Understanding design skills of the Generation Y: An exploration through the VR-KiDS project

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As university instructors prepare to teach the current generation (Generation Y), a dire need exists to continue learning and acquiring effective tools in teaching design to reach a different generation, since most instructors grew up in the Baby Boomer Generation and the Generation X cultures. The Virtual Reality for Kids interested in Design Studies (VR-KiDS) project is an exploratory study to understand design skills of Generation Y within a digital environment, specifically virtual reality. Using the Second Life interface and the multiple intelligence frame work students between the ages of 11 and 16 participated in the design of a virtual zoo. The project outlines the conception, application and evaluation of design skills within this interface.

Keywords: architectural design, design process, virtual reality, learning skills, design cognition

Design is a diverse and creative domain that exhibits individual styles of learning – from visual, to verbal, to kinesthetic styles. These individual styles have been amplified by the current technology-intensive environment of social-networking, 3D-gaming and virtual reality worlds. As Privateer (1999) cautions, the question of whether current technology will reinforce existing learning environments or fundamentally alter conventional learning is not yet known. However, he suggests that it makes little sense for academicians to continue the traditional way of learning, which is significantly at odds with technologies that are impacting learning communities. Part of the difficulty in doing research or learning new technology for teaching, is that these technologies are fragmentary in nature, develop at a rapid pace, and consist of diverse media and tools. In this context, there exists a need to develop and evaluate new learning environments, specifically for creative domains such as design – which demands individuals who can make synergistic connections between different tools.

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Hence, given the rapid changes in computational media, today's children are growing up in an entirely different learning environment than their design instructors. It would be reasonable to assume that their design thinking will be significantly influenced by the technology available to them. Today's children belong to the Generation Y or the Millennia Generation, who represent the latest cohort of young people to reach tertiary education age (Nimon, 2007). These children were born in or after 1980. However, most of today's university instructors belong to the previous generations – i.e. the Baby Boomer Generation born 1946–1964 and Generation X, born 1965–1979 (Freestone & Mitchell, 2004). While there are significant differences in the exact age boundaries, the critical factor according to Nimon (2007) is understanding a generation's characteristics and behavior, rather than fixation on an exact starting point.

According to Nimon (2007), perhaps the most predictable effect on Generation Y has been on attitudes towards technology itself. To Baby Boomer Generation and Generation X, phenomena such as mobile phones and the Internet represent tools that, while useful, are not essential. Generation Y however, consider them as inseparable from their daily existence as the clothes they wear or the food they eat. VR worlds such as Second Life even allow reinvention of the physical self through the use of personal avatars, allowing an unprecedented degree of control over appearance that can be continually updated or adapted. In other words, in the hands of the Generation Y, these technologies have been transformed from the simple tools of the Baby Boomer Generation into devices through which they experience and interact with their world.

1 *Bracing to teach the Generation Y*

Dobbins (2005) notes that the world of Generation Y is a '24/7' world, which has an impact on their attitudes and behavior in several ways. Firstly, they are often reported as having short attention spans. Sheahan (2005, p. 63) refers to them as 'Stimulus Junkies' and warns employers that 'if you can't keep Generation Y entertained, you can't keep them.' Secondly, the perceptual border that had separated privacy from accessibility for previous generations appears to be fading. Nimon also argues that the perception of time among Generation Y has contracted, which means they not only expect quick and immediate responses, but that they expect it within a rapid time frame that traditional institutions may not be structured to achieve.

Oblinger and Oblinger (2005a, 2005b, p. 2.9) identify the following characteristics as being typical for Generation Y: digitally literate in the sense of being comfortable and familiar with digital technology; connected to friends and the world through technology; rapid multi-tasking and quick response to communications; prefer to learn by doing rather than being told; gravitate toward activities that promote and reinforce social interaction; prefer to work and play

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in groups or teams; prefer structure to ambiguity; have an orientation toward action and inductive reasoning rather than reflection; show a preference for visual (i.e. graphics, video) and kinesthetic learning rather than learning through text In Grown Up Digital: How the Net Generation is changing your World, Tapscott (1998) notes that it's not what one knows that counts anymore; it's what one can learn. The current generation, he claims, needs a different form of education than the Baby Boomer Generation had. When Baby Boomers went to college, they learned a competency of profession and then moved on to their career. The educational model was to cram as much knowledge into one's head as possible to build up an inventory of knowledge before one entered the world of work. This, Tapscott says, worked in a relatively slow moving world and one in which mass education was a product of industrial economy. It came along with mass production—mass marketing and the mass media.

But now, Generation Y is faced with the fast-paced world of information age and an era of lifelong learning. Students have individual ways of learning and absorbing information. Some are visual learners; others learn by listening. Still others learn by physically manipulating something. In other words, Generation Y has entered a world in which the ability to think, learn and find out things is more important than mastering a static body of knowledge. Tapscott believes that one needs to abandon the 'broadcast style' of traditional teaching and adopt a more interactive one. Similarly, Sweeney (2006) considers the Generation Y smart but impatient and observes that they like to collaborate and reject one-way lectures. They want to learn, but they want to do it in a style that is best for them.

Within this context, as university instructors prepare to teach Generation Y, there is a dire need to continue learning and acquiring new tools. This is not to say that Generation Y students are necessarily different from instructors in their design judgments. But the process and skills that students bring to design today are significantly different from those of the instructors. One needs to understand the learning traits of current design students who are immersed in a technology-intensive environment of social-networking, 3D-gaming and virtual reality worlds. The Virtual Reality for Kids interested in Design Studies (VR-KiDS) was hence conceived an exploration into the design skills of the Generation Y within this context — specifically, virtual reality.

1.1 Virtual reality worlds and learning skills

Virtual Reality (VR) is a technology that allows users to interact with three-dimensional (3D) contents in real-time. VR provides users a unique experience through its interface, which is more immersive and engaging than 2D graphics-based interfaces because of 3D VR's capacity of seamlessly integrating graphics, animation, video, text and sound. In most VRs, users can travel

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and create designs by manipulating simulated objects, interact online with other people and access information in real-time.

Depending on the display and input system, a wide range of VR types are available, from the CAVE (an immersive VR display system consisting of 3–5 projected walls in an enclosed room-size cube) to simple product simulations on the Web. In the most successful VRs, users feel that they are truly present in the simulated world, and it is this quality that distinguishes Virtual Reality from other forms of human–computer interaction. While VR can be seen as functioning like other digital tools such as game environments, simulation and animation, it is important to make some distinctions (Cillay, 2007). Game environments set up competition comprised of rules, are structured and encompass a sense of win and lose. Simulation is imitation or representation of an event, situation or activity. Animation is usually a passive presentation, while VR worlds are interactive, exploratory and open-ended.

With increased accessibility, the unique characteristics of VR have attracted increasingly more attention in diverse contexts including education, military training, entertainment and e-commerce. In other words, because of their open-endedness and interactivity, VR worlds have immense potential for experimentation with learning tools and pedagogy. Bricken (1990) has theorized about VR as a tool for experiential learning based on ideas of John Dewey and Jean Piaget: 'Try experiments, safely. Experience consequences, then choose from knowledge' (Bricken, 1990, p. 2). Similarly, pointing to the versatility of VR tools, Bricken (1991) suggests that VR enables learners to practice skills in ways that cannot be achieved in the physical world (e.g. flying through; occupying an object of a virtual body to observe events from different perspectives, etc.). Bricken theorizes that VR provides a developmentally flexible, interdisciplinary tool within a single interface and an enormous variety of supply and virtual learning materials that do not break or wear out.

Gay and Greschler (1994), who studied the impact of VR on students learning biology cell building, suggest the advantages for VR in informal learning. Gay and Greschler suggest the ability of VR to create informal learning in a formal environment provides opportunity for more open-endedness and more exploration than the explanatory way of learning. McLellan (1994) describes a training program for pilots called Line-Oriented Flight Training (LOFT), which features simulators in a VR environment that exemplify situated learning in terms of apprenticeship, collaboration, reflection, coaching, multiple practice and articulation of learning skills. Apprenticeship is afforded by the instructor's decision to set the problem and control the environment. Collaboration, multiple practice and articulation are provided through solving problems by teamwork in different conditions. Reflection and coaching are afforded by an after-test critique.

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While VR's potential as an educational tool is promising, several researchers point out that VR's most powerful capability in education is as a data gathering and feedback tool on human performance (Lampton et al., 1994; McLellan, 1994). The Virtual Environment Performance Assessment Battery (VEPAB) developed by Lampton et al. measure human performance on vision, locomotion, tracking, object manipulation and reaction time performed on three-dimensional, interactive virtual environments. VR can be used to provide a general orientation for interacting in virtual environments and to determine entry-level performance and skill acquisition of users.

Fennington and Loge (1992) studied how learning styles are enhanced or changed by VR. They discuss uses of VR in military training, medical education, industrial design and development, the media industry and education; they identified three primary applications of VR in the learning process – visualization, simulation and construction of virtual worlds.

Merickel (1990) investigated whether a relationship exists between perceived realism of computer graphic images and the abilities of children to solve spatially related problems. She had students develop, displace, transform and interact with 2D and 3D computer graphics models. Merickel concluded that the relationships between perceived realism and spatially related problem-solving were inconclusive, but worthy of further study. Furthermore, Merickel points out that the ability to visualize and mentally manipulate two-dimensional objects is a predictor of spatially related problem-solving abilities. In summary, Merickel concluded that virtual reality is highly promising and deserves extensive development as an instructional tool.

In a literature survey of VR studies in higher education by Hew and Cheung (2010), virtual worlds are utilized for the following purposes: (i) communication spaces (both verbal and non-verbal), (ii) simulation of space (spatial), and (iii) experiential spaces ('acting' on the world). The virtual world research had been most frequently carried out in the media arts, health and environment disciplines. They also found that research is focused on participants' affective domain, learning outcomes and social interaction. In general, students liked using virtual worlds because they enjoy the ability to move around freely in a 3D space, to meet new people and experience virtual field trips and simulated experiences. Students, however, dislike the inability to access the virtual world environment through older computers, the general prohibition of the use of such virtual world software in public computers, having to instantaneously formulate responses and type fast in order to communicate textually through the chat tool, the lack of provision of turn-taking or threaded discussion because of the chat function, and unfamiliarity with the virtual world software. Studies also suggest that the use of virtual worlds could help foster social interaction among participants through the use of avatars.

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1.2 Virtual reality and architectural design

The application of VR is at an emerging stage in the architectural research community. Despite this early stage, VR tools such as Second Life are impacting the way in which architectural studio is taught; how students learn; and how they are becoming increasingly skilled with software used in architectural design, such as SketchUp, Google Earth Pro, Autodesk Revit and Autodesk 3ds Max, among others. Recent studies on VR have shown potential benefits to studio teaching and learning (Bertol, 1997; Kvan, Schmitt, Maher, & Cheng, 2000) as well as potential limitations (Kruijff, 1998; Kvan, 2000). Benefits include an effective tool for form-finding, and limitations include lack of communication and collaboration, among others.

Architectural design schools at Montana State and University of Sydney have been experimenting with virtual worlds in design. Since Fall 2005, Beaubois (2008) has taught an architecture course using Second Life at Montana State. Using Second Life's group creation platform, Beaubois and his students work together in the same 'virtual' place to manipulate geometric shapes and link them to make a variety of structures, such as a gallery space to display their work. Beaubois also finds it a good tool for showing students how building parts fit together.

Research at the University of Sydney architecture school has focused on the potential for VR in collaborative design. Maher, Bilda, and Marchant (2005, pp. 3–26) have conducted exploratory research on virtual worlds and by augmenting VR with other tools such as Groupboard, sketching area and online videoconferencing. In one study, Maher, Bilda, and Gul (2006) studied the impact of collaboration in virtual worlds on design behavior. They examined three pairs of designers collaborating on design tasks of similar complexity using a different design environment for each task: face-to-face sketching, remote sketching and 3D visual world. They concluded that in sketching, architects move between analysis and synthesis, while in 3D, they focused more on synthesis. The majority of the time on 3D modeling was spent on changing schemes, which they suspect demonstrates the relative richness of virtual world.

In another study, Rosenman, Merrick, and Maher (2006) concluded that VR allows designers in different disciplines to model their view of a building as different representations. By conducting a synchronous design session of a Mondrian school style tower between an architect and engineer, they developed a prototype system called Design World where Second Life is used as a platform, augmented with web-based tools, Groupboard sketch tool and SQL.

In other studies of collaborative design, Maher and Gero (2002, pp. 127–138) observed that VR integrated tools need to break away from their static nature

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to be more interactive. They propose that VR needs to afford three levels of reasoning in the virtual world: reflexive, reactive and reflective. In this regard they propose an agent-based approach to VR – a way to extend the concept of virtual worlds from preprogrammed interactive 3D models to places with objects that respond to their use by reasoning about the environment and then modifying the environment. Using the example of a 'wall' in a virtual seminar room, Maher and Gero proposed an array of mechanisms in which the wall should be able to respond to its environment, for example, by moving when the number of people in the room exceeds the capacity of the room, becoming opaque when visual privacy is needed or transparent when privacy is not needed, and locking the room when interruptions are not allowed.

1.3 The multiple intelligence framework

It is clear from the literature that VR has a variety of learning and educational benefits: as an exploratory learning environment, data gathering and feedback tool, and collaborative design, among others. However, the benefits for design education have not been fully investigated. Architectural design consists of a complex set of activities and the associated skills of visualization, drawing, formal logic and emotional reflection, among others (D'souza, 2006, 2009). Moreover, architectural design problems vary in content, scale and complexity, and a designer needs to apply a repertoire of mental representations to solve a design problem. Add to that the process of thinking at various scales (macro to micro) and at varied degrees of abstractions (abstract to concrete, symbolic to literal, etc.). Architects also deal with architectural dialectics of aesthetics (heavy v/s light, dark v/s bright), function (work v/s life, movement v/s static) and psychological/social (community v/s privacy, safety v/s freedom, etc.).

To deal with this wide array of activities, designers need to use multiple skill sets and representations. In his pioneering MI framework, Howard Gardner (1983), a fierce promoter of skill diversity, suggests that not only do all individuals possess numerous mental representations and intellectual languages, but individuals also differ from one another in the forms of these representations, their relative strengths, and the ways in which these representations can be changed.

Gardner proposed at least eight discrete mental representations and the ways in which individuals take in information, retain and manipulate that information, and demonstrate their understandings to themselves and others. The eight representations, popularly known as multiple intelligences (MI), include interpersonal, intrapersonal verbal/linguistic, logical/mathematical, musical, spatial, bodily-kinesthetic, and naturalistic intelligences (Table 1).

There is also a contention in the terminology of 'intelligences.' Gardner's use of the term 'intelligence' is meant to be provocative rather than literal. Hence,

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Table 1 Multiple Intelligence Framework proposed by Gardner (1983)

Intelligence type	*Description*
Linguistic/verbal	Use words in creative ways
Musical/rhythmic	Appreciate/perform sounds
Logical/mathematical	Think in abstract relations
Spatial/visual	Manipulate/transform spatial information
Bodily-kinesthetic	Use body to solve problems
Intrapersonal	Responsive to personal feelings
Interpersonal	Responsive to feelings of others
Naturalistic	Appreciate/manipulate nature

the term 'skill' is used in this paper in a loose-fit manner so as to render its meaning more inclusive – overlapping with terms such as aptitude, competency, intelligence or representation. For example, spatial skill could indicate both the visualization of space in the architect's mind and the graphical articulation of that space in the form of an architectural sketch. Hence, the use of MI framework for evaluating design skills could be relevant inasmuch as it affords a way to think of architectural designing as a diverse set of skills or representations. Because of its multi-sensory environment, we anticipate that a VR interface has great potential in teaching the multiple skills that are required in architectural design.

1.4 Multiple intelligence framework and architectural design

D'souza (2006) extended Gardener's MI framework to the specific skills of architectural design students. In a intermediate year design studio at a Midwestern school of architecture in the U.S., the following questions are asked: First, how multiple intelligences are used across specific design tasks; Second, whether there is a relationship between the possession of skills and nature of design tasks and; Third, whether there is a relationship between application of design skills and academic standing. The protocols of the students also revealed individual differences in the manner in which they applied their skills to the three design projects.

Figure 1 shows some examples. In the top left example, the designer posits several questions during the design process, and this verbal articulation allows creation of constraints/inspiration demonstrating the use of verbal intelligence. In the top right example, the designer reflects on an existential question about how culture can be represented through design, or how one even begins to represent culture. This demonstrates intrapersonal intelligence. The middle far left figure shows the sense of space that pedestrians experience in relation to their body movement, demonstrating bodily-kinesthetic intelligence. The middle figure shows the intention of interpenetration between natural and built spaces, demonstrating naturalistic intelligence. In the bottom right example, the designer attempts to position a sculptural object visually, accessing from outside by raking the Soffit. This demonstrates spatial intelligence. In the bottom middle example, a geometric grid is used to explore the layout of a row house project that can structure different aspects of orientation, zoning and

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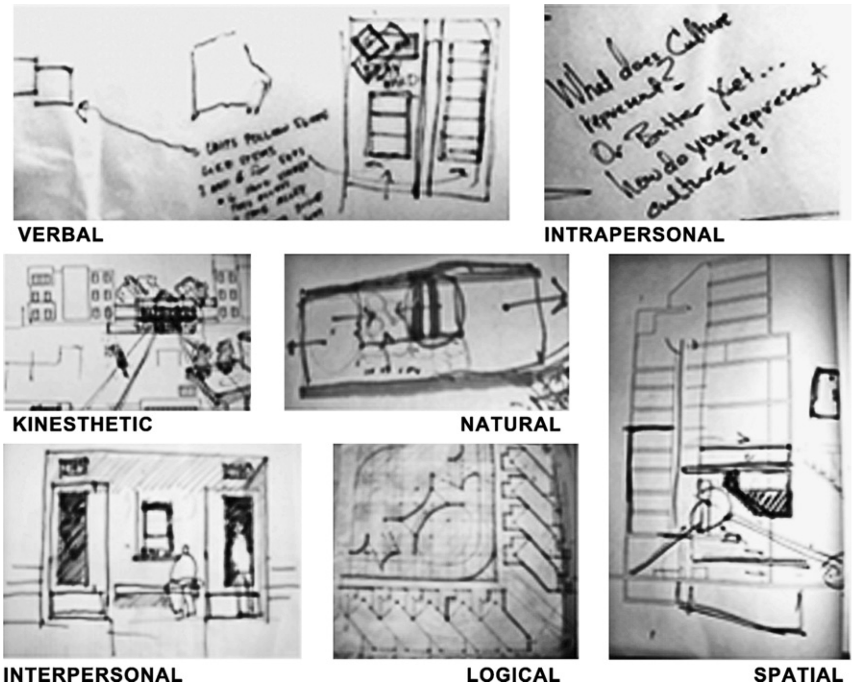

Figure 1 Some examples of evidence for multiple skills among architectural designers (D'souza, 2006)

layout, demonstrating a logical intelligence. In the bottom left example, the designer creates an 'inviting' entry to her row house in which the seating space, the low walls and the common entry become a response to the predicted pattern of human behavior. This demonstrates interpersonal intelligence.

The study thus demonstrates that designers are competent in multiple skills rather than specialized in one or two, and also that their success is related to how these skills are applied to specific design tasks. Based on these findings, D'souza offers a set of sub-skills more closely related to architectural design: spatial choreography, aesthetic cognition, expressive use of number and geometry, among others. He concludes that design skills cannot be restricted to one set of variables, but rather should be considered as a flexible framework consisting of multiple skills that can be adapted to produce desired outcomes.

1.5 Multiple skills and virtual reality

McLellan (1996) was one of the first to identify the potential of VR to the learning of Multiple Intelligences. According to McLellan, VR application can support learning through multi-sensory, multidimensional information-presentation capability bridging many disciplines and providing a powerful synergistic learning tool. She proposes that VR tools have potential not only to support different types of skills, but also help promote synergistic interconnections between them.

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Following are some select VR examples that McLellan proposes that could be examined for the affordance of multiple intelligences:

(i) Spatial intelligence: Virtual Kitchen developed by Mitsubichi in collaboration with VPL Research to try different models, colors and configuration of appliances.
(ii) Kinesthetic intelligence: A VR ski-training system, in which the learner practices with a head-mounted display developed by NEC.
(iii) Logical Intelligence: A Virtual Physics Laboratory where students can change form and gravity and track changes in the VR; developed by University of Houston and NASA's Johnson Space Center.
(iv) Musical intelligence: Hyperinstrument in which the cello is augmented by computer, developed by Tod Machover of MIT Media lab in collaboration with musician Yo Yo Ma.
(v) Linguistic intelligence: Groupware, which allows collaborators at different locations to connect verbally via video windows on the computer screen and also for creating and receiving text document interactions
(vi) Interpersonal intelligence: The Line-Oriented Flight Training (LOFT), a training program for pilots featuring simulators in which collaboration is afforded through solving problems by teamwork and in different conditions
(vii) Intrapersonal intelligence: Role-playing opportunities in VR are provided by VPL Research in which users can view the virtual world though the eyes of that creature (for example, a lobster).

The above-mentioned examples suggest a variety of dispersed tools. Within this diverse environment, creative domains such as design will demand individuals who can make synergistic connections between different tools, implying multiple skill learning. Hence, it is productive to consider an integrative interface that affords multiple skill learning. Second Life virtual world is used in this project as that single interface. We used the terminology of interface, similar to what Frost terms as the boundary object (Lowe, 2008). A boundary object facilitates the thought process similarly to a design sketch and serves as point of mediation and negotiation around the design intent. Second Life (SL) is a popular online social-networking VR platform that has been adopted by more than 60 schools and academic organizations for various educational purposes (Wong, 2006).

2 The VR-KiDS project

2.1 Conception and development of the project

The Virtual Reality for Kids interested in Design Studies project (VR-KiDS) attempts to test multiple skills through the SL interface (Figure 2). The following skills are tested: spatial skills (schematic modeling), kinesthetic skills (walk-through), logical skills (form manipulation), verbal skills (design concept

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Figure 2 Theoretical development of the VR-KiDS project

narration), interpersonal skills (instructor–student interaction) and intrapersonal skills (active reflection).

2.2 The VR-KiDS project was developed in three phases

Phase 1: Creation of an exploratory VR interface that affords the use of multiple skills in architectural design

Phase 2: Pilot-testing of the interface by incorporating students from a University Extension program called 4-H, which aims at providing students with career discoveries in subjects including architecture, interior design, and urban planning, among others.

Phase 3: Explore the validity of the tool in fostering multiple skills among 4-H students.

In phase 1 of the project, a storyboard of design exercises relevant to specific design skills (as proposed by D'souza, 2006) were developed. Second Life virtual world was then used to translate the story board into a design exercise.

In phase 2, students from the 4-H Summer Program at a state university in the Midwest were invited to participate in design exercises. Among several other activities, the 4-H program explores issues of human environment with the aim of providing students with career discoveries in agriculture, nutrition, fitness, exercise physiology, architecture, interior design and urban planning. Specifically, the architecture program in this university exposes students to Habitat for Humanity, solar design, landscaping design and interior finish design. Since these 4-H students were already participating in the architecture career development program, the VR-KiDS study was anticipated to further their experience in design.

The 4-H camp occurs every summer and consists of members between the ages of 5–19. A purposive sample of 14 students between 11 and 16, including six males and eight females, volunteered to participate in the VR-KiDS study. While we understand that there will be developmental differences between the ages of 11 and 16, the critical factor, according to Nimon (2007), is understanding a generation's characteristics and behavior. In this sense, we anticipated that this sample would be familiar with other 3D environments, such as gaming, to a similar degree. The sample size, although small, is considered

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adequate for the purposes of the study, considering the exploratory nature and time demands to document the design process.

In phase 3, the design project and its subsequent documentation were done through a mixed methods research. The design process was documented through protocol analysis, which consists of recording verbal and visual cues. An ADIAS survey (Architecture Design Intelligence Assessment Scale) developed by D'souza (2006) was administered to measure overall skills prior to introducing the design problem in the VR interface, and a follow-up interview was conducted after the design project was completed in the VR interface. Later, the two were compared to see which skills were reinforced and which skills were diminished.

2.3 The virtual zoo design problem

The design problem involved developing a 'Virtual Zoo' (Figure 3). We felt that young students could relate to animals, a zoo experience and the interactive nature of a zoo environment because of their familiarity with gaming environments such as 'Zoo Tycoon' and 'Farmville.'

The virtual zoo also provided an opportunity to simulate a real world scenario in deference to abstract logic tests (such as puzzle solving or missing object identification), usually administered for architectural aptitude in schools (Goldschmidt, Sebba, Oren, & Cohen, 2001; Greenway, 1990). While the logic tests are useful in some way, they may not accurately predict design aptitude because the composition and demands of design studios in universities rely heavily on context and the situation of the design problem (D'souza, 2007; Salama, 2005). As such, the testing propagates a lack of awareness about the composition and demands of design studios of universities when tertiary students are confronted with a career choice in design. In other words, these tests seem to be rigid and follow psychometric and universal forms of testing, rather than being tailored to specific architectural design tasks.

In contrast, the virtual zoo project emphasized context constraints, sensitivity to user-behavior, material expression and spatial manipulation (Table 2, Figure 3). Each zoo animal exhibited multiple preferences in terms of spatial, material and contextual preferences. For example, in terms of spatial preference, a cheetah can be put in a tall cage (because it likes to climb trees) or a tall and wide cage (to mimic the expanse of the forest). In terms of material preference, a cheetah could be placed in a wooded grilled cage (which has some material similarity to a forest) or an opaque stone cage (which has some material similarity to a stone cave). And in terms of contextual preference, a cheetah could be close to a mountain or a forest. The design problem also consisted of more complexity in affording overlapping preferences. For example, one could place either a cheetah or a fish in a tall

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Animal Type	*Spatial preference*	*Material preference*	*Context preference*
Cheetah	Tall	Wooded grilled (semi-transparent)	Forest
	Tall and wide	Stone (opaque)	Mountain
Fish	Small	Glass	Beach with water body
	Small and wide		Building in construction
	Tall and wide		
Snake	Small	Wooded grilled (semi-transparent)	Forest
	Small and wide	Stone (opaque)	Mountain
			Building in construction

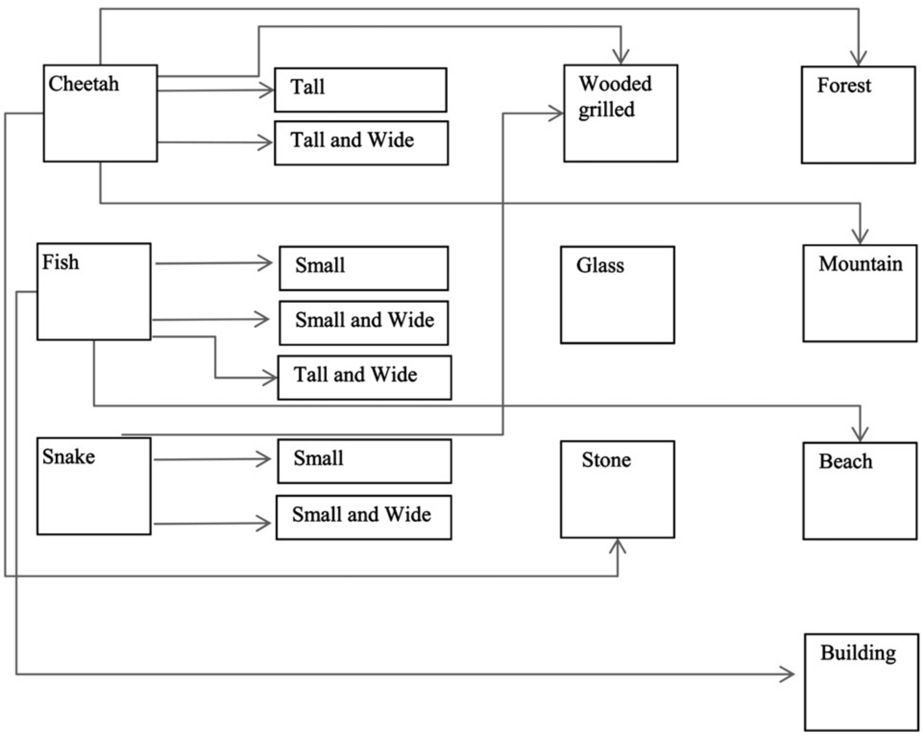


Figure 3 Design problem affording several alternatives

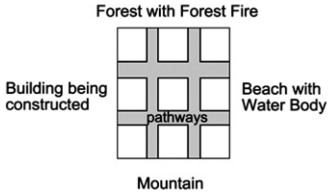
and wide cage (due to the affinity of these animals to live in expansive contexts).

In summary, the design problem consisted of several interacting variables regarding user-behavior, space, material and context and afforded the exploration of a wide range of skills and alternative design solutions.

2.4 The second life VR interface

The design project site is a three-dimensional tartar grid of 3 m × 3 m × 3 m (with 0.5 m offsets in between), within which a virtual zoo has to be designed. The 'offsets' between the site are created to allow for visitor pathways from

Table 2 Design criteria for the Virtual Zoo project

Design criteria		*Objects*	*Properties*
Context constraints		Beach with water body forest with Forest Fire Building being constructed Mountain	Claim and soothing Dangerous and dynamic Loud and disturbing Obstructive but serene
User Behavior		Fish	Lives in a large ocean Affinity to water Affinity to outdoors Cannot survive on trees Not affected by noise
		Cheetah	Lives in a dense forest Likes to climb trees Affinity to outdoors Mates noise Afraid of fire
		Snake	Lives in small holes Likes to climb trees Likes to be secluded Likes the indoors Afraid of fire
Material expression		Stone	Most opaque
		Wooden grilled	Semi transparent
		Glass	Transparent
Spatial Manipulation		Large/Tall	Sense of openess Dominant Massive
		Small/Wide	Sense of closeness Less dominant Coziness

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which the zoo animals could be visible. While this grid restricts the freedom of design to some extent, it allows for a more controlled evaluation of the product. Moreover, design problems are seldom open-ended, and it's not uncommon that a real world site will have height and width constraints, as well as construction and cost issues. The site context consists of a beach, a forest with potential hazard of a forest fire, and a noisy construction site to make the designer respond to real world elements (Figure 4).

Three 'cages' were used as a starting point. These 'cages' were fixed with a starting dimension of 1 m $\times$ 1 m $\times$ 1 m cube and were allowed to extend both horizontally and vertically within the confines of the site. The dimension of these cages could be modified based on the designer's sensibility of the size and needs of the animals housed within it. Three animals of different needs were introduced. They included a cheetah, a snake and a fish (Figure 5).

These three animals were to be housed in the three cages, and the designer had to modify the cubes to suit the behavior of the three animals. The degree of privacy and size of space were presented as major design issues, and students had to respond accordingly. The first cage was a stone cage made of random rubble masonry; it was the most opaque. The second cage consisted of a wooden grill and was semi-transparent. The third cage was made entirely of sheet glass and was the most transparent of the three cages. These cages also had different materials and varied levels of transparency so that the students thought about not only the volumetric composition, but also explored material symbolism, transparency and visual weight.

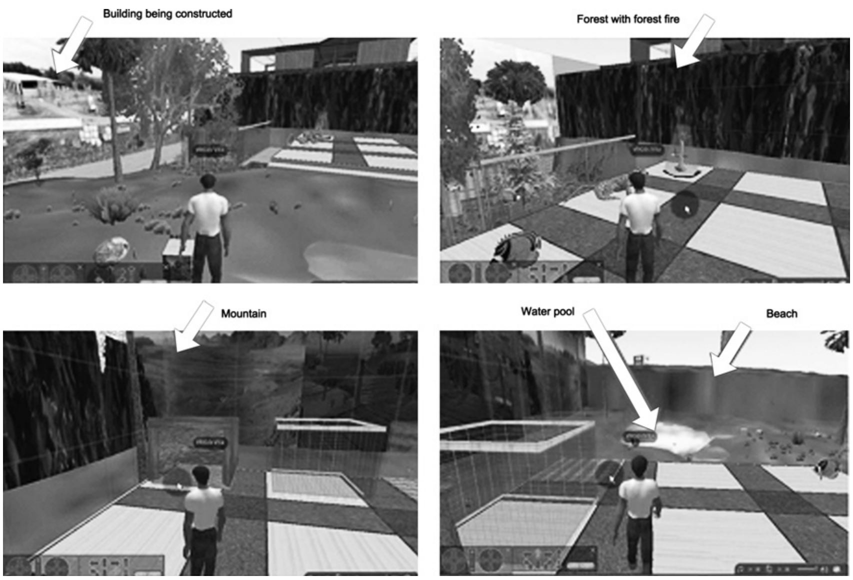

Figure 4 Virtual Zoo in Second Life showing the context

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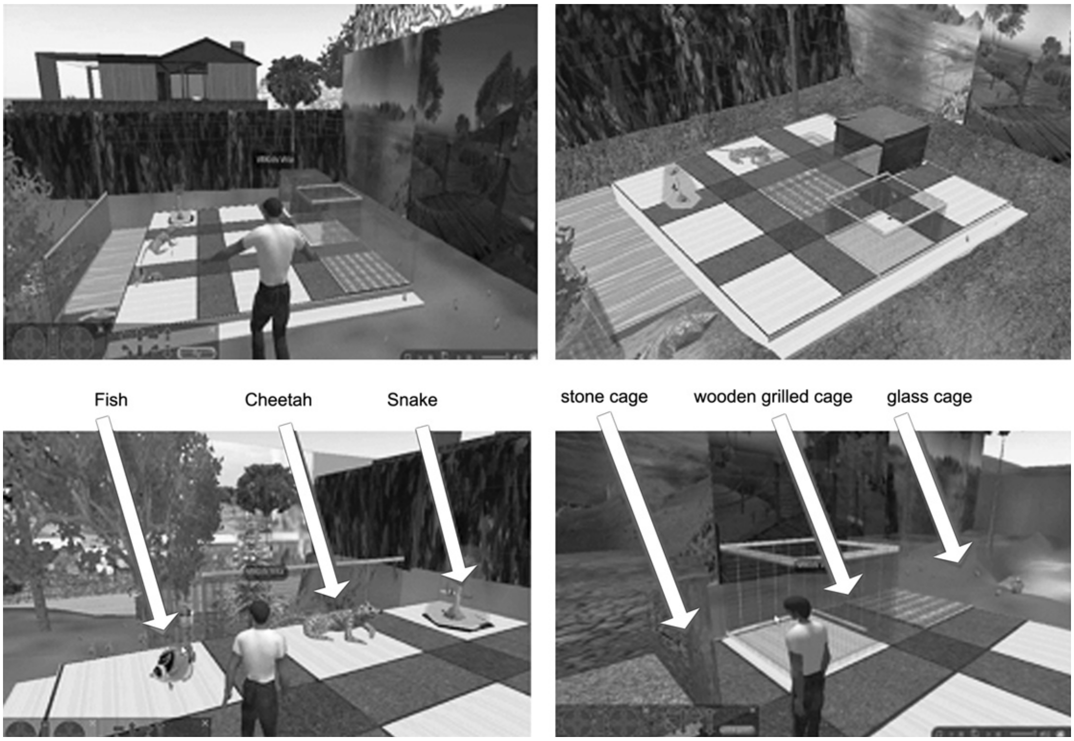

Figure 5 Virtual Zoo in the Second Life interface showing the three cages and animals

3 Data collection and analysis

Data collection and analysis was done through mixed methods strategy, involving ADIAS survey, recording the design process and an after-test interview. A survey scale called the Architecture Design Intelligence Assessment Scales (ADIAS) to examine design skills already possessed by the 4-H students before working on the VR interface. While the design exercise was in process, data from navigation history and screen captures were recorded. An after-test interview was conducted after the design problem was completed to analyze skills that were reinforced and skills that were newly absorbed.

3.1 Administration of the ADIAS scales

A survey instrument called the Architecture Design Intelligence Assessment Scales (ADIAS) was used to examine design skills already possessed by the 4-H students before working on the VR interface. The ADIAS was developed to assess design skills among architectural students through a prior study (D'souza, 2006). The ADIAS questionnaire was developed from the Multiple Intelligences Development Assessment Scales (MIDAS) developed by Shearer (1996), mainly to assess Gardner's multiple intelligence framework.

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The MIDAS profile is intended to give a reasonable estimate of the person's intellectual disposition in each of the eight main intelligence areas (linguistic, logical-mathematical, spatial, musical, kinesthetic, naturalist, interpersonal and intrapersonal). There are a total of 119 items within MIDAS for the eight scales related to the multiple intelligences of Gardner. MIDAS has been used previously in three domain areas: educational counseling, clinical psychology and neuropsychological assessment. It has been subjected to several tests of validity and reliability during the scale-construction process. For architecture students, the Cronbach reliability was found to be 0.7 for kinesthetic and 0.9 for spatial intelligences (D'souza, 2006).

The transformation from MIDAS to ADIAS occurred through a scale-construction process with 104 architecture design students in a prior study at a Midwestern architecture school (D'souza, 2006, 2007). Originally, the ADIAS consisted of 93 items for eight skill categories; 71 items from the original MIDAS scales and 22 new scales evolved during the scale-construction process. However, for this project, only 80 items with Cronbach alpha reliability more than 0.87 were tested (verbal, logical, spatial, kinesthetic, naturalistic, interpersonal and intrapersonal).

The ADIAS is a personality-based self report that is administered through a paper-and-pencil questionnaire. ADIAS uses a Likert-type scale (where participants are asked to indicate whether they agree or disagree with each item within a range of six options), and the scores for each scale are converted into percentage points. Scores within percentages of 100−60 are considered 'high', 60−40 are considered 'moderate' and 40−0 are considered 'low'.

The original MIDAS is a developmental scale; different tests are designed for different age group: adults, teens (14−18), kids (9−14) and children (6−9). According to MIDAS manual (Shearer, 1996), respondents who take the test should be able to read at least at fifth-grade level if self-completed, and they should take the help of family and friends if the participant has very limited education. The respondent should also be able to reflect accurately upon feelings and behaviors. Since the average age was about 14, we felt that parents in consultation with their children would be in a better position to complete the questionnaire, and hence the questionnaires were sent to their home addresses. Parents also gave permission for their child to participate by signing a parental consent form prior to camp. A youth assent form was also distributed to student participants. The assent form outlined the survey's purpose and instructed students that they were not obligated in any way to complete the survey.

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3.2 Introduction of the virtual zoo design problem in the VR interface

When students arrived at the lab, they were first tutored on the basics of the VR interface. The training included various techniques for moving within and interacting with different icons, as well as interacting with different browsers. Students then created basic design interventions and learned to blend different skills in the interface. Only one student worked on the design project at a time. This practice time took 10–30 min. After students achieved a reasonable competency in working with the system, they were given the 'virtual zoo' design problem. The project was introduced with a short Microsoft PowerPoint presentation describing the following rules and time limit of 90 min. The rules were as follows:

(i) Each animal had to be housed in one cage.
(ii) No cages could be placed next to each other without a gap.
(iii) The cages could not extend outside the red grid cube.

While the design exercise was in process, data from navigation history and screen captures were recorded by automated software, Camtasia Studio Screen Recorder. Hand/face gestures of the participants, as well as the interface, were captured through video logging. Two videos were used both for visual and verbal records. This data was supplemented with verbal data from the chat browser in the Second Life interface. Students were asked to conduct a chat interaction with a virtual visitor. One research assistant acted as the visitor and entered the zoo through another computer. As they were chatting, the students had to provide the visitor with directions within the zoo and describe why they located the cages in a specific way. The visitor moved only on specific directions from the students. This helped to understand the visualization of kinesthetic skill of the students, as well as their logical skill behind the sequencing of their cages. Verbal ability also played a part in providing good directions and persuading the visitor with the merit of their designs. On average, students took 10 min to understand the system and 20 min to complete the exercise.

An after-test interview was conducted to analyze skills that were reinforced and skills that were newly absorbed. These interview questions were geared to identify design skills specific to the virtual zoo design problem that students had just completed. The questions attempted to cover the types of skills students used for dealing with the design problem, specifically in the seven categories – spatial, interpersonal, intrapersonal, logical, naturalistic, kinesthetic and verbal (Table 3).

Because some students were more verbally articulate than others, the investigator had to further probe the students on the meaning and intentions of their

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Table 3 VR interface interview questions

Interview Question		Specific skills tested		Intelligence category
i	Describe why you put the cages in different direction	1	Ability to convey clarity in 3D Spatial Organization	Spatial
		2	Ability to solve problems based on function/zoning	Logical
		3	Sensitivity to natural features	Naturalistic
ii	Describe why you chose specific animals in specific cages	4	Sensitivity to spatial transparency & enclosure	Spatial
		5	Ability to think in different scales of space	Spatial
		6	Sensitivity to user behavior	Interpersonal
		7	Sensitivity to the properties of natural materials	Naturalistic
iii	Describe why you made the cages of specific sizes	8	Sensitivity to the use of geometry/grid	Logical
		9	Ability to think in different scales of space	Spatial
iv	If you were given another cage for a elephant, where would you put it and why	10	Ability to solve problems based on function/zoning	Logical
		11	Ability to choreograph space in a deliberate & meaningful way	Spatial
		12	Sensitivity to the use if geometry/grid	Logical
v	Here is a piece of white paper. Imagine the zoo from an aerial view and draw it	13	Ability to convey clarity in 3D Spatial Organization	Spatial
		14	Sensitivity to the use of geometry/grid	Logical
		15	Sensitivity and awareness of orientation	Kinesthetic
vi	Zahid will now enter the zoo as a visitor. Direct him through the zoo only by using the chat window	16	Ability in verbal articulation of design ideas	Verbal
		17	Sensitivity and awareness of orientation	Kinesthetic
		18	Ability to be socially persuasive of design ideas	Interpersonal
		19	Sensitivity to body movement in space	Kinesthetic
vii	What would you change in the zoo if you were given a chance	20	Ability to embody the senses in design	Intrapersonal
		21	Ability to pursue purpose and meaning of design ideas	Intrapersonal
		22	Sensitivity to personal strengths and limitations as a designer	Intrapersonal
		23	Ability in verbal articulation of design ideas	Verbal
viii	If you were asked to paint the cages, which color would you paint and why	24	Sensitivity to the use of natural materials	Naturalistic
		25	Ability to embody the senses in design	Intrapersonal
		26	Sensitivity to user needs	Interpersonal

design. The probe questions were an addition to the descriptions already recorded through the chat windows. Investigators felt that this improved the validity of the study because it was used as a confirmatory tool for the already recorded chat transcripts. Since the participants were non-designers, we were able to understand their design thought process much more clearly. Students were also asked to draw an aerial view of their completed design on a piece of white paper. Typically, conventional design training in architecture schools encourages students to work out a plan in 2D before translating it into 3D models. However, in this project, since students started within a 3D environment, the investigators wanted to know whether the students could translate their 3D spatial sense into a 2D logic. Students could refer to their 3D

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model to draw their 2D plan if they wanted, to avoid it being a memory test. We felt that this exercise would reveal spatial manipulation skills as well as sense of orientation and sequencing logic of zoo design.

Future design scenarios were also asked for the possible locations for a cage to house a new animal or the aesthetic decisions regarding the possible colors to paint the cages. The project team also asked questions on the background and usability of computers. Using these mixed methods, a reasonable protocol for each student was extracted. Time spent on each skill was also recorded so that skill and attention for each skill could be measured. The results from the parental ADIAS survey were then tabulated and measured against the interview questions to assess whether the VR interface was successful in fostering multiple skills.

3.3 Data analysis

After the data collection process, the ADIAS survey was tabulated separately. Percentage scores for each skill for each student were tabulated. Descriptive statistics were used to understand the distribution and individual differences in terms of mean and standard deviation. Mean aggregate scores were tabulated for all students in specific skills and then converted into percentage form to explain skill strength. Standard deviations were calculated to understand the distribution and variation of these skills across student sample.

The data gathered from the after-test interview of the VR interface and the screen/video captures were matched with the particular characteristics outlined in the multiple intelligence framework. A coding scheme from a prior study with architectural design studio was used (D'souza, 2006). Sample of coding scheme for spatial skills is presented below (Table 4). It should be noted that the scheme presented is for spatial skills alone. Similar codes are available for all other skills.

Data from the video and screen captures for each student were analyzed initially to get an overall idea. The two referees, the principal investigator and the research assistant, both of whom are architects and design studio instructors, analyzed the data simultaneously but coded the data confidentially. The purpose of the coding procedure was to understand and brainstorm the constructs of multiple skills as they relate to architectural design and to develop specific descriptors, rather than getting a perfect coding match between different referees.

Later, the video was replayed repeatedly to compare the codes and negotiate areas of contention and disagreement between the referees. These discussions focused on why certain intentions were placed in specific skill categories and whether or not certain descriptors were sufficient to describe specific skills.

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Table 4 Sample of coding scheme for spatial skills

Intelligence	*(Code)*	*General description of intelligence*	*Interpretation of Intelligence in relation to architecture design*	
Spatial	**(S)**	To think in pictures and to perceive the visual world accurately. To think in three-dimensions and to trans form ones perceptions and re-create aspects of ones visual experience via imagination. To work with objects effectively. To solve problems of spatial orientation and moving objects through space such as driving a car. To create artistic designs, drawings, paintings or other crafts. To make, build, fix, or assemble things	Ability to choreograph space	The intentions and drawings should convey a deliberate sense of spatial choreography. The use of space should engage deeper aesthetic faculties and sensation brought about by light, movement, smell and sound. The spaces should be able to convey mood and ambience appropriate to a particular context
			Sensitivty to spatial transparency and enclosure	The design intentions and drawings should convey the ability of the designer to be sensitive to the issues of transparency and enclosure. The designer should convey the ability to understand spatial layers in terms of shallow and deeps paces. The designer should have sensitivity to tactile properties such as spatial volume, texture, visual weight and material density
			Sensitivity to spatial transition	Is the designer sensitive to spatial transition (transition from open to close, or large scale to small scale, darkness to light, and so on). Do the drawings and intentions show a purposeful direction in drawings, spatial adjacency, bubble diagrams and so on
			Ability to convey clarity in three-dimensional spatial organization	The intentions and drawings should convey clarity in spatial organization in three-dimensions. The designer should have the ability to think and illustrate in sections and plans simultaneously. Ability for cognitive modeling and to imagine space for a sustained period of time. The intentions and drawings should convey a sense of how different systems of architecture are appropriately put together in terms of layering and tectonics
			Ability to think in different scales in space	The design intentions and drawings should convey the ability of the designer to think and maneuver at different scales of architectural spaces

The codes were then refined to reflect the consensus. Although the referees reached a fair agreement about 70% of the time, this was considered acceptable given that the coding process was prone to subjective interpretations of design intentions based on the design experience/background of the referees. Highest evidence for a specific skill was given 4 points, and a lack of evidence was given 0 points. After the coding was done, the two referee scores were averaged for each individual student and converted into percentage scores. The two sets of data (the ADIAS survey and the interview coding data),

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once in percentage form, could be compared to identify skills that were facilitated and skills that were inhibited in the VR interface.

4 Findings

4.1 ADIAS scores

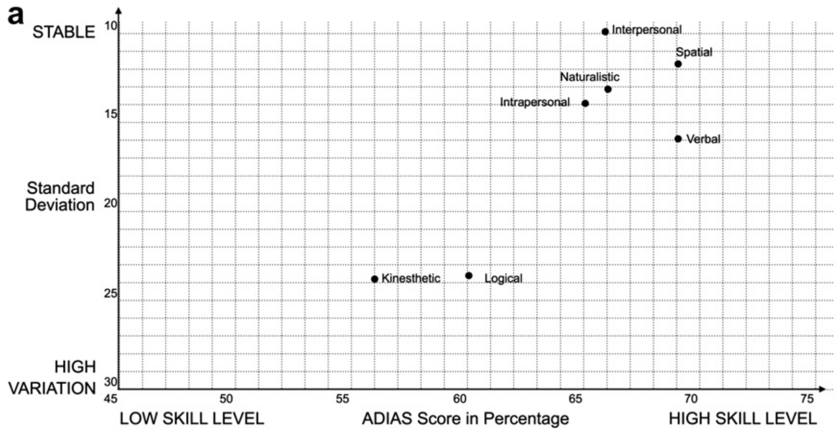
When the ADIAS scores were calibrated, in the aggregate, the overall skill level of 4-H students ranged from a low of 56% for kinesthetic to a high of 69% for spatial skills. The high scores for spatial skills corroborated with low-skill variation across the student sample, indicating the consistency of students in spatial skills. On the other hand, skills that the students were weak in showed high variation across the student sample, indicating that students were inconsistent in the use of these skills. Spatial and interpersonal skills showed lesser variation (with a standard deviation of about 11), indicating that these skills were relatively stable across student sample. Logical and kinesthetic skills (with a standard deviation of about 23) showed high variation, indicating that these skills were relatively unstable among students. When the two criteria of skill level and skill variation are plotted on a graph, it provides an overall strength of the pre-existing design skills of the students before the design problem was introduced (Figure 6a). One could infer from the graph that students had clear strengths in interpersonal and spatial skills.

4.2 VR after-test interview scores

When the scores from the interviews done in the Second Life VR interface were calibrated, in the aggregate, the overall skill level of 4-H students ranged from as low as 48% (for intrapersonal/verbal skills) to as high as 75% (for naturalistic skills) and 71% (for logical/kinesthetic skills). This was a surprising deviation from the skill level as revealed in the ADIAS scores prior to working on the VR interface. It could be inferred that working on the VR interface increased naturalistic, logical and kinesthetic skills for 4-H students.

These findings were also corroborated in skill variation across student sample; skills that the VR interface supported were relatively stable across student sample. On the other hand, skills in which the VR interface intruded showed high variation across the student sample, indicating that students were inconsistent in the use of these skills. Naturalistic and kinesthetic skills showed lesser variation (with standard deviations of 11 and 13, respectively), indicating that these skills are relatively stable across student sample and that the VR interface supported the students' strength in these skills.

On the other hand, intrapersonal and verbal skills showed high variation (with standard deviation of 27 and 24 respectively) indicating that these skills were relatively unstable among students and that the VR interface intruded upon these skills. When the two criteria of skill level and skill variation are plotted on a graph, it provides an overall strength of the design skills that were



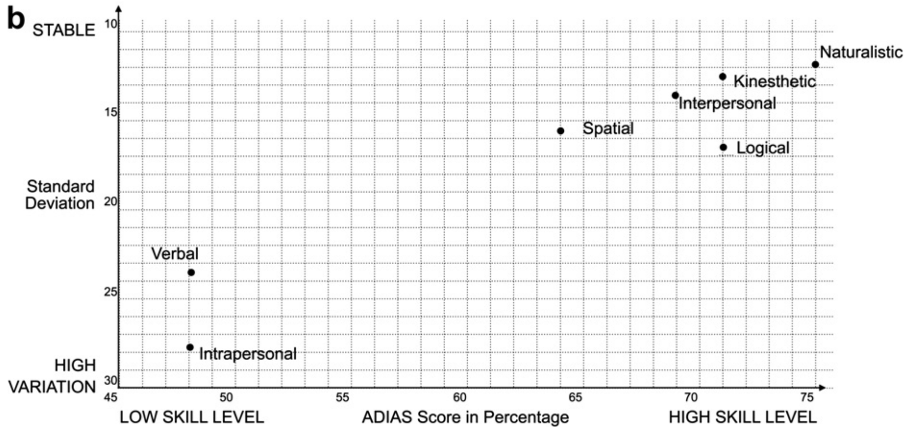


Figure 6 (a) Skill level and skill variation of design skills among 4-H students as measured through the ADIAS survey; (b) Skill level and skill variation of design skills among 4-H students as measured through the post VR interface interview

reinforced during the VR interface (Figure 6b). One could infer from the graph that students had clear strengths in naturalistic, kinesthetic and interpersonal skills.

4.3 Comparison of ADIAS and VR interface interviews

As shown in Figure 7, the comparison of ADIAS scores (which measure skill levels and skill variation before the VR interface introduction) and the interview scores (which measure skill levels and skill variation after the VR interface was introduced) helps cross-check whether the interface was successful in fostering skills. In terms of skill level, one can infer that there was a significant improvement in kinesthetic, logical and naturalistic skills (as shown by the upward pointing arrows in Figure 7). Kinesthetic skills improved from 56% to 71% (a 14% increase), logical scores improved from 60 to 71% (an 11% increase), and naturalistic scores rose from 66% to 75% (a 9% increase).

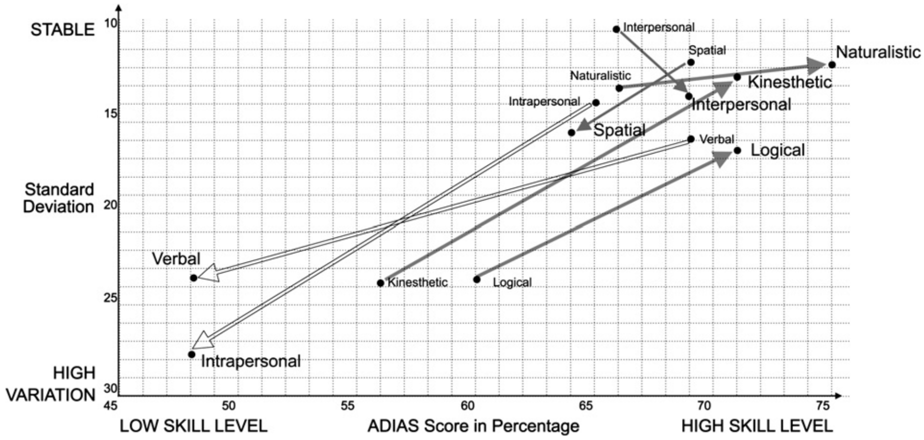


Figure 7 Comparison of skill level and skill variation between ADIAS survey and post VR interface interview among 4-H students

However, the VR interface intruded upon certain skills as there was a significant decline in verbal and intrapersonal skills (as shown by the downward pointing dashed arrows in Figure 7). Verbal skills declined from 69% to 48% (a 21% decrease), while intrapersonal scores declined from 66% to 48% (18% decrease). Only scores for spatial and interpersonal skills remained relatively similar in skill levels. Because some skills enhanced and some skills declined, it was a mixed result for the study because the VR interface did not improve all the skills, as anticipated.

In terms of skill variation, one can infer that there was a significant improvement in logical skills and kinesthetic skills, showing that students were more consistent among these skills in the VR interface. Logical skills improved from 23 to 16 in standard deviation, and kinesthetic skills improved from 23 to 13 in standard deviation. However, there was a high variation in intrapersonal and verbal skills, showing that students were inconsistent among these skills. Intrapersonal skills declined from 14 to 28 in standard deviation, and verbal skills declined from 16 to 24 in standard deviation.

The findings also reveal that students who were less skillful, as reflected in their relatively low ADIAS scores of lower than 50, improved their scores in naturalistic and kinesthetic skills after the VR interface was introduced. For example, for student 3, kinesthetic scores rose from 25% to 71%, and naturalistic scores rose from 61% to 79%. On the other hand, for students who were highly skillful, as reflected in their high ADIAS scores, the VR interface didn't sufficiently foster or alter their skills. In all, among 11 students, six students did not show large differences in their performance (students 4, 6, 7, 8, 10, 12), while four students showed substantial variation (students 3, 5, 9, 13).

4.4 The design product

While analysis of the final product was not the major focus of the study, the final zoo designs provide an insight into the variety of designs produced by the 14 participants. (Note that 14 students originally completed the study, although only 11 of them completed the survey). The final design and their two-dimensional plan representations are shown in Figure 8.

While it's difficult to come to conclusions in terms of whether high design skills lead to specific design products, the final schemes reveal that only three designs (8, 9, 13) were close to the investigator's expectations as an ideal design solution. The ideal design solution is presented in the paper as an example of satisfying most of the constraints, i.e. context, material expression, spatial manipulation and user-behavior, and not to say that there are other solutions that are possible. We evaluated these solutions on a case-by-case basis. The diversity of design solutions arrived by students indicates that multiple solutions are possible. Our inference is that the high variation from the ideal solution occurred because students got lost in the 3D-experience rather than considering it a strict case of spatial problem-solving. We are also sympathetic to the variation because design cannot be reduced to a mere pseudo-puzzle of constraint satisfaction and is as much about artistic creativity and accountability to invisible social forces. It would be unfair to judge the design product based solely on this criteria. However, it provides some insights into the design product and this could be an interesting area for future research.

4.5 Scope and limitations of the methodology

The mixed methods used in this study, namely, the ADIAS quantitative survey and the qualitative VR interface interview, provided an inclusive way of looking at architectural design. However, the variety of instruments used in this study sometimes posed a challenge for data collection and integration of the data. Moreover, the different scales contained very different content questions, and the testing was not always easy. Some scales, such as musical and spatial scales, are harder to determine than others because these are both skills in themselves as well as medium through which the skills are manifested. A survey can only provide a verbal description of the underlying skills. Moreover, since the ADIAS survey is mainly a self report, it is vulnerable to inaccuracies.

However, we have attempted to improve the validity and reliability of the scales to improve research quality. The validity of ADIAS was developed by eliminating scores less than 50%. For reliability purposes, only the Cronbach alpha reliability of scales over 0.87 was considered. We also feel that the reliability of ADIAS scores is strengthened by the use of other instruments such as protocol analysis and interview probes. In terms of the virtual zoo design problem, the prolonged duration of the study simulated the design problem usually conducted in a university architectural studio section. Since evidence

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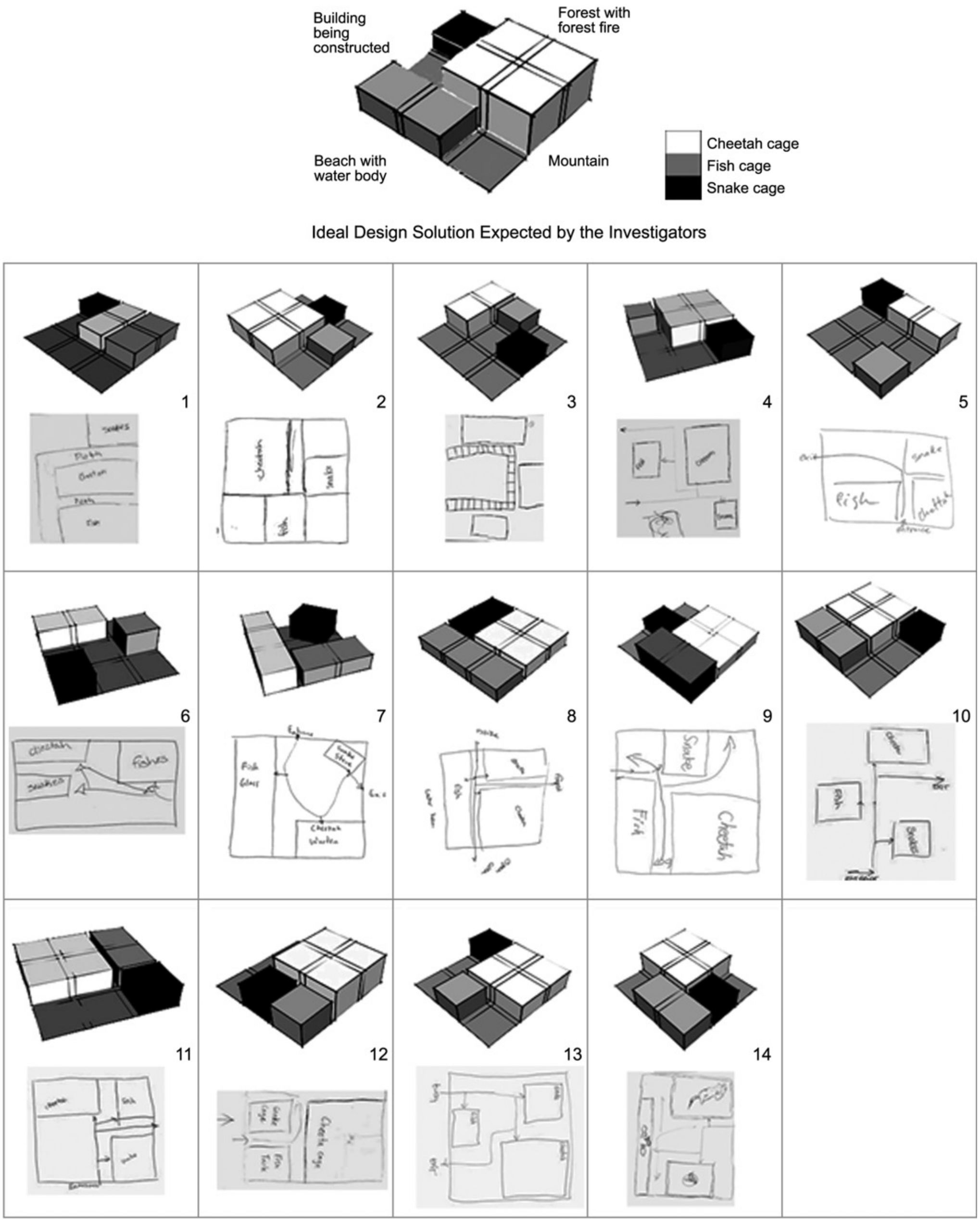

Figure 8 The final zoo designs produced by 4-H students after working on the VR interface

was collected both as verbal and visual data, this provided valuable cross-referencing. However, documentation of visual evidence may only tell a part of the complex cognitive process involved in architectural design. Also, each student possesses a different degree of verbal articulation in presenting design ideas, and it may not necessarily portray the cognitive processes that were truly involved in the design intents.

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Using the two referees to code the data helped increase the reliability of the study. The refereeing procedure was useful in understanding the constructs of multiple skills as it related to the design problem and thereby helped in creating specific descriptors of architectural skills. However, the coding was laborious and cumbersome because of coordinating between the video evidence, Camstacia interface recording and the verbal data. Perhaps increasing the number of cameras at critical viewpoints could help verify the data more reliably. While the agreement between referees was quite high, the coding process was prone to multiple interpretations based on the experience and background of the referees.

This study sample is made up of only one level of 4-H students, who may or may not have design as a future career option, which could deter understanding skills for students exclusively wanting to go to architecture schools. The sampling of girls and boys, as well as the diversity in age group (13–18), was critical and was strength of the study. However, because of the small sample size, any conclusions that are derived in this paper are limited. It only provides an indication that the process of interacting with the VR interface produced some change. In other words, our primary goal was to examine and describe the factors that caused the change, rather than the outcome itself. The transferability of the findings to the larger design population is also limited because the goals and challenges of advanced architectural studios are more complex compared to non-designers. However, the aim of this paper was not so much of transferring the results to more adult students as much as understanding the trends in technology that may inform design skills.

4.6 Conclusions

In summary, the VR-KiDS project provides useful insights into prospective student designers. The VR interface considerably increased logical, kinesthetic and naturalist skills. However, it intruded upon verbal and intrapersonal skills. While one cannot come to definitive conclusions upon the results of this small study, certain speculations can be made on why certain skills improved and why certain skills suffered. The dramatic increase in kinesthetic skills may be attributed to the ability of VR to afford a walk-through experience, where students could engage in the site at their own will. Logical skills may have improved due to the VR's ease in visualizing the problem in a more realistic manner. Naturalistic skills may have been improved because of the close-to-real simulated environment, rather than abstract graphics (plan, section and elevation).

On the other hand, the reason why intrapersonal skills suffered may have been because of inadequate time spent on self-reflection or criticism because of the immersion within the VR environment. For example, students did not think much about the aesthetic qualities of color. Rather, their choice of color was based on literal ideas, such as blue for the glass cage, brown for snake cage and orange for the green cage. Finally, the verbal skills may have been hampered because students spent relatively higher effort in processing visual information rather than verbal articulation. In this regard, Oblinger and Oblinger (2005) had speculated that because of availability of visual media, text literacy of the current generation may be less well developed than their cohorts. Interestingly, spatial and interpersonal skills showed no change when VR was used. The project also showed that the VR interface was useful for students who were less skillful (i.e. whose ADIAS scores were below 50).

In all, the instructors were surprised at the comfort level of students in the VR interface, although they were not specifically familiar with Second Life. While we expected some familiarity with the interface, we did not expect the extent to which students were able to absorb information and apply it with minimum training. The reason for this familiarity can be partly attributed to video game culture such as 'Zoo Tycoon', which most students were familiar of. As suggested by Squire and Jenkins (2003), the culture of video games provide a social order for a large section of this generation, and games encourage collaboration among players for peer-to-peer teaching and learning communities. In future research, one may need to pay more attention to gaming skills in the development of future virtual worlds, which may provide design instructors new opportunities to take advantage of students' immersion in game environments in teaching and learning of design skills.

The VR-KiDS project highlights the different processes and skills that students bring to bear into the design process, which are likely quite different from design instructors' skills. As university instructors it may be incumbent upon us to recognize these skills specifically in the ambiguous nature of current learning environments However, in the long run, improvisation of teaching in steady smaller steps will be critical in alleviating the challenges of working with the demands of a new generation.

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