
UNIVERSITY OF THESSALY
SCHOOL OF ENGINEERING
DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

# DESIGN AND IMPLEMENTATION OF A TUTORING FRAMEWORK USING VIRTUAL REALITY

Diploma Thesis

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# ΠΕΡΙΛΗΨΗ

Η εικονική πραγματικότητα στις μέρες μας έχει γνωρίσει ραγδαία εξέλιξη. Είναι πλέον διαθέσιμη στην αγορά και διατίθεται σε πολλές μορφές. Το γεγονός ότι το ενδιαφέρον για αυτήν την τεχνολογία είναι αρκετά μεγάλο οδήγησε στην δημιουργία ισχυρών εργαλείων για την ανάπτυξη εφαρμογών σε εικονική πραγματικότητα. Οι τομείς που εκμεταλλεύονται την τεχνολογία αυτή είναι πολλοί. Αρκετά μεγάλο ενδιαφέρον έχει η ένταξη της εικονικής πραγματικότητας στην σχολική διαπαιδαγώγηση. Αρκετές προσπάθειες έχουν γίνει και εξακολουθούν να γίνονται για την εκπαίδευση μέσω ψηφιακών παίγνιων (σοβαρά παιχνίδια), με εξαιρετικά αποτελέσματα. Η εικονική πραγματικότητα είναι το επόμενο βήμα αυτής της προσπάθειας.

Η πτυχιακή εργασία αυτή έχει να κάνει με την ανάπτυξη μιας μαθησιακής εφαρμογής σε εικονικό περιβάλλον με σκοπό την εκμάθηση και διαπαιδαγώγηση μαθητών σε σχολεία. Οι μαθητές καλούνται να χρησιμοποιήσουν γνώσεις που έχουν διδαχθεί με σκοπό να δραπετεύσουν από κάποιο εικονικό δωμάτιο. Η εφαρμογή είναι χωρισμένη σε τρία κυριά κομμάτια. Ένα φροντιστήριο για την καθοδήγηση του τρόπου παιξίματος του παιχνιδιού. Ένα δωμάτιο διαφυγής, και έξι μαθήματα. Τα μαθήματα αφορούν μαθηματικά και επιστήμες. Αναμεσά από κάθε μάθημα περιέχονται δυο κουϊζ. Οι υπόλοιποι μαθητές στην τάξη προσφέρουν βοήθεια μέσω εφαρμογών σε κινητά τηλεφώνα η ταμπλέτες οπού καθοδηγούν τον παίκτη δίνοντας του κατευθύνσεις είτε ψηφίζοντας για την σωστή απάντηση κατά την διάρκεια των κουϊζ. Καθ’ όλη την διάρκεια αυτής της εμπειρίας είναι απαραίτητη η καθοδήγηση του δάσκαλου. Και τα τρία βασικά μέρη του παιχνιδιού διεξάγονται χρησιμοποιώντας την έννοια της αναλογίας σήματος ως προς τον θόρυβο. Όλη η εμπειρία λαμβάνει μέρος σε μια εικονική μονοκατοικία.

# ABSTRACT

The virtual reality nowadays has been rapidly evolving. It is available on the market in various forms. The fact that the interest of this new technology is significantly led to the creation of powerful tools for the development of application in virtual reality. The sectors that are taking advantage of this technology are many. Considerable interest has the integration of virtual reality in school education. Many tries have been done for education by serious games with excellent results. Virtual reality is the next step of this effort.

This thesis is about the development of an educational application in virtual reality with the primary goal of the education of students in schools. Students are called to use their knowledge that they have been taught so they can escape from a virtual room. The application is separated into three main parts. One tutorial for guidance on how to play the game. One escape room and six lessons. The lessons are about mathematics and science. Between every lesson, there are two quizzes. The rest of the students in the classroom are providing help to the player, using an external application in their smartphone or tablet, by directing him or by voting for the correct answer during the quiz section. During the whole experience, the guidance of the teacher is necessary. The three main parts of the application are carried out using the concept of SNR (Signal to Noise Ratio). All the virtual reality experience is taking place in a detached house.

# Acknowledgements

I would like to express my appreciation to my supervisor Professor Korakis Athanasios, for his support and guidance during the deployment of this thesis. His passion and trust were my motive to do my best and fulfill my thesis with the best possible results. Without his valuable assistance, the completion of this work would be a lot harder.

I am also grateful to my family and friends who have provided me with moral and emotional support in my life. Their spiritual support through every hard time helped me to pass through all the obstacles that appeared along the way.

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# List of Abbreviations

| | |
|---|---|
| 2D | Two Dimensional |
| 3D | Three Dimensional |
| API | Application Programming Interface |
| AR | Augmented Reality |
| CPU | Central Processing Unit |
| GPU | Graphics Processing Unit |
| HDMI | High-Definition Multimedia Interface |
| HTTP | HyperText Transfer Protocol |
| IP | Internet Protocol |
| LTE | Long Term Evolution |
| MR | Mixed Reality |
| OBS | Open Broadcaster Software |
| PUN | Photon Unity Networking |
| RAM | Random Access Memory |
| RPC | Remote Procedure Call |
| RTMP | Real-Time Messaging Protocol |
| SNR | Signal to Noise Ratio |
| SSL | Secure Socket Layer |
| TCP | Transmission Control Protocol |
| TLS | Secure Transport Layer |
| UDP | User Datagram Protocol |
| USB | Universal Serial Bus |
| VR | Virtual Reality |
| XR | X Reality |

# 1 Introduction/Motivation

## 1.1 Introduction

As technology grows and starts appearing in our lives in every possible way, it creates opportunities to use it in ways that were impossible in the past. Take advantage of super-fast networks, using 5G technologies, in combination with potent hardware that is available to the public; we can create worlds that are accessible by everyone and everywhere using virtual reality (VR). Although this technology right now is most commonly used for gaming, many organizations are investing in creating applications for more specific purposes like Sport, Medical Training, Military, and many other things [1] (Alayna Mansell, 2019). Among all those things, virtual reality can be instrumental in education. Serious games (games with an educational purpose) has already used for learning while the students are having fun, with excellent results. So why not in Virtual Reality too.

Virtual reality (VR) is an experience taking place within a simulation, which can be similar to or completely different from the real world. Currently, standard virtual reality systems use either virtual reality headsets or multi-projected environments to generate realistic images, sounds, and other sensations that simulate a user's physical presence in a virtual environment. A person using virtual reality equipment can look around the artificial world, move around in it, and interact with virtual features or items. The effect is commonly created by VR headsets consisting of a head-mounted display with a small screen in front of the eyes but can also be created through specially designed rooms with multiple large screens. Virtual reality typically incorporates auditory feedback and video feedback but may also allow other types of sensory and force feedback through haptic technology.[2] (Wikipedia, n.d.)

With Virtual Reality, we can simulate environments that can be used to train students by interacting with almost everything into the virtual world while breaking the limitations of the real world. This way, they can learn by experience, in a safe environment, while they can observe the results of their activities in real time. What is more, those results can be stored, recording this way their progress and helping the teachers have a better understanding of how their students act by analyzing their data. Also, giving to the virtual world a game-like experience gives the motive to spend more time and effort, helping the students learn easier and more restful.

Finally, using today's high-speed networks, we can share the experience almost everywhere in the world. Creating this way, a bridge that connects students from all over the world, who can interact with each other, creating experiences and most importantly learn from each other.

This thesis is about creating an application in VR, using all the above, that teaches students how signals behave in relation with the distance and object interferences using the idea of an escape room [3] (Wikipedia, n.d.).

## 1.2 Motivation

The primary purpose of this thesis is to experiment with new educational methods that will help modernize and improve those that already exist. Combining traditional methods of learning with the capabilities that technology offers can contribute to the creation of new and more efficient educational plans.

Using virtual reality can help students discover and get familiar with any environment extremely fast, without the need of regularly changing locations. All this can take place in a single classroom. What is more, the ability to

interact with all the objects in those environments makes the experience closer to the real world. That way makes the students learn by experience which is more efficient than just theory. Also creates the opportunity to experiment with staff that was impossible in the past, because in the virtual world, we do not need all the resources and time that would be necessary in the real world.

Another essential feature is the isolation aspect, meaning that the environments are entirely free of real-world dangers. Creates the opportunity for the users to experiment freely without worrying about accidents that may occur. For example, in a chemistry lesson, it would be possible to see the reaction of a compound without the danger of an explosion or the harmful gases.

Getting familiar with virtual reality technologies and being able to create from scratches worlds it was a real challenge. By learning how to use tools that can help to do that, creates endless possibilities for future apps. Finally, the educational part in this thesis was a challenge that motived me to the implementation of this thesis.

# 2 Background

## 2.1 Game Engines

A game engine is a software development environment designed for people to build video games. Developers use game engines to construct games for consoles, mobile devices, and personal computers. The core functionality typically provided by a game engine includes a rendering engine ("renderer") for 2D or 3D graphics, a physics engine or collision detection (and collision response), sound, scripting, animation, artificial intelligence, networking, streaming, memory management, threading, localization support, scene graph, and may include video support for cinematics. Implementers often economize on the process of game development by reusing/adapting, in large part, the same game engine to produce different games or to aid in porting games to multiple platforms.[4] (wikipedia, n.d.)

Most commonly used Game Engines now days are [5] (gamedesigning, 2019) :

- Unity Engine
- Unreal Engine
- GameMaker Engine

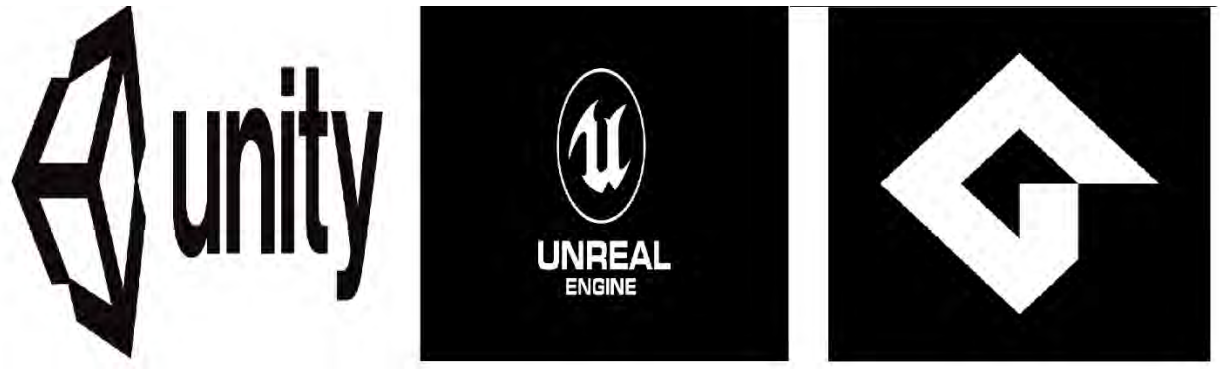


***Figure 2-1 Game Engines***

As all game engines share a common goal, the creation of virtual games, using a wide variety of similar tools, they also share many differences.

### 2.1.1 Unity Engine

Unity is a cross-platform game engine; it was developed by Unity Technologies. The initial product was launched in the year of 2005, June 6. Unity 3D is considered as one of the best game engines out there as the engine offers its users a wide range of tools and features that are easily accessible [6,7] (Thinkwik, 2019) (educba, n.d.).

Unity use C#, Boo, or JavaScript for coding. They are object-oriented scripting languages. This way allows to developers to write their code easier avoiding Java or C++. Scripting tells Game Objects, such as an avatar or any other object in the game, how to behave. This can be achieved by attaching the script to the object.

The main advantages Unity offers are:

1. Cross-platform integration. Giving the ability to developers to build their projects in about 25 platforms. Like Windows desktop, Mac OS desktop, Android, iOS, and many more.
2. Huge community. Provides an enormous amount of information online, which is great for research as someone can find all kind of examples without much effort.
3. A large Asset Store. Gives the option to developers to download already implemented assets , by other developers, by paying the price (which the owner determines) or in many cases for free.
4. Excellent XR support. Take advantage of the above unity has developed an excellent and user-friendly X Reality or Cross Reality environment.

### 2.1.2 Unreal Engine

The Unreal Engine is a game engine developed by Epic Games, first showcased in the 1998 first-person shooter game Unreal. Although initially developed for first-person shooters, it has been successfully used in a variety of other genres, including platformers, fighting games, MMORPGs, and other RPGs. With its code written in C++, the Unreal Engine features a high degree of portability and is a tool used by many game developers today, with it being source-available. The most recent version is Unreal Engine 4, which was released in 2014.[8] (wikipedia, n.d.)

The main advantages Unreal offers are:

1. Gaming graphics and performance.
2. Blueprint visual scripting system. An easy way for scripting using a node-based interface to create gameplay elements from within Unreal Editor.
3. Completely free to use.

## 2.2 X reality or Cross reality (XR)

Extended Reality (XR) is the umbrella term used for VR (Virtual Reality), AR (Augmented Reality), and MR (Mixed Reality), as well as all future realities such technology, might bring. XR covers the full spectrum of real and virtual environments.

To use an umbrella term is to recognize the intersection of these technologies, and the many ways they will work together to disrupt our everyday tasks.[9]

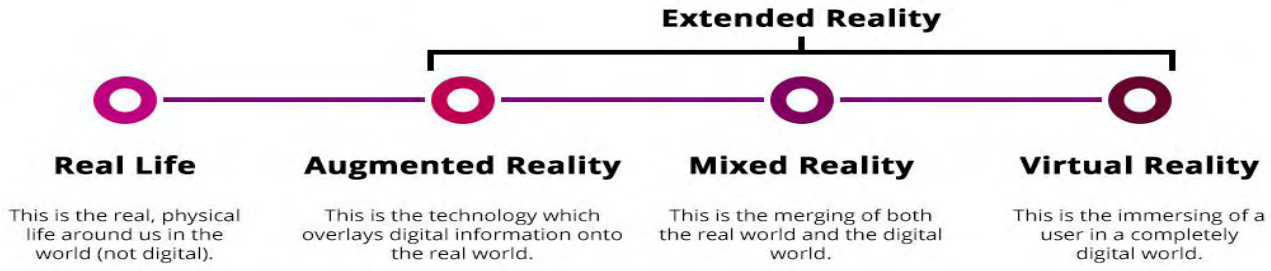


***Figure 2-2 X reality or Cross reality***

### 2.2.1 Mixed Reality

Mixed Reality (MR) lies somewhere in between VR and AR. It blends real and virtual worlds to create complex environments where physical and digital elements can interact in real-time. Like AR, it overlays synthetic content in a real-world environment; and like VR, this content is interactive, and users can manipulate the digital objects in their physical space.[9]

### 2.2.2 Augmented Reality

Augmented Reality (AR) is not a new reality, but a layer on top of your existing one. Rather than immersing users, AR relies on a device – usually the camera in a phone or tablet – to overlay digital graphics and sounds into a real-world environment. Pokémon Go and Snapchat filters are typical examples of this kind of technology.[9]

### 2.2.3 Virtual Reality

Virtual Reality (VR) applications use headsets to immerse users in a computer-simulated reality fully. These headsets generate realistic sounds and images, engaging all five senses to create an interactive virtual world.[9] (Jenny, 2019)

## 2.3 5G

Fifth-generation wireless (5G) is the latest iteration of cellular technology, engineered to increase the speed and responsiveness of wireless networks greatly. With 5G, data transmitted over wireless broadband connections could travel at rates as high as 20 Gbps by some estimates -- exceeding wireline network speeds -- as well as offer latency of 1 ms or lower for uses that require real-time feedback. 5G will also enable a sharp increase in the amount of data transmitted over wireless systems due to more available bandwidth and advanced antenna technology [10] (Rouse, n.d.).

### 2.3.1 5G Technologies

5G networks are digital cellular networks, in which the service area covered by providers is divided into small geographical areas called *cells*. Analog signals representing sounds and images are digitized in the phone, converted by an analog to digital converter and transmitted as a stream of bits. All the 5G wireless devices in a cell communicate by radio waves with a local antenna array and low power automated transceiver (transmitter and receiver) in the cell, over frequency channels assigned by the transceiver from a pool of frequencies which are reused in other cells. The local antennas are connected with the telephone network and the Internet by a high bandwidth optical fiber or wireless backhaul connection. As in other cell networks, a mobile device crossing from one cell to another is automatically "handed off" seamlessly to the new cell.

There are plans to use millimeter waves for 5G. Millimeter waves have a shorter range than microwaves. Therefore, the cells are limited to a smaller size; The waves also have trouble passing through building walls.

Millimeter-wave antennas are smaller than the large antennas used in previous cellular networks. They are only a few inches (several centimeters) long. Another technique used for increasing the data rate is massive MIMO (multiple-input multiple-output). Each cell will have multiple antennas communicating with the wireless device, received by multiple antennas in the device; thus, multiple bitstreams of data will be transmitted simultaneously, in parallel. In a technique called beamforming, the base station computer will continuously calculate the best route for radio waves to reach each wireless device and will organize multiple antennas to work together as phased arrays to create beams of millimeter waves to reach the device.

The new 5G wireless devices also have 4G LTE capability, as the new networks use 4G for initially establishing the connection with the cell, as well as in locations where 5G access is not available.

5G can support up to a million devices per square kilometer, while 4G supports only up to 100,000 devices per square kilometer. [11] (Wikipedia, n.d.)

## 2.4 VR Multiplayer (Photon Cloud)

The application offers Multiplayer and networking features. Unity has a networking system called UNet, but it is deprecated and will be removed from Unity in the future because a new system is under development. For that reason, I used an external networking engine called Photon [12] (Photonengine, n.d.).


***Figure 2-3 Photon Unity***

Photon is an independent networking engine and multiplayer platform offering fast, reliable, and scalable networking. It collaborates with Unity engine providing a package in unity' s assetstore called PUN 2 (Photon Unity Networking). PUN 2 comes with two options:

1) PUN 2 Free Edition. No-cost package with various demos, pre-made scripts and reference documentation. Exports to basically all platforms.
2) PUN 2 Plus Edition. Same content as PUN FREE, plus a 100 concurrent user plan for the Photon Cloud.

PUN features:

Benefit from a tight Unity integration to easily develop and launch multiplayer games world-wide. Export to all Unity supported platforms including consoles.

Specifically:

- Realtime Cloud: PUN games are hosted in their globally distributed Photon Cloud to guarantee low latency and shortest round-trip times for your players worldwide.

- Multiplayer: Easy Connect, Match and Play.
- Cross-Platform: Export to mobile, desktop, web or consoles.
- Scalability: Games built with PUN scale seamlessly and automatically in the Photon Cloud.
- Matchmaking API
- Customization: supports any type of room-based games on any popular gaming platform.
- Client to Server: PUN taking care of all Reliable UDP, TCP, HTTP or Websockets connections.
- Flexibility: you can match an iOS Game Center user with someone using Google Play Services, authenticate a user via Facebook or add a custom authentication, utilize a gaming service or hook in your own backend.

#### 2.4.1.1 Video Streaming

### 2.4.2 Real-Time Messaging Protocol (RTMP)

Was initially a proprietary protocol developed by Macromedia for streaming audio, video and data over the Internet, between a Flash player and a server. Macromedia is now owned by Adobe, which has released an incomplete version of the specification of the protocol for public use.

The RTMP protocol has multiple variations:

The "plain" protocol which works on top of and uses TCP port number 1935 by default.

RTMPS, which is RTMP over a TLS/SSL connection.

RTMPE, which is RTMP encrypted using Adobe's security mechanism. While the details of the implementation are proprietary, the mechanism uses industry-standard cryptographic primitives.

RTMPT, which is encapsulated within HTTP requests to traverse firewalls. RTMPT is frequently found utilizing cleartext requests on TCP ports 80 and 443 to bypass most corporate traffic filtering. The encapsulated session may carry plain RTMP, RTMPS, or RTMPE packets within.

RTMFP, which is RTMP over UDP instead of TCP, replacing RTMP Chunk Stream. The Secure Real-Time Media Flow Protocol suite has been developed by Adobe Systems and enables end-users to connect and communicate directly with each other (P2P).

While the primary motivation for RTMP was to be a protocol for playing Flash video, it is also used in some other applications, such as the Adobe LiveCycle Data Services ES.

RTMP is a TCP-based protocol which maintains persistent connections and allows low-latency communication. To deliver streams smoothly and transmit as much information as possible, it splits streams into fragments, and their size is negotiated dynamically between the client and server. Sometimes, it is kept unchanged; the default fragment sizes are 64 bytes for audio data, and 128 bytes for video data and most other data types. Fragments from different streams may then be interleaved and multiplexed over a single connection. With longer data chunks, the protocol thus carries only a one-byte header per fragment, so incurring very little overhead. However, in practice, individual fragments are not typically interleaved. Instead, the interleaving and multiplexing are done at the packet level, with RTMP packets across several different active channels being interleaved in such a way as to ensure that each channel meets its bandwidth, latency, and other quality-of-service requirements. Packets interleaved in this fashion are treated as indivisible and are not interleaved on the fragment level.

The RTMP defines several virtual channels on which packets may be sent and received, and which operate independently of each other. For example, there is a channel for handling RPC requests and responses, a channel for video stream data, a channel for audio stream data, a channel for out-of-band control messages (fragment size negotiation, etc.), and so on. During a typical RTMP session, several channels may be active simultaneously at any given time. When RTMP data is encoded, a packet header is generated. The packet header specifies, amongst other matters, the ID of the channel on which it is to be sent, a timestamp of when it was generated (if necessary), and the size of the packet's payload. This header is then followed by the actual payload content of the packet, which is fragmented according to the currently agreed-upon fragment size before it is sent over the connection. The packet header itself is never fragmented, and its size does not count towards the data in the packet's first fragment. In other words, only the actual packet payload (the media data) is subject to fragmentation.

At a higher level, the RTMP encapsulates MP3 or AAC audio and FLV1 video multimedia streams and can make remote procedure calls (RPCs) using the Action Message Format. Any RPC services required are made asynchronously, using a single client/server request/response model, such that real-time communication is not required. [13] (Wikipedia, n.d.)

### 2.4.3 Open Broadcaster Software (OBS)

Is a free and open-source software for video recording and live streaming. It is available in Linux, Mac and Windows Build. [14] (obsproject, n.d.)

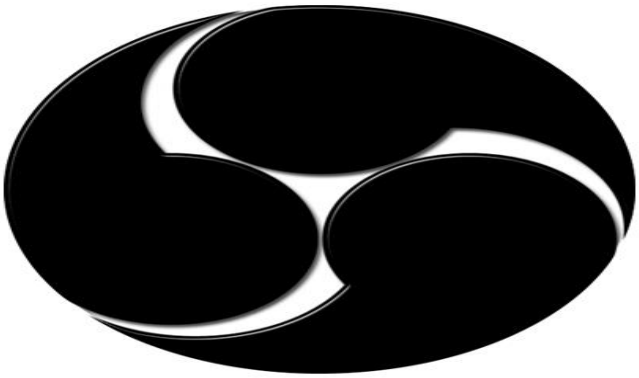

***Figure 2-4 OBS Logo***

OBS is written in C and C++ and Qt, OBS provides a real-time source and device capture, scene composition, encoding, recording, and broadcasting. Transmission of data is primarily done via the Real-Time Messaging Protocol (RTMP) and can be sent to any RTMP supporting destination, including many presets for streaming websites such as YouTube, Twitch.tv, Instagram, and Facebook.

For video encoding, OBS is capable of using the x264 free software library, Intel Quick Sync Video, Nvidia NVENC, and the AMD Video Coding Engine to encode video streams into the H.264/MPEG-4 AVC format and the H.265/HEVC format. Audio can be encoded using either the MP3 or AAC codecs. Advanced users can choose to use any codecs and containers available in libavcodec / libavformat as well as output the stream to a custom ffmpeg URL. [15] (Wikipedia, n.d.)

### 2.4.4 Signal to Noise Ratio (SNR)

Signal-to-noise ratio (abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of the desired signal to the level of background noise. SNR is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise.[16]

While SNR is commonly quoted for electrical signals, it can be applied to any form of a signal, for example, isotope levels in an ice core, biochemical signaling between cells, or financial trading signals. Signal-to-noise ratio is sometimes used metaphorically to refer to the ratio of useful information to false or irrelevant data in a conversation or exchange. For example, in online discussion forums and other online communities, off-topic posts and spam are regarded as "noise" that interferes with the "signal" of appropriate discussion.[19]

The Shannon–Hartley theorem connects the signal-to-noise ratio, the bandwidth, and the channel capacity of a communication channel.[19]

Signal-to-noise ratio is defined as the ratio of the power of a signal (meaningful information) to the power of background noise (unwanted signal):

$$\mathrm{SNR} = \frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}},$$

Where *P* is average power, both signal, and noise power must be measured at the same or equivalent points in a system, and within the same system bandwidth.[19]

# 3 Implementation

## 3.1 Hardware Architecture

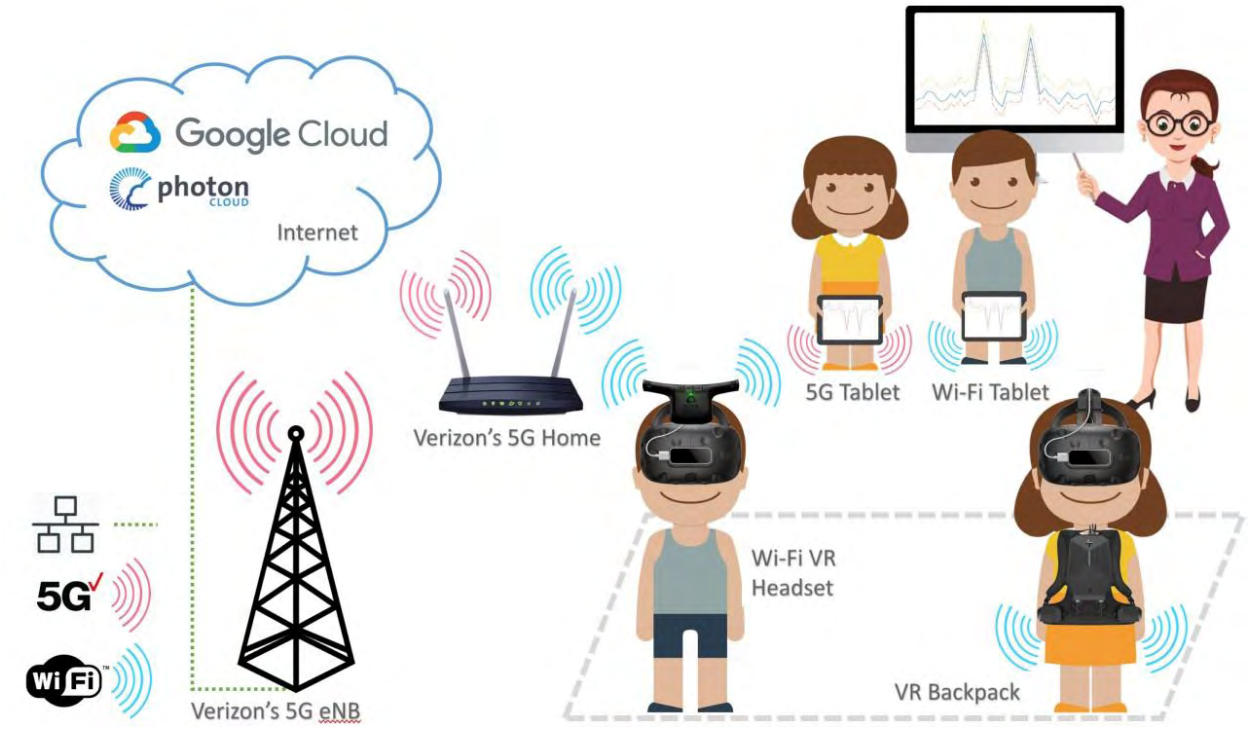


***Figure 3-1 Hardware Architecture***

### 3.1.1 Headsets

Virtual reality headsets are head-mounted devices that used to display the VR content using lenses responsible for mapping the up-close display to a wide field of view. Each headset comes with a different hardware architecture depending on the manufacturer.

There are lots of different kind of headsets. Some need external hardware to run like a PC or a smartphone, and there are others which are more autonomous. We can separate them in the following categories: high-end, mid-range, and low-range headsets.

1. High-end headsets: They are more expensive than the others, but they offer more features like lower latency, a better refresh rate of the display, better image quality, and more. Usually, because of the high performance, they cannot run alone, and they need an external computer with strong hardware to support them.
2. Mid-range headsets: They are a more affordable solution, but they have a significant loss in quality in comparison with the high-end headset. They usually can run with a smartphone, thing that makes them portable.

3. Low-range headsets: They are cheap headsets that run with a smartphone. Their construction is simple, and their potential is limited. They offer very basic interactions, and they usually used for entertainment.

#### 3.1.1.1 HTC VIVE

For the implementation of this thesis, the headset used is HTC VIVE headset. It is a high-end headset powered by SteamVR which uses two base stations wirelessly synchronized for the tracking. This base station offers 360-degree play area tracking coverage. It comes with two controllers, one for each hand.

Specs:

- Headset Specs

  Screen: Dual AMOLED 3.6'' diagonal

  Resolution: 1080 x 1200 pixels per eye (2160 x 1200 pixels combined)

  Refresh rate: 90 Hz

  Field of view: 110 degrees

  Safety features: Chaperone play area boundaries and front-facing camera

  Sensors: SteamVR Tracking, G-sensor, gyroscope, proximity

  Connections: HDMI, USB 2.0, stereo 3.5 mm headphone jack, Power, Bluetooth

  Input: Integrated microphone

  Eye Relief: Interpupillary distance and lens distance adjustment

- Controller specs

  Sensors: SteamVR Tracking

  Input: Multifunction trackpad, Grip buttons, dual-stage trigger, System button, Menu button

  Use per charge: Approx. 6 hours

  Connections: Micro-USB charging port

- Tracked area requirements

  Standing / seated: No min. space requirements

  Room-scale: 6'6" x 4'11" min. room size, 11'5" x 11'5" max

#### 3.1.1.2 Controllers

Each controller has two buttons, one trackpad, one trigger, and two grip buttons as shown to figure below.

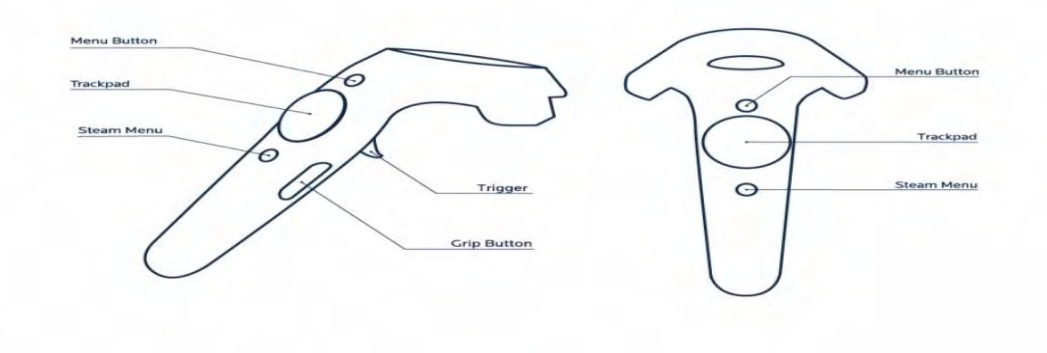


***Figure 3-2 VIVE Controllers***

1. Application Menu Button: Displays the tabbed menu in VR.
2. Touchpad: Usually used for moving around but this depends on the application. It can also be pressed.
3. System Menu Button: display the Steam system menu within VR.
4. Grip Buttons: Their actions depend on the application.
5. Trigger: Action depends on the application.

### 3.1.2 Computer Configuration

There is a variety of option for this section. Any computer configuration with the following specification or grater can run the application:

GPU: NVIDIA® GeForce® GTX 1060 or AMD Radeon™ RX 480, equivalent or better.
CPU: Intel® Core™ i5-4590 or AMD FX™ 8350, equivalent or better
RAM: 8 GB RAM or more
Video out: HDMI 1.4, DisplayPort 1.2 or newer
USB Ports: 1x USB 2.0 or better port
Operating system: Windows 10

### 3.1.3 Tablet/Smartphone

The end devices for capturing the stream from the application are either tablets or smartphones. They also used for chatting with the player inside the game.

## 3.2 Software Architecture

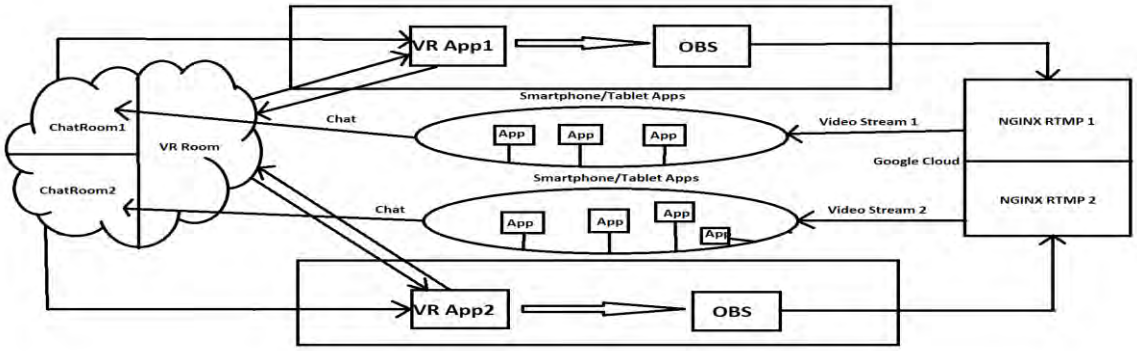


***Figure 3-3 Software Architecture Schematic***

### 3.2.1 Unity Editor

The primary tool used for this deployment was Unity Engine.

Let's look now at Unity's Editor.

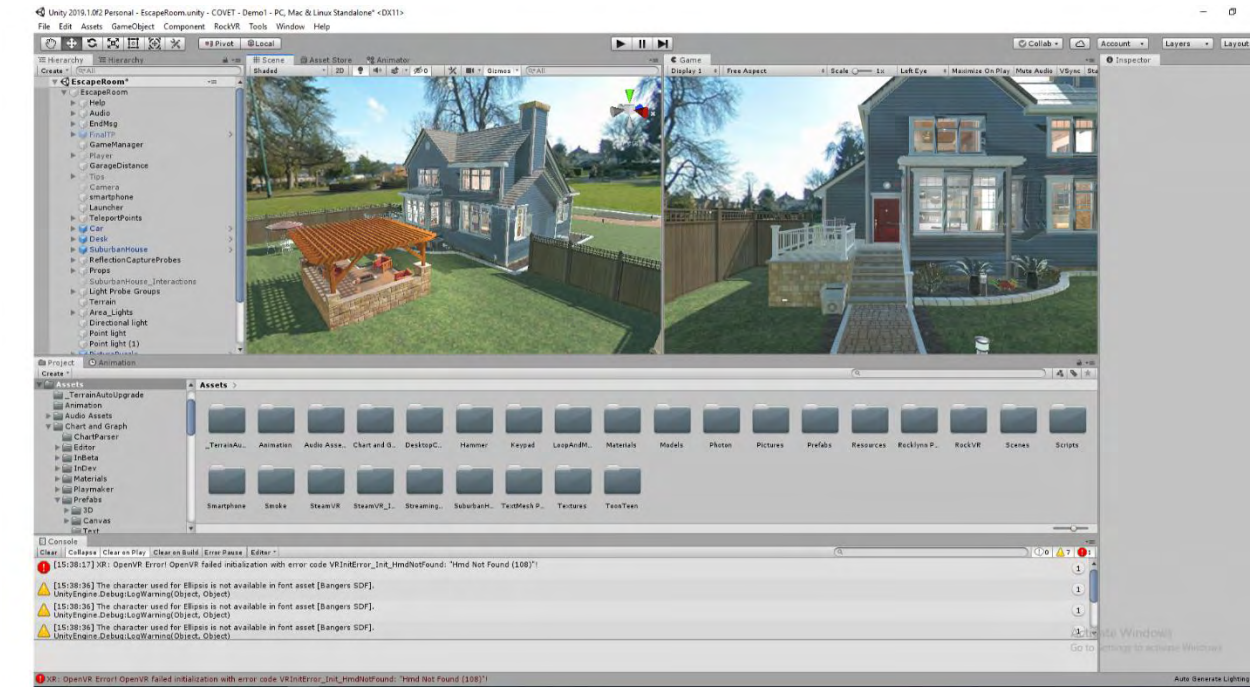

***Figure 3-4 Unity Editor***

The default Unity's Editor is separated in seven windows.

1. Scene View
2. Game View
3. Hierarchy Window
4. Inspector Window
5. Project Window
6. The Tool Bar
7. Console Window

### 3.2.1.1 Scene View

Scene view is the interactive window that you can position all your Game Objects, cameras, characters, etc. You can select, manipulate, and modify objects creating that way the desirable game scene.

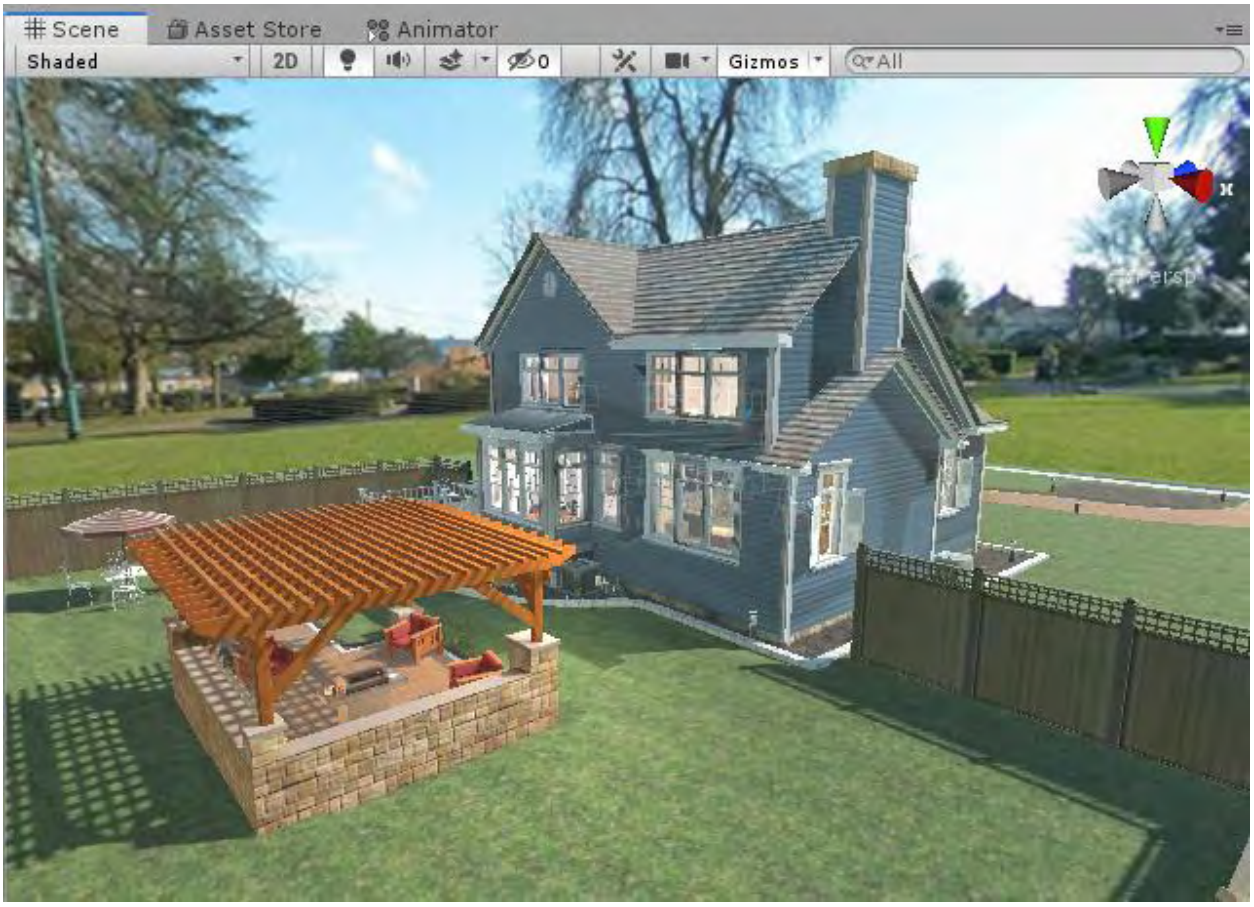


***Figure 3-5 Unity Scene View***

### 3.2.1.2 Game View

Game View is what the player sees. Is rendered from the Camera in your game and it is a representation of your final game. One or more cameras are necessary.

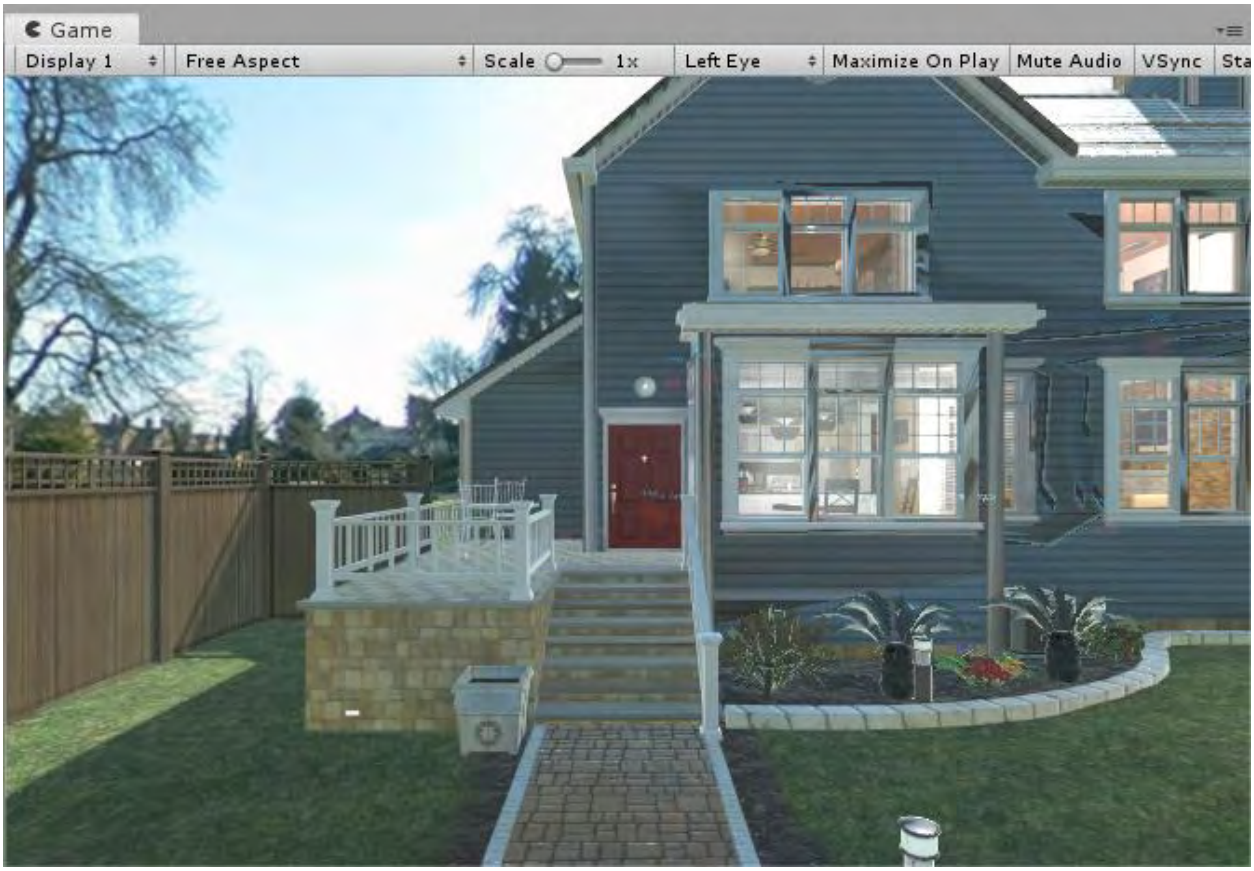


***Figure 3-6 Unity Game View***

### 3.2.1.3 Hierarchy Window

The Hierarchy window contains a list of every Game Object in the current Scene. Some of these are direct instances of Asset files (like 3D models), and others are instances of Prefabs, which are custom Game Objects that make up most of your game. When you add or remove Game Objects the Scene (or when your gameplay mechanic adds and removes them), they appear and disappear from the Hierarchy as well. By default, the Hierarchy window lists Game Objects by order of creating, with the most recently created Game Objects at the bottom. You can re-order the Game Objects by dragging them up or down, or by making them “child” or “parent” Game Objects.

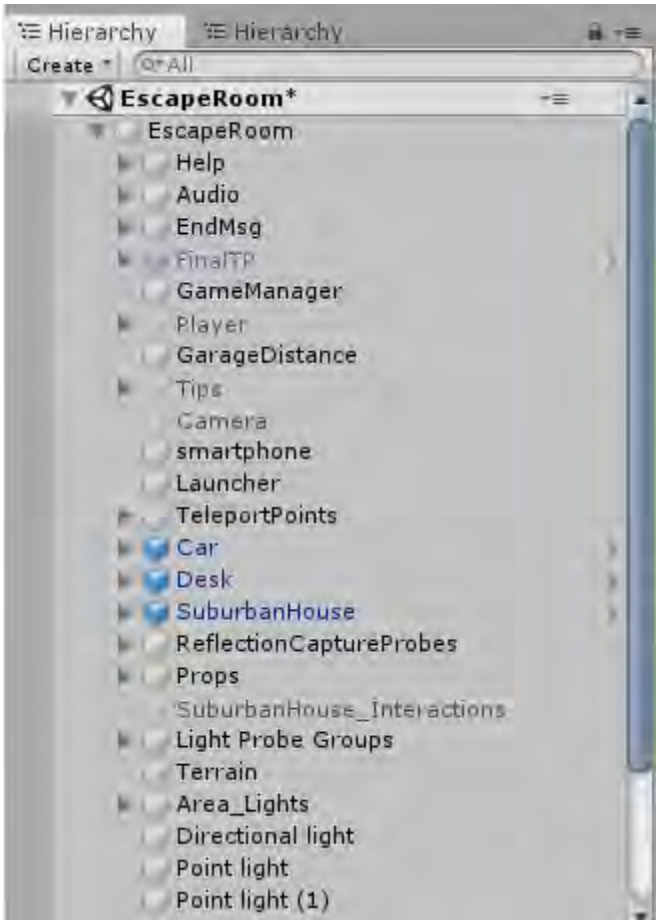


***Figure 3-7 Unity Hierarchy Window***

### 3.2.1.4 Inspector Window

Projects in the Unity Editor are made up of multiple Game Objects that contain scripts, sounds, Meshes, and other graphical elements such as Lights. The Inspector window (sometimes referred to as “the Inspector”) displays detailed information about the currently selected Game Object, including all attached components and their properties, and allows you to modify the functionality of Game Objects in your Scene.

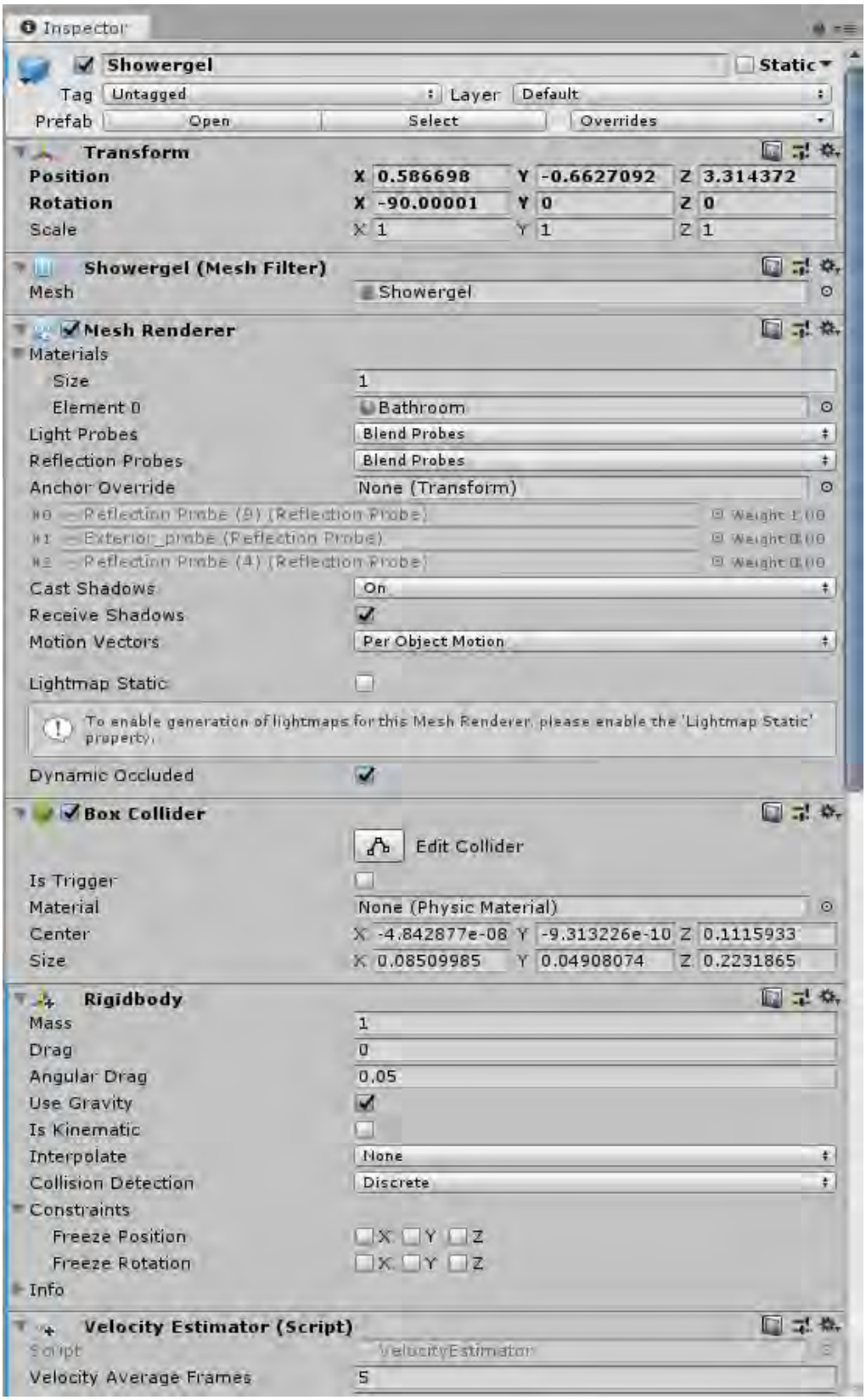


***Figure 3-8 Unity Inspector***

### 3.2.1.5 Project Window

In the Project window, you can access and manage the assets that belong to your project. You can create folders, scripts, add assets, images, sound, and more you are going to use in your game.

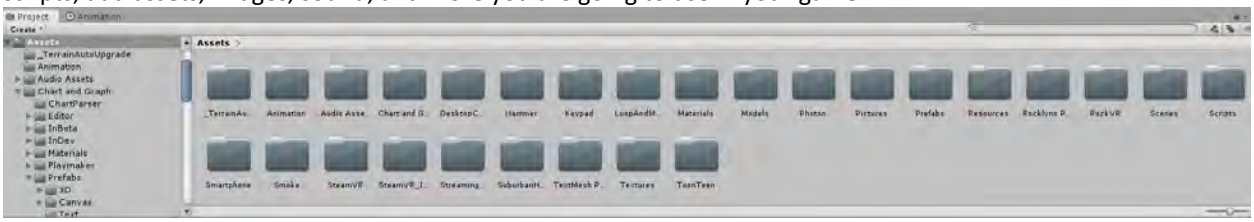

***Figure 3-9 Unity Project Window***

### 3.2.1.6 The Tool Bar

The Toolbar consists of seven basic controls. Each relate to different parts of the Editor.

- Transform Tools
- Transform Gizmo Toggles
- Play/Pause/Step Buttons
- Cloud Button
- Account Drop-down
- Layers Drop-down
- Layout Drop-down

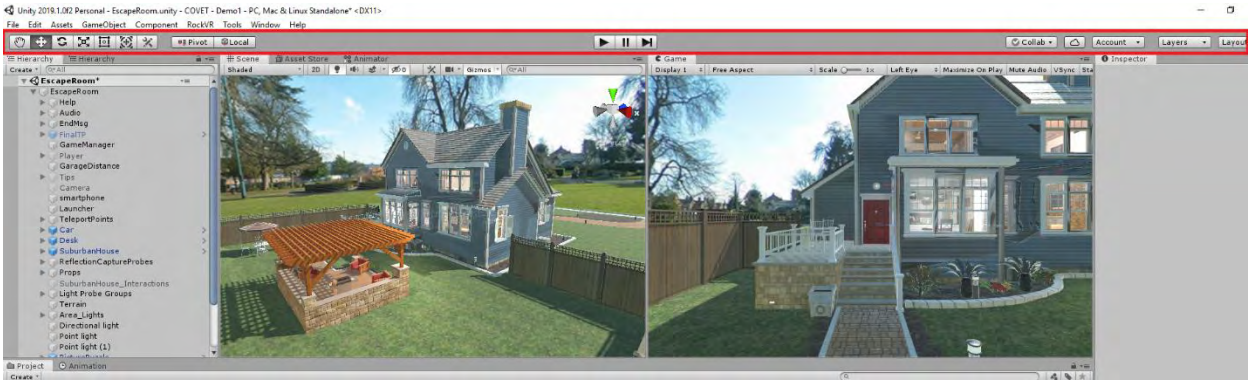

***Figure 3-10 Unity Tool Bar***

### 3.2.1.7 Console Window

Console Window displays all debugging information like errors, warnings, and other messages generated by Unity. It also displays Developer's messages that can be used for debugging or other purposes.


***Figure 3-11 Unity Console Window***

### 3.2.1.8 Unity GameObjects/Models/Assets

Every object used in Unity it is called GameObject. GameObject can be a simple or a complicated 3D model or just an empty GameObject (imagine an invisible object), which sometimes containing some behavior. Unity provides you with some basic 3D models like a cube or a cylinder and some other 3D objects. Sometimes they can be useful, but most of the times you will need more complicated models created from external tools for 3D modeling like Blender, Adobe's 3D's Max, etc. Unity offers a store that you can download 2D or 3D models called AssetStore. Every package in the Asset store, it is called Asset. An asset is not necessary a 3D or 2D model, but it can be a group of models or a tool or anything that can be used from Unity. Some assets are free, and some others need a payment to purchase them.

### 3.2.1.9 Unity Scripting

If you want to add a behavior to a game object like open or close a switch, you must attach a script on it. Scripts are code files that are written in C#, Boo, or JavaScript. The best option to write those scripts is to use Visual Studio as it is cooperating with unity providing a debugger, particularly for unity scripts. Of course, you can use any other editor for writing your code. One Important thing when writing a unity script is that it must derive from MonoBehavior. MonoBehaviour is the base class from which every Unity script derives.

### 3.2.1.10 Unity Build Options

Once you have finished your development, unity gives you many options for exporting your game. Off course, you cannot export a game for all the available platforms without making changes to your deployment. You must know in which platform you want to build your game from the beginning. Sometimes it is easy to move a game from one platform to another, but sometimes it is not. Here is a list of all available platforms that unity provides:

iOS, Android, Tizen, Windows, Universal Windows Platform, Mac, Linux, WebGL, PlayStation 4, PlayStation Vita, Xbox One, 3DS, Oculus Rift, Google Cardboard, Steam VR, PlayStation VR, Gear VR, Windows Mixed Reality,

Daydream, Android TV, Samsung Smart TV, tvOS, Nintendo Switch, Fire OS, Facebook, Gameroom,Apple's ARKit, Google's ARCore , Vuforia, Magic Leap

### 3.2.2 Photon could

Photon Unity, as said before, is a Unity package for multiplayer games available in Unity's asset store. First, you must download and import the photon asset into your game. Then it will ask you to fill your App ID. This is the room ID that you must set up on Photon's web page. It gives you a variety of options for your multiplayer app like Realtime apps, PUN apps, or Bolt apps. In my case, I used the PUN app. For the messaging between apps, you must set up another PUN room with a chat ID this time. The options you have here is Chat apps or Voice apps. In my case, I used the Chat app. Once everything is set up, you can go back to Unity and fill your app IDs. After that, you are ready to begin coding using Photon's libraries for networking. What Photon offers you is that it takes care of matchmaking and all synchronization is necessary between your apps. All the job is done on Photon's servers, so you do not need your own server.

### 3.2.3 Nginx server

NGINX is open-source software for web serving, reverse proxying, caching, load balancing, media streaming, and more. It started as a web server designed for maximum performance and stability. In addition to its HTTP server capabilities, NGINX can also function as a proxy server for email (IMAP, POP3, and SMTP) and a reverse proxy and load balancer for HTTP, TCP, and UDP servers. [17] (nginx, n.d.)

Using Nginx open-source software, I built an RTMP server for live streaming the VR content as a video stream. NGINX RTMP server receives the video and then multicast the video to multiple devices like smartphones or tablets. The server is built on a google cloud, and it needs a static IP.

### 3.2.4 OBS

For screen capture, I use OBS software. It captures the screen real-time, encodes the video, and then pushing the content to the RTMP server. You have to go to settings/Stream and then fill the Server field with the RTMP server address like this " rtmp://"Server_IP"/"domain_name" ". Then you can press Start Streaming, and it will push the video to the RTMP server. Notice that the Server needs to have a static IP address, or you must change the Server_IP every time the Server dynamically changes its IP. At Settings/Output/Streaming you can set the Video Bitrate, Encoder and Audio Bitrate. I have set them at the standard values:

- Video Bitrate: 2500Kbps
- Encoder: NVENC
- Audio Bitrate: 160

### 3.2.5 VLC

For catching and displaying the video stream from the RTMP server, I used VLC player. The VLC media player is a free and open-source portable cross-platform media player software and streaming media server developed by the VideoLAN project. VLC is available for desktop operating systems and mobile platforms, such as Android, iOS, iPadOS, Tizen, Windows 10 Mobile, and Windows Phone. VLC is also available on digital distribution platforms such as Apple's App Store, Google Play, and Microsoft Store. VLC supports many audio and video compression methods and file formats, including DVD-Video, video CD, and streaming protocols. It can stream media over computer networks and to transcode multimedia files. The default distribution of VLC includes many free decoding and encoding libraries, avoiding the need for finding/calibrating proprietary plugins. The libavcodec library from the FFmpeg project provides many of VLC's codecs, but the player mainly uses its own muxers and demuxers. It also has its own protocol implementations. It also gained distinction as the first player to support playback of encrypted DVDs on Linux and macOS by using the libdvdcss DVD decryption library.[18] (Wikipedia, n.d.)

VLC as said, is available to smartphones and tablets both for Android and iOs. You can download it for free from the store. For catching and displaying the stream, you must open the VLC app, navigate to menu/Stream and the fill the network address like this ""rtmp://""Server_IP"/" domain_name"". Then it will start displaying the stream content to the device screen. It can also work for Desktop or Laptop computers similarly.

### 3.2.6 Open VR / Steam VR

OpenVR is a software development kit (SDK) and application programming interface developed by Valve for supporting the SteamVR (HTC Vive) and other virtual reality headsets (VR) devices. The SteamVR platform uses it as the default application programming interface (API) and runtime. It serves as the interface between the VR hardware and software and is implemented by SteamVR.

Although OpenVR is the default SDK for HTC Vive, it was developed to have multiple vendor support. For instance, a developer can design OpenVR-based trigger button functions for controllers of Oculus Rift or Windows MR because these systems are both supported by the SDK.[1] (Wikipedia, n.d.)

Unity supports OpenVr SDK, but Steam and SteamVR required to run it. In general lines, SteamVr is the software that implements OpenVR, so game “talk” to SteamVr through OpenVR and then SteamVR talks to HMDs (head-mounted displays) and controllers via the OpenVR Device API.

## 3.3 Application

This project consists of three applications. The main application, which is the VR app and two smartphone/tablet applications for chat and voting. The concept of VR application is that using the idea of an escape room teaches students about mathematics and since. The other two applications are to make the courses more interactable for the rest of the students, giving them the possibility to communicate through chat with the one inside the VR experience. Also, they can help him/her make decisions through voting for possible answers. The VR experience can be displayed through a monitor or by watching the Livestream of the game, by connecting to the RTMP server.

### 3.3.1 VR Application

More specifically, the VR app consists of several lesson scenes for teaching math and since, an escape room scene, a settings scene, a tutorial, and the main menu scene for navigating through the scenes. Both lessons and escape room use the concept of SNR (Signal to Noise Ratio) between a virtual smartphone (receiver) and a virtual router (transmitter). By investigating the SNR behavior related to distance and interference through a graphical representation, while they can observe and save the values of distance and SNR, they called to answer some mathematical or since questions. The whole experience is taking place inside or at the yard of a virtual house.

#### 3.3.1.1 Main Menu

In this scene, the player can choose which scene desires to load by marking with a laser beam the scene he wants and then press the trigger button on the controller. He can choose between Lessons, EscapeRoom, Tutorial, Settings, or exit. By choosing Lessons, he will navigate to the lesson menu where he can choose which lesson, he wants to start. If he chooses EscapeRoom, then the escape room scene will start. The same goes for Tutorial. If he presses Settings, the settings scene will be loaded where he can decide for which grade would be the lessons. Finally, the Exit button will terminate the application.


***Figure 3-12 Main Menu Scene***

### 3.3.1.2 Settings

In the Settings scene, as said before, the player can choose for which grade would be the lessons. That will affect the difficulty of the questions that the player will be called to answer later. The way to choose the grade from the setting menu is the same as the main menu.


***Figure 3-13 Settings Scene***

### 3.3.1.3 Tutorial

This scene guide through the player into all the mechanics of the game that he will need in order to be able to use the app. The main mechanics of the game are:

1. pick up and interact with objects: For example, open a door or pick up a key
2. teleportation: The way the player moves around the house
3. Navigate through virtual smartphone menus.
4. Saving the SNR values.


***Figure 3-14 Tutorial Scene***

### 3.3.1.4 Escape Room

This is the main room that the player called to escape using the SNR values. The player must find two hidden antennas and place them to the router to maximize his signal strength. He also needs to minimize the noise from different objects like a microwave oven. Once the signal strength is the maximum he can achieve, he can open the garage door and escape the room using a menu on his virtual smartphone. He can observe the SNR's graphical representation and values using a specific app on his virtual smartphone. The room also contains hidden keys, that students can get by searching around or solving a puzzle, that opens various doors. Every item the player picks up, it is stored in the inventory and when it is used it disappears. The player can always see the items he possesses by navigating to the Inventory menu in his virtual smartphone. Finally, to make the experience more pleasant, there is a tip boy in various spots in the house that help the player through his quest by giving him hints.


***Figure 3-15 EscapeRoom Scene***

This room is also designed for multiplayer. One or more players (up to four players) can exist in the same room at the same time. All the players must cooperate to escape the room faster. Photon unity taking care of all synchronization needed.

### 3.3.1.5 Lessons

There are six lessons in total. Every lesson is guided by the teacher who gives instructions to the player and to the rest students in the classroom at specific points. The idea is that it needs to be an interaction between students and teachers to strengthen their bonds and make them collaborate better in the future. Every lesson is separated into six sections.

- First section: Introduction to the lesson and store a few measurements.
- Second section: Short quiz.
- Third section: Display results (Question-Player Answer-Correct Answer).
- Fourth section: Move around the house and collect measurements.

- Fifth section: Main quiz.
- Sixth section: Display results.

At first and fourth section the rest of the class is asked too, to record in a table the measurements in each room so they can help the player later to calculate and choose the right answer by voting.

At quiz sections (second and fifth section) there is a table that displays the measurements that the payer stored in each room. There are also a graphical representation of those measurements and a table with the votes (quantity and percentage) that the rest students suggested.

Each lesson comes with a written plan to guide through the teachers conduct the lesson.

- Lesson 1 – Mathematics, Grade 6th – Measures of Central Tendency on Signal Strength and Distance
- Lesson 2 – Mathematics, Grade 7th – Percentages Using Signal Strength and Distance
- Lesson 3 – Mathematics, Grade 8th – Proportional/Non-Proportional Relationships Using Signal Strength and Distance
- Lesson 4 – Mathematics, Grade 6th – Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and Distance
- Lesson 5 – Science, Grade 8th – Investigating the Propagation of Electromagnetic Wave Signals
- Lesson 6 – Science, Grade 8th – Investigating the Interference of Waves

### 3.3.2 Chat Application

Chat Application is an Android and iOS app, that students in the classroom use to communicate with the player inside the VR EscapeRoom. It has four predefined messages: Go Front, Go Back, Go Left, Go Right. That way, they can help the player escape the room and make the students pay attention to the course of the game as they participate too into the experience. The chat app also was built in Unity using Photon for networking.

### 3.3.3 Vote Application

Vote Application is an Android and iOS app, that students in the classroom use to vote which answer they believe is the right one at quiz sections. The votes are displayed on a table at the quiz section in the VR lesson. The voting app also was built in Unity using Photon for networking.

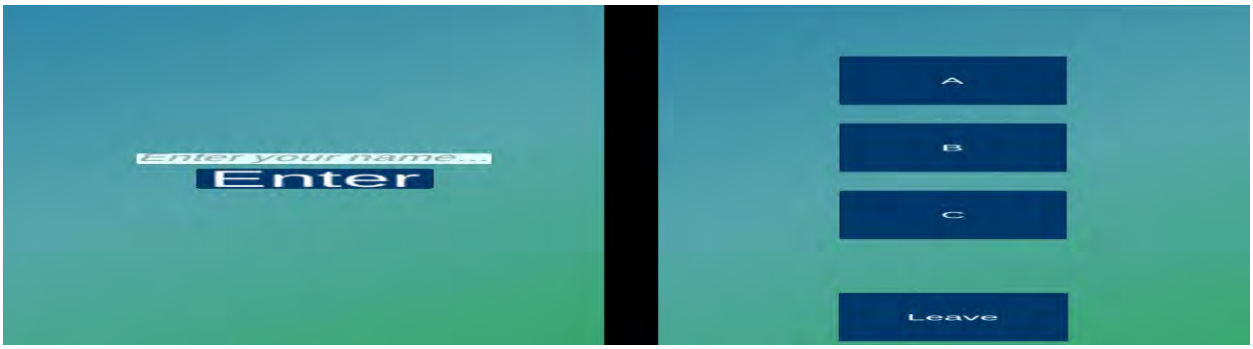


***Figure 3-16 Vote Application***

## 3.4 MATLAB Simulation

MATLAB (*matrix laboratory*) is a multi-paradigm numerical computing environment and proprietary programming language developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran, and Python.[20] (wikipedia, n.d.)

I used MATLAB to simulate the signal strength measurements needed for the SNR simulation. The simulation is done using indoor propagation with multipath models.

## 3.5 Unity Assets

Unity assets used for this project:

- Photon Unity Networking Classic version 1.99
- Procedural fire version 1.0
- Hammer version initial
- TextMesh Pro version 1.2.2
- Desktop PC Set version 1.1
- Graph And Chart version 1.81
- HQ Suburban House version 1.3
- PUN 2 – FREE version 2.15
- FREE Smartphone version 1.0
- Handpainted Keys version 1.0
- SteamVR Plugin version 2.2.0
- 1 toon teen version 1.0
- Water Splash Pack version 4.1

# 4 Conclusion and Future Work

## 4.1 Conclusion

Virtual Reality is the future of education. It can be used not only inside a classroom but for e-learning too. Limitations of the past, like distance or cost, are now out of the question. My engagement in virtual Reality for this thesis saw me the potential of this technology and the possibilities that offer. Features like simulations that can be observed from all over the world real-time, user interaction with virtual worlds and virtual objects and many more are possible, creating that way an experience that can educate while the user is having fun. That makes education more pleasant and more desirable.

In this thesis, I created a virtual reality application that teaches the concept of signal to noise ratio (SNR) and using this concept, educates students in mathematics and science through some virtual reality lessons. The application has the feature of multiplayer, meaning that more than one person can participate in the experience at the same time. Also, while the experience taking part, game streams the content in the form of a 2D video that can be watched from anywhere. The rest students outside of the VR experience can participate in using some external applications on their smartphones or tablets that can give directions to the player or vote for possible answers. The central development of the application was done with the Unity engine.

To make the application more fun and alluring for the students, all its rooms have the concept of an escape room. Students called to escape the room, completing some tasks while they learn about since and mathematics through this process. That way, it is more like playing a video game than taking part in a lesson. That way, students entertain their selves while learning.

## 4.2 Future Work

Some optimizations that can be done to make the application more comprehensive are:

1. Design and development of the “Teachers’ Administrator Framework”. Through this framework the teacher will be able to:
    a. Control and setup several functionalities of the VR experience.
    b. Receive the feedback from the execution of the labs for the students (observe the performance of the students, right/wrong answers, statistics, etc.).
2. Design and development of new education labs based on the signal strength VR scenario that will focus on chemistry and physic.
3. Implementation of potential new software features that will enhance the involvement of the rest of the students of the class into the lab.
4. Port the VR application to more virtual reality hardware.

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# 6 Appendices

## 6.1 Appendix 1. Lesson Plans

# Lesson 1: Measures of Central Tendency on Signal Strength and Distance

Mathematics, 6th Grade

### Introduction

Students will investigate the concept of signal strength and distance in the real-world through an experiment in the Virtual World. The students will also explore other factors that affect wireless communications like obstacles that are present in our surroundings.

| Learning Goals | Description |
|---|---|
| **6.SP.3** Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. | In this lab activity, students will apply what they have learned in **Statistics** specifically on **Measures of Central Tendency** and **Range**. |

### Math Vocabulary

| | |
|---|---|
| **Mean** | The average of the numbers. It is easy to calculate: add up all the numbers, then divide by how many numbers there are. In other words, is the sum divided by the count. |
| **Mode** | The number which appears most often in a set of numbers. Example: in {6, 3, 9, 6, 6, 5, 9, 3} the Mode is 6 (it occurs most often). |
| **Median** | To find the Median, place the numbers in value order and find the middle number. Example: find the Median of {13, 23, 11, 16, 15, 10, 26}. Put them in order: {10, 11, 13, 15, 16, 23, 26}. The middle number is 15, so the median is 15. When there are two middle numbers we average them. |
| **Range** | The difference between the lowest and highest value. In {4, 6, 9, 3, 7} the lowest value is 3, and the highest is 9, so the range is 9 − 3 = 6 |

# Lesson 1: Measures of Central Tendency on Signal Strength and Distance

Mathematics, 6th Grade

## Lesson Plan & Worksheets

**Teacher:**

- Welcome to the Virtual World of Wireless Technology! Today, we are going to learn statistics specifically focusing on signal strength and distance. Watch very closely every move that __<student name>__ do in the virtual world and each team is responsible to take note of all the data gathered all throughout the experiment. __<student name>__, as you enter the Virtual World, look for all the Bubbles that contain all the instructions that the kid helper will give you. Always be alert and be keen to read all the prompts because the success of this experiment is highly dependent on how well you pay attention to all the instructions.

**VR Kid Helper:**

- How are you? Welcome to my beautiful place! Feel at home and I'm hoping you will enjoy being with me today.
- Before you enter my house, I wanted you to pick up your cell phone that is on the table using the trigger button. *<wait for the kid pick-up the cell phone>*
- Now using your cell phone, remember that each time you use the grip button, you can always change the application on your virtual phone. Press grip button only once. *<wait for the kid to press the grip button>*
- First look at your inventory, you will see empty boxes. Look for the key on the table and pick it up using your trigger button. After doing this, you will see the key in your inventory list. Press grip button only once. *<wait for the kid to press the grip button>*
- You will see the Signal to Noise Ratio (SNR) measured in dB while distance will be measured in feet. You will see these units displayed on the cell phone. Press the trigger button only once to save any measurement. *<wait for the kid to press the trigger button>*

# Lesson 1: Measures of Central Tendency on Signal Strength and Distance

Mathematics, 6th Grade

**Teacher: (Addressing to the whole class)**

- Take note at this point, watch what happens as __<student name>__ is outside the door and observe very closely the changes when the door opens. Record the data in your graphic organizer.

**VR Kid Helper:**

- Use the key in the inventory list to open the door by pressing the trigger button. *<wait for the kid to press the trigger button>*
- Did you observe the signal strength when the door opens? Take note how far you are at the moment from the transmitter/router. If you Press the trigger button only once it will save the current measurement that you have right now. *<wait for the kid to press the trigger but button>*
- Enjoy my beautiful home! Now that you are inside my house, use the trackpad button to move to my living room. *<wait for the kid to press the trackpad button>*
- Check the signal strength and your distance from the access point/router.

**Teacher: (Addressing to the whole class)**

- I wanted you to observe the changes in signal strength and distance among the three locations. Compute the differences between the signal strengths. Do the same with the distance as recorded in your graphic organizer.

**NOTE**: Round off values to the nearest whole number.

| Signal Strength [Signal-to-Noise Ratio (SNR) in decibels (dB)] | Distance (feet) | Location |
|---|---|---|
| 24.97≈25 | 17.61≈18 | Outside at doorstep (with the door closed) |
| | | Outside at doorstep (with the door open) |
| | | Living Room |

# Lesson 1: Measures of Central Tendency on Signal Strength and Distance

Mathematics, 6th Grade

**VR Kid Helper:**

- Look for the blue circular teleport point. When you step on top of it, it will turn green which means that it's available for you to use. The red teleport points indicate that you need to perform actions inside the room in order to turn them blue. Now, press the touchpad button to allow you to enter my house. *<wait for the kid to press the trackpad button>*
- You've entered the house. Look for the router/access point on the table. To go near it, use the blue teleport points by pressing the touchpad button. Check the signal strength on your cell phone as well as distance. Have it change? *<wait for the kid to press the trackpad button>*
- Your next task is to explore the house and take the measurements of the signal strength in various locations.

**Teacher: (Addressing to the whole class)**

- Everyone, at this point you need to take down the measurements of the signal strength as your classmate moves at the different locations of the house. Observe very closely the data as it changes and take note when and why it changes. Record the signal strength and the distance away from the transmitter as _____<student name>____ moves around the house. Use your graphic organizer. Using your graphing paper, plot the points on the Cartesian Plane and find out what you see. Is the signal strength proportional to its distance from the transmitter.

| Signal Strength (dB) | Distance (feet) | Location |
|---|---|---|
| | | In front of the router |
| | | Kitchen near the microwave oven |
| | | Hallway |
| | | Parents' Bedroom (2nd floor) |
| | | Boy's Room ( 2nd floor) |
| | | Bathroom |
| | | Garage |

# Lesson 1: Measures of Central Tendency on Signal Strength and Distance

Mathematics, 6th Grade

**Teacher: (Addressing to the whole class)**

- Each team of the class at this point will plot the points of the data combined in Graphic Organizer #1 and #2. Observe the data you have and find out the following information:

| Signal Strength (dB) | Distance (feet) |
|---|---|
| 24.97≈25 | 17.61≈18 |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |

| | Mean | Mode | Median | Range |
|---|---|---|---|---|
| SNR | | | | |
| Distance | | | | |

# Lesson 1: Measures of Central Tendency on Signal Strength and Distance

Mathematics, 6th Grade

**Guide Questions:**

1. What is the meaning of Mean, Median, Mode and Range representing the strength of the signal in the different locations of the house?
2. How is the strength of the signal influenced or changed as_____<student name>____ distance from the transmitter becomes nearer or farther from it.
3. Discuss the meaning of these measures of central tendency and range with regards to the Lab activity that you just did in this VR.

**Teacher: (Addressing to the whole class)**

- In order to escape from the house, __<student name>__needs to answer all the questions correctly! You need to assist in the whole process by giving the clues. Only those Program Runner/Operator from every team will interact with the student on the VR but all members of each team will be helping to give the nearest clue.

**Quiz:**

1. What is the median signal strength of the places visited by _____<student name>____in the house?
2. What is the average distance that _____<student name>____travelled around the house?
3. What is the difference between the highest signal strength and the lowest based on where_____<student name>____moved inside the house?
4. What is the mode of signal strength?
5. What is the average signal strength among the different parts of the house where_____<student name>____?

**Reflection Questions:**

Think about your experiment!!

Your discussion must be detailed and include answers to the following questions:

- Do you feel the data is valid (reliable and accurate)? Why or Why not?
- What were the sources of error in this experiment (factors that may have affected your results)? Explain.
- If you had the opportunity to redo the experiment, what changes would you make? How would you improve it? Explain.
- What new questions did the experiment generate? Explain.
- What did you learn from the experiment? Explain.

# Lesson 2: Percentages Using Signal Strength and Distance

Mathematics, 7th Grade

## Introduction

Students will investigate the concept of signal strength and distance in the real-world through an experiment in the Virtual World. The students will also explore other factors that affect wireless communications like obstacles that are present in our surroundings.

| Learning Goals | Description |
|---|---|
| **7.RP.3** Use proportional relationships to solve multistep ratio and percent problems such percent increase or percent decrease and percent error. | In this lab activity, students will reinforce their learning about **percentages** as well as **percent increase** or **percent decrease**. |

## Math Vocabulary

| | |
|---|---|
| **Ratio** | A numerical comparison of 2 or more quantities with the same unit. |
| **Rate** | A ratio that is used to compare two or more quantities with different units. |
| **Percent** | A ratio whose second term is 100. Percent means parts per hundred. The word comes from the Latin phrase per centum, which means per hundred. In mathematics, we use the symbol % for percent. |
| **Percent Increase** | Computed when a quantity grows bigger. |
| **Percent Decrease** | Computed when a quantity shrinks or gets smaller |

# Lesson 2: Percentages Using Signal Strength and Distance

Mathematics, 7th Grade

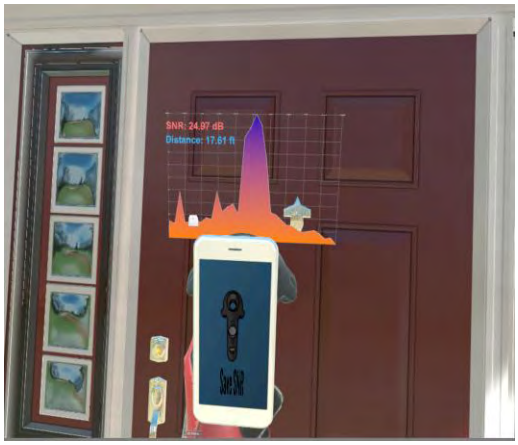
## Lesson Plan & Worksheets

**Teacher:**

- Welcome to the Virtual World of Wireless Technology! Today, we are going to learn percentages specifically focusing on signal strength and distance. Watch very closely every move that __<student name>__ do in the virtual world and each team is responsible to take note of all the data gathered all throughout the experiment. __<student name>__, as you enter the Virtual World, look for all the Bubbles that contain all the instructions that the kid helper will give you. Always be alert and be keen to read all the prompts because the success of this experiment is highly dependent on how well you pay attention to all the instructions.

**VR Kid Helper:**

- How are you? Welcome to my beautiful place! Feel at home and I'm hoping you will enjoy being with me today.
- Before you enter my house, I wanted you to pick up your cell phone that is on the table using the trigger button. *<wait for the kid pick-up the cell phone>*
- Now using your cell phone, remember that each time you use the grip button, you can always change the application on your virtual phone. Press grip button only once. *<wait for the kid to press the grip button>*
- First look at your inventory, you will see empty boxes. Look for the key on the table and pick it up using your trigger button. After doing this, you will see the key in your inventory list. Press grip button only once. *<wait for the kid to press the grip button>*
- You will see the Signal to Noise Ratio (SNR) measured in dB while distance will be measured in feet. You will see these units displayed on the cell phone. Press the trigger button only once to save any measurement. *<wait for the kid to press the trigger button>*

# Lesson 2: Percentages Using Signal Strength and Distance

Mathematics, 7th Grade

**Teacher: (Addressing to the whole class)**

- Take note at this point, watch what happens as __<student name>__ is outside the door and observe very closely the changes when the door opens. Record the data in your graphic organizer.

**VR Kid Helper:**

- Use the key in the inventory list to open the door by pressing the trigger button. *<wait for the kid to press the trigger button>*
- Did you observe the signal strength when the door opens? Take note how far you are at the moment from the transmitter/router. If you Press the trigger button only once it will save the current measurement that you have right now. *<wait for the kid to press the trigger but button>*
- Enjoy my beautiful home! Now that you are inside my house, use the trackpad button to move to my living room. *<wait for the kid to press the trackpad button>*
- Check the signal strength and your distance from the access point/router.

**Teacher: (Addressing to the whole class)**

- I wanted you to observe the changes in signal strength and distance among the three locations. Compute the differences between the signal strengths. Do the same with the distance as recorded in your graphic organizer.

**NOTE**: Round off values to the nearest whole number.

| Signal Strength [Signal-to-Noise Ratio (SNR) in decibels (dB)] | Distance (feet) | Location |
|---|---|---|
| 24.97≈25 | 17.61≈18 | Outside at doorstep (with the door closed) |
| | | Outside at doorstep (with the door open) |
| | | Living Room |

# Lesson 2: Percentages Using Signal Strength and Distance

Mathematics, 7th Grade

**VR Kid Helper:**

- Look for the blue circular teleport point. When you step on top of it, it will turn green which means that it's available for you to use. The red teleport points indicate that you need to perform actions inside the room in order to turn them blue. Now, press the touchpad button to allow you to enter my house. *<wait for the kid to press the trackpad button>*
- You've entered the house. Look for the router/access point on the table. To go near it, use the blue teleport points by pressing the touchpad button. Check the signal strength on your cell phone as well as distance. Have it change? *<wait for the kid to press the trackpad button>*
- Your next task is to explore the house and take the measurements of the signal strength in various locations.

**Teacher: (Addressing to the whole class)**

- Everyone, at this point you need to take down the measurements of the signal strength as your classmate moves at the different locations of the house. Observe very closely the data as it changes and take note when and why it changes. Record the signal strength and the distance away from the transmitter as ____<student name>___ moves around the house. Use your graphic organizer. Using your graphing paper, plot the points on the Cartesian Plane and find out what you see. Is the signal strength proportional to its distance from the transmitter.

| Signal Strength (dB) | Distance (feet) | Location |
|---|---|---|
| | | In front of the router |
| | | Kitchen near the microwave oven |
| | | Hallway |
| | | Parents' Bedroom (2nd floor) |
| | | Boy's Room ( 2nd floor) |
| | | Bathroom |
| | | Garage |

# Lesson 2: Percentages Using Signal Strength and Distance

Mathematics, 7th Grade

**Teacher: (Addressing to the whole class)**

- Each team of the class at this point will plot the points of the data combined in Graphic Organizer #1 and #2. Observe the data you have and find out the following information:

| Locations | Amount of Increase/Decrease | | Percent of Increase/Decrease | |
|---|---|---|---|---|
| | Signal Strength (dB) | Distance (feet) | Signal Strength (dB) | Distance (feet) |
| Front of Router versus Kitchen | | | | |
| Kitchen versus Hallway | | | | |
| Hallway versus Parents' bedroom | | | | |
| Parents' Bedroom versus Boy's Room | | | | |
| Boy's Room versus Garage | | | | |

**Teacher: (Addressing to the whole class)**

- In order to escape from the house, __<student name>__needs to answer all the questions correctly! You need to assist in the whole process by giving the clues. Only those Program Runner/Operator from every team will interact with the student on the VR but all members of each team will be helping to give the nearest clue.

# Lesson 2: Percentages Using Signal Strength and Distance

Mathematics, 7th Grade

**Quiz:**

1. How many percent was the increase of signal strength from the backyard to the spot near the router?
2. How far from the router can you be to get 25% drop of the highest/strongest signal in this activity?
3. Which spot in the house has the highest % of increase in signal strength?
4. What is the % decrease of signal strength from the location near the router to the boy's bedroom?
5. How far should you be from the router to get a 75% drop of signal strength?

**Reflection Questions:**

Think about your experiment!!

Your discussion must be detailed and include answers to the following questions:

- How did your data from Graphic Organizer #1 and Graphic Organizer #2 the same?
- How are both data different?
- What are some factors that could've led to differences between the two parts?
- Do you feel the data is valid (reliable and accurate)? Why or Why not?
- What were the sources of error in this experiment (factors that may have affected your results)? Explain.
- If you had the opportunity to redo the experiment, what changes would you make? How would you improve it? Explain.
- What new questions did the experiment generate? Explain.
- What did you learn from the experiment? Explain.

# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

## Introduction

Students will investigate the concept of signal strength and distance in the real-world through an experiment in the Virtual World. The students will also explore other factors that affect wireless communications like obstacles that are present in our surroundings.

| Learning Goals | Description |
|---|---|
| **8.F.B.5** Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). | In this lab activity, students will specifically find out if the two variables compared are **proportional** and **non-proportional** as well as **linear** or **non-linear**. |

## Math Vocabulary

| | |
|---|---|
| **Constant of Proportionality** | Constant value of the ratio of two proportional quantities x and y; usually written y = k*x, where k is the factor of proportionality. |
| **Ordered Pair** | A pair of numbers used to locate a point on a coordinate plane is called an ordered pair. An ordered pair is written in the form (x, y) where x is the x-coordinate and y is the y-coordinate. |
| **Cartesian Coordinate System** | A system that specifies each point uniquely in a plane by a set of numerical coordinates, which are the signed distances to the point from two fixed perpendicular oriented lines, measured in the same unit of length . Each reference line is called a coordinate axis or axis (plural axes) of the system, and the point where they meet is its origin , at ordered pair (0, 0). The coordinates can also be defined as the positions of the perpendicular projections of the point onto the two axes, expressed as signed distances from the origin . |
| **Regression Analysis** | A process of creating a mathematical model that can be used to predict the values of the dependent variable based upon the values of an independent variable. In other words, we use the model to predict the value of Y when we know the value of X. (The dependent variable is the one to be predicted). |
| **Independent variable** | A variable that represents a quantity that is being manipulated in an experiment. |
| **Dependent variable** | Represents a quantity whose value depends on those manipulations. |

# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

## Math Vocabulary

| | |
|---|---|
| **Scatter Plot** | A graph of plotted points that show the relationship between two sets of data. |
| **Linear Regression** | A linear approach to modeling the relationship between a scalar response (or dependent variable) and one or more explanatory variables (or independent variables). The case of one explanatory variable is called simple linear regression. |
| **Non-Linear Regression** | A form of regression analysis in which observational data are modeled by a function which is a nonlinear combination of the model parameters and depends on one or more independent variables |
| **Correlation** | A measure of relationship between two variables. A value of +1 means a perfect positive relation between the variables, that is, they are related by an increasing linear function |
| **Pearson's correlation coefficient** | A type of correlation coefficient that represents the relationship between two variables that are measured on the same interval or ratio scale. The Pearson coefficient is a measure of the strength of association between two continuous variables. |

# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

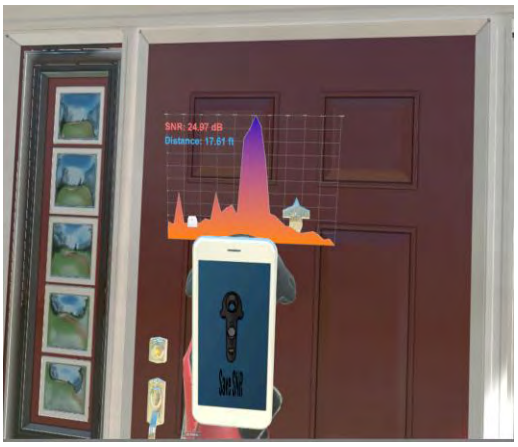
## Lesson Plan & Worksheets

**Teacher:**

- Welcome to the Virtual World of Wireless Technology! Today, we are going to learn proportionality specifically focusing on signal strength and distance. Watch very closely every move that __<student name>__ do in the virtual world and each team is responsible to take note of all the data gathered all throughout the experiment. __<student name>__, as you enter the Virtual World, look for all the Bubbles that contain all the instructions that the kid helper will give you. Always be alert and be keen to read all the prompts because the success of this experiment is highly dependent on how well you pay attention to all the instructions.

**VR Kid Helper:**

- How are you? Welcome to my beautiful place! Feel at home and I'm hoping you will enjoy being with me today.
- Before you enter my house, I wanted you to pick up your cell phone that is on the table using the trigger button. *<wait for the kid pick-up the cell phone>*
- Now using your cell phone, remember that each time you use the grip button, you can always change the application on your virtual phone. Press grip button only once. *<wait for the kid to press the grip button>*
- First look at your inventory, you will see empty boxes. Look for the key on the table and pick it up using your trigger button. After doing this, you will see the key in your inventory list. Press grip button only once. *<wait for the kid to press the grip button>*
- You will see the Signal to Noise Ratio (SNR) measured in dB while distance will be measured in feet. You will see these units displayed on the cell phone. Press the trigger button only once to save any measurement. *<wait for the kid to press the trigger button>*

# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

**Teacher: (Addressing to the whole class)**

- Take note at this point, watch what happens as __<student name>__ is outside the door and observe very closely the changes when the door opens. Record the data in your graphic organizer.

**VR Kid Helper:**

- Use the key in the inventory list to open the door by pressing the trigger button. *<wait for the kid to press the trigger button>*
- Did you observe the signal strength when the door opens? Take note how far you are at the moment from the transmitter/router. If you Press the trigger button only once it will save the current measurement that you have right now. *<wait for the kid to press the trigger but button>*
- Enjoy my beautiful home! Now that you are inside my house, use the trackpad button to move to my living room. *<wait for the kid to press the trackpad button>*
- Check the signal strength and your distance from the access point/router.

**Teacher: (Addressing to the whole class)**

- I wanted you to observe the changes in signal strength and distance among the three locations. Compute the differences between the signal strengths. Do the same with the distance as recorded in your graphic organizer.

**NOTE**: Round off values to the nearest whole number.

| Signal Strength [Signal-to-Noise Ratio (SNR) in decibels (dB)] | Distance (feet) | Location |
|---|---|---|
| 24.97≈25 | 17.61≈18 | Outside at doorstep (with the door closed) |
| | | Outside at doorstep (with the door open) |
| | | Living Room |

# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

**VR Kid Helper:**

- Look for the blue circular teleport point. When you step on top of it, it will turn green which means that it's available for you to use. The red teleport points indicate that you need to perform actions inside the room in order to turn them blue. Now, press the touchpad button to allow you to enter my house. *<wait for the kid to press the trackpad button>*
- You've entered the house. Look for the router/access point on the table. To go near it, use the blue teleport points by pressing the touchpad button. Check the signal strength on your cell phone as well as distance. Have it change? *<wait for the kid to press the trackpad button>*
- Your next task is to explore the house and take the measurements of the signal strength in various locations.

**Teacher: (Addressing to the whole class)**

- Everyone, at this point you need to take down the measurements of the signal strength as your classmate moves at the different locations of the house. Observe very closely the data as it changes and take note when and why it changes. Record the signal strength and the distance away from the transmitter as _____<student name>____ moves around the house. Use your graphic organizer. Using your graphing paper, plot the points on the Cartesian Plane and find out what you see. Is the signal strength proportional to its distance from the transmitter.

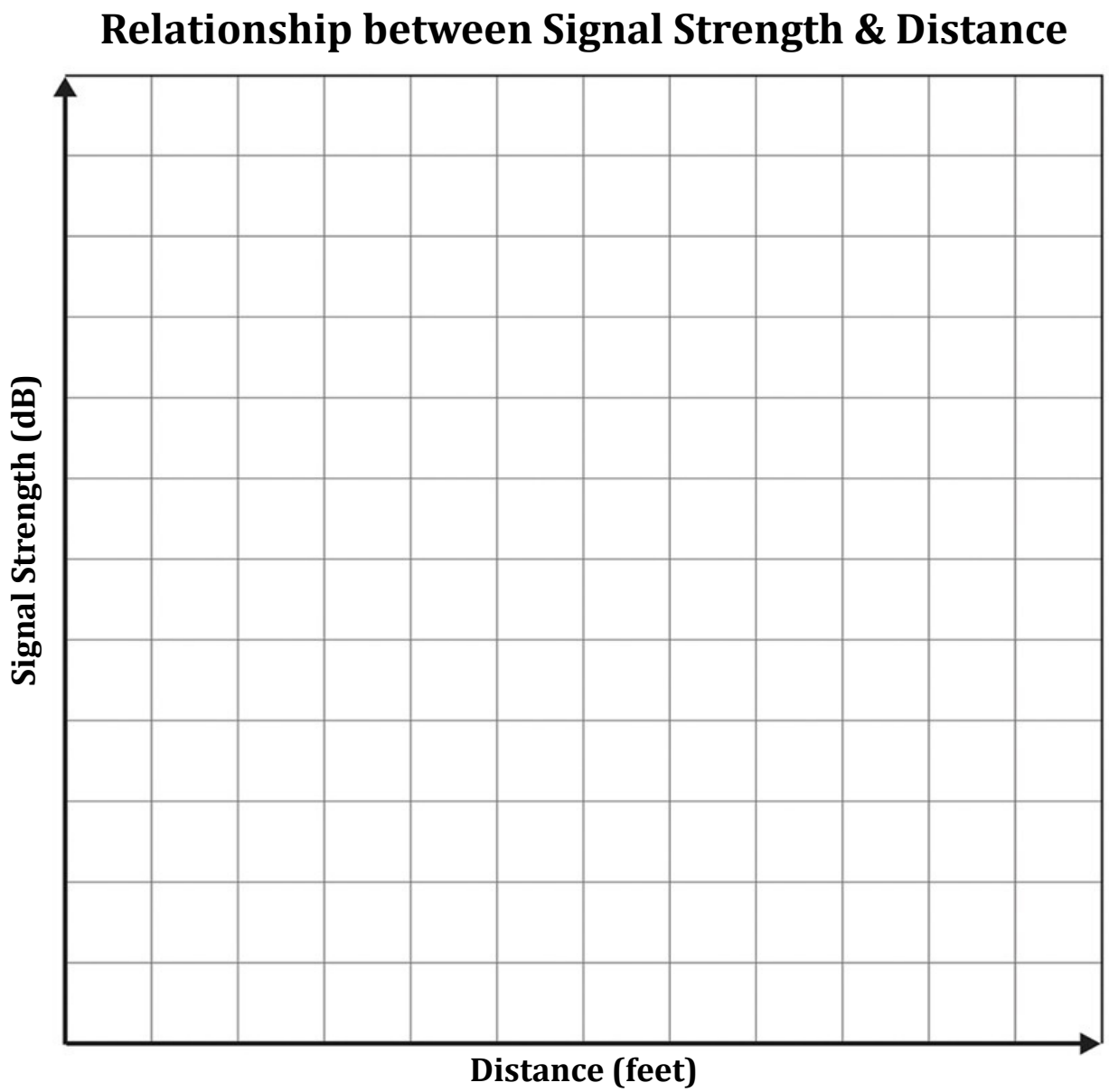
| Signal Strength (dB) | Distance (feet) | Location |
|---|---|---|
| | | In front of the router |
| | | Kitchen near the microwave oven |
| | | Hallway |
| | | Parents' Bedroom (2nd floor) |
| | | Boy's Room ( 2nd floor) |
| | | Bathroom |
| | | Garage |

# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

**Teacher: (Addressing to the whole class)**

- Each team of the class at this point will plot the points of the data combined in Graphic Organizer #1 and #2. Observe the data you have and find out the following information:



# Lesson 3: Proportional/Non-Proportional Relationships Using Signal Strength and Distance

Mathematics, 8th Grade

**Quiz:**

1. What is the ratio of signal strength and distance near the microwave?
2. What is the difference between the ratio of signal strength and distance between the kitchen and the Parents' bedroom?
3. What is the ratio of signal strength and distance in the hallway?
4. Is there a constant of proportionality between signal strength and distance among the data points?
5. Is the relationship between the distance and signal strength in this Lab proportional or non-proportional?

**Reflection Questions:**

Think about your experiment!!

Your discussion must be detailed and include answers to the following questions:

- How did your data from Graphic Organizer #1 and Graphic Organizer #2 the same?
- How are both data different?
- What are some factors that could've led to differences between the two parts?
- Do you feel the data is valid (reliable and accurate)? Why or Why not?
- What were the sources of error in this experiment (factors that may have affected your results)? Explain.
- If you had the opportunity to redo the experiment, what changes would you make? How would you improve it? Explain.
- What new questions did the experiment generate? Explain.
- What did you learn from the experiment? Explain.

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

## Introduction

Students will investigate the concept of signal strength and distance in the real-world through an experiment in the Virtual World. The students will also explore other factors that affect wireless communications like obstacles that are present in our surroundings.

| Learning Goals | Description |
|---|---|
| **8.F.B.5** Describe qualitatively the functional relationship between two quantities by analyzing a graph (e.g., where the function is increasing or decreasing, linear or nonlinear). | In this lab activity, students will apply what they have learned about **converting fractions into decimal**s as well as **changing decimals into fractions**. |

## Math Vocabulary

| | |
|---|---|
| **Fractions** | A fraction simply tells us how many parts of a whole we have. You can recognize a fraction by the slash that is written between the two numbers. We have a top number, the numerator, and a bottom number, the denominator. |
| **Decimals** | Any number in our base-ten number system where the decimal point is used to separate the ones place from the tenths place in decimals. (It is also used to separate dollars from cents in money.) As we move to the right of the decimal point, each number is divided by 10. |
| **Changing Fractions to Decimals** | We divide the numerator by the denominator using long division |
| **Changing Decimals to Fractions** | 1. Write down the decimal divided by 1<br>2. Multiply both top and bottom by 10 for every number after the decimal point. (i.e., if there are two numbers after the decimal point, then use 100, if there are three then use 1000, etc.)<br>3. Simplify (or reduce) the fraction. |

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

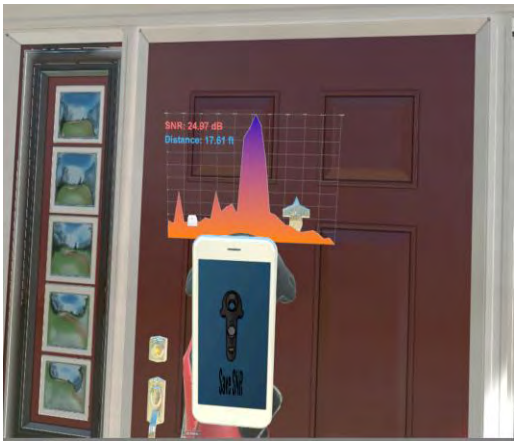
## Lesson Plan & Worksheets

**Teacher:**

- Welcome to the Virtual World of Wireless Technology! Today, we are going to learn percentages specifically focusing on signal strength and distance. Watch very closely every move that __<student name>__ do in the virtual world and each team is responsible to take note of all the data gathered all throughout the experiment. __<student name>__, as you enter the Virtual World, look for all the Bubbles that contain all the instructions that the kid helper will give you. Always be alert and be keen to read all the prompts because the success of this experiment is highly dependent on how well you pay attention to all the instructions.

**VR Kid Helper:**

- How are you? Welcome to my beautiful place! Feel at home and I'm hoping you will enjoy being with me today.
- Before you enter my house, I wanted you to pick up your cell phone that is on the table using the trigger button. *<wait for the kid pick-up the cell phone>*
- Now using your cell phone, remember that each time you use the grip button, you can always change the application on your virtual phone. Press grip button only once. *<wait for the kid to press the grip button>*
- First look at your inventory, you will see empty boxes. Look for the key on the table and pick it up using your trigger button. After doing this, you will see the key in your inventory list. Press grip button only once. *<wait for the kid to press the grip button>*
- You will see the Signal to Noise Ratio (SNR) measured in dB while distance will be measured in feet. You will see these units displayed on the cell phone. Press the trigger button only once to save any measurement. *<wait for the kid to press the trigger button>*

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

**Teacher: (Addressing to the whole class)**

- Take note at this point, watch what happens as __<student name>__ is outside the door and observe very closely the changes when the door opens. Record the data in your graphic organizer.

**VR Kid Helper:**

- Use the key in the inventory list to open the door by pressing the trigger button. *<wait for the kid to press the trigger button>*
- Did you observe the signal strength when the door opens? Take note how far you are at the moment from the transmitter/router. If you Press the trigger button only once it will save the current measurement that you have right now. *<wait for the kid to press the trigger but button>*
- Enjoy my beautiful home! Now that you are inside my house, use the trackpad button to move to my living room. *<wait for the kid to press the trackpad button>*
- Check the signal strength and your distance from the access point/router.

**Teacher: (Addressing to the whole class)**

- I wanted you to observe the changes in signal strength and distance among the three locations. Compute the differences between the signal strengths. Do the same with the distance as recorded in your graphic organizer.

**NOTE**: Round off values to the nearest whole number.

| Signal Strength [Signal-to-Noise Ratio (SNR) in decibels (dB)] | Distance (feet) | Location |
|---|---|---|
| 24.97≈25 | 17.61≈18 | Outside at doorstep (with the door closed) |
| | | Outside at doorstep (with the door open) |
| | | Living Room |

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

**Teacher: (Addressing to the whole class)**

- Express the ratio (fraction) between the signal strength and distance using the data recorded in your graphic organizer. Based on our knowledge of conversion, change each fraction to its decimal equivalent and vice-versa. Approximate the signal strength and distance to the nearest whole number.

| Location | Fraction to Decimal | Decimal to Fraction |
|---|---|---|
| Backyard (outside with the door closed) | $\frac{25}{18} = 1.388888889$ | |
| At the doorstep with door open | | |
| Living Room | | |

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

**VR Kid Helper:**

- Look for the blue circular teleport point. When you step on top of it, it will turn green which means that it's available for you to use. The red teleport points indicate that you need to perform actions inside the room in order to turn them blue. Now, press the touchpad button to allow you to enter my house. *<wait for the kid to press the trackpad button>*
- You've entered the house. Look for the router/access point on the table. To go near it, use the blue teleport points by pressing the touchpad button. Check the signal strength on your cell phone as well as distance. Have it change? *<wait for the kid to press the trackpad button>*
- Your next task is to explore the house and take the measurements of the signal strength in various locations.

**Teacher: (Addressing to the whole class)**

- Everyone, at this point you need to take down the measurements of the signal strength as your classmate moves at the different locations of the house. Observe very closely the data as it changes and take note when and why it changes. Record the signal strength and the distance away from the transmitter as _____<student name>____ moves around the house. Use your graphic organizer. Using your graphing paper, plot the points on the Cartesian Plane and find out what you see. Is the signal strength proportional to its distance from the transmitter.

| Signal Strength (dB) | Distance (feet) | Location |
|---|---|---|
| | | In front of the router |
| | | Kitchen near the microwave oven |
| | | Hallway |
| | | Parents' Bedroom (2nd floor) |
| | | Boy's Room ( 2nd floor) |
| | | Bathroom |
| | | Garage |

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

**Teacher: (Addressing to the whole class)**

- Based on the second graphic organizer, express the ratio (fraction) between the signal strength and distance. Approximate the signal strength and distance to the nearest whole number and use the table below to show your conversions.

| Location | Fraction to Decimal | Decimal to Fraction |
|---|---|---|
| In front of the router | | |
| Kitchen near the microwave oven | | |
| Hallway | | |
| Parents' Bedroom (2nd floor) | | |
| Boy's Room ( 2nd floor) | | |
| Bathroom | | |
| Garage | | |

# Lesson 4: Changing Fractions to Decimals or Decimals to Fractions Using Signal Strength and

Mathematics, 6th Grade

**Quiz:**

1. What is the fraction representing the signal strength and distance if you are in the hallway?
2. What is the decimal representing the signal strength and distance if you are in the living room? Round off to the nearest tenth.
3. How do you convert the fraction to decimal representing the signal strength and distance near the microwave oven?
4. Which spot in the house is the ratio of signal strength to distance the lowest?
5. What fraction represents the signal strength between the Parents' Bedroom and the garage?

**Reflection Questions:**

Think about your experiment!!

Your discussion must be detailed and include answers to the following questions:

- How did your data from Graphic Organizer #1 and Graphic Organizer #2 the same?
- How are both data different?
- What are some factors that could've led to differences between the two parts?
- Do you feel the data is valid (reliable and accurate)? Why or Why not?
- What were the sources of error in this experiment (factors that may have affected your results)? Explain.
- If you had the opportunity to redo the experiment, what changes would you make? How would you improve it? Explain.
- What new questions did the experiment generate? Explain.
- What did you learn from the experiment? Explain.

# Lesson 5: Investigating the Propagation of Electromagnetic Wave Signals

Science, 8th Grade

## Introduction

Students will investigate the concept of signal strength and distance in the real-world through an experiment in the Virtual World. The students will also explore other factors that affect wireless communications like obstacles that are present in our surroundings.

| Learning Goals | Description |
|---|---|
| **MS-PS4-3.** Integrate qualitative, scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. | In this lab activity, students will investigate on how distance and obstacles affects the transmission of **electromagnetic signals**. |

## Science Vocabulary

| | |
|---|---|
| **Definition of a wave** | 1. A wave is a kind of oscillation (disturbance) that travels through matter and space. Wave motion transfers energy from one place to another.<br>2. Verb.: To move to and from with a swaying or undulating motion while remaining fixed to one point.<br>3. Noun.: A long body of water curling into an arched form and breaking on the shore. |
| **Types of Waves** | There are 2 main types of waves, mechanical waves and electromagnetic waves.<br>1. Mechanical waves can only travel through matter. They cannot travel through space. Transverse waves and compressional (longitudinal) waves are examples of mechanical waves.<br>2. A transverse wave is a mechanical wave that can only travel through matter. Transverse waves cause particles in matter to move back and forth at right angles to the direction in which the wave travels.<br>3. A compressional wave (also known as a longitudinal wave) is a mechanical wave that can only travel through matter. Compressional waves cause particles in matter to move back and forth along the same direction in which the wave travels.<br>4. Electromagnetic waves consist of 2 transverse waves. They have an electric part and a magnetic part. The 2 waves vibrate at right angles (perpendicular) to the wave motion. Electromagnetic waves make up the electromagnetic spectrum. This is the complete range of electromagnetic wavelengths and frequencies. The spectrum consists of radio waves, microwaves, infrared waves, visible light, ultraviolet waves, x-rays, gamma rays. |

# Lesson 5: Investigating the Propagation of Electromagnetic Wave Signals

Science, 8th Grade

**Science Vocabulary**

| | |
|---|---|
| **Transmitter** | A transmitter is a set of equipment used to generate and transmit electromagnetic waves carrying messages or signals, especially those of radio or television. The messages or signals can be voice, text, video, or photograph |
| **Receiver** | Electronic receivers are any of various devices that accept electromagnetic wave signals, such as radio waves, and convert them (frequently with amplification) into a useful form. Examples are telephone receivers, which transform electrical impulses into audio signals, and radio or television receivers, which accept electromagnetic waves and convert them into sound or television pictures. |

# Lesson 5: Investigating the Propagation of Electromagnetic Wave Signals

Science, 8th Grade

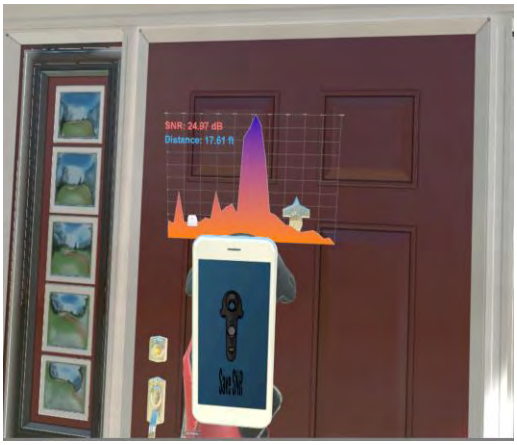
## Lesson Plan & Worksheets

**Teacher:**

- Welcome to the Virtual World of Wireless Technology! Today, we are going to learn how electromagnetic signals propagate specifically focusing on signal strength and distance. Watch very closely every move that __<student name>__ do in the virtual world and each team is responsible to take note of all the data gathered all throughout the experiment. __<student name>__, as you enter the Virtual World, look for all the Bubbles that contain all the instructions that the kid helper will give you. Always be alert and be keen to read all the prompts because the success of this experiment is highly dependent on how well you pay attention to all the instructions.

**VR Kid Helper:**

- How are you? Welcome to my beautiful place! Feel at home and I'm hoping you will enjoy being with me today.
- Before you enter my house, I wanted you to pick up your cell phone that is on the table using the trigger button. *<wait for the kid pick-up the cell phone>*
- Now using your cell phone, remember that each time you use the grip button, you can always change the application on your virtual phone. Press grip button only once. *<wait for the kid to press the grip button>*
- First look at your inventory, you will see empty boxes. Look for the key on the table and pick it up using your trigger button. After doing this, you will see the key in your inventory list. Press grip button only once. *<wait for the kid to press the grip button>*
- You will see the Signal to Noise Ratio (SNR) measured in dB while distance will be measured in feet(ft). You will see these units displayed on the cell phone. Press the trigger button only once to save any measurement. *<wait for the kid to press the trigger button>*


**Teacher: (Addressing to the whole class)**

- Take note at this point, watch what happens as __<student name>__ is outside the door and observe very closely the changes when the door opens. Record the data in your graphic organizer.

# Lesson 5: Investigating the Propagation of Electromagnetic Wave Signals

Science, 8th Grade

**VR Kid Helper:**

- Use the key in the inventory list to open the door by pressing the trigger button. *<wait for the kid to press the trigger button>*
- Did you observe the signal strength when the door opens? Take note how far you are at the moment from the transmitter/router. If you Press the trigger button only once it will save the current measurement that you have right now. *<wait for the kid to press the trigger but button>*
- Enjoy my beautiful home! Now that you are inside my house, use the trackpad button to move to my living room. *<wait for the kid to press the trackpad button>*
- Check the signal strength and your distance from the access point/router.

**Teacher: (Addressing to the whole class)**

- I wanted you to observe the changes in signal strength and distance among the three locations. Compute the differences between the signal strengths. Do the same with the distance as recorded in your graphic organizer.

**NOTE**: Round off values to the nearest whole number.

**Guide Questions:**

1. Did the signal strength increase or decrease as you went closer to the access point/router?
2. So, if you were to go far away from the access point/router would you expect the signal strength to get stronger or weaker? Why do you think this happens?
3. When you reduce the distance between yourself and the router and that causes the signal strength to get stronger, that is a special kind of relationship. In other words, as you decrease the distance the signal strength increases. Explain what kind of relationship exists between the signal strength and distance?
4. If you were to go to the bedroom upstairs what would you expect to happen to the signal strength? Explain why this would happen?

| Signal Strength [Signal-to-Noise Ratio (SNR) in decibels (dB)] | Distance (feet) | Location |
|---|---|---|
| 24.97≈25 | 17.61≈18 | Outside at doorstep (with the door closed) |
| | | Outside at doorstep (with the door open) |
| | | Living Room |

# Lesson 5: Investigating the Propagation of Electromagnetic Wave Signals

Science, 8th Grade

**VR Kid Helper:**

- Look for the blue circular teleport point. When you step on top of it, it will turn green which means that it's available for you to use. The red teleport points indicate that you need to perform actions inside the room in order to turn them blue. Now, press the touchpad button to allow you to enter my house. *<wait for the kid to press the trackpad button>*
- You've entered the house. Look for the router/access point on the table. To go near it, use the blue teleport points by pressing the touchpad button. Check the signal strength on your cell phone as well as distance. Have it change? *<wait for the kid to press the trackpad button>*
- Your next task is to explore the house and take the measurements of the signal strength in various locations.

**Teacher: (Addressing to the whole class)**

- Everyone, at this point you need to take down the measurements of the signal strength as your classmate moves at the different locations of the house. Observe very closely the data as it changes and take note when and why it changes. Record the signal strength and the distance away from the transmitter as _____<student name>____ moves around the house.

| Signal Strength (dB) | Distance (feet) | Location |
|---|---|---|
| | | In front of the router |
| | | Kitchen near the microwave oven |
| | | Hallway |
| | | Parents' Bedroom (2nd floor) |
| | | Boy's Room ( 2nd floor) |
| | | Bathroom |
| | | Garage |

# Lesson 5: Investigating the Propagation of Electromagnetic Wave Signals

Science, 8th Grade

**Quiz:**

1. What is the unit for measuring signal strength?
2. What type of wave is used to transmit the signal you measured outside and inside the house?
3. Inside the house the electromagnetic wave signal was coming from the _____ .
4. When one factor increases and another factor decreases at the same time, the two factors are said to have an _____ relationship.

**Reflection Questions:**

Think about your experiment!!

Your discussion must be detailed and include answers to the following questions:

- What other things do you think could affect the strength of electromagnetic wave signals?
- Why do you think that your cell phone loses service sometimes when you go in the mountains on a camping trip?
- In recent time people can now get cell phone service unground in the subway. How is this possible?
- What things do you think can block cell phone signals?
- What do you think could cause the world wide cell phone service to crash? How could we prevent that?

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

## Introduction

Students will investigate the concept of signal strength and distance in the real-world through an experiment in the Virtual World. The students will also explore other factors that affect wireless communications like obstacles that are present in our surroundings.

| Learning Goals | Description |
|---|---|
| **MS-PS4-3.** Integrate qualitative, scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. | In this lab activity, students will how **interference** affects the **strength** and **quality** of the **electromagnetic wave signal**. |

## Science Vocabulary

**Definition of a wave**

1. A wave is a kind of oscillation (disturbance) that travels through matter and space. Wave motion transfers energy from one place to another.
2. Verb.: To move to and from with a swaying or undulating motion while remaining fixed to one point.
3. Noun.: A long body of water curling into an arched form and breaking on the shore.

**Types of Waves**

There are 2 main types of waves, mechanical waves and electromagnetic waves.

1. Mechanical waves can only travel through matter. They cannot travel through space. Transverse waves and compressional (longitudinal) waves are examples of mechanical waves.
    2. A transverse wave is a mechanical wave that can only travel through matter. Transverse waves cause particles in matter to move back and forth at right angles to the direction in which the wave travels.
    3. A compressional wave (also known as a longitudinal wave) is a mechanical wave that can only travel through matter. Compressional waves cause particles in matter to move back and forth along the same direction in which the wave travels.
4. Electromagnetic waves consist of 2 transverse waves. They have an electric part and a magnetic part. The 2 waves vibrate at right angles (perpendicular) to the wave motion. Electromagnetic waves make up the electromagnetic spectrum. This is the complete range of electromagnetic wavelengths and frequencies. The spectrum consists of radio waves, microwaves, infrared waves, visible light, ultraviolet waves, x-rays, gamma rays.

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

**Science Vocabulary**

| | |
|---|---|
| **Transmitter** | A transmitter is a set of equipment used to generate and transmit electromagnetic waves carrying messages or signals, especially those of radio or television. The messages or signals can be voice, text, video, or photograph |
| **Receiver** | Electronic receivers are any of various devices that accept electromagnetic wave signals, such as radio waves, and convert them (frequently with amplification) into a useful form. Examples are telephone receivers, which transform electrical impulses into audio signals, and radio or television receivers, which accept electromagnetic waves and convert them into sound or television pictures. |
| **Radio wave** | A radio wave is an electromagnetic wave, and part of the electromagnetic spectrum. The vast majority of modern electronic communications are done using radio waves. Radio waves have different frequencies, and by tuning a radio receiver to a specific frequency you can pick up a specific signal. All FM radio stations transmit in a band of frequencies between 88 megahertz and 108 megahertz. |
| **Microwaves** | Microwaves are shorter than radio waves with wavelengths measured in centimeters. We use microwaves to cook food, transmit information, and in radar that helps to predict the weather. Microwaves are useful in communication because they can penetrate clouds, smoke, and light rain. Common equipment that use microwaves include motion detectors, radar guns for speed-limit enforcement, weather radar and radar altimeters (instrument used to measure height above the ground). |
| **Infrared Radiation waves** | Infrared radiation (IR), sometimes referred to simply as infrared, is a region of the electromagnetic radiation spectrum where wavelengths range from about 700 nanometers (nm) to 1 millimeter (mm). Infrared waves are longer than those of visible light, but shorter than those of radio waves. Infrared is used in a variety of applications. Among the most well-known are heat sensors, thermal imaging and night vision equipment. In communications and networking, infrared light is used in wired and wireless operations. Remote controls use near-infrared light, transmitted with light-emitting diodes (LEDs), to send focused signals to home-entertainment devices, such as televisions. Infrared light is also used in fiber optic cables to transmit data. |

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

**Science Vocabulary**

**Interference of Waves**

- Interference is the process in which two or more waves combine to reinforce or cancel each other out. The amplitude of the resulting wave will be equal to the sum of the amplitudes of the combining waves.
- When two waves collide, they form a new signal altering the properties of the wave, this phenomenon is called interference. Interference effects can be observed with all types of waves, for example, light, radio, acoustic, surface water waves, gravity waves, or matter waves

**Types of Interference**

Wireless interference is an important consideration when you're planning a wireless network. Interference is inevitable, but the trick is to minimize the levels of interference. Wireless Local Area Network communications (WLANs, or Wi-Fi) are most often based on radio frequency signals that require a clear and unobstructed transmission path. The following are some factors that cause interference:

- Physical objects: Trees, masonry, buildings, and other physical structures are some of the most common sources of attenuation and interference. The density of the materials used in a building's construction determines the number of walls the RF signal can pass through and still maintain adequate signal strength and geographical coverage. Concrete and steel walls are particularly difficult for a signal to pass through. When signal pass through different materials, they are attenuated in different amounts. These structures will weaken or completely prevent the propagation of wireless signals.
- Radio frequency interference: Wireless technologies such as Wi-Fi routers like 802.11b/g use an RF range of 2.4GHz and so do many other devices, such as cordless phones, microwaves, and so on. Devices that share the same channel (set of frequencies) can cause noise and weaken the signals.
- Electrical Interference: Electrical interference comes from devices such as computers, refrigerators, fans, lighting fixtures, or any other motorized devices. The impact that electrical interference has on the signal depends on the proximity of the electrical device to the wireless access point. Advances in wireless technologies and in electrical devices have reduced the impact that these types of devices have on wireless transmissions.
- Environmental factors: Weather conditions can have a huge impact on wireless signal integrity. Lightning, for instance, can cause electrical interference, and fog can weaken signals as they pass through.

Many wireless implementations are found in the office or at home. Even when outside interference such as weather is not a problem, every office has plenty of wireless obstacles. The following table highlights a few examples.

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

**Interference Table**

| Obstruction | Severity | Sample Use |
|---|---|---|
| Wood | Low | Inside a wall or a hollow door. |
| Dry Wall | Low | Inside walls. |
| Furniture | Low | Couches or office partitions. |
| Clear glass | Low | Windows. |
| Tinted glass | Medium | Windows. |
| People | Medium | High-volume traffic areas that have considerable pedestrian traffic. |
| Ceramic tile | Medium | Walls. |
| Concrete blocks | Medium/High | Outer wall construction. |
| Baby monitor | High | To listen to a baby in another room. |
| Mirrors | Medium/High | Mirror or reflective glass. |
| Metals | High | Metal office partitions, doors, metal office furniture. |
| Water | High | Aquarium, rain, fountains. |
| Microwave oven | High | Appliance used to cook and heat food |

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

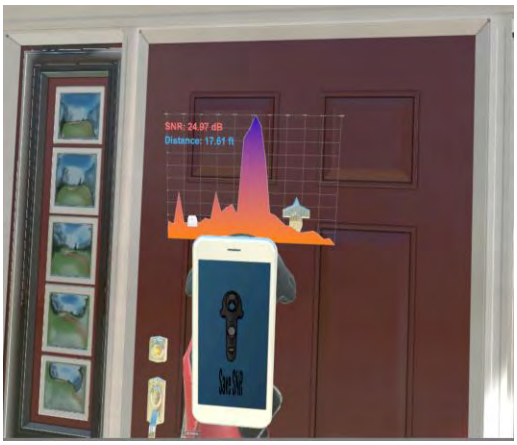
## Lesson Plan & Worksheets

**Teacher:**

- Welcome to the Virtual World of Wireless Technology! Today, we are going to learn about interference on electromagnetic waves specifically focusing on signal strength and distance. Watch very closely every move that __<student name>__ do in the virtual world and each team is responsible to take note of all the data gathered all throughout the experiment. __<student name>__, as you enter the Virtual World, look for all the Bubbles that contain all the instructions that the kid helper will give you. Always be alert and be keen to read all the prompts because the success of this experiment is highly dependent on how well you pay attention to all the instructions.

**VR Kid Helper:**

- How are you? Welcome to my beautiful place! Feel at home and I'm hoping you will enjoy being with me today.
- Before you enter my house, I wanted you to pick up your cell phone that is on the table using the trigger button. *<wait for the kid pick-up the cell phone>*
- Now using your cell phone, remember that each time you use the grip button, you can always change the application on your virtual phone. Press grip button only once. *<wait for the kid to press the grip button>*
- First look at your inventory, you will see empty boxes. Look for the key on the table and pick it up using your trigger button. After doing this, you will see the key in your inventory list. Press grip button only once. *<wait for the kid to press the grip button>*
- You will see the Signal to Noise Ratio (SNR) measured in dB while distance will be measured in feet. You will see these units displayed on the cell phone. Press the trigger button only once to save any measurement. *<wait for the kid to press the trigger button>*


**Teacher: (Addressing to the whole class)**

- Take note at this point, watch what happens as __<student name>__ is outside the door and observe very closely the changes when the door opens. Record the data in your graphic organizer.

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

**VR Kid Helper:**

- Use the key in the inventory list to open the door by pressing the trigger button. *<wait for the kid to press the trigger button>*
- Did you observe the signal strength when the door opens? Take note how far you are at the moment from the transmitter/router. If you Press the trigger button only once it will save the current measurement that you have right now. *<wait for the kid to press the trigger but button>*
- Enjoy my beautiful home! Now that you are inside my house, use the trackpad button to move to my living room. *<wait for the kid to press the trackpad button>*
- Check the signal strength and your distance from the access point/router.

**Teacher: (Addressing to the whole class)**

- I wanted you to observe the changes in signal strength and distance among the five locations. Compute the differences between the signal strengths. Do the same with the distance as recorded in your graphic organizer.

**NOTE**: Round off values to the nearest whole number.

| Signal Strength [Signal-to-Noise Ratio (SNR) in decibels (dB)] | Distance (feet) | Location |
|---|---|---|
| 24.97≈25 | 17.61≈18 | Outside at doorstep (with the door closed) |
| | | Outside at doorstep (with the door open) |
| | | Living Room |
| | | Kitchen (away from microwave) |
| | | Kitchen (close to microwave) |

# Lesson 6: Investigating the Interference of Waves

Science, 8th Grade

**Guide Questions:**

1. Did the signal strength increase or decrease as you went closer to the access point/router?
2. What happened to the signal strength when you went close to the microwave oven?
3. Explain what caused the signal strength to change when you went close to the microwave oven?
4. Was the signal strength greater or less than what it was when you took the first measurement in the living room? What do you think caused this change? Explain

**Teacher: (Addressing to the whole class)**

- In order to escape from the house, __<student name>__needs to answer all the questions correctly! You need to assist in the whole process by giving the clues. Only those Program Runner/Operator from every team will interact with the student on the VR but all members of each team will be helping to give the nearest clue.

**Quiz:**

1. The interference caused by metals and water are regarded as?
2. If your next door neighbor has the same router as you and is using it on the same frequency and channel as your router the interference with your router will be?
3. We are able to get cell phone service underground in some subway stations because?
4. Concrete blocks and mirrors provide _____ interference

**Reflection Questions:**

Think about your experiment!!

Your discussion must be detailed and include answers to the following questions:

- What can people do to prevent interference of electromagnetic waves?
- Why do you think antennas are usually placed on tall buildings?
- In recent time people are having their electronic equipment like cell phones and computers hacked and their information stolen. What things can people do to prevent that?
- Bad weather like thunderstorms can cause high interference levels. Think of measures people can take to reduce the levels of interference during bad weather.