Learning on the Holodeck:
Transforming Classrooms for All Learners

David D. Thornburg, PhD
Thornburg Center for Space Exploration
dthornburg@aol.com
www.tcse-k12.org

Gene Roddenberry's "holodeck" has captured the imagination of millions since it first appeared in the TV series, *Star Trek: The Next Generation*. One 1993 episode, *Ship in a Bottle*[1], takes place largely in this immersive virtual world where all objects are computer constructs, allowing the holodeck to become anything the users want – a Victorian living room, a pirate ship, etc.

Figure 1: Holodeck view from *Ship in a Bottle*

One feature of the holodeck is that the virtual constructs are tangible – according to the writers, future haptic technology allows objects to be felt, picked up, even thrown around the room. While haptic holography is in its infancy today[2], many of the features and benefits of the holodeck can be built with inexpensive existing technology, and can be used to provide rich immersive educational experiences for learners of any age.

Years ago, MIT Professor Janet Murray predicted in her book, *Hamlet on the Holodeck*, that the nature of narrative would change as a result of the growth on interactive software and the Web[3]. More recent work at Google has resulted in the *Liquid Galaxy*, an immersive virtual "elevator" with which a participant can navigate the entire planet using *Google Earth*[4]. The downside of *Liquid Galaxy* is that it is currently restricted to one or two people at a time, not a classroom full of students. That said, the resulting environment is staggering. Users feel more like they are on a ride than using a piece of software. The fact that users are already familiar with the software does not diminish the willingness to suspend disbelief – a feature of well-designed immersive environments in general.

Figure 2: Google "Liquid Galaxy holodeck

In this document we will define a holodeck as a reconfigurable immersive learning space in which tasks are carried out in support of various "missions," each of which has strong curricular ties, yet is formulated in the context of a systemic operation that is transdiciplinary to the extent it cuts across subject areas and supports learner inquiry, and in-depth projects.

To see why such an environment would make good pedagogical sense, let's start with existing classroom presentations. For generations, teachers have generally been at the front of the classroom using a wall mounted drawing surface as a visual aid to instruction. Students were largely confined to their seats where they received the information from their teachers. This process works for some students, but not for all of them. The motivation for learning in this environment is extrinsic – students learn so they can do well on examinations; their classroom experience is largely passive. It is fair (I think) to suggest that the largest transformation in many schools has been the gradual replacement of the chalk board with interactive whiteboards. New technologies, in this case, are being used to support a curricular model familiar to our grandparents, and known to not be as effective as other pedagogical models (e.g., inquiry-driven project-based learning) when it is the dominant method of instruction.

Figure 3: Typical use of technology for lectures.

Some educators have recognized the shortcomings of this model, and turned their classrooms into interactive domains where students can, for example, role-play grand historical events. This type of teaching was a subplot in the 1984 film, *Teachers*[5] in which an escaped mental patient accepts a job as a substitute history teacher in a beleaguered school, and is loved by the students because he has them enact historical events such as Washington crossing the Delaware. Excepting for student costumes, though, his classroom remained unchanged. Today we have the opportunity to build extremely engaging learning environments that bridge the gap between the 1984 vision and the holodeck of the future.

Why an educational holodeck makes sense

Much technology use in education uses new tools to largely replicate learning models of the past. Instead of physical libraries, many students do research on the Internet. Instead of reading paper books, some schools are looking at e-book readers. Yes, powerful computers are still being used to provide directed instruction and to measure competence using multiple-choice examinations but the true power of modern technologies lies hidden. Nowhere is this more evident than in the afore-mentioned use of technology in support of the lecture-based classroom. In this kind of environment, the move to a more inquiry-centric project-based approach to education is very difficult.

It is possible, though, to create a learning environment for which the traditional lecture-based model can *not* be sustained – an environment where students are freed to explore domains of understanding and knowledge through direct experiences. Imagine, for example, the difference between a teacher showing a NASA image of Saturn on a screen and giving a lecture on the rings, vs. students being able to be on the bridge of a starship where they can fly to a computer model of Saturn themselves, explore the rings in detail, and use a variety of resources to help them understand more of what they are seeing.

Another group using the holodeck might explore life under the sea, exploring lifeforms that live near amazingly deep underwater volcanoes – and at the end of the activity emerge into the school without experiencing the "bends" or even getting wet. Still others might explore historical events by traveling backward through time.

The kinds of topics students can explore on the holdeck is limited only by their imagination and the teacher's willingness to be a co-learner and fellow explorer on this activity, and the support resources needed to sustain the simulation. Potential topics include:

- Space exploration (using *Celestia*)
- Exploring the oceans
- The geology of Earth
- Geography (using *Google Earth*)
- Atmosphere and weather
- Navigating through the human body
- Exploring atoms and molecules
- Traveling through time to historical events
- etc.

Essential to all these domains are the cross-curricular connections that can be made. Students can acquire the skills taught in traditional classes through their engagement as active participants in this new world.

Why it matters...
From a pedagogical perspective, the holodeck facilitates the movement of students to the boundary between anxiety and flow (using the terminology of Csikszentmihalyi[6]). His work shows that, based on perceived challenge and skill, when confronted with a task, we may experience anxiety (where our challenge is very much greater than skill), boredom (our skill greatly exceeds the challenge), or a third state, "flow," where challenge and skill are more closely matched and are both high. This construct reveals a major problem with lecture-

based delivery – the diversity of skill levels in any classroom makes it impossible to meet the needs of all learners simultaneously. Csikszentmihalyi's research has shown that the anxiety/flow boundary of the Challenge/Skill diagram is home to optimal learning experiences, and is a place people will place themselves when they have the chance.

This region is shown as the blue line in the following figure.

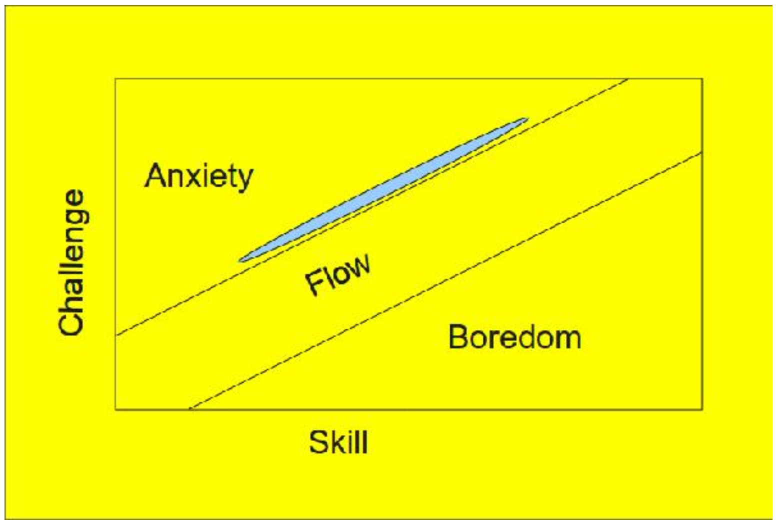

Figure 4: Flow diagram based on the work of M. Csikszentmihalyi showing the added region (in blue) between anxiety and flow associated with optimal learning.

People want to be close to flow whenever they can, and to approach it from the anxiety side[7]. This characteristic of the boundary between anxiety and flow accounts for the popularity of many videogames. They create some anxiety, but not so much as to shut down the willingness to play. Once players enter the flow region, the game level increases putting them on the brink of anxiety yet again.

Research on videogame use by young people confirms this. According to a study by the Pew Internet and American Life project[8], 97% of America's youth play videogames, with the following ranking in popularity:

- Racing (NASCAR, Mario Kart, Burnout) 74%
- Puzzle (Bejeweled, Tetris, Solitaire) 72
- Sports (Madden, FIFA, Tony Hawk) 68
- Action (Grand Theft Auto, etc.) 67
- Adventure (Legend of Zelda, Tomb Raider) 66
- Rhythm (Guitar Hero, etc.) 61
- Strategy (Civilization IV, StarCraft) 59

• Simulation (The Sims, etc.)	49
• Fighting (Tekken, etc.)	49
• First-Person Shooters (Halo, etc.)	47
• Role-Playing (Final Fantasy, etc.)	36
• Survival Horror (Resident Evil, etc.)	32
• MMOGs (World of Warcraft)	21
• Virtual Worlds (Second Life, etc.)	10

It is interesting to note that the more popular games have tension built into them and that the virtual worlds category is the least popular, possibly because it does not have the "anxiety edge" built into it.

The holodeck envisioned here is not a videogame – far from it. It is a powerful tool for exploring academic content in context. The "game-like" qualities arise purely from the time pressure and problem solving associated with the simulation.

How it can be built

Because holographic displays are in their infancy, a model for our holodeck will make use of relatively inexpensive existing technology. The first (and hardest) challenge is finding a location for the deck. A simple effective configuration can be built in an existing classroom, provided that the furniture is movable and the projection and computer technology is available. Ideally, it would be an otherwise-unused classroom. The room would be windowless and rectangular. If the room has windows, these can be covered with boards sealed flush with the walls. The entire room would be painted white, and used only for holodeck events. Because there is no visual connection to the world outside, participants can easily get the feeling that what they are experiencing is "real."

The next step is to provide the capacity to cover each of the walls with images showing the interior surfaces of, for example, a starship. This can be done with special slide projectors using images that define the wall patterns, etc. Because these images do not change during a single simulation, there is no need to spend money on video projectors for background images. "View-ports," though, will require either computer projectors or large flat-screen monitors. For example, a starship's bridge might have a viewing port into space at the front, with data screens on both sides. Other props (flashing lights, etc.) can be provided as needed. The interior design of the holodeck could be an art project done by the students themselves.

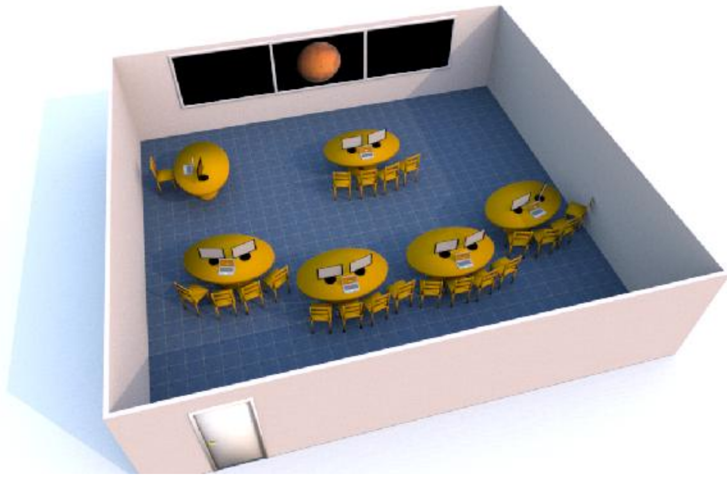

Figure 5: Schematic view of a space exploration holodeck on a mission to Mars to explore the potential for extant microbial life..

The interior of the room can be outfitted with furniture providing seating and equipment for the “crew.” Each crew member is a member of a team and has specific tasks, and a computer terminal and other tools from which these tasks can be carried out. The captain (who may or may not be the teacher) would direct the adventure from a special seat. The room should also have a good sound system (with sub-woofers) so that when alarms go off (for example, a holodeck submarine hits the ocean floor), this is accompanied by a loud scraping sound. Multiple computers make it easy for many things to be happening at once (just as in the real world). This fits with today's students comfort with multi-tasking and builds creative tension into the activity.

In addition to computer systems, microscopes and other tools can be incorporated in special areas in the room. For example, a sample of red clay could be “teleported” from the Martian surface for microscopic analysis by students who, with a digital microscope, could display their images on a view-port for everyone to see.

Assuming much of the computing equipment already exists in the school, it is possible that a fully-equipped holodeck could be built for $10,000 to $20,000 – maybe much less than that. The critical component is not the mechanical aspect of the room, but the deep pedagogical shift educators will make when using this environment. Staff development around the holodeck concept is imperative.

What about the software?

Effective software is the key to making a functional learning environment. Students can help find the software tools themselves. For example, for space exploration, the free *Celestia* program is amazingly good for the front view-port Images for the other screens are brought into views by teams showing what they have found to help the mission achieve its goal. This means that any student computer must be able to have its image directed to a view-port

Aside from the crew actually "driving" the craft, other student teams will be needed to conduct research on the items being explored. This can be done using the Internet on their own computers and other tools for gathering and analyzing data. While much of this research would be done during the mission, before using the holodeck, students would need to prepare for their voyage and fully understand their roles in the adventure. This preparation would take place in the days preceding their first use of the system.

How it can be used

Because the holdeck is immersive and dynamic multi-tasking is commonplace, this is not an environment conducive to lectures. It is, instead, a stage on which there is no audience, only actors. Everyone will have a role to play to assure the success of the mission. The learning opportunities for such an environment are incredible.

Once built, the holodeck may find its first uses in science courses where students visit remote sites, explore, and learn about what they find there. Prior to starting their mission, the students need to define their own roles and responsibilities as crew members – who will be piloting the craft? Who will be doing research on the scientific portion of the mission. Who will attend to the technology itself?

Next students need to explore other questions: Why are we embarking on this mission? What resources will we need? How long will the mission take? What questions do we hope to answer as a result of our trip? Myriad other questions can be developed, all of which become impetus for research prior to and after completion of the mission itself. Through these questions, the "content" of the mission is clarified, and students will locate and learn this content themselves with the teacher's help.

If students are allowed to choose their destination for each journey (e.g., Jupiter's moon, Io), they can build a body of knowledge that, through this intensely immersive experience, will likely stay with them forever. If the traditional classroom was based on extrinsic motivation, the holodeck is home to intrinsic motivation and, potentially, a new way of teaching and learning that can engage all learners.

About the author:

David D. Thornburg, PhD

David is the Founder and Director of Global Operations for the Thornburg Center for Space Exploration. He is an award-winning futurist, author and consultant whose clients range across the public and private sector throughout the planet.

He is engaged in helping a new generation of students and their teachers infuse STEM skills through the mechanism of inquiry-driven project-based learning.

His educational philosophy is based on the idea that students learn best when they are constructors of their own knowledge. He also believes that students who are taught in ways that honor their learning styles and dominant intelligences retain the native engagement with learning with which they entered school. A central theme of his work is that we must prepare students for their future, not for our past.

Please contact Dr. Thornburg if you are interested in presentations and/or workshops around the holodeck concept described in this paper.

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