# Preliminary Study on the Characteristics of Virtual Environments for Reaching New Heights in Education

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## Abstract

In researching virtual environments for educational purposes, it has been found that there are no set characteristic guidelines to develop educational material using virtual environments. Recognizing this fact, this paper is an attempt at listing and defining key characteristics for virtual environments for education. The approach that was used to identify these characteristics was a combination of literature reviews and experimental exploration of virtual reality over the Internet. The results from this project identify and document four key categories, namely interaction, navigation, fidelity, and components of education. Each of these key categories is further divided into sub-categories that provide the needed guidelines to develop educational materials using virtual environments. It is the intent and desired impact of this paper to establish criteria for virtual environments for education, which will enrich collaboration and knowledge of this technological resource for educational facilities. This is important because with the ever-increasing technological advancements available in most universities, virtual environments could help education to reach new heights

## 1. Introduction

Educational communities are facing many challenges. One of these challenges is the lack of educational resources to accommodate the ever-growing student population needs [1]. As more and more students seek out education at all levels – primary, secondary, and tertiary – educational institutions are hard pressed to expand enough for accommodating their enrollment. However, with this in mind, and the advent of the communication revolution, distance education has begun its' push to the forefront in helping rectify this problem [1]. One emerging technological resource in this push for distance education is the ability of virtual reality to be used over the Internet on desktop computers. The use of virtual reality over the Internet allows a group of geographically separated users to interact in real time for a broad expanse of educational applications such as physics, archaeology, chemistry, astronomy, construction, engineering, etc [2].

Research results on the use of Virtual Reality Environment for Educational communities are very encouraging [3,4]. However, upon examination into virtual reality, it has been found that desirable characteristics for an educational virtual environment are not clearly stated or defined. This is a major concern in that these defined characteristics are desperately needed for proper implementation to be fully realized and the design process is not one of confusion and probabilities.

The importance of establishing characteristic guidelines for virtual reality in educational communities is critical in promoting understanding, collaboration, and acceptance. Without these understood characteristics, educators are left without a proper format in which to clearly design and implement a virtual environment, and thus ambiguity and confusion take hold. Therefore, this paper is an attempt at listing and defining key characteristics for virtual environments for education. These characteristics, while co-dependant on the content and goals of the environments' objective, should be fully understood, utilized, and designed to help enrich the users experience, and aid in eliminating any distractions and deterioration from the learning goals. These characteristics can be categorized as:

1. Educational Component
2. Interaction
3. Navigation
4. Fidelity

It should be noted that these categories define a broad expanse, and, while some elements may overlap, are listed in such a manner to aid in the implementation and understanding of their use. The following sections are intended to cover the elements in each category and the desired characteristics.

## 2. Educational Component

The implementations of Virtual Reality environments in educational communities require detailed analysis of the educational aspects. Although, there is not a consensus regarding these educational aspects for the use of virtual reality environments for education, following are some ideas proposed by Johnson et. al. that could be used as a starting point. Johnson et. al. states that there are four criteria for the implementation of virtual reality, 1. The learning goal must be important, 2. The learning goal must be hard, 3. The learning goal must be plausibly enhanced by the introduction of virtual reality technologies, 4. Virtual reality based learning environments must be informed by contemporary research in the learning sciences and educational practice [5]. Another concept that should be addressed is the implementation of collaboration.

### 2.1 Learning Goal is Important

First and foremost, the goal of the environment's educational component must be important. Simply stated, if the goal of the educational curriculum is unimportant, why teach or learn it. Johnson's et. al. "Round Earth Project" addresses this element by citing AAAS Project 2061: Benchmarks for Science Literacy, stating that fifth-grade graduating students should know "things on or near the Earth are pulled toward it by the Earth's gravity" and "the Earth is approximately spherical in shape", as two examples on how their virtual environment meets this first educational element [5].

### 2.2 Learning Goal is Hard

The learning goal should be that of one in which it is recognized in the national standards and challenging enough that the user(s) benefit and gain knowledge from exploration and interaction in the environment. The environment should address a concept that the user(s) is not already

familiar or knowledgeable about and is accepted as one in which the ease of comprehension is not quickly understood.

### 2.3 Learning Goal is Enhanced

Another important factor, and the driving force behind the implementation of virtual reality is whether or not virtual reality is actually lending itself to the educational goal. Better stated, the learning experience must be positively enhanced by the implementation of virtual reality, which could be determined by the 3D nature of the environment for better conceptualization, the usefulness of a safe environment to practice and experience unsafe activities and tasks, etc. "The Round Earth Project" is an example in which virtual reality is well suited to giving a student the sense of walking on a spherical object, as objects appear from below the horizon and the student eventually returns to the starting point after circumnavigating the sphere [5].

### 2.4 Grounded in Educational Practice

Finally, the credibility of the environment must be fully established. When being used for educational objectives, the virtual environment must be grounded in an already established educational practice and mode of educating students. This, if for no other reason, will be the determining factor on acceptance and use by educators. In essence, the understanding that virtual reality should not be looked upon as a replacement for already established educational practices, but rather, a tool that lends itself to distance education and global learning communities for challenging visual concepts, unsafe environments, etc.

### 2.5. Collaboration

Another element that is beginning to be fully explored is the ability of the environment to allow for multiple users, or collaboration. This, in large part, is due to collaboration encouraging conversation, which in turn aids learning by presenting each learner with a slightly different view of the subject matter [5]. When introduced, collaboration can greatly increase the sense of social interaction and teamwork. It should be stated, that whether or not the virtual environment is to support single users or collaboration, the purpose of the environment should be the same in its' underlying intention, and that intention should be based on already recognizable educational goals.

## 3. Interaction

In general, one may think that simply sitting at a PC, viewing the virtual environment and attempting to move or explore within the environment, can be defined as interaction. However, interaction as a desirable characteristic is more narrowly defined as, and subcategorized into "object selection" and "object manipulation" [6]. "Object selection" is defined as when the user acquires control of an object or group of objects, and "object manipulation" is any operation performed on an object or group of objects once selected [4], thus, object selection is a precursor to object manipulation, or, it establishes access to the object.

### 3.1. Object Selection

This may seem simplistic at first glance, however, there are several variables that come into play and are key for interaction inside the environment. The first is the spatial relationship between the user inside the environment and the object(s) being selected. This should be determined by the objects' behavior and type of manipulation to be performed. For example, if the object is a tower located somewhere in the distance, and the user is selecting the object for a visual query, the spatial relationship can be within the line of sight. This narrows the definition of "object selection" to that of one where physical contact inside the environment is not totally necessary. What is necessary, however, is some form of targeting the object(s) and feedback to the user that the object(s) have been selected [6]. Some examples of this characteristic would be a crosshair for targeting the object via a mouse cursor and highlighting the object once selected. Another important factor in this characteristic is that the bounding polygons for each object should be adjusted appropriately for the size and accessibility of the object(s), that is, while smaller objects may need large bounding polygons for selection from a distance, a bounding polygon should not be too large in that it may overlap nearby objects, and thus introducing ambiguity [6].

### 3.2. Object Manipulation

"Object manipulation", and the types of actions available to users for given objects, can be viewed upon as the qualifying element to which defines the power and usefulness of the virtual environment as a whole [2]. One mode of manipulating an object has already been introduced in 2.1 in the tower example, in that it may be necessary for a user to query an object and receive some information, albeit textual or aural, based on that query. Other forms of manipulation include the ability to rotate or relocate an object(s), as well as changing said object(s) attributes and behavior [6]. An example of rotating and relocation can be envisioned in an educational environment where it is necessary for the user to acquire the correct vial from similar vials on a table by reading the various labels, and then placing the vial on a separate table for further work. An example of changing an object(s) attributes and behavior could be described in construction education, where it is necessary to take an existing wall and create a door and window. By dragging the desired components onto the wall and releasing, the wall can incorporate the door and window into its' frame. Envisioning these concepts, it can be seen how said environments are made more beneficial by the power of "object manipulation".

## 4. Navigation

What can be one of the more frustrating components of virtual environments is its' ability to handle navigation. What good does it to have a visually enriched environment, full of educational resources and tools, if you can't navigate through the environment fully, and experience all of the given material? Another problem introduced by this characteristic is the time consuming and confusing instance in which the user(s) must travel throughout the environment, however, continuously is lost and often must backtrack in hopes of finding the correct path. This, in turn, redirects the user(s) attention on the continuous effort of having to find the proper path to take, and the environments' intent becomes overlooked. There are several ways of handling this problem, all of which should be discreetly introduced for the purpose of keeping the educational environments integrity. These navigational aids should be looked upon as having no hierarchical approach, each aiding the environments' navigation while

not keeping the user(s) attention off the intended purpose(s) of the environment. Besides the need to keep a consistent layout/floor plan, other factors that will properly aid navigation are open spaces, directional cues, and key location points.

### 4.1. Layout of the Environment

Outside the environment being a replication of a real world location, such as the crawlspace of a pyramid, etc., the environment should have a consistent layout/floor plan and be designed with wide hallways and doors, and with enough room between objects such as tables, chairs, trees, etc., so that a user may pass freely between them. The user(s) should also have enough room to turn around inside each area of the environment. By considering these factors in the design of an environment, navigation will be greatly enhanced and less problematic. Another key factor in this facilitation, but one that should be implemented for purposes later explained in the Fidelity section is dividing a large environment into smaller segments. This helps minimize the amount of information to be understood by the user(s) in various forms such as on-screen maps discussed in the next section 3.2, and thus, is not so overwhelming on the user(s) and display screen.

### 4.2. Directional Cues

Another key component that should be considered is the use of directional cues, such as landmarks, signs, and on-screen maps or compass. Landmarks can be prominent structures such as a large statue, an individual, recognizable painting on the wall placed at a key location, or anything else that is located at a single instance inside the environment so that the user(s) can refer to. Signs, such as street names or easily recognized and understood <EXIT>, are obvious forms of directional cues and are easily to incorporate inside the environment. One element that takes a little more consideration if implemented, however, and is a great reference for the user(s) to find their way through the environment, is the use of on-screen maps or a compass. The user(s) can access or view the on-screen map or compass to determine where in the environment they are located. By implementing these directional cues, the environment becomes more navigation friendly and aids in keeping the focus on the overall intent.

### 4.3 Key Location Points

The last navigational aid mentioned is the use of key location points. These are predetermined locations in the environment that hold some order of importance. By accessing these points, the user is automatically taken to that location, and thus, saves the amount of time that would have been necessary to “walk through” the environment to get there. These “jumps” in the environment greatly aid the user(s) in navigating to key points, and enables maintained focus on the educational purpose of the environment. This concept can also be implemented so that these key location points are the only means of exploring the environment, or rather, the user(s) is only allowed to move through the environment by jumping to the next viewpoint, such as the means in which they are used in “Ocean Walk” [7]. By only allowing navigation through the use of individual location points, much of the problematic issues are eliminated, however, this confines the user(s) ability to explore the environment, and should only be implemented if the educational purpose is aided by this static arrangement.

## 5. Fidelity

Fidelity is used to cover a range of elements that individually determine the realistic approach to the environment. These elements can drastically affect how the environment is perceived, and therefore, whether or not the overall intent of the environment is being met. These elements are the frame rate, user(s) point of view, introduction of avatars and agents, colors and textures, sound, and temporal change.

### 5.1. Frame Rate

One of the most important elements in media similar to virtual reality, such as video and film (motion pictures), is the concept of "persistence of vision", or the ability for the brain to conceive motion from still images. So much so, standards in these forms of media have been set at 24 frames per second (fps) for film and 30 fps for video. Ideally, the application of one these standards, 24 fps, could be set for virtual reality as well, but this is very unrealistic at this stage of virtual reality and computing power. However, the environment should strive for minimal to no lag so that this distracting element is eliminated. With this in mind, a frame rate of 15 fps should be achieved so that the human eye will view the images as fluid and not a series of changing still pictures [8]. There are a few techniques that can be used to help in this area, such as texture mapping, adaptive rendering, and animated video clips [6]. All of these are designed to speed up the rendering process and aid in increasing the frame rate for the environment, which in turn will allow the user(s) to interact, explore, and achieve the desired educational goals without the extreme distraction and frustration of a slow frame rate.

### 5.2. Point of View

There are two ways of considering the user(s) point of view, *egocentric* vs. *exocentric* [6]. Both have their usefulness inside the environment and should be implemented as such. An egocentric point of view is that of the first person, and an exocentric point of view is the third person point of view, or giving the user(s) the ability to see them-selves inside the environment. A determining factor for the use of each would be whether a strong sense of presence is needed, egocentric, or a detailed relative position and understanding of motion between the user(s) and other objects is needed, exocentric [6].

### 5.3. Avatars and Agents

While being discussed in the same manner and location, these elements are two different concepts. Avatars are the representation of the user(s), whether full embodiment, or individual elements such as an arm operating a lever. Agents are used to aid, guide, and tutor the user(s) inside the environment. Both avatars and agents should only be used when necessary, otherwise, they could prove to be unnecessary distractions and detour the user(s) focus away from the main goal. When using these elements, it must be determined what representation is to be presented. This is decided upon by the overall intent of the learning environment and target audience, or rather, what educational level of the user(s) will be exploring the environment. If the educational level and goals are designed towards early education, avatars and agents represented

could be implemented in a more cartoon-like or fun manner [9]. However, this could be a distraction for use in higher education. Also, while giving the user(s) the ability to decide what representation is to be used for an avatar might be more enjoyable, aid in the ability of the user(s) to relate to oneself, and provide other users with a general understanding of the user(s) personality, this can be an area in which the focus and intention of the educational environment is once again taken away from.

### 5.4. Colors and Textures

The driving force behind these elements should be based on the content and purpose of the environment. In most cases, these elements should be addressed in an obvious and realistic manner. Specifically, the problem arises when a user(s) expectation is undermined for no reason other than a bad design decision. To clarify, in choosing the environments color scheme, it should be understood that, a green sky for example, becomes a focal point for the user(s) attention because it is outside the realistic norm, and thus, detours from the learning objectives. An example of the use of colors and correlation of the user(s) understanding and desired effect from the environment is the choice of blue and green throughout the virtual environment "Ocean Walk" [7]. While a simple design choice, a different color scheme such as red would force the loss of all desired effects because it is outside the user(s) conception of what underwater should look like. This can be manipulated for desired dramatic effects, as well, such as the way in which brain damage can cause totally new perceptions after severe medical trauma [10].

### 5.5. Sound

Often, this is an underestimated element of a virtual environment. However, this can be just as distracting as any other virtual reality element. For example, using a crashing sound such as pots and pans dropping to the floor for each time a user(s) opens a door, can distract the user(s) and focus the user(s) attention on this fact and take away from the environments purpose. Another example would be background music that draws the user(s) attention away from the goal and tasks at hand. Once again, the use of sound(s) should be implemented with the understanding of the dramatic effects it has on the user(s).

### 5.6. Temporal Change

One last sub-category of Fidelity is the time quality in the virtual environment. This temporal change can be understood as the dynamic quality of the objects inside the environment. A plant growing in a garden [9] or the propagation of water waves [11] are just two examples of this concept. Another, more recognizable idea of this concept is the changing from day to night inside the environment, as well as weather properties such as rain being introduced. This dynamic quality is often key in the educational goals, allowing the environment to present changes in time. In fact, without this characteristic, the concept of virtual reality cannot be fully achieved, because we live beyond a single moment.

## 6. Conclusion

Desirable characteristics are easily recognized once some thought has been placed into the implementation and outcome. However, not much has been done in the labeling and setting of guidelines for virtual environment characteristics for reaching new heights in education. It should be understood that these guidelines are important for the use and success of virtual reality in educational practice, and must be placed in the forefront if virtual reality is to succeed and grow in this area. Once set, these guidelines will enable collaboration and understanding in all sects of the educational field. With this collaboration, understanding, and continual implementation, virtual reality will offer tremendous benefits to global educational communities, and thus improve as we move forwards each day.

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