# Understanding User Interface Preferences for XR Environments When Exploring Physics and Engineering Principles

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**Abstract.** In this investigation we seek to understand user technology interface preferences and simulation features for exploring physics-based concepts found in engineering educational programs. A 3D magnetic field emanating from a bar magnet was used as the representative physics concept. The investigation developed three different virtual environments using three different technologies and exploiting the capabilities available through the use of those technologies. This provides a suite of platforms to compare and identify the types of interactions and control capabilities a user prefers when exploring this type of phenomena. These environments will now enable the behaviors and preferences to be identified through observation of the user as they navigate the event and manipulate various options available to them depending upon the technology used.

**Keywords:** Augment Reality · Virtual Reality · XR · Physics · Engineering

## 1 Introduction

Technology is readily available and affordable for creating visual and interactive simulated experiences across the spectrum from screen displays to fully immersive experiences using head mounted displays. This simulation capability can be used to create visual experiences that facilitate learning and understanding for engineering students as they explore physics concepts, particularly 3D events, those with steep gradients in the field response, and time dependent events. These simulations can help students connect basic principles and event geometries to the mathematical representations that explain the phenomena being presented to them.

There are multiple platforms for which to create visual and interactive virtual environments. For example, a mobile device can be used to create an augmented reality (AR) experience based on a predefined target. The user can then change their

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perspective by controlling the position of the device camera. Interactive features can be controlled via touch screen capability. On the computer display this same interaction can be accomplished with the use of a mouse or gesture-based system. Likewise, interaction in the full Virtual Reality (VR) experience can be accomplished with handheld wands or a gesture-based control system. The challenge for the educator is to decide which to select for a given learning experience and the design of the overall environment. It is a natural touch point between education and human factors.

Effective computer interface design has been a primary objective of human factors and engineering professionals since the advent of digital displays and technologies began to be widely available in the late 1970s and early 1980s. Beginning with simple monochrome cathode ray tube (CRT) screens for a visual display and a keyboard for user input, the computer interface has evolved to include many different aspects, characteristics, qualities, and features that may or may not contribute to the functionality, goals, and objectives of the overall system. Enhanced keyboards, color displays, split keyboards, mice, trackballs, joysticks, and other such devices all began to flood the markets in search of the ideal ergonomically designed and user preferred configuration. Color, for example, can be used to the user's advantage to help highlight important information that will increase understanding, but it can also be used ineffectively and inconsistently in a way that will add little to the user experience or to achieving the goals of the system in general. When colors are chosen at random for use in similar applications, their effect can be one that promotes confusion and misinterpretation of information instead of enhancement of knowledge and understanding. Meteorology is a good example of an application that has applied color in a consistent and effective manner to make reporting of weather conditions clear and understandable to almost any viewer. Colors are effectively applied to depict temperature and other weather phenomena, and are used consistently to convey information in a way that enhances understanding and situational awareness. And, the weather industry in general has implemented the use of color and symbology in a consistent manner across applications, so regardless of what weather report is being viewed, the information is displayed in a consistent manner to convey understanding of weather conditions and phenomena in a clear and concise manner.

In the same way, interfaces whose objective is to impart information about a particular topic, in this case with the goal of producing enhanced learning and comprehension of physics and engineering based educational concepts, must be designed in a specific and intentional manner to be able to exploit the capabilities available in different interfaces and technologies in order to enhance understanding and information transfer about those topics. All interfaces can impart some information just by virtue of presenting the information for viewing to the user, but interfaces that are specifically designed to exploit the capabilities of the technology being used may present certain advantages that will enhance learning in a measurable way. These specific capabilities, if desirable to the user, can then be incorporated and developed further to benefit the learner.

State of the art technology began revolutionizing the Human-Machine Interface with the movement away from legacy control devices such as joysticks and other physical controls, toward more innovative interface technologies such as touchscreens, virtual reality displays (VR), augmented reality displays (AR), and mixed reality displays (MR). VR displays or VR-like displays are now affordable and commonplace, and are regularly used as the display of choice when immersion into a 3D environment is preferred [1]. Additionally, when used in combination with technologies such as head tracking, the ability to "move around the environment" and to "become immersed in the environment" is also possible, thereby affording the learner the opportunity to view new perspectives that could only previously be presented in two dimensional (2D) format.

A major reason for using more advanced type of displays is to enhance the user's ability to learn the concepts being presented. Several encouraging examples of applying virtual environments in the classroom have been documented (see for examples, [2–4]). More recently studies based in the augmented reality technology have emerged (see for examples, [5, 6]). These, and other, examples, show the promise of using this technology but they point out that the technology is just that-technology. For the educational environment the main focus is on learning, and the optimal implementation of technology needs to be carefully considered. Otherwise the effectiveness can quickly disappear after the initial excitement begins to fade. If the application or the interface is one that is not preferred by the user and does not facilitate learning beyond the level produced by 2D displays, then there would be little justification for using that technology. The ultimate goal in this research is to better identify the types of interactions and control capabilities a user prefers when exploring this type of phenomena, and to determine if the use of different interactions and control capabilities enhances learning and comprehension. The use of advanced display and control technologies is trendy and state-of-the-art, but for our purposes, it still needs to facilitate learning and enhance the learning experience for the user.

In summary, technology is available and documented results of its potential have shown the promise of integrating the capability 3D simulation offers with innovative instructional design. The challenge is beyond just developing a simulation though; that is doable. The technology is just another tool in the toolbox. The challenge is identifying those learning objectives, particularly those that are the best match of the given technology, and the design of the overall learning environment to include basic informational content, training, assessment components, and ease of navigating through the environment; that is the long-term objective of this investigation. This paper focuses on the design of the physics simulation itself and those desirable interactive features.

## 2 Learning Environment Design and Development

### 2.1 Learning Environment

Designing a simulation of a physics or engineering concept is certainly achievable. The challenge is more in the design of the overall learning experience. It needs to guide the student to the desired learning outcomes (instructor controlled) but also enable the student to control the learning experience. In this case the instructor can layout a sequence of learning events for which the student can proceed at their own pace and have the ability to check back with certain components. It also needs to contain training on the use of the simulation otherwise the student can quickly get frustrated. The overall goal of this research is the establishment of the complete learning environment (Fig. 1).

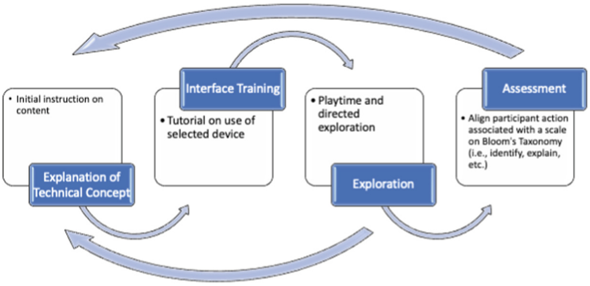


**Fig. 1.** Simulation environment

## 2.2 Platforms

To get started with this investigation three different technology options were selected to create the Exploration component of the learning environment shown in the figure above. This will provide the future participant with different sets of capabilities for exploring the learning environment. The first technology platform was a tablet-based platform consisting of a Samsung Galaxy Tab 8 with a 10.1-inch color display and a screen resolution of 1920 × 1200. The tablet platform is controlled using a touch screen to manipulate the visuals and navigate around the environment. The second technology platform was Screen Space utilizing an Alienware 19-inch laptop with a screen resolution of 1920 × 1080. Actually, any computer screen would do, the point is that it is a 3D representation in a 2D space. The Screen Space interaction was limited to use of a typical mouse interface. The third technology platform was the Oculus Rift which is an immersive VR headset with OLED color display and screen resolution of 2160 × 1200. The Oculus Rift platform can be used with either a Leap Motion Controller (LMC) or the use of handheld wands provided by the manufacturer.

## 2.3 Physics Model

A rectangular, magnetic bar shown in Fig. 2 was selected as the model concept for this investigation. It is a good concept to start with since it has several representative features and principles that cut across engineering concepts. For example, there is a source and a sink model (i.e., north and south poles of the magnetic). This concept is found in other engineering principles such as fluid mechanics and aerodynamics. There is a direction element as the magnetic flux flows from the north to the south pole and there is a gradient associated with the field strength as the distance from the source and sink increases. Some of the mathematical details to support these points are discussed below.

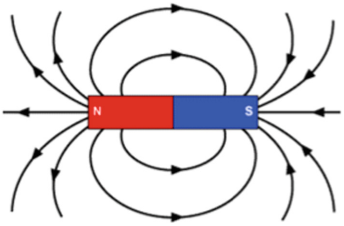


**Fig. 2.** Bar magnetic field model [7]

The model contains a magnetic source at the north-pole and a magnetic sink at the south-pole. It is a low order model that sufficiently captures the basic physics principles and visualizes field gradients and streamlines. The magnetic induction, B, at a point due to a monopole is governed by the following equation:

$$B = \frac{\mu_0 m}{4\pi \vec{d}} \tag{1}$$

Where
μo: permeability of free space = $4\pi * 10^{-7} \frac{Newtons}{ampere^2}$
*m*: is the magnetization $\left[\frac{ampere}{meter}\right]$
*d*: a vector from monopole center to point of interest *[meter]*

The two-bar magnet is modeled as a source and sink combination or a dipole. The resulting governing equation is shown in Eq. 2. The effect of a magnetic dipole on an arbitrary point P(x, y) is shown in the schematic in Fig. 3 below. This model is easily extended to 3D in the simulation.

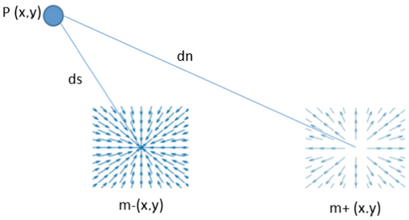


**Fig. 3.** Dipole model

$$B(x, y) = \frac{\mu_0 m}{4\pi}\left(\frac{1}{\vec{d_s}} + \frac{1}{\vec{d_n}}\right) \tag{2}$$

## 2.4 Simulation Development

The simulations were developed using Unity3D®. An AR simulation was created for the tablet in Unity with the aid of Vurforia, which can be used to create marker-based AR applications. In this case the user simply points the camera at an image or object and then the simulation is superimposed over it. The simulation is shown below in Fig. 4. The marker image is that of the bar magnet. Once that is detected, the directional arrows are displayed along with their magnitude. Careful consideration had to be given to the placement of the touch screen buttons on the right side. These buttons controlled the view options of grid point display, direction indicators, and streamlines. In their current position they are easily activated without moving the user's hand (i.e., can reach with their thumb). This approach allows the users to view the 3D field representation from several angles and even dive down into the field itself. The only drawback is that the marker image needs to be always in the camera's view.

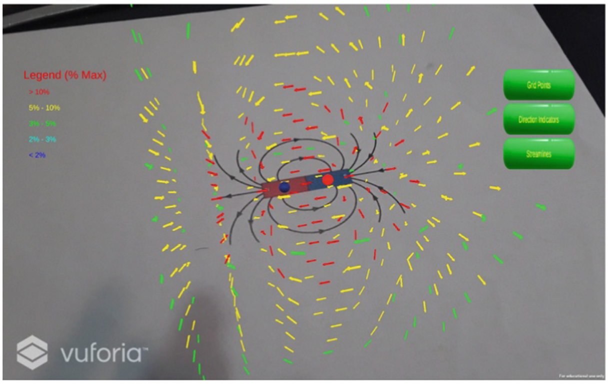
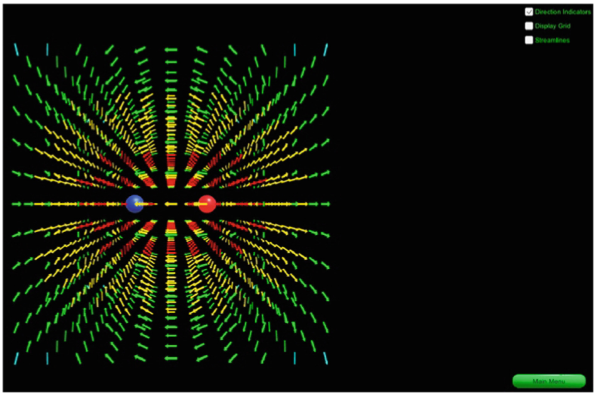


**Fig. 4.** AR application using samsung tablet

Figure 5 shows the visual display using the laptop and Fig. 6 shows the streamlines. The arrows provide good information on the strength and the streamlines provide good information on the field gradient and flow direction. The latter feature is illustrated through the use of the moving red spheres. In this case the interaction is controlled via the mouse, which typically has sub-millimeter accuracy. It controls the orientation and position of the camera as well as the selection of display options. It is interesting to note that the size of the interactive display selections can be small in this case, which may reduce cognitive loading. The fully immersive VR environment is similar to this one, but the user navigates around the visuals by physically moving their head and body.



☑ Direction Indicators
☐ Display Grid
☐ Streamlines

**Fig. 5.** Simulation using laptop

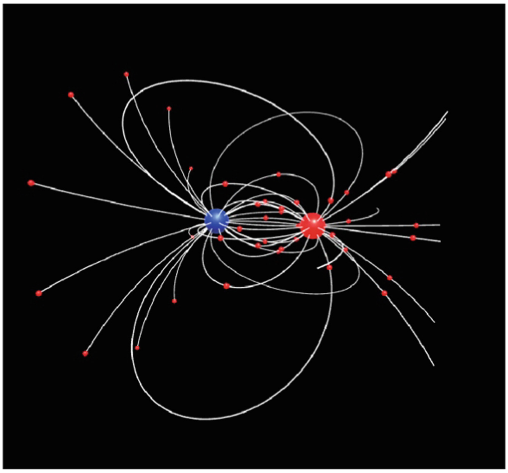


**Fig. 6.** Streamlines

## 3 Test Methodology and Procedure

The objective of this study is to identify what technologies would be better suited as an educational medium that would facilitate enhanced learning and comprehension of physics and engineering based educational concepts. Now that the environments are setup we will proceed into the assessment phase. This assessment needs to be based on (1) user preference for the technology being employed in a typical online learning environment, and (2) assessment by the participant regarding the capabilities of the specific technology being employed. These assessments will be based on observations of the user as they navigate the event and manipulate and employ the various capabilities available in each different technology platform. Post scenario discussions and interviews with the user after exposure to the various technology platforms will also be utilized in this study. This information would then be used to determine the most suitable platform for use in this application based on user preference and the platforms ability to enhance learning and comprehension of physics and engineering based educational concepts.

As a first step each participant will play in an environment that contains the same physics-based model and concepts regarding visual illustration of a rectangular bar magnet and the associated magnet field generated by that magnet. This allows participants to become familiar with the user environment produced by a combination of the model developed for the rectangular bar magnet and associated magnetic field technology being employed. As stated previously, the magnetic field model was visually represented by building the required models in Unity and then using that model as the basis for the learning application presented in each of three different technology platforms.

This free-flow approach of allowing the participant to examine and explore the concepts to be learned, and allowing the participant to utilize the different capabilities available in each different type of technology platform will provide some insight into the future selection of the most efficient and desirable platform for these types of educational opportunities. Data gathered in this study will include live observations of the participant while using the different platforms, and time spent in the exploratory environment. Posttest interviews will be used to collect structured data using Likert type questions, and free-flow open ended interview questions at the conclusion of the exploratory period for each platform. It is expected that all participants will be exposed to each type of technology platform in a randomized order of presentation to minimize learning effects produced by exposure to each platform in the same order every time.

## 4 Summary

This paper described the development of a representative physics-based simulation. The intent was to provide platforms for users to communicate their preferences for how they would like to interact with the simulation and what visual representations they thought are the most helpful for learning the proposed concept. Three types of simulations were developed. One was an AR using a typical tablet, the other was the 3D representation on the 2D computer screen and the third was a fully immersive VR capability. Finally, a general methodology was presented for how to measure participant's responses. It is anticipated that the information obtained will be seminal in the design and development of future interactive physics and engineering based educational applications that place high importance on user preference on use of technology at the fore front of any design initiatives to produce enjoyable and effective applications. This information will also be extremely important in designing applications that focus on enhanced learning and comprehension.

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