisions; therefore emulating workplace practices. |
| Juxtapose instructional content and include access to multiple modes of representation, allowing multiple perspectives. | Students are provided with the ability to investigate problems and solutions visually, exploring alternatives to reveal underlying mathematical models. |
| Nurture reflexivity, supporting critical thinking and increasing self-awareness in the knowledge construction process. | Students are offered immediate feedback to nurture reflexivity. Learning materials and case studies are designed to foster critical thinking. |
| Emphasise student-centred instruction whereby students take ownership of the process. That is, students actively engage in how and what they will learn. | Students are confronted with open-ended issues of business and social urgency, where they can decide what, how and where they will engage with problems. |

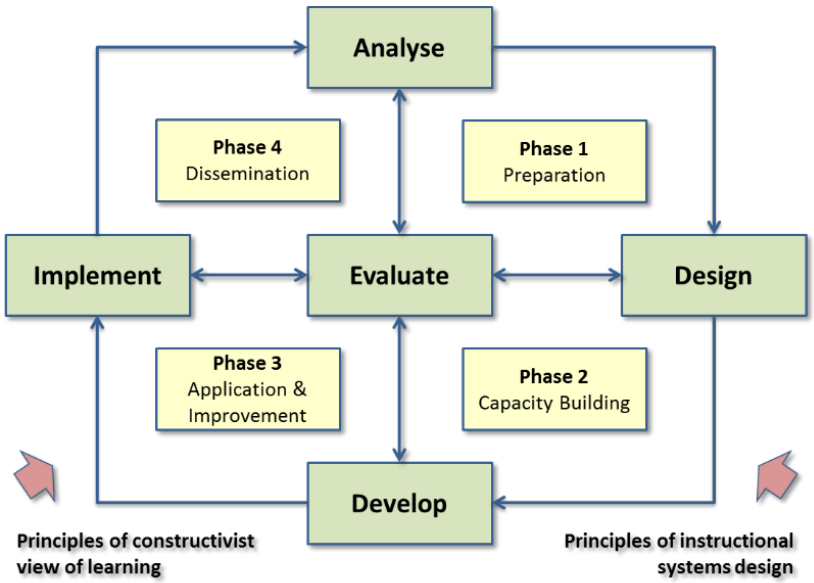



**Figure 1: Conceptual roadmap for the project**

## Methodology

The planning and execution of the project was guided by the conceptual roadmap shown in Figure 1. The development of the educational experiences and the technology underpinning the project are tightly integrated and the project team used the high-level instructional design model ADDIE (analyse, design, develop, implement and evaluate) to inform design, development and delivery (Dick and Carey, 1996; Leshin, Pollock & Reigeluth, 1992).

Figure 1 shows the five components in the ADDIE process (in green) and highlights the importance of evaluation and feedback loops. To operationalise the ADDIE model, the project was broken into four phases (shown in yellow in Figure 1). These four phases provided support for three rounds of formative evaluation, a summative evaluation of the project and a schedule of project dissemination. The four phases are outlined below.

**Phase 1 – Preparation (6 months):** consolidated the domain literature, elaborated the project plans, acquired the necessary technology and data sets, and appointed the necessary staff.

**Phase 2 – Capacity building (6 months):** designed, developed and trialled some of the project technology and teaching and learning resources, as well as created the infrastructure to support VA in teaching and learning.

**Phase 3 – Application and improvement (6 months):** conducted further development and refinement of the previously piloted tools and resources in teaching at the partner institutions. Future technologies and practices in VA were also explored.

**Phase 4 – Completion and dissemination (6 months):** completed and subsequently disseminated all project outcomes within the partner institutions, and at national and international forums for VA practice.

## Project outcomes

The conceptual aspects of the Collaboratory included design *of a new way of working and thinking together*. This included a conceptual framework that was used to guide the project work in very diverse environments – in terms of contexts, students, units, and educational objectives – in a systematic and consistent way. The framework provided the ways of aligning learning objectives, industry expectations, design of student activities, and research methods with the outcomes of this project (see Table 2).

**Teaching and learning objectives:** The teaching and learning objectives shared between the two partner institutions (see column 'A' of Table 2) included for students: (1) initial exposure to VA; (2) the ability to conduct data analysis with the support of VA tools in business contexts; (3) development of a reflective attitude to VA tools and methods; (4) the ability to collaborate with others in an analytic process and negotiate shared insights from visualisations; and finally (5) the chance to engage with novel and unfamiliar forms of data visualisation, collaboratively establish new data interpretations in new contexts, and creatively engage in visual problem-solving.

**Teaching and research activities:** Teaching and research teams at both partner institutions planned a series of highly interrelated activities that would support teaching of VA curriculum and advance the project research agenda (columns 'B' and 'C' of Table 2).

***Activities at Deakin:*** research at Deakin University focused predominantly on undergraduate students. Phases 2 and 3 of the project utilised custom-made visualisations in tutorials to compare students' learning outcomes when using visual and traditional methods of teaching. Phase 4 used a series of lab experiments to investigate how students work individually and collaboratively with conventional (2D) and novel (3D) VA systems; video data was collected and analysed using protocol analysis. Differences in students' behaviour were determined to create guidelines for the development of future VA systems to support educational curriculum.

***Activities at Sydney:*** The Sydney team focused on the design, implementation and evaluation of a series of innovative collaborative activities with undergraduate and postgraduate students, using the state-of-the-art cloud-based VA tools provided through TUN. The activities were initially conducted with the mainstream business intelligence and analytics students and later expanded to include non-BA specialists. Research at The University of Sydney focussed on the conceptual aspects of the *Collaboratory*, as well as, development and evaluation of learning designs and online collaborative environments.

***Project outcomes:*** The practice-informed education research resulted in learning designs, software resources and research publications (see column 'D' of Table 2).

**Audience needs:** The project outcomes fulfil the needs of *industry*, *academics* (both teachers and researchers) and *developers* of educational and software resources (see column 'E' of Table 2, which briefly explains what project outcomes are useful to what audiences and how).

**Table 2: Learning objectives aligned with student activities, research methods and outcomes *(D – Deakin, S – Sydney)***

| Phase | A. Learning objectives<br>*As shared across Deakin and Sydney* | B. Tasks at Deakin University<br>**Undergraduate focus**<br>*+ Deployed research method* | C. Tasks at The Uni. of Sydney<br>**Postgraduate focus**<br>*+ Deployed research method* | D. Project outcomes<br>◆ *Research reports / publications*<br>⊙ Educational resources | E. Audience needs<br>*Explanation of outcomes to the intended audience* |
|---|---|---|---|---|---|
| **1** | Preparation | *Literature review* | *Literature review* | ◆ BI-based organisations (D)<br>◆ Creative visual analytics (D) | **Academics and Industry:** Visual analytics in business |
| **2** | Initial exposure to VA | Tutorials 6 and 7 (Music Store)<br>*Statistical analysis of students' achievements in tutorial tasks* | Homework SAS VA Assign. 1<br>*Development and evaluation of learning designs* | ⊙ Animated CD Store (D)*<br>◆ Interactive visual narratives (D)<br>⊙◆ Learning designs for VA (D&S) | **Academics:** Explanation of how to implement and evaluate VA learning designs |
| **3** | Data analysis in business context<br>VA in practice | Tutorial 3 (SAS VA) and Assignment 1 (Excel)<br>*Text mining of students' assignments to determine their views on the applicability of visual methods to problem-solving* | Homework SAS VA Assign. 2<br>*Development and evaluation of learning designs* | ⊙ Simulated Online CD Store (D)* | **Academics and Developers:** Large scale simulation based on the previously evaluated learning designs |
| | Reflective thinking on VA tools and methods | | Homework SAS VA Assign. 3 & 4 / workshop<br>*Development and evaluation of learning designs* | ◆ Student perception of VA (D)<br>◆ Using practitioner stories (S) | **Academics:** Methods of measuring and evaluating knowledge learnt from exposure to VA learning |
| **4** | Collaborative development and negotiation of shared insights from visualisations | Lab experiment (Visual Analyst 2D and 3D)<br>*Protocol analysis of videos of students working individually and in teams using 2D and 3D visualisations, to determine design principles of interactive visualisations to support individual and collaborative learning* | Workshop in S1<br>*Development and evaluation of learning designs* | ⊙ Collaboratory web site (D)<br>⊙ Visual Analyst 2D (D)*<br>⊙ Visual Analyst 3D (D)* | **Academics and Developers:** Environments for sharing VA software and resources |
| | Exploring new types of data visualisation<br>Collaborative negotiated meaning in a new context; exposure to unfamiliar visualisations and visual thinking | | Homework / workshop<br>*Development and evaluation of learning designs*<br>*New sources of data (social media); student collaboration across functional boundaries (to gain data insights)* | ◆ Metaphors in interactive VA (D)<br>◆ Explorations with metaphors (D)<br>◆ Designing 2D and 3D VA (D)<br>⊙ Demonstration videos (D)<br>◆ Sharing and co-creation (S)<br>◆ VA & social media integration (S)<br>◆ Student collaboration (S)<br>◆ VA collaborative platform (S) | **Academics, Industry and Developers:** Publications and video demonstrations reporting experiences in teaching and collaborative learning with VA, as well as, best practice in designing VA tools suitable for educating analytics professionals |

** The project software is described on the Collaboratory software site and available in executable and source forms on the Open Source platform GitHub.*

# Project outputs and findings

## The Collaboratory – The shared repository of VA knowledge

**Over the project lifetime, the notion of the *Collaboratory* evolved to include not only the repository of resources but more importantly a place, a space and a community dedicated to exploring methods and ways of thinking and working together that could be embodied in newly designed educational practices.**

**Project website:** The project website has been established in a shared space outside the partner institutions' web sites. Its purpose is to report project-related details, such as information about the project team, objectives, activities and downloadable deliverables.
visanalytics.org/info/projects/visual-analytics-collaboratory/

***Visual Analytics Collaboratory* website:** The *Visual Analytics Collaboratory* (see Figure 2) spans partner institutions and provides a repository that allows members to share their insights, experiences and data. The *Collaboratory* has now grown beyond this project and also describes the work of other groups.
visanalytics.org

The *Collaboratory* website (see Figure 2) is the main VA dissemination hub and provides a blog of news related to current projects in VA, and an index of VA tools, data sets and business cases, some of which have been developed in this project and can be used by teachers, students and the general community. *Collaboratory* members can also provide access to synopses of their articles.

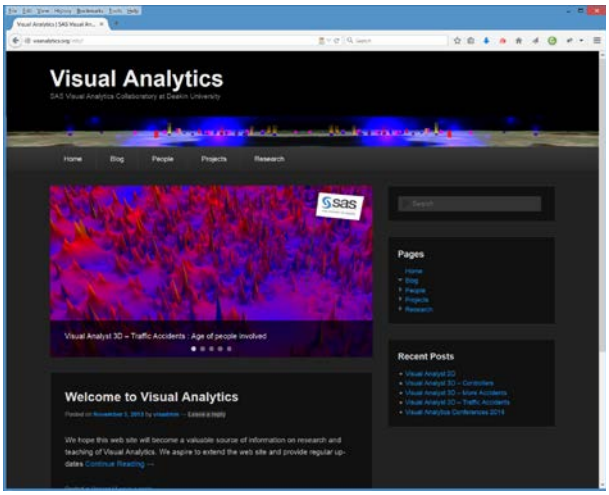


**Figure 2: Visual Analytics Collaboratory website**

**Other sites:** Other project websites, such as the Wikispaces and Yammer Site, were created to share project information; however, they require registration, login ID and password – details and access can be arranged by the project co-director Olivera Marjanovic.

The ***Visual Business Analytics (VBA) project on Wikispaces*** is a repository of VA learning designs (see Figure 3).

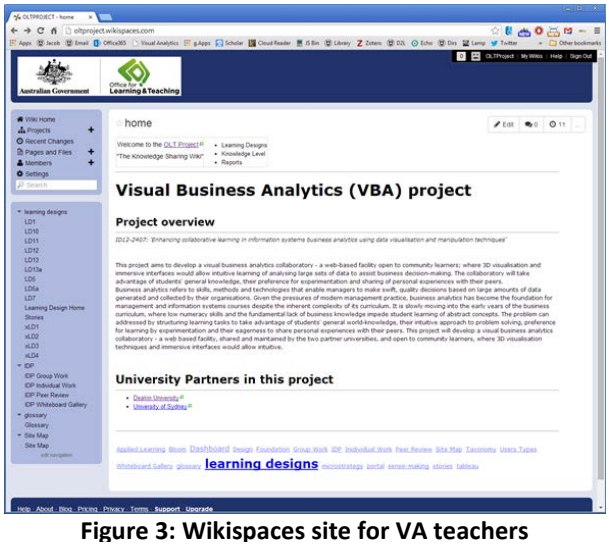


**Figure 3: Wikispaces site for VA teachers**

The ***Yammer site for the Australian/NZ Community of Business Analytics Educators*** is a discussion space developed by Sydney researchers for debating teaching BA at the tertiary level within the Australian context. It is designed as a (local) complement to the international community of TUN.

## The Collaboratory – A method of creating industry informed innovative learning designs

In order to create realistic learning experience for students, we designed a method of analysing industry practices to discover patterns of underlying challenges, and combining these patterns into innovative learning activities (see Figure 4), which were studied in this research. These activities were subsequently shared through the *Collaboratory* repository (that is, wiki spaces) by teachers to facilitate the design of engaging and collaborative student activities.

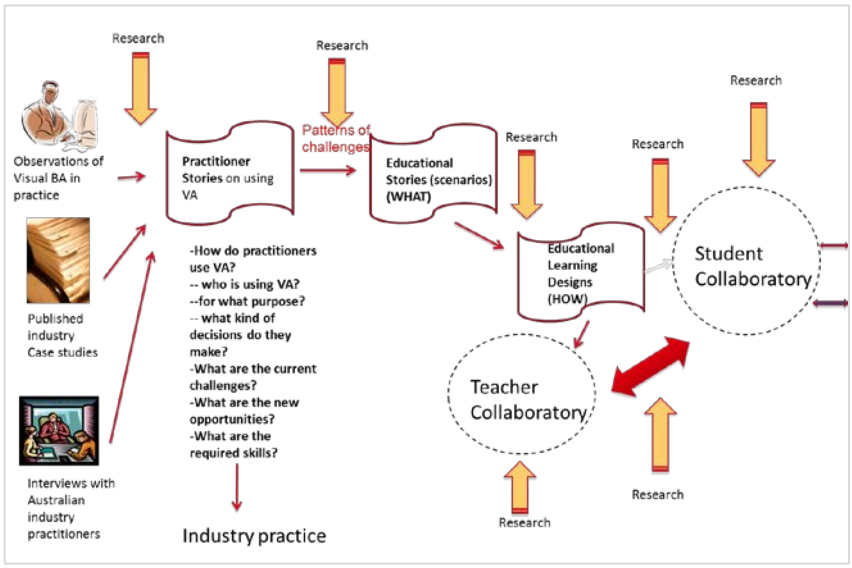



**Figure 4: Method of creating industry informed learning designs**

## *The Collaboratory – The conceptual tools for systematic description of innovative teaching activities*

Informed by educational research and frameworks, such as the Extended Bloom's Taxonomy and the Theory of Learning (Anderson, Krathwohl, Airasian, Cruikshank, Mayer, Pintrich, Raths & Wittrock, 2000), we designed a conceptual language for expressing innovative learning activities in visual analytics in a systematic and non-prescriptive way. The language was used to facilitate knowledge sharing and co-creation within our respective teaching practices (at both Deakin University and The University of Sydney) and set the foundations for such activities among any

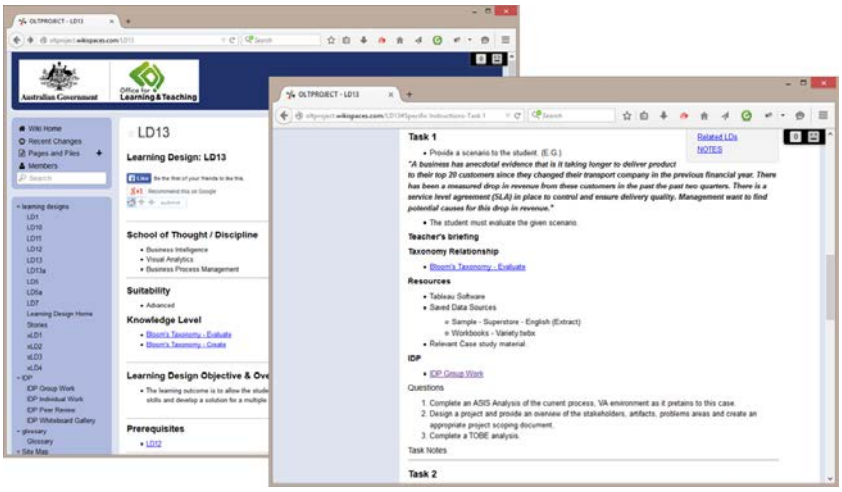
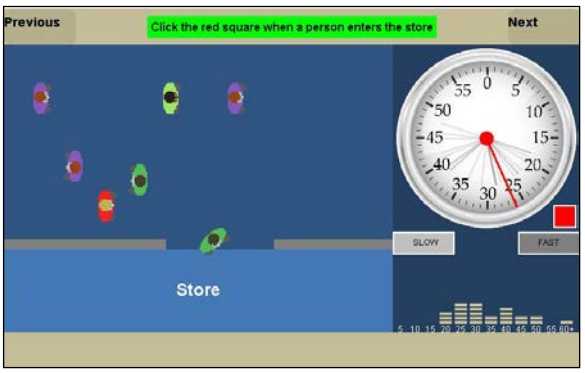



**Figure 5: A systematic description of innovative learning design in online repository**

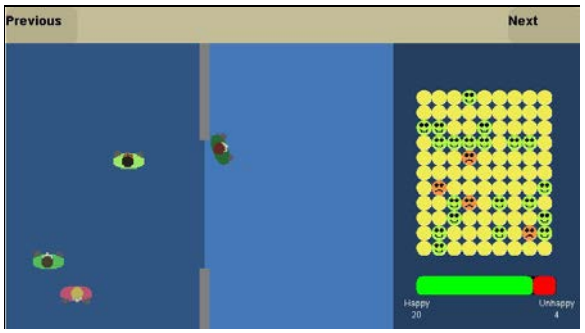
other users of the online wiki space environment (see Figure 5).

## The Collaboratory – Visualisation tools and their use

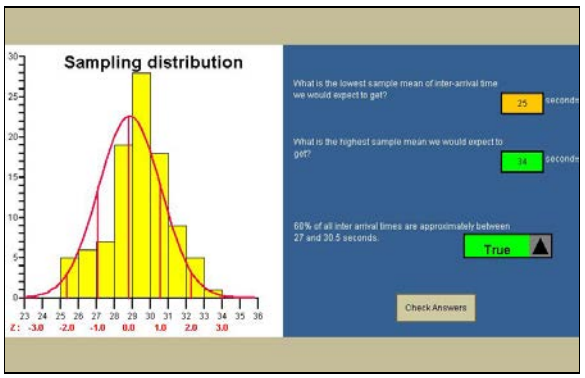
**One of the project objectives was to design, implement and evaluate the *Visual Analytics Collaboratory* and its tools, to support teaching and learning of BA (see column 'D' of Table 2).**




*(a) Measuring customer inter-arrival time*




*(b) Surveying customers leaving the store*




*(c) Analytics built into a 'game'*

**Figure 4: Animated *CD Store* analytic games using a custom-made Visual Tutor in Statistics (implemented as a Java applet)**

The *Collaboratory* VA tools were developed primarily by the Deakin University team, whereas the Sydney team relied on state-of-the-art cloud-based software tools provided through Teradata University Network (SAS-VA and Tableau) as well as an enterprise social media platform (Yammer) and web 2.0 collaborative platform (Wikispaces). The VA tools developed by the Deakin team simplify and highlight the fundamental aspects of analytic principles for classroom and online teaching. These tools were designed to utilise data visualisation, interactivity and often immersive data manipulation techniques, commonly used in 2D and 3D computer games and simulations. All software tools are open source and available online from the project software web site.

**Animated CD store:** One of the first tools developed, as part of a pilot study, was the Visual Tutor in Statistics, which provided an animated CD store (see Figure 6). At Deakin University it was used in Phase 2 of the project, to assist learning the fundamental concepts of BA (in two tutorials, see column 'B' of Table 2).

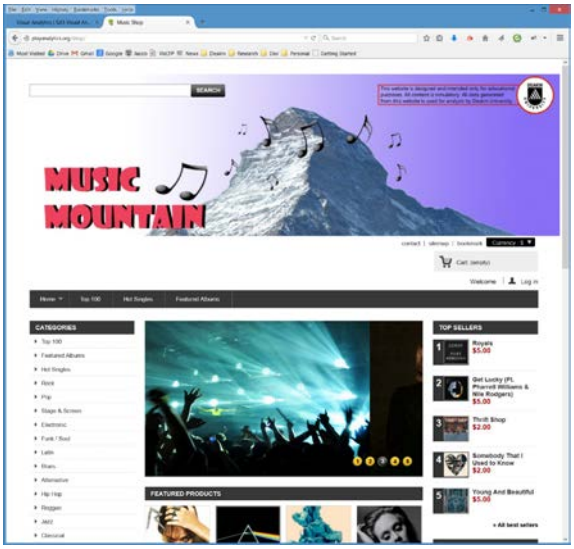
*CD Store* was presented as an online game with a business narrative where students were able to collect data, either by measuring customer inter-arrival time (see Figure 6a), or customer satisfaction with their shopping experience while departing the store (see Figure 6b). Subsequently, students were asked to perform a variety of analytics on the collected data (see Figure 6c).

After the tutorial, students participated in a quiz testing their knowledge of the newly learnt concepts and their answers were compared against the answers of those students undertaking the conventional tutorial. The results indicated significantly better learning outcomes when using visual methods of learning (Saundage, Keller, Marjanovic, Cybulski, Dharmasena & Matharage, 2015).

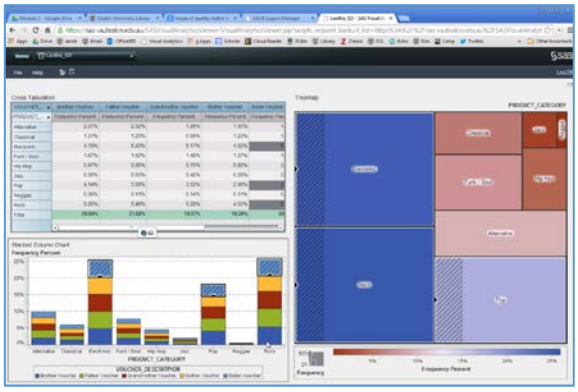
**Simulated online CD store:** While systems in use and cases deployed at each institution were vastly different, both teams utilised exactly the same set of learning designs (Keller, Marjanovic, Cybulski, Dharmasena & Saundage, 2015).

*At Deakin University, in Phase 3 of the project, students participated in day-by-day purchasing of music from a simulated online store, Music Mountain (see Figure 7a; demonstrated at playanalytics.org).*

Transactions generated by students were uploaded to a VA system, SAS Visual Analytics, so that in lectures students could be presented with the unfolding patterns of their own activity, and then in tutorial (tute 3, see column 'B' of Table 2) undertake an analysis of this data (see Figure 7b). Students also completed a quiz testing their learning and were asked to reflect on the VA used in this process. The reflections were analysed using text mining and compared against the reflections on the end-of-semester VA assignment. The results indicated significant changes in student perceptions of VA in problem-solving, as well as their growing ability to evaluate the benefits and challenges of different analytic technologies (Cybulski, Keller, Saundage & Dharmasena, 2015).




***(a)* Music Mountain *online music store***



***(b) Measuring customer purchasing patterns***

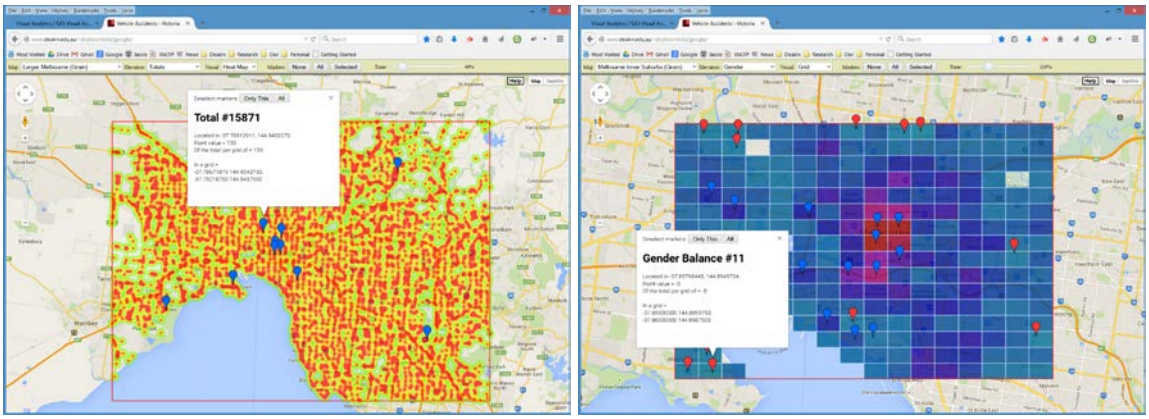
**Figure 5: The simulated online CD store and its analytic games in the SAS Visual Analytics system**

It should be noted that deployment and use of a web site available at playanalytics.org requires very significant technical skills. As such we do not share the site content with other educators. However, we can provide a "dump" of the site to those interested in the development of their own "online shop".

*While the Sydney researchers also utilised SAS Visual Analytics to support teaching BA to postgraduate students, the focus was predominantly on the students' collaboration in class.*

**Visual Analyst 2D and 3D:** Phase 4 of the project focused on collaborative work with unfamiliar data and visual forms (see columns 'A' and 'B' of Table 2). At Deakin, this involved students who had previously completed a BA unit. Consequently, experimental VA environments were used in this phase (Cybulski, Keller & Saundage, 2015), with some participants exposed to data represented in 2D (Figure 8) and others immersed in a 3D data terrain (Figure 9). Both groups of students relied on their ability to 'roam' the data terrain of motor vehicle accidents and identify data characteristics from terrain features, such as elevation, colour and shape. Previous experience with video games provided advantage to 3D terrain users. The two experimental groups demonstrated significant differences in behaviour, attitudes and performance, especially when working in teams. The results provided insights into the design of future VA systems for new

generations of analytic users (Cybulski, Namvar, Saundage, Keller & Dharmasena, 2015), especially in educational contexts.



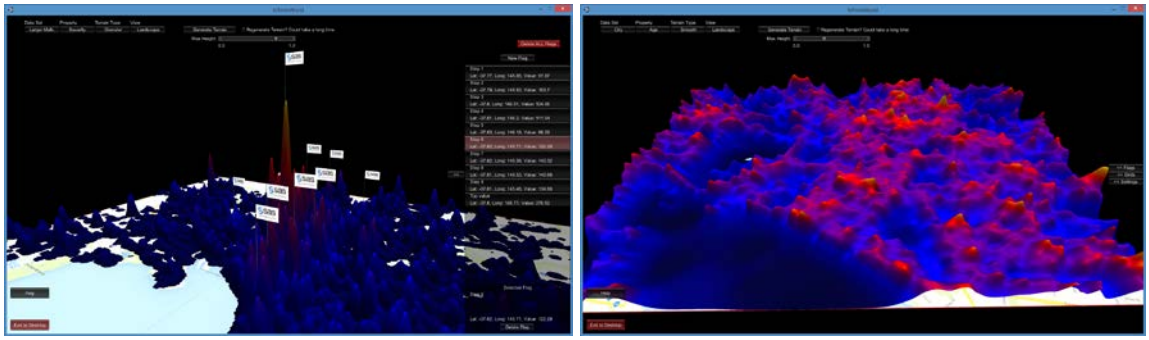

*(a) Total number of accidents (heatmap)* *(b) Gender balance of accidents (grid)*

**Figure 6: Motor vehicle accidents analytics (2D) developed in JavaScript**

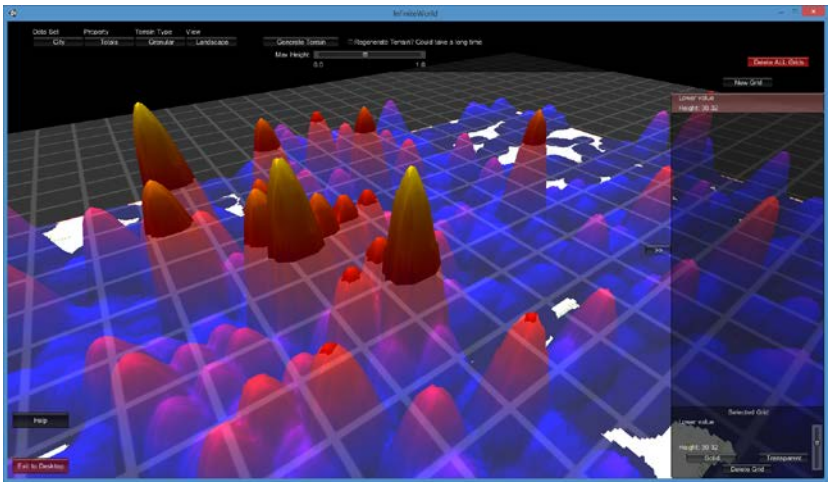
Visual Analyst 2D and Visual Analyst 3D, together with their executable files, sources for developers and user guides, can be downloaded from our software web site.

Visual Analyst 3D can be experimented with by accessing the following test site:
visanalytics.org/vademo/va2d/

Visual Analyst 3D is large and cannot be used online. However, examples of the tool use by the co-located groups of students (for example, in labs) can be found here:
visanalytics.org/info/projects/immersive-and-collaborative-decision-making-environments/



*(a) Total number of accidents (granular + flags)* *(b) Age of people in accidents (smooth)*



*(c) Navigation, measuring and comparing of data terrain features (grids)*

**Figure 7: Terrain of motor vehicle accidents (3D) developed in Unity3D with C#**

## Research reports and publications

**Synopses of the following articles describing the project-related research (in the order of appearance in Table 2, column 'D') are available for download from the *Collaboratory* website, as indicated below.**

**BI-based organisations:** Two articles that describe how BA can assist decision-makers in making sense of their business environment – an aspect that is at the core of any analytics curriculum (Namvar, Cybulski & Perera, 2015; Namvar & Cybulski, 2014). http://visanalytics.org/articles/olt/Namvar_BI_Based_Org.pdf

**Creative visual analytics:** This article provides an overview of VA as a method of creative problem-solving, which relies on analytic models and involves an iterative process of generation and evaluation of ideas in digital media (Cybulski, Keller, Nguyen & Saundage, 2015). http://visanalytics.org/articles/olt/Cybulski_Creative_IVA.pdf

**Interactive visual narratives:** This article describes in-class experiments which demonstrate that interactive visualisations and storytelling could assist students in developing essential BA skills (Saundage et al., 2015). http://visanalytics.org/articles/olt/Saundage_Narratives_in_IVA.pdf

**Student perception of visual analytics:** This article reports on a study of student perceptions of VA learning, when exposed to tutorial exercises and assignment work (Cybulski et al., 2015). http://visanalytics.org/articles/olt/Cybulski_Perception_of_IVA.pdf

**Learning designs for VA:** This article presents a method of using the Revised Bloom's Taxonomy to design VA curriculum, teaching materials and support activities to improve effectiveness of business analytics education (Keller et al., 2015).
http://visanalytics.org/articles/olt/Keller_Bloom_in_IVA.pdf

**Metaphors in interactive visual analytics:** This article provides some preliminary insights on the use of metaphors in VA design to reduce the cognitive load of VA analysts and users (Cybulski, Keller & Saundage, 2014).
http://visanalytics.org/articles/olt/Cybulski_Metaphors_in_IVA.pdf

**Explorations with metaphors:** This article describes a conceptual framework of primary metaphors to support the design of immersive 3D VA environments; it also discusses an architecture of VA based on such metaphors (Cybulski et al., 2015).
http://visanalytics.org/articles/olt/Cybulski_Metaphors_in_Data.pdf

**Designing 2D and 3D visual analytics:** This article describes sensemaking processes of (naïve) VA analysts when working with 2D (conventional) and 3D (novel) visualisations, individually or in teams (Cybulski et al., 2015).
http://visanalytics.org/articles/olt/Cybulski_2D_and_3D_IVA.pdf

**Sharing and co-creation of innovative teaching practices in business analytics:** This article offers the key insights from the action design research project resulting in an online wiki-based collaborative environment for VA educators ('*Teacher Collaboratory*') (Marjanovic, 2014a).
http://visanalytics.org/articles/olt/Marjanovic_Cocreation_in_BA.pdf

**Using practitioner stories to design learning experiences in visual analytics:** This paper describes an applied research project that aims to capture and analyse leading real-life industry practices in using visual analytics (VA) and 'translate' them into innovative learning activities. The main idea is to enable business students to experience the types of problems that industry practitioners are dealing with and help them to develop skills to tackle these problems, using state of the art VA tools (Marjanovic, 2014b). This paper received two awards: Best Paper at International Academy for Information Management AIS-SIG-Ed Int. Conference 2014; and Best Paper in Information Systems Education across all AIS Conferences in 2014.
http://visanalytics.org/articles/olt/Marjanovic_Stories_in_VA.pdf

**Combining visual analytics and enterprise social media to enable innovative practice-inspired learning activities:** This paper describes an innovative learning activity designed to extend data visualisation with collaboration structured around sharing co-creation and negotiation of departmental/disciplinary insights, using both internal and external data. Student collaboration is enabled and supported by a 'Student Collaboratory' that combines existing SAS-VA platforms, currently available on TUN, with the leading enterprise social media platform (Yammer). In addition to giving students access to state-of-the-art tools for visualisation and collaboration, an even more important educational objective is to expose students to current industry practices, with individual data-driven disciplinary insights no longer considered sufficient when dealing with complex multidisciplinary challenges (Marjanovic and Min, 2014a).
http://visanalytics.org/articles/olt/Marjanovic_VA_and_Social_Media.pdf

**Data visualisation and enterprise social media platform:** This practical teaching resource offers a step-by-step introduction to an innovative teaching activity designed to combine visual analytics (SAS-VA) and enterprise social media (Yammer). The activity takes students

through the challenges of producing and sharing functional (silo) data-driven insights and collaborative data-driven decision-making. The paper also explains how to design the same activity using different visualisation and collaboration tools (Tableau and Facebook) (Marjanovic & Min, 2014b).
http://visanalytics.org/articles/olt/Marjanovic_VA_with_Yammer.pdf

**SAS-VA assignments: Through my student's eyes:** This practical teaching resource offers valuable insights into the student perspective of working through SAS-VA assignments that were used at The University of Sydney (see column 'C' in Table 2). The paper covers all four assignments and as such could be used by both students and VA educators intending to use the same tool and learning activities. This paper was posted on TUN and shared with an international community of more than 2000 educators (Marjanovic and Min, 2014c).
http://visanalytics.org/articles/olt/Marjanovic_VA_in_Students_Eyes.pdf

## Other deliverables and methods of their dissemination

**The original project objective was to disseminate research findings via workshops, seminars and conferences, and by publishing results in journals.**

**Publications:** All project publications in journals and conference proceedings, as well as those currently in review and preparation, have been identified on pages 20-21.

**Educational Videos:** A number of YouTube videos have been prepared to demonstrate various aspects of the software developed as part of this project. The collection of videos is continually expanding to cover new educational topics (such as teaching analytics with R) and new projects. The Collaboratory web site has been used as an access point for all such resources.

**Open Source Software:** We initiated engagement with an open source community. We rely on the commonly used GitHub repository to archive all software tools developed in this project. The repository can be used to "spawn" the archived software to create new applications and projects.

**Presentations and seminars:** The project team represented some of the research, as well as teaching and learning project results, at numerous events at the hosting organisations, nationally and internationally, the most recent of which are detailed here.

**Table 3: Recent seminars and presentations by the project teams (2014-2015)**

| Deakin team | Sydney team |
|---|---|
| • 'Interactive Visual Analytics for Business and Education', School of Information Systems and Business Analytics, Deakin, Burwood (4 April 2014)<br>• 'Immersion, Creativity and Teamwork – Three Factors of Collateral Learning', ACDICT Learning and Teaching Forum UTS Sydney (8–9 May 2014)<br>• 'Graph Visualisation and Analytics' Postgrad Forums, Deakin, Burwood (3 October 2014)<br>• 'Metaphors in Interactive Visual Analytics', SAS International, Oslo, Norway (19 November 2014)<br>• 'Information Visualisation and the Library', Library Staff Day, Deakin, Burwood (4 December 2014)<br>• 'Interactive Visual Analytics and Intelligence Analysts', DSI-Deakin Research Workshop, Deakin, Geelong (8 December 2014) | • Scholarly Conversations on Learning and Teaching (SCOLT) seminar: 'Using Practitioner Stories to Design and Implement Innovative Learning Activities in Visual Analytics', The University of Sydney (15 May 2014)<br>• 'Addressing the Analytical Skill Shortage Via Cloud', Joint Australian Statistical Conference 2014/IMS Annual meeting Sydney (7–10 July 2014)<br>• 'Design and Implementation of a Visual Atlas of the Australian CMEs', (21 November 2014)<br>• 'A Visual Atlas of the Australian CMEs' Invitation from the Australian Business Council of Cooperatives and Mutuals, (March 2015) |

## Disciplinary linkages

**The original project objective was to create a community of visual BA academics in Australia with international links.**

Project co-leader Associate Professor Jacob Cybulski established a strong partnership with SAS, a global leader in VA. The company sponsored the *Visual Analytics Collaboratory* (see Figure 10) at Deakin University and provided free licenses of SAS software.

Project co-leader Associate Professor Olivera Marjanovic established new links with the rapidly growing international community of cooperative and mutual enterprises (CMEs) researchers and practitioners, and strengthened her academic leadership within TUN (see Figure 11) – the leading international community of BA educators, currently with more than 2000 academic members from more than 100 countries. She also established strong links with SAS Institute Australia, which continues to actively promote her innovative teaching practices in SAS-VA nationally and internationally (for example, SAS Institute Inc, 2014, pp. 31–33, with current readership of over 60,000).

**Figure 8: SAS support for the *Collaboratory* at Deakin – SAS Wall and SAS VAC Lab**

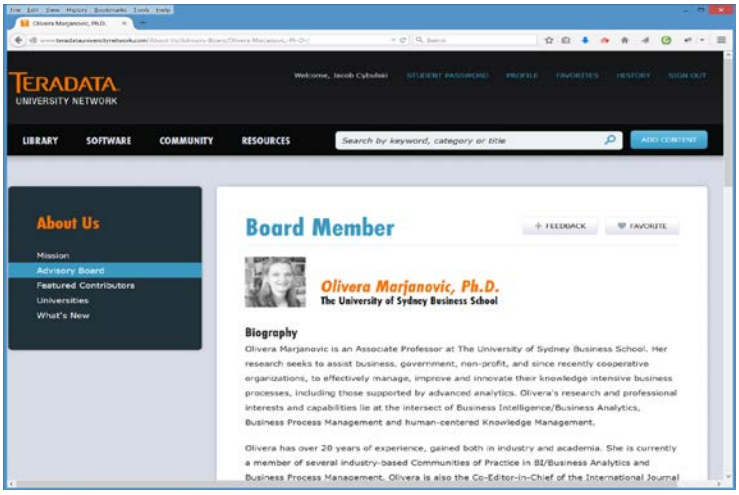



**Figure 9: Olivera Marjanovic with Teradata University Network**

# Factors influencing project outcomes

The project involved cross-institutional team members contributing a range of expertise. The project dynamics embodied a set of enablers and inhibitors (see Table 4), which is to be expected in any major undertaking. On balance, the enablers overcame any inhibitors, and in the end the project achieved all of its main objectives.

**Table 4: Success and inhibiting factors in the project**

| Success factors | Inhibiting factors |
|---|---|
| • Interest and enthusiasm of team members<br>• Skill and experience mix of team members<br>• Leadership by the project co-leaders<br>• Employing an experienced project manager<br>• Regular team meetings<br>• Project conferences<br>• Reference group with industry participation<br>• Clear responsibilities of partner institutions<br>• Clear roles and tasks of each team member<br>• Ongoing sharing of information<br>• Good management of project work<br>• Focus on academic publication of results<br>• High quality of the project website<br>• Promotion of results via YouTube, TUN, industry events and local and international academic conferences | • High academic workload, at times<br>• Early departure of the project manager<br>• Career changes for some team members<br>• Study leave of Associate Professor Marjanovic in Semester 2, 2014 (who continued to work on the project in spite of long and frequent overseas travels)<br>• Late release of parts of the OLT funds<br>• Difficulty in recruiting research assistants, with many leaving immediately upon graduation and many taking full-time (and much better paid) employment in the BA industry (especially at The University of Sydney)<br>• Steep learning curve for research assistants<br>• Tasks scheduled for the holiday periods<br>• Due to difficulties in recruiting and retaining casual research assistants, project co-leaders having to spend more than (initially estimated) one day per week working on the project, in order to meet and exceed the project requirements and expectations<br>• SAS-VA software released in Australia and made available on TUN in February 2014, with Semester 1, 2014 at The University of Sydney starting just two weeks later |

# Evaluation of results

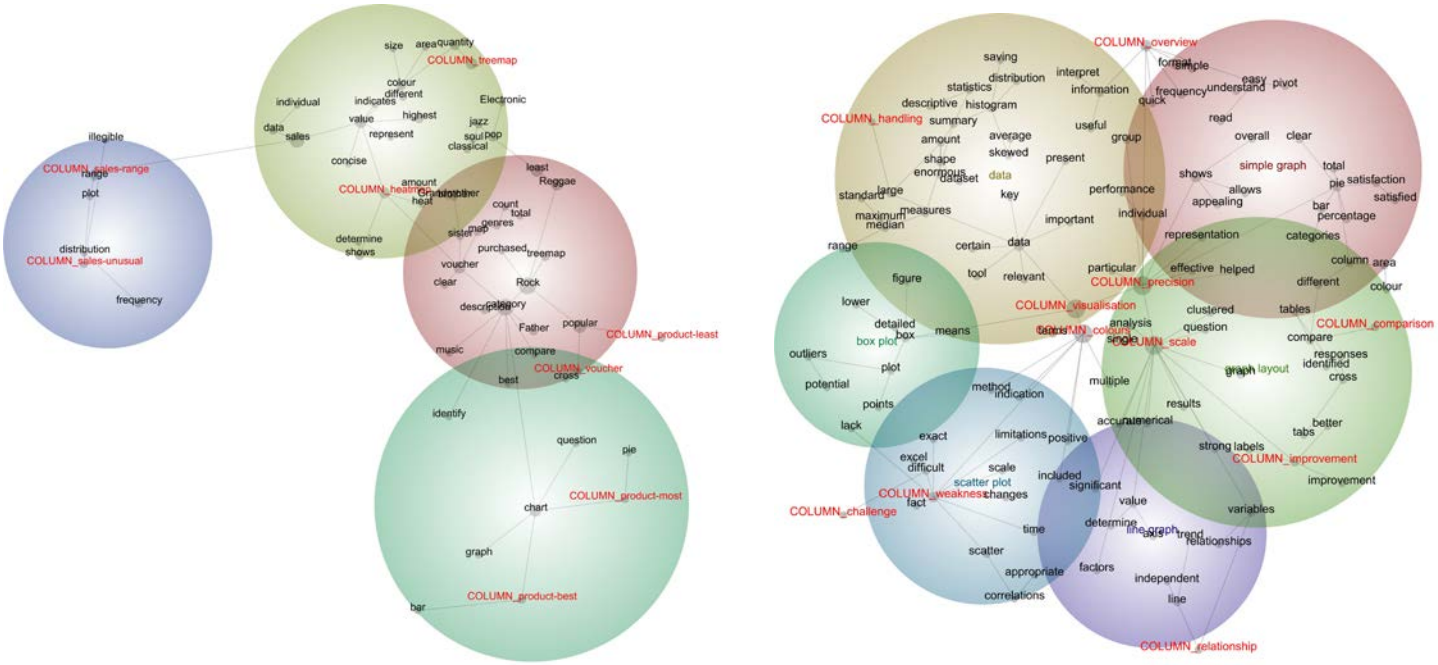
We conducted a number of evaluation studies on tools we developed as a part of the project. In general our evaluations suggest that interactive visual analytics tools and methods had a significant positive effect on student learning of the fundamental analytic knowledge and skills. Brief summaries of the articles submitted for journal publications - some under review - follows.

One of our studies involved the Animated CD Store. The analysis of an in-class quiz made a contribution to our understanding of how interactive visualizations can be used to help students develop BA skills. A comparison of students using visualisations and those following traditional methods of learning showed that the visual approach was effective in facilitating learning and recall of new concepts and techniques, application of newly learnt analytic methods in new situations and the ability to analyse and reason about new problems and their analytic solutions ("knowledge", "application" and "analysis" as per Bloom's extended taxonomy) (Anderson et al., 2000). Our analysis of engagement in tutorial tasks relied on the Net Promoter Score (NPS), which indicated that a visual approach was perceived by students as helpful in understanding difficult concepts, making them easier and quicker to understand, more enjoyable and less challenging than the traditional methods of teaching analytic concepts.

The study involving the Simulated On-Line Store (Music Mountain) had a different purpose. It allowed monitoring of the knowledge growth throughout the semester. By employing text analytics of students' submissions in tutorials and assignments, we were able to reveal the details and the complexity of knowledge transferred from teachers to learners over time (see Figure 12). Such analysis allows identification of the curriculum and methods in need of improvement.

The final lab study involving Visual Analyst 2D and Visual Analyst 3D focused primarily on the principles of designing 2D and 3D interactive visualisations to support student collaborative work.

**Figure 12: Text analytics to assess the growth of knowledge in response to teaching with IVA**
**After one of the first tutorials (left) and after submission of the final assignment (right)**



# Final remarks

This report summarises the main contributions of the project: *Enhancing collaborative learning in information system business analytics using data visualisation and manipulation techniques*.

The project was funded within the 2012 Office for Learning and Teaching *Innovation and Development Grants Programme, innovation and new technologies*, and offered insights into the global demand for BA professionals; the rapidly changing body of knowledge underpinning analytics education, and the methods and tools that are eminently suitable for teaching analytics to business students.

The project developed and deployed new approaches to the design, implementation and evaluation of the analytics curriculum for classroom and online delivery – areas vigorously pursued over the years by the OLT (and previously ALTC).

Due to the complexity of the subject area the project members had to explore many distinct disciplines, including data analytics, information systems, statistics, artificial intelligence, computer graphics, business and education. In the process many research investigations were conducted, which resulted in several academic publications (some still in preparation or review), presentations and resources that have been made available to teachers of VA, students undertaking related courses and the community at large.

The project assisted development of new methods of teaching analytics to support existing curriculum in Business Intelligence (for postgraduate students at Sydney) and Business Analytics (for undergraduate students at Deakin). The principles of interactive VA have also been adopted for teaching advanced new subjects in Predictive Analytics (at undergraduate and postgraduate levels at Deakin). Already developed project resources (such as Open Source software) and future educational materials (such as online blogs and YouTube videos currently in preparation) are made available via the *Visual Analytics Collaboratory* and TUN to entice others to join a growing community of VA academics sharing and exchanging their field expertise and experience.

Finally, the project provided new opportunities for members and partner institutions to establish research and industry links and initiate new ventures in this project area. For example, Deakin University partnered with SAS Australia to promote visual analytics research and education. The University of Sydney established new global links and projects with TUN and SAS Australia, as well as with the rapidly growing international community of researchers and practitioners in the CME sector. For example, one of the key project outputs of The University of Sydney – a prototype of a Visual Atlas of the Australian CMEs – attracted the unprecedented attention of CME academics and industry practitioners after it was presented at the first Australian CME Teaching and Research Conference (November 2014). The Australian Business Council of Cooperatives and Mutuals is now actively promoting the project among their industry members and looking for further funding to support and transfer the innovative thinking and learning activities developed in this OLT project to non-BA specialists in the CME sector, both students and practitioners. We also intend to submit future Australian Research Council and OLT grant applications to expand the Visual Atlas of CMEs internationally.

Our team would like to thank OLT for the opportunity to undertake and complete this project.

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# Appendix A: Certification

***Certification by Deputy Vice-Chancellor (Education)***

I certify that all parts of the final report for this OLT grant provide an accurate representation of the implementation, impact and findings of the project, and that the report is of publishable quality.

Name: Professor Beverley Oliver Date: 8 April 2015

# Appendix B: Update to project activities

Table 5 shows and explains changes from the original project proposal. It should be read by referring to Table 2 for various project alignments.

**Table 5: Alignment between the project dissemination and evaluation**

| Project phase | Activity planned | Activity carried out | Justification |
|---|---|---|---|
| Year 1 | | | |
| 1. Project preparation / *Assess* | Dissemination<br>• Literature review<br>• Project website | All completed<br>• J. Creativity & VA<br>• Deakin project website | |
| | Evaluation<br>• Literature review compiled | All completed<br>• J. Creativity & VA | |
| 2. Capacity building / *Engage* | Dissemination<br>• ACIS'2013 Aus. conf. paper<br>• National BA workshop I<br>• Report on BA current practice<br>• Creation of BA community<br>• Report on BA T&L framework<br>• Project conference I<br>• Project website | <br>• J. Blooms & pilot<br>• N/A<br>• J. BI in orgs<br>• TUN/Wikispaces<br>• Oral to ref. group<br>• Done<br>• Visanalytics.org | <br>• More appropriate<br>• Too early<br>• More appropriate<br>• Completed<br>• Too early<br>• Completed<br>• Completed |
| | Evaluation<br>• Evaluation of the current practice with a student survey, two focus groups with staff and a lab study<br>• Evaluation of the pilot study with a video conference focus group with all participants | <br>• A survey of analytics professionals was conducted instead<br>• Fully mature pilot was deployed in teaching with full statistical analysis of results produced | <br>• Deemed more reliable than involving students<br>• Pilot was completed early and curriculum changed to accommodate it |
| 3. Application & improvement / *Re-assess* *Re-engage* | Dissemination<br>• Report to BA community<br>• Report on the partner-based BA *Collaboratory*<br>• Project website | <br>• J. Student perceptions<br>• Conf. Practitioner stories<br>• Continuing | <br>• By publication / in prep.<br>• Published |
| | Evaluation<br>• Two cycles of formative evaluation each with a student survey<br>• Two focus groups with staff and a lab study with students | <br>• Deakin – tute with survey, assignment with survey Sydney – dev. and eval. of learning designs<br>• Monthly project progress reports sent to ref. group members for their comment / feedback | <br>• Quicker cycles<br>Assign. 1, 2, 3 and 4<br>• Continuous feedback; this was discontinued in Phase 4 to focus on completion |
| At this point all project activities were completed ahead of time – see the progress report submitted on 18th project month. Unfortunately, due to changes in the project membership, unavailability of staff and the ensuing miscommunication, the last OLT payment was received in October 2014 instead of July 2014. This caused massive rescheduling of activities, which impacted many scheduled evaluations (as students were no longer available). Consequently, the focus changed from continuing project activity to publication of results. | | | |

| Project phase | Activity planned | Activity carried out | Justification |
|---|---|---|---|
| Year 2 | | | |
| 4. Dissemination / *Transfer* | Dissemination<br>• ECIS'2014 int. conf. paper<br>• AMCIS'2014 int. conf. paper<br>• Journal pubs BA T&L<br>• National BA workshop II<br>• Report on the community-based BA *Collaboratory*<br>• Report on BA T&L framework to reference group<br>• Project conference II<br>• Project website | <br>• Conf. ICIS on BI sensemk<br>• Conf. ACIS on Co-creat<br>• J+Conf Visual metaphors<br>• Int. TUN workshops<br>• Not ready<br><br>• J+Conf papers With final report<br>• 12 March 2015<br>• Visanalytics.org | <br>• International conf.<br>• Regional conf.<br>• Large pipeline<br>• Invited to internat. forum<br>• More work required<br><br>• Completed, in review and in prep / synopses<br>• Scheduled<br>• In use by other groups |
| | Evaluation<br>• The third cycle with a survey, two focus groups and a lab study with community participants<br>• Independent summative evaluation of the project | <br>• Deakin – only lab study completed<br><br>• In progress | <br>• Other studies abandoned due to OLT late payment – no more students! |
| Finalisation / *Transfer* | Dissemination<br>• OLT final report and guide<br>• Project website | <br>• This report<br>• Visanalytics.org, wikispaces, project web | <br>• To be lodged on time<br>• Many journal papers still in review or revision |
| Note that despite the massive changes to the project schedule (see the comment above), all project phases were completed on the extended deadline, but within the project overall 2 year timeframe and within budget. | | | |

Note that due to the space restrictions the table applied some abbreviations, i.e.
J. = journal paper; Conf. = conference paper / presentation

# Appendix C: Report of the independent evaluation

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## 1. Executive summary

The hallmarks of a successful project such as this are that it meets a demonstrated need and that, through effective leadership and management, it achieves its intended outcomes with a high probability that the project will, indeed, make a significant contribution to student learning in its specified context. Ideally, such a project will lead to gains for the community as students apply what they have learned. The independent evaluation of this project indicates that these criteria were substantively met and both tertiary educators and the broader community stand to gain from a well conceptualised and largely well executed study.

The grant proposal and the interim and final reports offer convincing arguments of the importance of dealing effectively with the massive volumes and complexities of 'big data' where it is asserted "the development of analytics skills and expertise has lagged" (Final Report, p8). There is an apparent need to reduce the gap between the knowledge and experience of learners and the abstract concepts and methods of Business Analytics in the field of Information Systems. The educational challenges outlined (rapid change, complexity, abstractness, factual orientations, as well as students' isolation and resistance to the subject matter) have been addressed by what the Grant Proposal (p2) promised would be "an innovative collaborative environment for intuitive learning of Business Analytics" – a Visual Business Analytics Collaboratory [the Collaboratory] that would be open for use by students and teachers in real-time via the web. By the completion of the project this had become as well as a space on the web, a place (university labs) and a community of students, teachers and researchers (Final Report, p8 & p17).

Through the learning experience offered by the Collaboratory - shared resources for visualisation and direct interaction with real-world business problems, featuring analytic tools, methods and information resources expected to be used in Business Analytics practice - it was anticipated that intuitive thinkers would be transformed into analytical thinkers. To one young member of the project team:

> This project addressed the lack of evolution in traditional teaching in statistics and analytics in accordance with the evolution of technology and its involvement in our lives. Education has been stagnant as the industry which students aim to work in evolves to utilise the immense power of visualisation technology. Methods of teaching have not changed to accompany the opportunities provided by visualisation technology. [2]

This project does change teaching methods in a discipline area that a Head of School described as 'always challenging' and the research undertaken as a core outcome of this project evidences that innovative data visualisations offer valuable tools to stimulate learning and engagement. Further, experience so far demonstrates that it has real potential to be applied in other areas and contexts.

Importantly, the development of a conceptual/theoretical framework for the design and implementation of systems to support effective teaching of analytics and the construction of visual metaphors should help shape future data-driven systems. The tools and methods developed in the process are, of themselves, valuable but their value also lies in the fact they can be used in future projects. As one of the co-leaders saw it:

[2] All direct quotations are drawn from comments by members of the project team and reference group. Where possibly identifiable, it is with the person's knowledge and consent. There has been some minor editing for clarity.

> Given the highly dynamic nature of this discipline, the acquired industry-informed and research guided method of designing, implementing and evaluating these research and practical artefacts is the most valuable aspect for me. This is because it enables us to continue to innovate for the unknown future, regardless of software applications, mobile devices, data sources and yet-to-be invented decision-support environments.

Given the importance of this field of tertiary study to industry, it is pleasing to note that one of the project alignments of the teaching and learning objectives (Final Report, pp13-14) is with perceived industry needs. Direct industry involvement was sought through the 3 industry representatives of the reference group and, beyond this, ongoing contact with industry is evidenced by the Acknowledgements in the Final Report (p4). The project provided, and should continue to provide, new opportunities for the partner institutions and project team members to establish research and industry links and initiate new ventures in this project area. Links with SAS[3] "the leader in business analytics software and services, and the largest independent vendor in the business intelligence market" (website 10/2/15) and TUN "a free, web-based portal that provides teaching and learning tools that is used by more than 45,000 students around the world" (website 10/2/15) are already established and compelling evidence of the value of this project in terms of its approach and deliverables. With the Australian Business Council of Cooperatives and Mutuals seeking funding to support and transfer the innovative thinking and learning activities developed in this project to non-BA specialists in the CME sector, and the intention of the project team to submit future grant applications to expand the Visual Atlas of CMEs internationally (Final Report, p25), this project marks an important stage in assisting creative problem-solving in any data-driven organisation.

The excitement this project generated is reflected by comments such as:

> From my work developing the three-dimensional model, I saw data in a totally new light. Being able to successfully place data into a model and have it produce a three dimensional, explorative environment opens an unfathomable amount of possibilities. The model could now be used for any means of analytic exploration from industry to environmental. And the most exciting thing about that is who knows what solutions could be derived from such an ability?

## 2. Evaluation and the role of the independent evaluation auditor

The Grant Proposal (p6) stated that, as well as formative 'iterative' evaluation throughout the project, a summative evaluation would be conducted "of the project itself, its methods and outcomes". It is beyond the scope and timeframe of this evaluation to draw conclusions regarding the usefulness of the Collaboratory and the related resources beyond seeking informed perceptions from the project team members and reference group.

From the experience of the independent evaluator with similar projects, salient elements that contribute to the success of projects such as these are:

- Effective project leadership and strong project management
- Sustained effective partner contributions supported by adequate institutional support
- Shared understanding of the project's desired outcomes and what is needed to achieve these
- Appropriate guidance from the reference group

Leading to

- Useful deliverables and the meeting of the project's stated outcomes

Supported by

- An effective dissemination strategy.

Each of these is considered below.

[3] For a list of acronyms please refer to page 5.

To determine the extent to which each of the indicators of success was achieved the independent evaluator:

- Reviewed the documentation related to the project.
- Attended the face-to-face project conference on March 12, 2015 and facilitated a focus group discussion with 5 members of the project team and 1 member of the reference group as well as having 2 face-to-face discussions with the project co-leaders.
- Prepared, administered and analysed surveys sent electronically in February 2015 to the 9 members of the project team (100% response rate) and the 6 members of the reference group (33% response rate).
- Had follow-up email and telephone discussion where required for clarification and/or amplification with members of the project team and reference group.

The evaluation brief did not include contact with academic teaching staff outside of the partner group, students, or members of the relevant professional bodies and employers. Given the budget and timing, these constraints are reasonable but, as noted above, these constraints preclude the kind of evaluation that does assess value and impact of the project's outcomes for stakeholders.

# 3. Indicators of success

## 3.1 Effective project leadership and strong project management

The project team was unanimous that the co-leaders provided very good leadership (all – including the co-leaders – gave a '5/5' rating) and both project leaders could document significant contributions that evidenced their commitment to the project's success. Their stated contributions again reinforce the demands such projects make on academics who, as well as leading and managing, are actively involved in conceptual and technical development, design, implementation and evaluation, experimental work and publication. Both believed they contributed more time and effort than proposed and allocated and this, rather than poor planning, evidences their professionalism and commitment when unexpected issues arose. The leaders were praised for 'visionary' and 'passionate' leadership and for their management and communication skills – 'an open door leadership policy' - with several commenting on the leaders' ability to provide clear directions and distribute workload effectively.

> The project's expectations were clear and conveyed efficiently. Where I was involved, my work was clear and, through working in an agile development style, meetings were conducted efficiently with a clear direction at their conclusion with evident progress towards the deliverable at each point.

In the face of some significant challenges, most especially team members leaving the project to take other employment opportunities with related recruitment problems, the co-leaders were instrumental in driving the project forward and in motivating the team. The project faced a serious setback with the resignation of an experienced project manager in June, 2014. After 2 failed replacement attempts, the Deakin co-leader assumed the role. He claimed that from then "the project team adopted an agile approach to its task development, with focus on shared objectives and responsibilities rather than mediating documentation". This means that, while there is a clear well-documented series of team and design meetings to June 3, 2014 providing solid evidence of the project progressing well, there is no documentation regarding meetings from that point. However, those involved were unanimous that there were frequent meetings (weekly for some) and the management style, where people worked in sub-groups to achieve specified and agreed outcomes, was effective. With 7 of the 9 project team members giving ratings of '4/5' and '5/5' (the other 2 ratings were '3/5' so 'reasonable'), most considered the project was well managed.

It is probable that the financial problems suffered through miscommunication would also have been circumvented had the first appointed project manager remained in that role. The late payment of the final tranche of funding resulted in significant delays and a redefinition of some of the deliverables. Even with the granted extension, its major impact was the 'massive' re-scheduling of activities, which meant that, as students were no longer available, some studies had to be abandoned or moved from classroom teaching to labs. However, as Appendix B of the Final Report (pp29-30) claims, all project phases were completed within the project's overall 2 year time frame.

### 3.2 Sustained effective partner contributions supported by adequate institutional support

Two universities (Deakin University and The University of Sydney) participated in this project with a leader drawn from each. As envisaged in the Grant Proposal (p8), outlined in the Final Report (p13) and explained by the Deakin co-leader:

> The two teams had very clear responsibility for the overall project contribution, with Deakin focussing on undergraduate teaching and technology development to suit large class support, Sydney on graduate teaching and collaboration to suit small classes of advanced students. Joint designs, development of learning designs and publication were the focal points of cross-institutional collaboration.

With the different emphases, and also coming from different technological bases, the project was enriched by different perspectives and gained from a collaboration that resulted in knowledge and outcomes that could be used in different contexts.

The project team was drawn from Deakin with 4 named staff from the outset and 3 further members added with additional support staff (one of whom was problematic) at various times. In contrast to Sydney University, where the 7 appointments were also casual, the 3 Deakin members employed to support the design and development of the visualisation technologies were seen as integral to the project team and there was greater continuity. The risk of isolation with just 1 team member based in Sydney working with short-term and changing support was mitigated by the frequent contact with others by Skype and Yammer, inter-institutional visits and the academic support provided by the academics from Deakin.

The Deakin School of Information and Business Analytics went through major change in 2014 as part of a Faculty restructure. This resulted in some staff changes (including the resignation of 1 member of the project team who, however, still maintained involvement), reduction in resources and considerable uncertainty. It is to be commended that, in this context, project team members felt the Deakin co-leader managed the challenges in such a way that the project stayed on track. Despite some tensions, the Deakin co-leader, the person in the best position to make an informed judgement, stated that both participating institutions provided "tremendous support in terms of finance, accounting services, equipment, space, software, research assistants, and flexibility in teaching". Participants, too, believed that institutional support was good, with 2 rating it at '5/5' so 'very good'.

For any such project to succeed, it is vital that the members of the project team are not only keen to participate but the team has the appropriate mix of skills, expertise and experience. Team members, while pointing to 'strong collective knowledge', acknowledged that

> This project was successful because we were able to draw on the diverse set of skills of our team members. Our team had a good mix of strong analytics people, design people & educational people as well as excellent research assistants.

The 2 project leaders and 4 originally named team members are well credentialed in terms of this project (see Grant Proposal, Appendix 4) and each was in a strong position to make a valuable contribution. 3 of the 4 made substantive contributions and retained active involvement throughout,

while the fourth supported the project more indirectly but still usefully. In response to a survey invitation to list and rate their individual contributions, each member of the project team could specify significant areas of input and all but the 1 person with less involvement, who gave a '3' so 'reasonable', rated their contributions as '4/5' 'good' or '5/5' 'very good'. Their list of contributions is not only impressive but also speaks to the role of the project leaders in engaging all members of the project team with various activities. Both project leaders felt the team had performed very well and the group was unanimous that sustained effective contributions had been made to a 'good'/'very good' extent. The mutual respect, camaraderie and delight in the project and its outcomes, as well as the professionalism and high standards of this group, were abundantly evidenced at the second conference attended by the summative evaluator. The fact that the project team is already planning future collaborative work is further evidence of the strength of the bond of this group and their shared satisfaction with the experience of working together.

Project team members were asked to state what – if anything – they gained from contributing to the project. Their responses indicated the project's value in using innovative approaches to teach in a demanding and challenging area. For the more junior academics it gave important experience and useful exposure:

> An important benefit of the project was that it created important learning and employment opportunities for young graduates, providing them with a much needed stepping stone into their industry-based professional careers.

Senior members of the team also gained from 'increased visibility' and valued the knowledge gained through the experience that enhanced their own teaching and also led – and should continue to lead – to valuable collaboration within and beyond the tertiary sector.

### 3.3 Shared understanding of the project's desired outcomes and what is needed to achieve these

Some indications of different viewpoints – even at the end of the project – emerged from the project team's responses to the survey. The most troubling of these was a different understanding of the key element of the project, the Collaboratory. When a co-project leader stated:

> Many people may not be aware of the term "Collaboratory". We often talked about "interactive visualizations", which is the term people will be familiar with (Email 22/2/15),

the impression was given that the term used throughout the Grant Proposal and Final Report had not gained currency. However, the team seemed comfortable with the term and used it frequently. Where differences emerged, it was whether there was a single Collaboratory or multiple Collaboraties and if the Collaboratory was for students, who are given direct access to state-of-the-art tools for visualization and collaboration, or for academics nationally and internationally. In discussion, the co-leaders acknowledged uncertainty in this area – "it means many different things" – but welcomed the 'fluidity' implied and, with some justification, saw the evolving notions of the Collaboratory and what it would, and could, entail as a sign of growth within the project.

A further area of apparent confusion was the status of the Guide. Both co-leaders explained that, once a guide was no longer mandated for OLT projects, it was dropped in favour of scholarly publications. Yet some project team members in their survey responses still referred to a Guide, seeing it as being on the OLT site and having a very large audience.

The project team was unanimous that there was a strong shared understanding with 7 of the 9 considering this was to a 'very good' '5/5' extent and the other 2 rating it at '4/5' so to a 'good' extent. For some Deakin staff this was assisted because they had been working as a team prior to this project, but the main reason team members gave for their positive feeling was that frequent meetings with open discussion ensured a collective understanding as everyone worked towards a united outcome. Because the Deakin co-leader provided his team with well-defined objectives and

responsibilities for specific deliverables, every person owned some part of the project and could be confident of their role within it. The 2 face-to-face project 'conferences' gave important opportunities for the team to share their work and to observe, comment and reflect.

### 3.4 Appropriate guidance from the reference group

As outlined in Table 2 of the Grant Proposal (p7) it was envisaged that the reference group would have a role in 3 of the 4 project stages (capacity building, application & improvement and dissemination). Further:

> The project reference group, consisting of senior academics and industry experts, will play a major role in advising the team on various aspects of Business Analytics, the profession, educational design and a research approach. … The overall success of the project will be judged by an independently appointed evaluation auditor and by the reference group (p8).

In practice, the reference group contributed during the project formulation to a claimed 'invaluable' extent and industry members provided useful feedback at the 2 project conferences. While it is customary to regard members of the reference group as giving their time and expertise, such occasions also offer the opportunity for industry to become more informed of academic issues and perspectives with gains for all parties and sectors and there is some evidence this occurred here. One academic member made no contribution and it is apparent that the reference group did not play the direct role envisaged – certainly not a 'major role' – nor were they in a position to make definitive judgements about the project's overall success and the ones who were contacted had no sense this was an expectation.

Not surprisingly, then, the project team rated appropriate guidance from the reference group well below any other element, with the bulk of responses being in the '2/5' so to a 'moderate' extent. Those who gave higher ratings did so on the basis of individual contributions at discrete times, especially by the industry representatives. The project leaders claimed they had considerable experience and did not really need to call upon this group except during the project's formulation and for reviews at the mid- and end-point. This view is supported by the following comment from a member of the reference group:

> Important only to the extent that the reference group is simply a listening post. The clever thinking and research design lay with the research/development team at the 2 universities. I think reference groups become essential and critical in those instances where projects are unclear, immature or something happens to affect the project significantly – not the case here.

As well, the kind of advice anticipated from the reference group was more than adequately compensated for by peer review of journal articles which, on some cited occasions, had direct positive impact on the development of the research design and the visualisation models.

## 4. Outcomes

The stated aim of the project was to "use data visualisation and immersive data interaction to reduce the gap between the knowledge and experience of learners and the abstract concepts and methods of Business Analytics in the field of Information Systems" (Grant Proposal, p1). By the Final Report this had been simplified to the development of **"**effective methods and tools for teaching analytics by visual interaction with data" (Final Report, p8) and discussion with the co-leaders, in particular, surfaced that this project had outcomes that were more broadly applicable. 6 of the 9 project team members believed the aim as stated in the grant proposal had been achieved to a 'very good' '5/5' extent, and the remaining 3 and the 2 reference group members felt the aim had been achieved to a 'good' '4/5' extent.

Given the project's title is "Enhancing collaborative learning", and collaboration is clearly fundamental to the development of the Collaboratory, it is noteworthy that this was not featured in

survey responses and discussion and much of the writing that resulted from this project. It was part of the teaching design (there are some references to teamwork and student collaboration in the Final Report (for example, p14 and p20) but it remains an area that seems not to been tested empirically.

From the project's conceptualisation, the project's aim was to be achieved through the creation of a Visual Analytics Collaboratory, "a shared repository for resources for the growing community of teachers and researchers in visual analytics".[4] With its vibrant visual presence, and promising 'engagement as never before', it offered 'engaging business simulations', 'new ways of viewing and analysing data', 'data to inspire and data to admire', and, probably the most salient contribution, a socio-techno space where others are invited to join the Collaboratory and explore its potential further. As the 3D models can only be accessed in restricted controlled spaces, such as a designated computer lab, those outside the project are restricted to descriptions and screen shots.

The project team, on the whole, believe the Collaboratory (however understood) was well designed and implemented and supported teaching and learning at both the partner institutions and within the broader community of learners. While there were 2 ratings of '5/5' (so 'very good') in this regard, the person in the best position to make an informed judgement considered this had been achieved to a '2/5' so 'moderate' extent and both leaders felt the creation of a community of VBA academics had been achieved to a '3/5' so 'reasonable' extent given the time span of the project. Looking at usage data for the site, there is national and international interest but access past the Home Page and, from there, participation by others appears to be scant. As a co-leader stated:

> The open community of learners is slowly growing via the network of educators and researchers in the area. At this stage what is evident are the effects of project dissemination, in terms of concepts, ideas and methods. It is not as yet successful in sharing existing tools and materials.

Through the Collaboratory, and also through the dissemination strategies discussed below, the research methods developed as part of this project, as well as the resources developed, are being shared so that practitioners can further refine them to suit their own purposes and contexts. Ideally, they, too, will evaluate them and use these findings for nuanced artefacts as they, too, become virtual designers expressing their own narratives. In this sense, the project is a starting, rather than ending, point.

As discussed above, while some confusion/uncertainty remained regarding its intended audience, there is agreement, and evidence to support that agreement, that the Collaboratory has been designed and developed in such a way that embedded evaluation through quantitative surveys, laboratory experiments, text mining and action research informed it and ensured the approaches were consistent and the outcomes fully aligned as delineated in the Final Report (pp13-14). As promised in the Grant Proposal (pp4-7) and described in the Final Report (pp11-12), the Collaboratory has been developed on sound pedagogical principles. The project approach was, as intended, informed by constructivism and Table 1 of the Final Report provides a useful summation of how these conditions were applied to the design of the Collaboratory.

The project is underpinned by research and this is reflected in the scholarly writing produced from it. Educational research is almost invariably constrained – as here – by University Ethics Committees that deny having control groups as no student can be disadvantaged, but there are instances described in detail in journal articles (read in draft) where students were randomly assigned to traditional teaching and teaching using the interactive visual narrative method. Although the research could not rule out the impact of a range of variables and the innovations tested were not replicated across several groups, what was achieved is reasonable for the timespan of this project. The findings validated the research premise that the combination of interactive visuals and narratives enhanced and facilitated better comprehension, application and analysis skills, but seem not to have dealt explicitly with the issue of enhancing collaborative learning.

[4] http://visanalytics.org/articles/olt/OLT_Project_Achievements_V4_0.pdf - accessed 11/3/15.

While a member of the reference group expressed his concern that students involved with the project would expect to have expensive tools such as SAS in their workplaces, it is an attribute of this project that much of it is technologically agnostic. The project team is fully cognisant of the rapidity of technological development in this space and prudently focused on engaging students with statistical data to provide deeper understanding, rather than with a particular tool or suite of tools.

## 5. Effective dissemination

It is a strength of this project that dissemination was embedded from the outset and again the project team was unanimous that this was achieved to a 'good' or 'very good' extent. As outlined in the Grant Proposal (pp1-2), this was to be 4 pronged: through 2 national workshops, the international TUN community, conference papers and journal articles and by a guide that would document the principles, methods and technologies.

The 2 national workshops were abandoned when it became apparent that the project tools and methods were not sufficiently mature to stage a workshop to teach others how to use them. As discussed above, a guide was also not produced. Instead, the project was brought to national and international attention through university and conference presentations. These, supported by the impressive list of scholarly writing delineated in the Final Report (pp15-16), became significant dissemination avenues. It is both noteworthy and commendable that one of the articles published as a result of this project received 2 international best paper awards, providing endorsement by leading information systems scholars. Whilst scholarly articles are critical for academia, being able to reach large audiences of international, industry practitioners through publication in relevant magazines is clearly advantageous and it is pleasing to see evidence of this.

For the project leaders:

> Emphasis on academic publication was an excellent strategy as it provided a natural pathway towards new projects. It supported early career development and also created opportunities for future collaboration with other academics. The project also utilised Web 2.0 (web sites) and social media (YouTube and Yammer) to promote the project and its team members which resulted in the increased visibility for the team and its research results.

Through their effective dissemination strategies (rated by most project members as '5/5' so 'very good'), the project team were able to inform colleagues of the project. The co-leaders made the sensible choice to align their efforts with existing communities (SAS and TUN) rather than forming yet another interest group. The Grant Proposal (pp1, 3 & 6) made much of the role of the Teradata University Network [TUN] in terms of creating a community of VBA academics, especially through one of the co-leaders who is on its academic board. The TUN channel was used to submit and, upon approval, disseminate two sets of learning resources from this project. Other members of TUN provided feedback on specific conference papers and continued collaboration with TUN is planned post-OLT around OLT outcomes. Two TUN visitors were invited to both Sydney University and Deakin University but, unfortunately, for reasons outside of anyone's control, this did not eventuate.

Hence the team provided opportunities for interested others to learn about the project, its methods, tools and findings. Although originally an anticipated outcome, the project leaders acknowledged that within the lifetime of the project the creation of a large cohesive multi-institutional community with a singular vision, aims and objectives for teaching analytics by visual methods was unrealisable. For one senior member of the project team:

> While the deliverables were very measurable and in line with the outcomes promised by the project, for these to be of broader use and adopted by other academics, there is more work to be done BUT not as part of this project. I think this project should be extended to ensure the deliverables are converted to a form that can be implemented more broadly by others.

## 6. Conclusion

This evaluation identified specific indicators of success and has assessed the project against these. Through the experience, skills and commitment of the project team this project has increased our understanding of the role of visualisation and narrative in particular as ways of engaging students with data. While it is apparent that some overestimation occurred and the reference group did not work as well in practice as envisaged, these deficits were in large measure either overcome or counterbalanced. In my experience it is almost inevitable that projects as conceptualised in grant proposals do not proceed entirely as envisaged. As here, as well as enforced amendments due to unexpected circumstances such as the late arrival of essential funds, this can be caused by increased understanding of the complexities and a more accurate awareness of the time needed for processes and products to mature.

Preparatory work for this project commenced as early as 2012 and, now at its completion, those who conceptualised it were remarkably prescient. While VA is now far more mainstream, as evidenced by the growth of conference and scholarly publications in this area, at that time the world of visual analytics was in its infancy and SAS VA, an important element of this project, did not exist. This project makes a valuable contribution to our understanding of what VA can offer and it also situates the project team in a strong position to take the next steps as they have a fuller awareness of the next cycle of issues to explore and questions to consider and possibly resolve.

Initially confined to business analytics, the discipline base of the team and the teaching and learning for this project, project findings have already been applied in other contexts with exciting future possibilities. This has been recognised:

> The Collaboratory is an exciting concept, which was applied very well and tested in ways that were convincing. I can see many many applications in other data based disciplines in their learning context, for example, Engineering, Construction.
>
> What has been discovered through this project and the approach adopted in integrating learning theory, gamification and analytics is amazing and should be showcased as an approach that would work in domains/disciplines other than analytics.
>
> I think the underlying goal of such a concept is to find a solution to an issue that hasn't been found yet, predictive analytics. The only real data that went into the model wasn't exactly rich BUT still allowed users to easily derive basic predictions in an instant. I am confident that we could visualize almost any data set with our developmental foundation, and I would be exceedingly excited to see this model tested to its fullest because I believe it has the capacity to deliver.

This appears to be an area, and an instance, where tertiary educators are responsive to the needs of industry but also in a position to give students the skills and experiences to help shape data mining and statistical analysis in ways most companies have not begun to envisage.

As the Final Report (p9) claims, this project not only demonstrated the role of visualisation in teaching and learning but, with its teaching emphasis on collaboration, it provided students with work and life skills to enrich them and the broader community. That this project achieved as much as it did is largely attributable to the project leaders encouraging a 'blue sky' approach, freeing participants from constraints and giving them opportunities and encouragement to push boundaries as they strived for the greatest possible results.