Unexpected Issues and Solutions: Emerge from Environmental Manipulation Strategy

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Abstract

Environmental manipulation removes students from their everyday worlds to unfamiliar worlds, to facilitate learning. This article reports that this strategy was effective when applied in a university design unit, using the tactic of immersion in the Second Life online virtual environment. The objective was for teams of students each to design a series of modules for an orbiting space station using supplied data. The changed and futuristic environment led the students to an important but previously unconsidered design decision which they were able to address in novel ways because of, rather than in spite of, the Second Life immersion.

Keywords: design, teams, media, outer space, Second Life, communications, architecture, constructivist learning, strategies

Introduction and Background

An undergraduate interior design learning environment within a design unit at a university[1] was developed to integrate the application of three-dimensional tools within design, not as a presentation stage, but rather as a conceptual design tool. Teaching and learning in design and engineering disciplines using computer-based technologies within a higher education context is not unusual. Many students are required to undertake digital technology foundation units which focus primarily on skills development and digital communication for design documentation and presentation. There is an expectation that the applications of such skills are evident within specific design and engineering courses as part of a four-year degree. Although such courses are useful in the teaching of particular technologies such as computer-aided design (CAD) and building information modelling (BIM), this has restricted students in their exploration of technology and limited their exploration of new ways of learning their 'craft' – in this case, designing. This limits potential outcomes, since 'healthy disciplines remain tolerant of a state of flux by constantly questioning the inclusion/exclusion, import/export, and collaboration/isolation to/from new ideas, new techniques, new disciplines, and new technology' (Bermudez & Klinger, 2003).

To mitigate this, the current study tests the hypothesis that a virtual environment can be utilised as a collaborative tool as well as a conceptual design visualisation stage: If a designer or design team is able to test and explore a future design through interactive virtual environments, is there also potential to gain new insight into, and design more appropriately for, the end user's requirements?

The three-dimensional (3D) screen-based virtual environment *Second Life* (SL) was selected opportunistically as the tool for the study for reasons outlined later in this article (in the review of literature). Other environments were not considered and might be candidates for selection in any future research on this topic.

Review of Available Literature

Design

Designing *in* practice, and *as a* practice, is characterised by the co-operation of multiple participants from different disciplines:

> *The nature of designing is complex. Complexity is inherent because the object, building, landscape or environmental situation is not isolated but exists through relationships with people, activities and environmental components (Smith, Sanders, Demirbilek, & Scott, 2005).*

There is general agreement that the task of design and creation of objects, environments and spaces is almost impossible using only the knowledge of a singular discipline or person: 'Large and/or complex design projects cannot be executed any more by a single designer, since expert knowledge on various domains needs to be combined to develop a successful design' (Van Nederveen, 2007). As the complexity of design objectives increases, however, so does the complexity of the task of collaboration, as a result of the emergence and growth of 'virtual project teams' in which participants are geographically distributed and communicate mainly over the Internet using server networked design spaces such as Google Documents[2] and Microsoft SharePoint[3], networked voice and vision communications such as Skype[4] and videoconferencing, and more basic applications such as email.

McAuliffe (2007) argues that because technology is accelerating, designers are responding by creating more 'intelligent' and technologically sophisticated built environments. In designing these environments, both existing traditional media – such as two-dimensional drawings and cardboard models – and digital technology – such as virtual 3D programs – are deployed primarily to show rather than to test architecture and design examples. Visualisation enhances client understanding and visual connection with a project (Ormerod & Aouad 1997) but until now there has been only a relatively superficial use of these tools during the design process to understand a futuristic environment. Due to cost constraints until the turn of the century, digital representation in the design development stage of a project was rarely viewed as a viable option as a pre-visualization tool ('previz') but more recently in such fields as interior design, architecture and landscape architecture, software in modelling and presentation has become a more viable and economical option. This study tests and reports on its efficacy.

Virtual environments

Digital online worlds or virtual environments such as *Second Life* form a natural medium for design as they provide visualization, real-time creation and manipulation of 3D shapes, and allow collaboration through the use of a personalized onscreen character called an *avatar*. This approach provides an environment similar to real-world design activities and communication where users create and manipulate objects in a shared workspace and communicate with each other as they do so. It has been suggested (Brouchoud, 2009) that the virtual design world is even more effective than the real, noting that virtual reality platforms such as *Second Life* and *OpenSIM* are less rigid, and far more flexible than physical architecture. It is argued that architecture 'should be driven by the end-use, in an ongoing and constantly evolving design process that doesn't have an arbitrary 'end'. Virtual architecture doesn't have to shape *us*...we can and should keep shaping *it*' (Brouchoud, 2009).

Second life

Second Life is a software application launched in 2003 by Linden Labs (Ondrejka, 2004), a Californian company founded in 1999 by Philip Rosedale 'to create a revolutionary new form of shared experience, where individuals jointly inhabit a 3D landscape and build the world around them' (Linden Labs website, 2009). The software, a kind of massively-multiplayer online role-playing game (MMORPG, see Yee, Bailenson, Urbanek, Chang & Merget, 2007) has been widely investigated and discussed as a vehicle for education, especially in language learning (Stevens, 2006), chemistry, law, computer science, meteorology, aeronautics, literary and museum studies, and distance learning (Gollub, 2007 n.p.) but also journalism (Brennan, 2009) and nursing (Skiba, 2007). The field has grown to the extent that 170 universities had set up virtual campuses in *Second Life* by 2008 (Jennings & Collins, 2008) and many more were using the software explicitly or implicitly as part of teaching programs at the time of writing this article (Simteach website, 2009). The university employers of both collaborating authors of this article each maintained at least a small presence in *Second Life* in 2009. The contested nature of *Second Life* as a teaching and learning resource, of course, is recognized and represents a certain limitation to the discoveries reported in this article, but is outside the scope of this investigation.

Research Observations

Access to *Second Life* is freely available to individuals with a suitably powerful computer and a reasonably fast Internet connection with sufficient broadband to allow high-volume traffic. Its interface is more like a video game than that of highly accurate 3D modeling or CAD software. The user experience, referred to as *inworld* compared with the real-life *outworld* (Gollub, 2007) is of a continuous and persistent world that attempts to model the surface of a reasonably Earth-like world. The sun rises and sets, objects fall under the effect of gravity, trees and grass blow in the wind and clouds form and drift (Ondrejka, 2004). Organisation is on a grid system, where each grid represents 6.5 hectares. Within a year of its launch in 2003 constructed space had grown to 1240 hectares; by December 2008 this had risen to 36080 hectares.

Users are referred to as 'residents' and are represented by fully customisable virtual-body *avatars* who can walk, run, and even fly. Avatars can teleport, a process which involves disappearing from one location and appearing in another, selected on the grid system. Avatars can manipulate the land form and create shapes, to which they can apply textures and colors. The only limitations are set by 'land owners' who can choose who they allow to access and/or build on their land. *Second Life* provides two types of land: 'Mainland' regions which allow access to all registered users; and private pieces of land called 'islands' where access is by invitation only. Land – including islands – is purchased using the game's *inworld* currency, the Linden Dollar. Educational institutions such as those participating in this study typically purchase islands as flat and barren pieces of virtual real estate with no constructions on them, and allow academics and students to build and go about various activities there.

The avatar as an extension of the user in the synthetic world increases the user's feeling of immersion as a 'digital double' (Rankin & Cokley, 2006). It is suggested that this provides designers with an enhanced 'sense of being' in the environment that they are designing, allowing them to experience that space and connections instantly without the need to produce or read plans, sections or elevations. Additionally, not only do users see their own avatar: they also see their colleagues', teachers' and visitors' avatars and can interact with them, including asking for opinions and advice. They can also see the work in progress of other avatars or groups of avatars (groups of students). This crosses an important divide, since conventional architectural and design software does not allow the experience of two or more individuals working simultaneously on the same object. In shared virtual environments such as *Second Life*, however, this is not only possible but is enhanced by the availability of simple tools for building content and communicating, so that people in disparate locations can work together on the same object and discuss the design through voice or text chat. This synchronous collaboration is augmented by the availability of asynchronous collaboration, since teams and individuals need not necessarily be online at the same time, but can form an analogy of shift-work, in which one's colleagues might be present, or have finished parts of the project before one's arrival, or about to commence work after one's departure.

In summary, *Second Life* 'provides the setting for imaginative and fascinating hours of construction', capitalizes on a 'visceral feel' of togetherness and 'provide people with a chance to try out living very different lives' (Gollub, 2007).

Rational of this Study: Why a Space Station?

The subject of this study – 'future teaching of design' – intersects conveniently with the chosen methodology – 'use of virtual environments' – in the emerging area of proposing, planning for, designing and constructing human space communities of the present (the orbiting and now-complete International Space Station, *ISS*), the near-term (a colony on the Moon by 2020) and the long-term future (Mars by 2037).

The International Space Station (ISS) – the first permanent civil settlement of humans to be located in low-earth orbit at an altitude of approximately 386km – is the most ambitious and transcendental project of human settlements in outer space. It anticipates a return by explorers to the lunar surface and further on toward Mars but beyond that, emphasises that more research and experimentation is required for long-duration space missions and settlements to be viable. New requirements for human liveability are becoming apparent when compared with current space shuttle environments.

The overall modular system of constructing the ISS has been, to date, the most successful system for space stations, including as it does the existing mechanical, electrical or Environmental Control and Life Support Systems (ECLSS) framework. Internally, however, the adaptable racking system – how units are attached to the internal skin of each module – is of interest and is explored in this study. Improvements to habitable spaces can be achieved through the interior planning and redesign of static and dynamic surfaces and interfaces of this racking system to enable crew living, tasks and functions to achieve optimal levels of liveability for long-term occupation.

Nelson and Bagian (2000:1) suggest that when designing, building, and operating space systems it is essential to consider three intersecting perspectives:

- The Mission Perspective: Those aspects of the system that describe the goals and objectives of the mission;
- The System Perspective: Those aspects associated with the actual hardware and software components that are used to carry out the mission, and last, but not least;
- The Human Perspective: Those aspects associated with the flight crew and the tasks that they must perform to carry out the mission.

Figure 1 (adapted from Nelson and Bagian, 2000:2) illustrates these three dimensions of space systems, how they interact and some factors that are situated at the boundaries between the three. This approach allows all three dimensions to be considered simultaneously in an integrated fashion. The incorporation of human aspects with the engineering assists in positioning all three perspectives in the development of space missions and systems. Since the current study focuses on the human perspective and is closely related to design and human-factors engineering, it is highlighted.

Various research teams since 2005 have also investigated these intersections, reporting on who will be living in these space communities (Cokley, Rankin & Söhnlein, 2005) and what living there will be like (Babidge, Cokley, Gordon & Louw, 2005; Rankin & Cokley, 2006). These findings were later used to investigate how forward planning is taking place for the design-and-construct phases of space bases (Cokley, Kavanagh, Johnson-Woods & Bloomer, 2007). The most recent of these studies suggests that if present design trends persist – which refer more to 'hard' scientific, engineering and construction standards imposed by the US-Government's National Aeronautics and Space Administration (NASA) than to long-held but 'softer' terrestrial principles of architecture and design – then the structures in which people live will be 'structurally safe and theoretically sound ... but not very *livable*: structural and engineering elements (will) fall within acceptable standards but "livability" elements could be enhanced by improvements to educational syllabi and communicative processes' (Cokley, Kavanagh, Johnson-Woods & Bloomer, 2007:1).

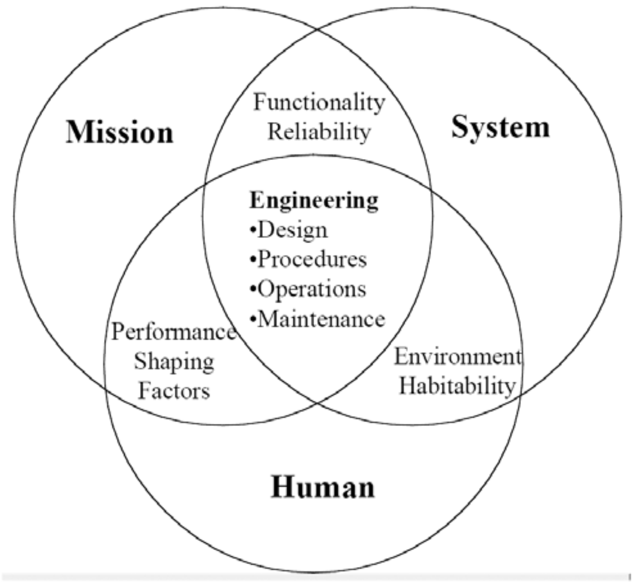


Figure 1. The Three Dimensions of Space Systems (adapted from Nelson & Bagian, 2000)

Design Brief

The student participants of the current study were tasked with breaking into teams, then designing and virtually 'constructing' a community space to support individuals living in a 'Space Station' in Lower *QUT Island* Orbit (LQIO) approximately 1250m above the island surface grids. The space should be operational and allow for future expansions. The space was to be of similar design to the International Space Station (ISS), should be able to support 20 people for 14-18 months and five other individuals for six days, allow 'Earth' views, be a microgravity environment with all the same risks as real LEO (Lower Earth Orbit), and allow for expansion. Students were encouraged to 'map out' the space on an X, Y, Z axis, considering the transition of movement through the spaces on these planes.

The basic shape of the exterior shell of the habitation module was to be cylindrical with a shallow cone at either end. Openings at the narrow end of the cones would provide hatch entry openings into connecting modules that, in turn, opened into one or more of the adjacent activity modules. Dimensions of modules were dictated by the payload bay of a space shuttle, which is approximately 60ft long and 15ft wide (Blume, 2002). Realistic data for space flights, such as the transition to Mars for a crew of six astronauts, were acquired from space habitat sources (Vogler, 2004).

Thus the brief contained a two-part objective: of designing (1) a group proposal for community living (2) in a microgravity environment. The aim was that student teams would identify, manipulate and design interior spaces – sleeping compartments, a kitchen, dining area, exercise area, hygiene facilities, medical equipment and a central command area – based on the given design problem. The inhabitants would be able to sleep, prepare food, relax, converse, communicate with those on Earth, eat and drink, use showers and lavatory facilities, operate computer workstations, and monitor scientific experiments.

The desired outcome was a series of conceptual structures, one per team, designed from the interior out. Vertical as well as horizontal volumes and flow from one space to another were permitted in the brief, as were observation windows, control stations and storage compartments. Interior details and hardware were to be considered, rethinking the idea of 'ornament':

> *In a Gothic cathedral, the job of ornament is to connect to the heavens – from the smaller details to the rose window, which is the cosmic diagram, a metaphor for the relationship of the Earth to the cosmos (Yale professor Kent Bloomer, in Rappaport 1999, n. p.).*

Bloomer suggests there is a metaphor between the cathedral and a space station, where one of the functions of ornamentation was to take the viewer 'home' again. Ornamentation within these remote environments aims to take the inhabitants 'home' and away from the reality of the harsh and isolated environment in which they exist.

Background lectures and readings with the brief included consideration of the 'material' and the 'immaterial'. These emphasized that the environment they were to design should be for 'the body in space' (and Outer Space), so they should consider issues including views, landscape, and the concept of 'being-at-home'. Thinking as positioning 'self-in-space' (McAuliffe, 2009) is done by imagining oneself in the space being designed, a cognitive activity that is the ability to position yourself (in the mind's eye) as being within the space and participating in activities or experiencing the sensory elements of the space – for example, smells, sounds and temperature. The ability to position self-in-space comes with experience. Designers are categorized by their knowledge and ability within the practice (Dreyfus, 2003, 2003a). There are several categories of designers, but for the sake of this study, intermediate and expert designers are explained. Intermediate designers (higher level undergraduate students), although they have the ability to partially position self-in-space (cognitively) as a fragmented series of images of the space, are generally not able to conceive the space in totality with complex design issues resolved. However, expert designers (those who have a reasonable amount of experience in designing with practical work experience) tend to have the ability to position self-in-space (McAuliffe, 2009) as a space in total with complex issues resolved, including the transition of spaces horizontally, or vertically. This ability relates to experience in that as designers, they undertake the act of designing on a day to day basis and have experience of doing so for a significant amount of projects.

Material: During lectures the professor (co-author of this article) emphasized that 'immaterial spaces are expressed physically through spaces, represented through a form of ornamentation. Interior architects 'shape' space, rather than 'decorate' a space, she said (Gadamer, 2003: 150).

Architecture gives shape to space. Space is what surrounds everything that exists in space ... a building should certainly be the solution of an artistic problem and thus draw to itself the wonder and admiration of the viewer. At the same time it should fit into a living unity and not be an end in itself. It seeks to fit into this unity by providing ornament, a background of mood, or framework.

Immaterial: During lectures the professor also drew the students' attention to her view that they were designing 'a place in the world, a place of community' and 'having a place in the world makes the human animal a social being....a place for forming loyalties and responsibilities: human connection through shared experiences' (Ellin, 1997).

This space, she continued – or interconnected spaces – would provide a shelter in which people could hold shared experiences. It was not just about the space and the community: it is also about social behavior and culture, ideas that are deeply embedded in contemporary life and which are displayed as domesticity in specific cultures and societies, generating feelings of intimacy and homeliness.

What is comfort? Is it the reduction of discomfort? Is it a scientific definition? Perhaps, it is like an onion, in layers? Maybe it is a range of attributes – convenience, efficiency, leisure, ease, pleasure, domesticity, intimacy and privacy – and then, maybe it's a little more than that: that which cannot be explained – it just feels right.

These experiences of 'needing shelter, comfort and well-being' were created, simulated, enlivened and emphasized by the simulation of risk and danger lurking outside the 16 inch-thick skin of the *Second Life* space station.

The professor introduced the idea of a 'narrative of inhabitation', which means that even although a space is not 'owned' by a person (a place such as a hotel room) after a few hours it begins to acquire characteristics of the inhabitant, and resembles a portrait of the person/people. Their objects (both seen and unseen) create atmosphere, as do their habits and personality. 'This is a narrative, a story, the traces that are left behind,' she said. 'The space "speaks": in it bodies are washed, adorned and perfumed; people take the time to live and dream. People pass, embrace, touch – deliberately and accidentally, then separate. Here, the body experiences joys, sadness; a tear will dry, unnoticed on a surface. A laugh will silently echo within, perhaps captured in a memory. These spaces, both "public" and private, will become denser places, both materially and emotionally.'

Specifics

Unique to the design of interior environments for survival in space is the problem of how humans interact with the built environment in micro-gravity conditions (Dunn, 1995). Unlike Earth gravity environments, every surface of the micro-gravity environment must be designed to be benign as well as functional, since it is likely that humans living or working in such an environment will come in frequent contact with all surfaces. The complexity of the design problem is increased by issues such as privacy, and continual enclosure in a limited space. Previously (Blume, 2002) privacy cubicles have been excluded from habitation modules due to cost and spatial considerations. More recently designed environments such as the International Space Station (ISS) include multiple modules and astronauts are able to seek privacy by moving to another, unoccupied module (Blume, 2002). This is an important consideration since the interior space in the subject module measures approximately 6.5 feet by 26 feet.

Engineers at Marshall Space Flight Center suggest that there is still a need for research into interior design in micro-gravity environments:

> *The lessons to be learned here are that questions of space-station interior design are as amenable as those of engineering design to rigorous analysis, and that there are some surprises in store that take the evaluation of interiors well beyond their visual or other casual impressions (Wise, 1990, p.10).*

The students in this study were not from within engineering disciplines and so the minute details of Systems, Mechanical, Electrical, Aerospace or Construction Engineering aspects of this design task were outside the scope of the unit. Nevertheless they were encouraged to consider the above disciplines, and other necessary aspects including Environmental Control and Life Support Systems (ECLSS). Design tactics and colour strategies were recommended to mitigate the lack of 'up' or 'down' orientation in the orbiting space-station environment, thus aiding in the reduction of confusion and space sickness.

Since this was an experimental design studio, the students were free to 'think without gravity'. However, they were alerted to the nature of micro-gravity environments in which there is virtually no gravitational pull and from which astronauts have reported that they are much more comfortable being able to visually orient themselves to a recurring vertical position (Aoki, Ohno & Yamaguchi, 2005, p.1005). Both authors of this article undertook lengthy visits to the *Second Life* space station during and after design and construction and their experiences differed significantly. In terms of manipulating the avatar, the co-author quickly became accustomed to the simulated micro-gravity environment and moved about efficiently and with ease; whereas the lead author was uncomfortable with the feeling of weightlessness, and found it very difficult to adapt his keyboard and mouse game controllers to get around efficiently and easily. Data from the students supported this variety of experiences.

Methodology

The specific teaching methodology deployed for this study was environmental manipulation (Matthews, Farrell & Blackmore, 1996, p.440), an established practice in health sciences which is also applicable in this study. As these authors note, environmental manipulation is 'based on the theory that the environment affects the individual and the individual affects the environment'. In the present study, the manipulation amounted to announcing to the 13 enrolled students (three teams) that all work for the unit would take place online *inworld* at the *Second Life* island ... in fact, above the island, in bare grids of what amounted to 'outer space', or Lower Earth Orbit (LEO). At the end of the semester, presentations of design work also took place *inworld*, but there was an *outworld* component, in that student teams conducted presentation seminars of the *inworld* design in person to judges, other teams and interested university staff and students.

This incorporates an approach which 'requires students to do meaningful learning activities and think about what they are doing', in which the core elements are student activity and engagement in the learning process (Prince, 2004, p.1). It deploys what has been described (Gibbs, 1992) as 'structured outcomes', in which students are presented with content identifying how their learning relates to real targets, assessment is based on real-life experiences and interactions with audiences, assessments include group work and peer-evaluation as well as individual work assessed by instructors, expectations that build on students' technological knowledge and skills, and knowledge of design at work developed through previous subjects.

This also supports the deployment of collaborative, cooperative and problem-based learning, where 'collaborative' is described as any instructional method in which students work together in small groups toward a common goal; 'cooperative' is described as taking place in 'a structured form of group work where students pursue common goals while being assessed individually'; and 'problem-based learning' is an instructional method 'where relevant problems are introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning that follows' (Prince, 2004, p.1-2). This is broadly similar to 'project-based learning' which Dym et al (2005, p.109) note is described by researchers at Aalborg University in Denmark as 'problem-oriented, project-organized, learning' in which both 'know-how' and 'know-why' are key goals. The Dym study concludes that these kinds of courses 'appear to improve retention, student satisfaction, diversity and student learning', even though they are more expensive to run (2005, p.114) and require more effort (Parker & Becker, 2003, p.40). This is consistent with the co-author's experience in this study. Various forms of small-group learning have been demonstrated as strongly effective (Springer et al, 1999, p.21) in 'promoting greater academic achievement (and) more favorable attitudes towards learning'. Others (Felder et al, 2000, p.26) note the importance of covering material in frontier areas ... emphasising the connections between technology and society. There is evidence (Parker, Becker, & McCullough, 2003, p.252) that formal collaboration between students in the arts and in computer sciences should be encouraged at an early stage of their development. This can involve development and deployment of computer games and simulations, which result in capturing students' 'imagination and their energy' (Becker, 2001, p.31). The injection of this kind of fun is supported by Appelbaum & Clark (2001, p.583) as being valuable for providing motivation for students.

While working inworld in *Second Life*, the students encountered a 'real-life' aerospace designer employed by the space design and operations company Bigelow Aerospace. This individual, who remains anonymous in this article but whose avatar is known *inworld* as 'Rocket Sellers', provided a copy of all the virtual models for a commercial project to the students so they could see the conceptual design of modules in real-life problem solving. Designs obtained included the A330 and Sundancer modules, realistic digital prototypes of the Bigelow Aerospace *Genesis II* modules currently orbiting at an altitude of 342 miles.

Each of the three student teams provided a written report about their project and experiences in *Second Life* during the semester. These provided the combined data archive, and analysis of the three documents was conducted by computer-assisted text analysis using the social-sciences software *Leximancer*, which provides a concept-mapping and textual trend facility to interrogate the reports (see Rooney, 2005, p.409-410 for a full explanation):

> *Leximancer is a computer-assisted text (content) analysis application that uses a machine-learning technique. The machine-learning process learns in a grounded fashion what the main concepts in a corpus are and how they relate to each other... Overall, Leximancer rank orders concepts, and tells the investigator about the strength of association and semantic similarity between concepts.*

Specific terms investigated were drawn from the most-recent formative study cited earlier (Cokley, Kavanagh, Johnson-Woods, & Bloomer, 2007) which suggested 'NASA', standards' and 'design'. The researchers then relied on the machine-learning characteristics of *Leximancer* to interpret, expand, rank order and co-relate these and related terms to provide visual models of the relationships between the 'harder' engineering standards and the 'softer' architectural and design principles. Some qualitative hand-coding of words highlighted by the software was carried out by the researchers.

Sample sizes and reliability

The small size of the student cohort raises the obvious question of reliability of these study data. On the one hand, 13 students divided unevenly into three teams during a semester unit can realistically provide only indicative results rather than predictive results. The researchers can say – as we do – that these results showed what happened in this study at this time under these circumstances. Further discussion and conclusions are made in the light of substantial other studies referred to in the review of available literature. Mitigating this limitation, however, is the researchers' application of minimally interpretative *descriptive* coding which relies on agreement between the researchers (Thompson, McCaughan, Cullum, Sheldon, & Raynor, 2004, p.16). Further, we rely on the other characteristics of this method – 'closeness to primary qualitative research data, working relationships over time, and focused research team discussion' – which 'can all lead to greater agreement and convergence at the level of descriptive coding' (Thompson et al, 2004, p.15).

On the other hand, the sample size in the textual analysis is more substantial. The student reports examined using the *Leximancer* software contained a total of 19,199 words which is a useful sample, and the software offers a high degree of reliability and thus a degree of predictability which underpins this study:

> *Leximancer addresses reliability in two ways. First, it affords stability and second, reproducibility. Stability in Leximancer is equivalent to intercoder reliability. That is, the automated and deterministic machine-learning phase will be highly consistent no matter how many times a corpus is processed and reprocessed (coded and recoded) by the application. It can therefore be said that Leximancer has a high level of coding stability. Reproducibility in the context of Leximancer is seen in its consistency in classifying text given the same coding scheme. Consistent classifying manifests in a consistently constructed stochastic concept map (Rooney, 2005, p.410).*

Beyond reading each team's report, individual analysis was not conducted as ranking the student teams was outside the scope of this study, and the sample size within teams was insufficient for meaningful data. This allowed the complete anonymisation of the student data and mitigated any risk of identification of any individuals. Under these circumstances, no ethical issues or considerations were identified by the researchers before or during the research and none have been identified or brought to our attention since that time.

Findings

The researchers read each of the student groups' reports and each explicitly referred at least once to 'collaboration', 'group decisions' and 'conscious decisions (by the group)'. In this way the students' reports at least weakly supported the study's aim of having them encounter and engage with the collaborative mechanisms enabled by the immersive *Second Life* software.

After working in *Second Life*, it was noted that the students gained a greater understanding of the implications of their designs, simply by 'being there'. The students began to design with ease, using all horizontal and vertical planes (described to the students as designing in *cubic meters*, rather than using *square meters*, the traditional means of designing spaces).

Data displayed in Figure 2 show the main concepts and word prevalence discovered during the *Leximancer* analysis. The concepts 'NASA', 'standard' and 'design' were introduced as controls (top section of Figure 2) based on the available literature and the course lecture content which indicated that the first two of these contained the 'hard' engineering concepts while the third contained the 'soft' livability concepts. Leximancer machine-identified other words (lower section of Figure 2) and rank-ordered them by prevalence. Words in this list were hand-coded by the researchers as either 'soft', 'hard' or 'unrelated' (Table 1).

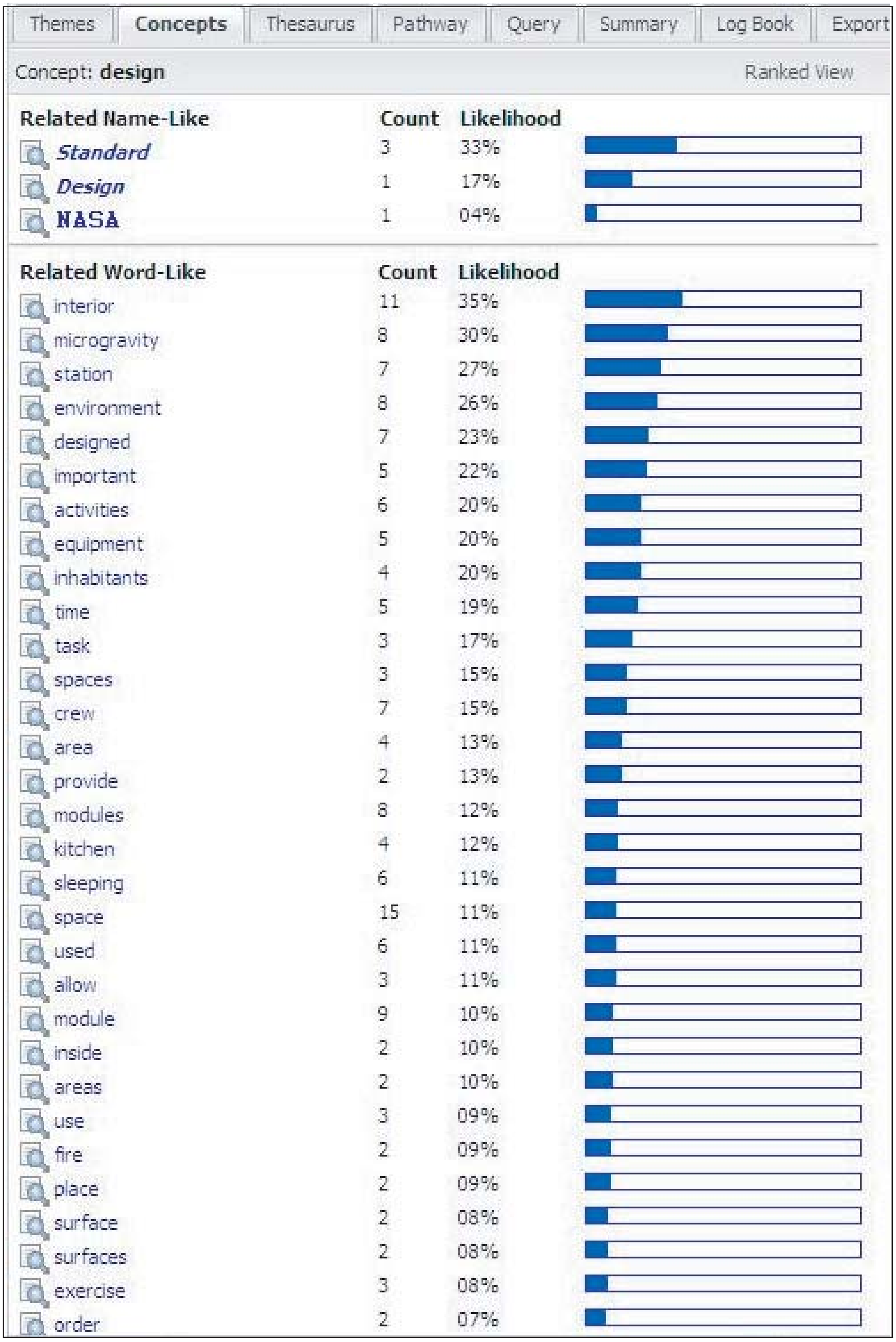
Table 1.
Codings Selected by the Authors for Words Identified During Textual Analysis: "n" Indicates the Combined Prevalence of Each Category in the Texts

Soft (*n* = 68)	Hard (*n* = 51)	Unrelated
Interior, microgravity, designed, activities, spaces, area, kitchen, sleeping, space, inside *and* areas	station, environment, equipment, inhabitants, task, crew, modules *and* module	important, time, provide, used, allow, *and all words to which Leximancer ascribed a likelihood of occurrence of 9% or less*: use, fire, place, surface, surfaces, exercise and order

Analysis of the control concepts suggests that the student reports strongly emphasised standards over design considerations. However, this was challenged by the thematic summary (Figure 3) produced by the software after an examination of the themes evident in the student reports, in which combined relevance of 'soft' themes – space, area and design – exceeded the combined relevance of 'hard' themes – module and modules.

Analysis of the coded words (listed lower in Figure 2) suggests weak but clear support for the themes data. The researchers coded the listed words as either 'soft', 'hard' or 'unrelated' and the textual prevalence of the concepts codes as 'soft' – 'interior', 'microgravity', 'designed', 'activities', 'spaces', 'area', 'kitchen', 'sleeping', 'space', 'inside' and 'areas' (*n* = 68) – was greater than that of the concepts coded 'hard' – 'station', 'environment', 'equipment', 'inhabitants', 'task', 'crew', 'modules' and 'module' (*n* = 51).

It is suggested that this tension – perhaps 'uncertainty' – is reflected in the more detailed relationship modeling provided by *Leximancer* and shown in Figures 4-6. In general the students' reports identified/displayed clear relationships between 'design' and many other concepts, and 'standard' and many other concepts. The graphical separation evident in each of these models might refer to the difficulty the students had in reconciling the dichotomy of the physical requirements of launching, staging and constructing components of a space base from Earth, with the emotional and psychological requirements of human living, rather than merely survival.



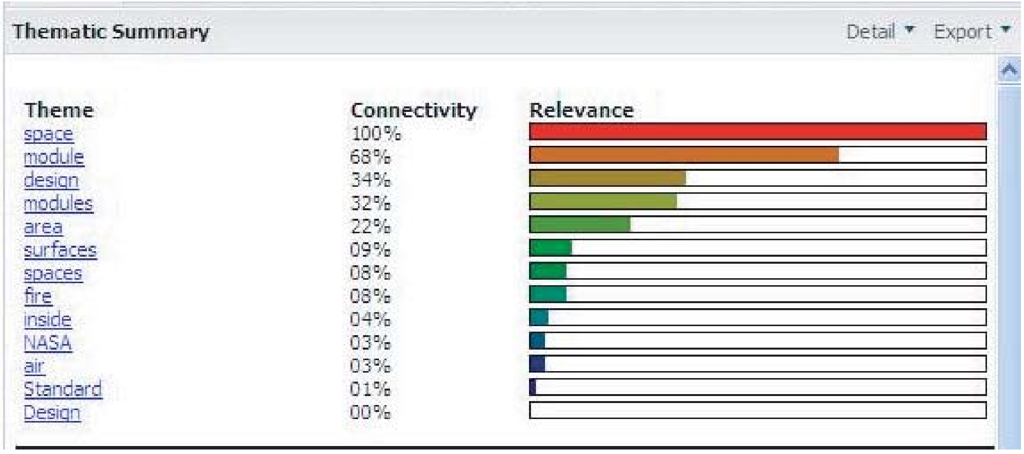
Themes | Concepts | Thesaurus | Pathway | Query | Summary | Log Book | Export

Concept: **design** Ranked View

Related Name-Like	Count	Likelihood
Standard	3	33%
Design	1	17%
NASA	1	04%

Related Word-Like	Count	Likelihood
interior	11	35%
microgravity	8	30%
station	7	27%
environment	8	26%
designed	7	23%
important	5	22%
activities	6	20%
equipment	5	20%
inhabitants	4	20%
time	5	19%
task	3	17%
spaces	3	15%
crew	7	15%
area	4	13%
provide	2	13%
modules	8	12%
kitchen	4	12%
sleeping	6	11%
space	15	11%
used	6	11%
allow	3	11%
module	9	10%
inside	2	10%
areas	2	10%
use	3	09%
fire	2	09%
place	2	09%
surface	2	08%
surfaces	2	08%
exercise	3	08%
order	2	07%

Figure 2. Words and Trends Discovered in the Leximancer Analysis



Thematic Summary

Theme	Connectivity
space	100%
module	68%
design	34%
modules	32%
area	22%
surfaces	09%
spaces	08%
fire	08%
inside	04%
NASA	03%
air	03%
Standard	01%
Design	00%

Figure 3. Relevancy Table Produced by Leximancer

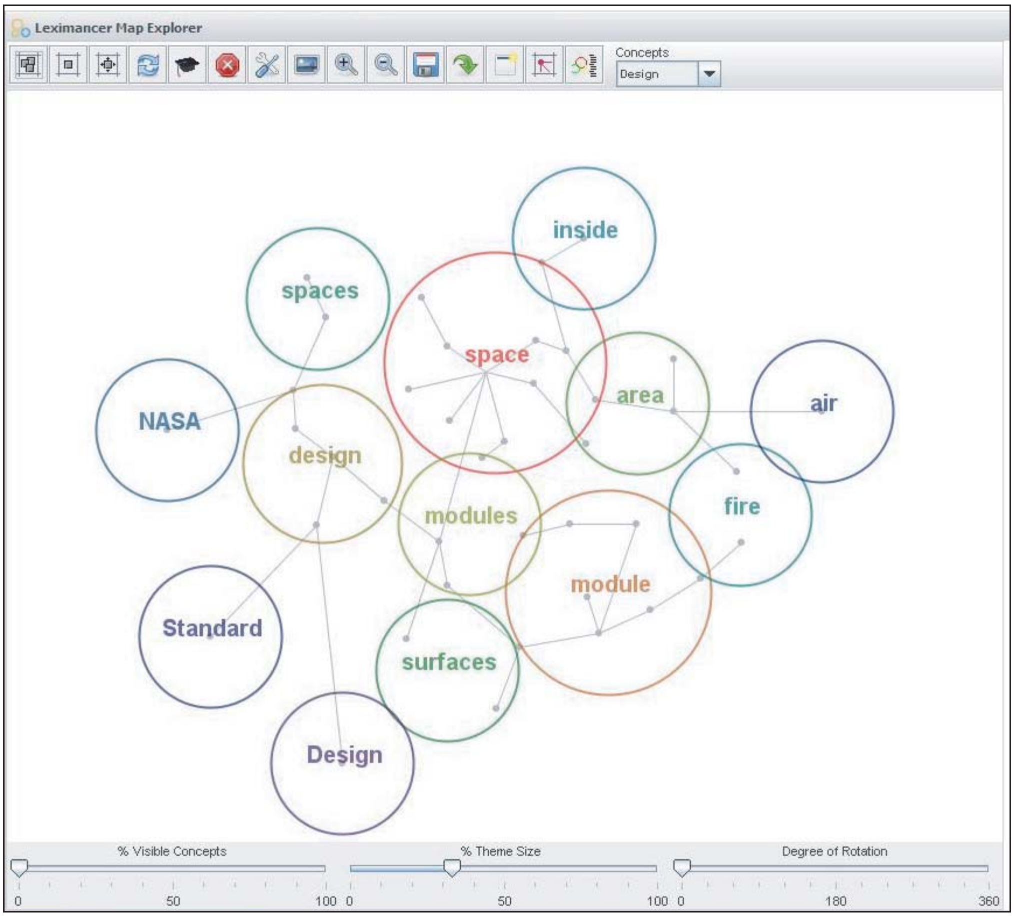


Figure 4. Overall Relationship Modeling of Concepts and Words Throughout the Three Reports

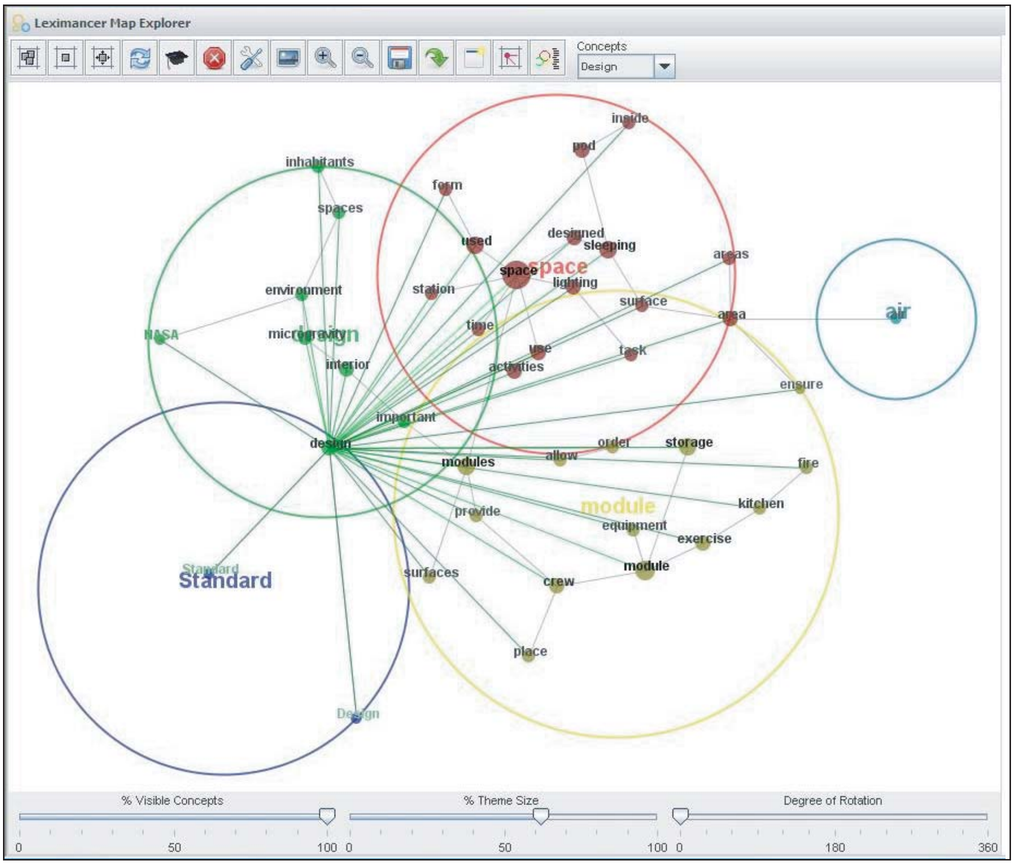


Figure 5. Relationship Between 'Design' and All Other Words and Concepts

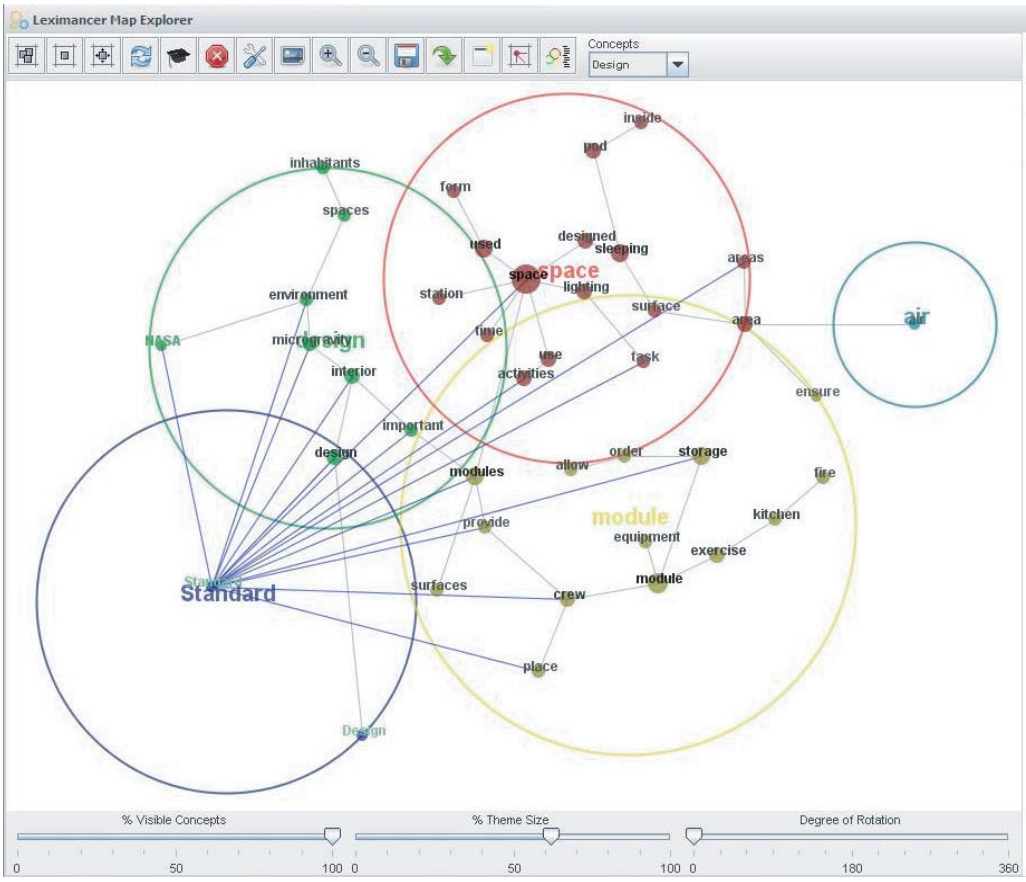


Figure 6. Relationship Between 'Standard' and All Other Words and Concepts

Discussion

Overview: Literature reviewed for this study suggested that the task of whether to design for people simply to survive in space, or for people to *live well* and sustain a home-like life and relationships, had been noticed but not sufficiently addressed by designers in the past. The authors hypothesized that addressing this task would require a bridge between the hard engineering standards deployed by NASA on one hand, and the 'soft' architectural principles grounded in 'habitability' and 'livability'. They attempted to build that bridge by encouraging students to design 'from the inside out', rather than from the more conventional 'outside in', a 'gut process' normally only achieved after at least 10 years in the profession. This accelerated development was achieved using the teaching methodology of environmental manipulation which presented students with the above unexpected design decision, since most novice (*i.e.* student) designers begin with a structure and then fill it; in this case, they were asked to live in a space and design around it. The experiential constructivist learning opportunities offered by the planned *Second Life* immersion – compared with other lesser opportunities identified as notional and instructivist – supported the students in framing their reports to accommodate the challenges offered by one set of concepts to the other. By being able to perceive themselves as being really within the space being designed and able to act collaboratively there, rather than merely imagine themselves there, the students were able to feel some of the tension and incorporate it in their 'narrative of inhabitation' and thus deal with it emotionally as well as intellectually.

The widespread uptake and acceptance of *Second Life* by universities mitigated any risk to the students during this study. The free availability of the software, combined with the ease of operation on the fast university computer network, enhanced both individual and group student uptake during the study. The researchers noted during the study that the students' ability to see and converse with their colleagues' and instructor's avatars, and to meet other designers' avatars (especially that of 'Rocket Sellers') was beneficial to the outcomes of the study, as was the availability of use of the simple *inworld* building tools. These observations support Gollub's description (2007) of *Second Life* as offering a 'visceral feel' and 'a chance to try out living very different lives'.

Details: The data presented suggests the students successfully engaged with each other (individually and as teams) in the collaborative virtual environment, and successfully integrated engineering and design concepts. Textual analysis data (Figures 2-3) suggest a reframing of emphasis away from both strict adherence to NASA engineering standards and more emotional design concepts, arriving at a blending of both emphases but with a trend to design and livability. Modeling of the textual analysis (Figures 4-6) supports this reframing and suggests not only reframing in progress but a tendency to integrate the various – and previously poorly integrated – engineering and design areas. This supports the general position of Nelson and Bagian (2000) that integration of mission, system and human perspectives is beneficial to the design process.

Conclusions and Further Research

The efficacy of using the immersive *Second Life* software as a design tool which improves on existing methods is supported by this study. This supports the position of Wise (1990, p.10) that 'questions of space-station interior design are as amenable as those of engineering design to rigorous analysis'. It also supports the use of problem-based learning and structured outcomes in this discipline, and suggests their use in other related disciplines. While the researchers concur that the study required more effort to run than a conventional design studio, the free availability of the *Second Life* software challenges the position of Dym et al (2005) that this kind of course is necessarily more expensive to run.

Further research

The authors now propose a study which would attempt to extract some of the *inworld* design products from *Second Life* to the *outworld* environment. At this stage, the *inworld* designs are analogous to concept sketches which must be transferred manually to desktop computer-aided design packages in order to achieve dimension-correct working diagrams which could be handed to prototypes makers, manufacturers, and construction teams. We suspect that this manual transfer will result in a dilution of the experiential benefits obtained in *Second Life* and risk a skew back to hard engineering standards away from the integrated results of this study. Issues of intellectual property and digital rights management (i.e. code copyright) within *Second Life* must be explored and hopefully negotiated for an in-machine transfer to be enabled. If that is achievable – and clearly it is theoretically *possible* – then integrated *inworld* interior design and export to *outworld* working drawings is likely to improve design outcomes, enhance livability of space station modules, and reduce time and cost involved in planning, design, staging and manufacture of the space bases of the future.

We also suspect – and propose to test in future studies – whether the behavioral change evident among the 13 students of this study is scalable and transferable to students in other disciplines which show similar characteristics of 'crossing over' between science/engineering disciplines and design/humanities disciplines. Also, we propose to test whether the experiential learning enabled by the immersion in *Second Life* are useful for students in other, apparently unrelated, disciplines. The lead author of this study works principally in journalism and communication and suspects that *Second Life* immersion in scenarios might be useful to condition novice reporters to critical situations such as courtrooms, disaster scenes or large-scale political interviews known as 'media scrums', and to enable researchers to study how best to cope with and manage these situations from communicative perspectives.

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Notes

1. The institution was the Queensland University of Technology, Australia.

2. https://www.google.com/accounts/ServiceLogin?service=writely&passive=true&nui=1&continue=http%3A%2F%2Fdocs.google.com%2F&followup=http%3A%2F%2Fdocs.google.com%2F&ltmpl=homepage&rm=false
3. http://sharepoint.microsoft.com/Pages/Default.aspx
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5. http://www.bigelowaerospace.com/

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