

# Contextualizing Construction Accident Reports in Virtual Environments for Safety Education

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## ABSTRACT

Safety education is important in the construction industry. While research has been done on virtual environments for construction safety education, there is no set method for effectively contextualizing safety information and engaging students. In this research, we study the design of virtual environments to represent construction accident reports provided by the Occupational Health and Safety Administration (OSHA). We looked at different designs to contextualize the report data through space, visuals, and text. Users can explore the environment and interact through immersive virtual reality to learn more about a particular accident.

## 1 INTRODUCTION

Safety is important in the construction industry. Construction companies, educational institutions, and the government spend millions to ensure that people who will work in the industry are properly educated. While safety generally improves over time, the rate of construction injuries have nearly plateaued since 2009 [3]. It is clear that there is room for improvement. Many safety training courses, such as those provided by the Occupational Safety and Health Administration (OSHA) [5], are taught in a standard classroom format (slides, lectures, and tests). Researchers have explored 3D virtual environments (VEs) for safety education (e.g., [1, 2, 4]) as a means of increasing engagement and contextualizing safety information, but there is no established design approach to do this.

Our goal is to formulate guidelines for designing educational VEs for the purpose of teaching construction safety. We conducted a case study in design using data from accident safety reports because reviewing prior accidents and their causes can help prevent the same mistakes from occurring over and over again [6]. We base our case study on accident reports provided by OSHA because each report is similarly formatted yet unique in scenario. For the preliminary stage, we developed one environment based on a single report. In the described incident, a wall collapsed, killing two people and injuring another. Throughout the design process, we made decisions regarding the level of interactivity and how to contextualize the information in a visual 3D space.

## 2 APPLICATION DESIGN

The user explores the environment to learn more about the accident using an HTC Vive and controller. To navigate, the user can either use the touchpad on the controller to move around or click a map to teleport to the desired location (Figure 1). The user can interact with the VE by aiming and pressing down on the controller trigger.

Development of the application began with data preparation from accident reports. Most accidents are the result of numerous factors leading up to an incident and undesired results. Reports also include a large amount of supplemental information with varying

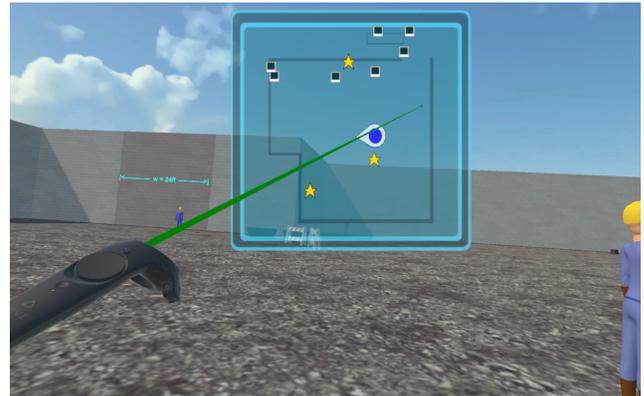


Figure 1: Navigating the VE with a map. Icons show informational items and the user's position.

levels of relevance to the accident itself. For consistency with the reports, we decided to contextualize as much data as possible rather than trimming it down. The information was represented through spatial, textual, and visual display.

### 2.1 Spatial Information

If we designed a virtual environment solely based on the report's drawings, it would be largely empty. The drawings were often so low in resolution that they were barely legible or contained little detail on the environment beyond the accident location. We compromised by deviating from the report only when it did not directly change the main layout. For the report used for the case study, we made sure the fallen wall was at the proper location and the user felt present at the construction site described in the report.

Since the environment was large, we spaced out information to encourage exploration. There are three key areas (*documents*, *how to*, and *time events*) symbolized as stars on the map. The documents area is located at a table in the VE. Should the user click it, drawings related to case will appear on a HUD. The how to section explains the correct construction procedures. Lastly, the time events area contained all of the events that led up to the accident.

### 2.2 Visual Information

One of the hardest challenges we faced when contextualizing the information was temporal order of events. The accident itself probably happened in a few seconds, but the events leading up to it spanned a few months. It is difficult to show a time change in a virtual environment when the user's sense of time is linked with the time they have spent interacting with the application. We decided to show these events by visually changing the scene to match one of the event time steps. We ended up with three time steps: beginning of construction, completion of the wall, and the fallen wall. The user can select any of these via the menu to change the look of the environment.

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Figure 2: Contextualized photographs in the environment.

Since our focus was not on fidelity, we chose a more simplified visual aesthetic. However, we did want the user to have a realistic understanding of the environment. Using photographs from the report, we placed images at locations corresponding to where they would have been taken in the environment (Figure 2). The user can use the trigger button to toggle image visibility.

### 2.3 Textual Information

The application used text to explain objects of interest. In certain areas, the user could initiate a learning module to learn more about it. For example, the user could choose the first time step (when construction began), then use the menu to initiate the lesson, and a text box would then appear to give a brief overview. The user would then have to look around for all objects or people that were highlighted in pink (also shown on the map). Figure 3 shows a text box that appears when the person is selected.

Aside from the learning modules, we included textual information on the menu and in the documents table. When the learning module is initiated, the main tab on the menu shows a brief overview related to that particular lesson. There is also an overview tab for the basic details of the report. The documents table has a good amount of text from the drawings, but we suspect that a majority of it will be overlooked. We also attempted to use text to explicitly state the dimension of a wall panel.



Figure 3: Learning module, clicking interactive objects.

## 3 PRELIMINARY EVALUATION

To understand the impact of our design decisions on the effectiveness of the virtual environment, we had five participants test our

application and provide qualitative feedback. Participants used our application with the prompt of exploring the environment for details on the incident. We were mainly interested in how the user interacted with the information and any difficulties they encountered.

Although we provided an overview of the controls before starting the application, a menu option with controller configuration, and initial verbal guidance the users spent a while trying to understand and achieve familiarity with the controls and guidance mechanisms. This also led to confusion on where to go and what to do. Often, the users would only look at one portion of the environment. Most users enjoyed engaging with the integrated photos that were positioned to correlate to the real world incident. We suspect this was due to the ease of toggling their visibility via direct raycasting rather than through a menu or as part of a learning module. Overall, the users liked looking around the environment, but desired more guidance.

Going forward, we are looking into the feasibility of including a tutorial to better prepare users with the controls and interactions. We will use the results of our preliminary evaluation to prepare a formal evaluation in the future.

## 4 CONCLUSION

It is important that people are properly educated in construction safety, and virtual reality can be used to engage users in interactive learning experiences. We developed a virtual environment based on information found in an accident case report and discussed the the core design components, and we are in the process of creating additional environments based on other reports. Currently, most people are familiar with traditional mouse and keyboard interfaces (as with common desktop or laptop computers) but have little experience with virtual reality. For this reason, we are also designing alternative desktop versions of the application to help study how the learning experiences differ.

We discussed design choices based on spatial, visual, and textual types of information. We acknowledge that developing more virtual environments may require alternative decisions and there are many other ways to represent the information that we have yet explore (e.g., audio). In the future, we will conduct users studies to better understand the influence of our decisions. Our study will also compare different methods of guidance and varying levels of interactivity. In addition to observations and qualitative feedback, we will assess information acquisition. By including desktop versions we can still learn about our design impact and more importantly, whether or not using virtual reality hinders the learning process in this situation. Our research provides the first steps towards the creation of design guidelines for building effective virtual environments for construction safety education.

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