CHAPTER 4

INDUSTRY TRAINING THROUGH VIRTUAL REALITY

Industries are very large and diverse businesses and are significant employers, cash generators, and contributors to the economy. Industries face increased national and international competition, stringent governmental regulations, and an environmentally conscious populace. The industry also encounters issues such as organized labor, challenges of new technologies and new materials, and construction of complex projects. These forces emphasize the value of strong engineering and management skills required for delivering high quality constructed facilities. In reality, many industrial application programs fail to provide their trainees with an arena where they can acquire the skills and experience necessary to successful professional practice and on-site performance. Most of them have to practice in the field in order to assimilate an adequate knowledge about actual industrial performance. Lifelong learning and training has become an important issue in industry, because keeping track of innovations and adopting new developments is necessary for maintaining competitiveness in the market. Training has always been an essential aspect of successful business operations.

Industries plan their investment in training for employee development performance, such as training as they begin to recognize that the knowledge, skills and competencies of their employees give them an advantage that is difficult for competitors to imitate. The business organizations have devoted considerable expense in training, whether provided by in-house personnel or out-of-house experts. Priorities are given on trainee competence related to acquisition of desired knowledge and skills that provide a foundation for the retention of knowledge and skill to the employees. Industries use the e-learning technologies of training to deliver most of in-house training or across training via web. The training will be delivered and controlled via computer using a variety of methods, including text, sound, graphics, still photography and motion video. The wide accessibility and low cost of VR on the World Wide Web with the advent of the VRML and it’s interpreters makes it ideal for use in providing cost-effective training for operators in selected complex technical environments.
4.1 Introduction

In today’s markets, competition is increasingly fierce, whether it’s the tech market, corporate operations, government services, or even education. Developing and sustaining a competitive advantage has become more challenging than ever before, but the need for such an advantage has not diminished at all. For this reason, organizations must do everything in their power to increase efficiency of operations, in order to maximize every advantage possible. One area where most organizations could stand to improve is in the realm of training. Due to ever changing market dynamics, the rapidly evolving labor market and the constantly changing employment culture, it is important in the industry field to have a lifelong learning and training on an individual, team and organizational basis in all hierarchy levels from top management down to the work force.

An individual training consists of internal training of personnel, initial training and preparatory training for new tasks, the continuation of employee education and on the job training. Team training is also necessary on group dynamics, psychological aspects and assistance for team communication. Apart from internal training, external training of suppliers and sales agents on new products is other frequently arising training situations. The recent technological developments in the IT sector and the globalization of markets need sharing of information and documents. The quest for more compelling visualization and information access is increasing and the demand for 3D graphics is rising.

Industries look for graduates that are better prepared to manage the complex dynamics, pressures, and demands of industry sites. The availability of “job-ready” graduates is becoming crucial in trying to meet the demands of the industry today. A fresh employee while starting his project lack adequate experience in the dynamics and complexity of the project site and lack of guidance and interaction with subject experts. The curriculum one graduates from is often inadequate in preparing students for the complex process of real-time job. It does not permit the inclusion of issues of importance to subject of concern, the limited access to practitioners and hands-on experience, and limited use of advanced computing tools to improve student learning.

The traditional teaching methods are often not fully capable of providing students with all the skills to solve the real-world problems encountered or convey complex engineering knowledge effectively. Enough opportunities are not provided to
interact with professionals or to pool the knowledge acquired in several courses to solve real-world problems. It is not possible to bring real machinery into the classroom and on the other hand it is not easy to teach students outside the classroom particularly in the workshop. Therefore there is a need to have some medium of teaching that is easily available and allow students to learn interactively.

Ideally, visits to sites or site training would constantly complement the more conventional classroom instructional tools. However, there are various complicating issues that make it impossible to rely on the sites. Foremost, the instructor cannot control the availability of a project at the necessary stage of completion. Also, visits of larger groups to sites may not be welcome, involve risk, and are unpractical. Finally, the high cost of site training is a further impediment to its extensive use for construction education. General computing and information technologies, and simulation in particular, have the potential to complement engineering and management education. The enhanced practitioner involvement and industry input, increases practical content and can provide students with increased familiarity with the industry. Visual technologies have enhanced the preparation of workforce specialists and technicians by bringing into classrooms and laboratories a breadth and depth of realism that has enhanced comprehension, increased learning performance, and reduced training time.

3D animation and Virtual Reality can be applied in industry as a medium for vocational training and for continuing education in the context of lifelong learning. For instance, in order to train technicians, engineers, but also users on a newly launched product or on special tasks to be performed with that product, such as installation or maintenance, manuals and courses are usually provided. The use of VRML for such training manuals allows taking advantage of features such as a true 3D representation of the product, the display of animations showing special actions to be performed, the definition of interaction and behavior, the integration of links to additional information, or the addition of sound, such as spoken instructions. A server stores the worlds in VRML. A VRML browser is used by the users to navigate and interact with the virtual environment.

VRML, as a web-based technology, is well suited for distributed information access and offers the option to use 3D interfaces. To access technical information on a product or on its parts, a 3D interface that shows an exploded 3D view of the product is a very compact and intuitive interaction metaphor. Because programmed code can
be easily integrated into VRML scenes and objects, the VRML representation of the product and its parts can be dynamically related to additional information, such as a part list or bill of materials, where each entry in the list can be dynamically related to the parts in the VRML model. 3D navigation interfaces, representing a product or production plant, are well suited for training applications due to the intuitively and immediately understandable metaphor. They can be equally used for training of new personnel, anticipant training on new products and on new production facilities.

4.2 Virtual Training through Computer Games and Simulations

By embracing new technologies it is possible for organizations to turn training into an advantage by actually employing superior training methods for a fraction of the cost of traditional methods. Organizations across the world are beginning to achieve this goal by embracing the use of computerized 3D learning environments such as 3D training simulations and 3D serious games to improve the effectiveness and efficiency of in-house training operations. Numerous innovative tools have been used to enhance the learning process. A number of active learning systems aimed at training students in different aspects of construction management, have been designed and implemented. Use of site-videos and computer simulation and gaming are a few examples.

Computerized heuristic games were used for the education of engineers and planners engaged in the construction industry [148]. A scheduling game for construction industry training was described [149]. A model for the project gaming system was presented that allows students to plan, monitor, and control hypothetical projects [150]. A road construction simulation game was developed for site managers focusing on the planning and control of linear construction projects [151]. A construction game that simulates the progress and project reporting structure of an industrial construction project was designed [152]. The systems mentioned above are either manual or have been developed with limited use of advanced computing tools. They are not geared towards the dissemination of knowledge related to construction processes, methods, equipment, and decision-making factors related to site execution of construction processes.

No matter how the game is set up, however, the purpose of a “serious game” ultimately lies in training and the effective transmission of knowledge that can then be used outside the game, in the real world. Cisco has openly acknowledged the
successful use of serious games in their in-house professional training operations and continues to be a major supporter of the technology throughout all industries [153]. With 3D serious games there is more of a competitive element to the experience. The goals include the successful application of the knowledge and skills needed to meet the desired serious game learning outcomes. Games can be useful for teaching critical skills because the inherent competition provides an automatic measure of training effectiveness.

Traditionally, simulation has been defined as a tool that can be used to mimic reality and provide responses of a system under consideration to external and internal factors. Simulation has been applied in the design and analysis of construction processes by researchers and by some large construction organizations [154]. In addition to industrial uses, simulation can also be used for educational purposes, especially for civil and construction engineering education. This is based on the hypothesis that “simulated environments” can act as excellent catalysts in the learning process. In a recent study, it was reported that “simulation can be a powerful trigger to learning of project management principles” [155]. Their main purpose is to accurately model some aspect of reality and let one interact with that model in a trial-and-error fashion. If one were forced to “practice” sensitive skills in a real life setting and failed, the consequences might be disastrous. Instead, by practicing them in a simulated 3D environment, failure becomes a useful learning experience, and one can practice until one gets it right. Of course, in such a context, it is imperative that the simulation is designed in such a way that the relationship between choices and outcomes is extremely accurate and believable; otherwise, the learned skills will not meaningfully translate to reality.

A virtual reality system is essentially an interactive simulation that can represent a real or abstract system. The simulation is a representative computer based model, which provides appropriate data for visualization or representation of the system [156]. The virtual environment can take many forms and for example, it could be a realistic representation of a physical system. Basic manufacturing operations such as unload, load, process, move and store in a 3D virtual environment can be simulated. When one engages in 3D learning, one is exposed to visual and auditory stimuli within the 3D training simulation, and the act of interacting with elements in the simulation provides the feedback that kinesthetic learners require. The result is
that one effectively learns not by receiving, but by doing, which is referred to as cognitive learning.

Guided tutoring and computer simulations through studios/labs that are properly designed and implemented could revolutionize technological education. The computer-based simulation software enables students to experiment interactively with the fundamental theories and apply those using electronic devices. If the educational goal is for students to transfer and apply the knowledge to real-world problems, then simulation integration into the class structure is an effective learning strategy. 3-D modeling and simulation provide students with an interesting and realistic view of the selected industrial processes and equipment. The 3D training simulation is very specific and allows users to practice the skills and decision making abilities needed in a virtual situation that mirrors the real world experience. Users will be exposed to the virtual consequences of their decision making to develop the correct use of skills and decision making in real world applications.

4.3 Virtual Training through Virtual Reality

Virtual reality (VR) may be emerging as a key communication and learning technology for the 21st century. VR can be described as the science of integrating man with information. It is based on three distinct environments: three-dimensional, interactive and computer-generated. It has come to the Internet in the form of VR modeling. VR systems are simulation environments that aim to involve as many senses of the user as possible. VR is clearly making its presence felt as a potentially important technology for technical and industrial training. Investigators of VR appear to be impressed with its unique capabilities and optimistic about its value as an instructional tool. Numerous industries are utilizing VR to boost their training success and it is reported for its important contributions. The emergence and apparent success of VR in numerous industry environments is probably reason enough for it to be introduced as a virtual trainer.

Instructors while training use case studies, classroom examples, guest lectures, and laboratory exercises to explain the application of classroom knowledge in solving real problems. However, the current approach is often inadequate in preparing the trainees for the on-site construction processes. Training aims at reducing expenses and saving time while training remote users/engineers to operate some equipment. Effective training on the usage of various facilities and design of the facility layout
become a crucial for the success for an industry company. Teaching students to be critical thinkers is essential in the virtual classroom. Throughout the world of industry, VR technology is impacting the way companies do business and train their workers. As it becomes increasingly necessary for skilled workers to use VR on the job, its use in pre-employment training becomes equally necessary. However, until the recent developments in desktop VR, creation of virtual learning environments was too complex and expensive for most industry educators to consider.

VR became a new science that joins several fields as computers, robotics, graphics, engineering and cognition that allow user interaction and movements with three or more degrees of freedom [157]. VR worlds are 3D environments, created by computer graphics techniques, where one or more users are immersed totally or partially to interact with virtual elements. VR has been used to simulate several kinds of training, particularly in areas which involve risk for the trainee or other people [157]. Simulators based on VR can improve skills of new professionals trained by it [158]. One of the advantages of simulators based on VR for training of procedures is keep safe trainee and preserve materials [159]. Besides, a simulate procedure can be repeated as many time as it is necessary [160].

Virtual reality systems for training can provide significant benefits over other methods of training, mainly in critical procedures. Innovative VR applications bring to learners

(a) Simulation of industry environments and experiences that is difficult, dangerous, or unavailable for them to enter in the real world;
(b) Entry into innovative environments that is impossible to explore in reality, such as the inside of a computer or an engine;
(c) Participation in interactive and collaborative industry situations that learners would otherwise have no opportunity to experience.

Age may be a promising learner variable in multi-factor VR research in industry education. Both pre-service and in-service industry training programs must address learners across a wide age spectrum, and some career training instructors must serve both adult and younger students in the same class. Several authors have raised the prospect of a generational "digital divide", suggesting that age-related differences in skills, comfort, and expectations in digital environments may be a significant factor in both classrooms and workplaces [161, 162, 45, 163, 164, 165, 166, 167].
4.4 Design of Complex Objects

Complex objects are built from other simple and/or complex objects. They are composed by connecting two or more simple and/or complex objects. The connected objects are called components. All components keep their own identity and can be manipulated individually. However, manipulating a component may have an impact on the other components of the complex object. The impact depends on the type of connections used. Looking to this description, the following issues seem to be important.

1. Complex objects are composed of other objects (components)
2. Components are connected by means of connections and there exist different types of connections
3. The motion of a component may be restricted by the connection type used.

Normally an object has six degrees of freedom, three translational and three rotational degrees of freedom. The translational degrees of freedom are translations along the three axes of the coordinate system used while the three rotational degrees of freedom are the rotations around these three axes. The way components of a complex object are connected to each other may restrict the number of degrees of freedom in their displacements with respect to each other. Three possible connection types, namely over a center of motion, over an axis of motion and over a surface of motion are established.

4.4.1 Connection Point Relation

A first way of connecting two objects to each other is over a center of motion. In the real world an example of object connected over a center of motion is the shoulder of the human body connecting the arm to the torso. A center of motion means that there is somewhere a point in both components that needs to coincide during the complete lifetime of the connection. This point is called the connection point. Connecting two objects over a center of motion removes all three translational degrees of freedom of the components with respect to each other. Specifying a connection point relation implies specifying the connection point for both components. This can be done by means of exact coordinates. Therefore, the position of the connection point is specified relative to the position point of the object. This is a (default) point in the object that is used to specify the position of the object in the VE, i.e. when an object is positioned at the coordinates (x,y,z) this means that the position point of the object is at position (x,y,z).
The position of a connection point is specified relative to the position point of the component. This is done in terms of zero or more translations of this position point. If no translations are given the connection points coincides with the position point of the object. A translation is specified by a distance and a direction. The distance is expressed by an arithmetic expression and a unit.

4.4.2 The Connection Axis Relation

A second way to connect two components is over an axis of motion. A lot of examples of this connection type can be found in the real world. For example: a wheel that turns around an axis, a door connected to a wall, the slider of an old-fashioned typing machine. Actually, an axis of motion means that there is an axis that restricts the displacements of the components with respect to each other in such a way that the connected objects may only move along this axis or around this axis. The axis of motion is called the connection axis. A connection by means of a connection axis removes four degrees of freedom leaving only one translational and one rotational degree of freedom.

To specify a connection axis relation between two components, the connection axis for each of the two components has to be specified. These two axes need to coincide during the complete lifetime of the connection. Looking for an easy way to specify these axes, the intersection between two planes can be specified as an axis. Therefore, three planes through each object are predefined. These are the horizontal plane, the vertical plane and the perpendicular plane. These planes are illustrated in figure 4.1.

![Figure 4.1 Planes of an object](image)

(a) Horizontal Plan (b) Vertical Plane (c) Perpendicular Plane
A connection axis is defined as the intersection between two of these planes. To allow more flexibility, the predefined planes can also be translated or rotated. Each plane may rotate over two possible axes. The horizontal plane may rotate over the left-to-right axis or the front-to-back axis; the vertical plane may rotate over the front-to-back or the top-to-bottom axis; and the perpendicular plane over the top-to-bottom or the left-to-right axis. Next to define the connection axes it is also necessary to give the initial positions of both components. This is done by specifying for each component a point on its connection axis. These points should coincide. By default this connection point is the orthogonal projection of the position point of the component onto the connection axis. However, this default can be changed by translating this default point along the connection axis.

4.4.3 The Connection Surface Relation

The last way to connect two components to each other is over a surface of motion. A real world example of this type of connection is a boat floating over a water surface. A surface of motion means that there is a surface that allows the components to move along the directions of this surface. This connection type removes three degrees of freedom. The only degrees of freedom left with respect to each other are the two translational degrees of freedom in the directions of the surface and one rotational degree of freedom around the axis perpendicular to the surface. The surface of motion is called the connection surface.

To specify a connection surface relation we actually need to specify the connection surface for each of the components. The connection surfaces of both components need to coincide during the complete lifetime of the connection. To specify these connection surfaces, again we apply the three predefined planes (the horizontal plane, the vertical plane, and the perpendicular plane). For each of the components, an initial plane to work with is selected. This plane can be translated and rotated. A connection point is needed to specify the initial position of both components on the connection surface similar to the connection axis relation. By default, this point will be the orthogonal projection of the position point of the component on the corresponding connection surface. Also for the connection surface relation, this point can be translated to specify other positions.
The capabilities and possibilities for VR technology may open doors to new vistas in industrial and technical instruction and learning, and the research that supports them. Use of VR technology is growing rapidly in industry. The growing use of VR in industry is provided by the National Institutes of Standards and Technology (NIST). The NIST web site currently lists more than 60 projects in which it is providing grants to industries to develop and apply VR technology. These include medical technology, machine tooling, building and fire technology, electronics, biotechnology, polymers, and information technology [168]. Another VR application is a virtual machining laboratory is for knowledge learning and skill training in an interactive environment. This virtual lab is specifically designed for helping students to virtually operate a lathe or set machining parameters and input CNC G-code programme to turn the work piece automatically [169].

The use of VR to build prototypes will reduce the costs of finished products, changes in the physical product can be costly but modifications can be made in the virtual prototypes inexpensively. VR has been applied to many areas of manufacturing. It provides 3D visualization of manufacturing environment and has great potential in manufacturing applications to solve problems and help in important decision making. Structural design concept visualization whether in reinforced concrete or steel structure is a subject that depends on geometric and physical perception, and every effort should be made by educators to enhance this ability. This makes it an interesting challenge in an exciting area, requiring creativity and imagination as well as knowledge and systematic thinking.

4.4 Virtual Learning Environment

Training in an industrial context is becoming more dynamic and time consuming due to the daily emergence of new technologies and the onset of globalization. Thus computerized training requires more realistic and rapid modeling techniques and training environments. From an industry perspective, Virtual Environments (VEs) can be an attractive solution for reducing training expenses. Instead of working with physical objects, these are represented by virtual objects that can then be placed in a virtual environment accessible to many users. Users can then manipulate and interact with the objects as in the real world, gaining valuable experience and training before using the real equipment. VEs have a great potential for learning and training purposes, by allowing one to circumvent physical, safety, and cost constraints.
By combining virtual online classrooms, live webcasts, social networking tools, and other Web-based collaboration tools, the virtual learning environment creates a highly adaptable and engaging learning experience for wide-ranging employee needs. The virtual learning environment should motivate and activate the user and also make him/her more interested in new knowledge [170]-[174]. For manufactures and operators of complex systems, plants and machines, this method can provide effective training and fast familiarization with operation, control and process. The virtual environment provides a framework for representing a facility layout in 3D that consists of the static and dynamic behavior of the manufacturing system [175].

To build such training environments, the developers need to have a total comprehensive understanding of the problem domain, such as the relationship between the input and output data, in order to interpret and codify the knowledge into the module. The developers must convert this discrete data into procedures the computer can understand. Generally, the environment the user will interact with is predicted and predefined in the system. In these systems the users study the underlying knowledge by following the routines and scenarios which have been preset in the simulation.

A number of emerging scientific studies have shown that traditional 2D training methods are just simply not as engaging to today’s learners as 3D. When one learns in a 3D environment, one is more immersed in the learning process, and is thus more likely to acquire and retain the lesson material than one would by simply watching a 2D non-interactive training tool, such as a Power Point presentation. In short, anything but 3D training tools are in danger of losing the learner’s engagement. When the theories are exemplified in a virtual environment with multimedia, animation, interaction, and manipulated image visualization techniques, students' conceptual understanding are enhanced. If one practices new techniques and procedures in a virtual environment, one is more likely to retain the experience, and the organizational training will have its desired effect as the new efficient and effective methods will achieve wider adoption.

The web-based virtual factory enables students to learn the industrial knowledge collaboratively through a realistic continuously running manufacturing environment. It provides the student with the experience of applying theory to the practice of operating a factory in real-time. Students are able to “live” with the
problem and research over a significant time period and eventually develop solutions. It has always been a problem to teach effectively over the interface between disciplines. This virtual factory addresses this problem and enhances the learning experience by providing a realistic scenario over an extended time frame.

This Internet based simulator is platform independent because of its ability to run fully at the server side. As long as the lecturers or students have Internet access and a web browser, they can manage the virtual factory anywhere, anytime. One of the main advantages of using this approach is that the students are able to develop a methodology for quality improvement techniques rather than just an appreciation of the individual tools. Therefore one of the challenges of developing the simulation is to ensure, for example that students are not able to improve a process through experimental design unless they have first got the system in statistical control.

Virtual learning environments (VLEs) are defined as "computer-based environments that are relatively open systems. VLEs are distinguished from computer micro-worlds, where the students individually enter a self-contained computer-based learning environment, and classroom-based learning environments, where various technologies are used as tools in support of classroom activities [176]. VLEs have many similarities with computer aided instruction (CAI), or computer micro-worlds. For example, learners can access the material independently; individuals can follow different paths through it, and can utilize different material displays. But the VLE concept is broader than CAI and adds the communication dimension to a previously individualized learning experience.

The virtual learning environment can be designed to mimic any desired learning workflow, leading users on a simple intuitive path through the required coursework. Using VLE, companies can leverage their managers’ valuable knowledge and experience by making it easy for them to interact with and mentor new hires and other employees. Subject experts from anywhere in the world can participate as online facilitators, further enhancing the real-world applicability of lessons and quality of learning experiences. Job competencies and career paths can be personalized for learners so they can be more effective in their current jobs and progress more quickly to higher levels within the organization.

VLEs provide high levels of student control; support participant contact and interaction throughout the learning process, and provide an opportunity to restructure the learning experience in ways not feasible with CAI alone. Proponents of VLEs
suggest that they can potentially eliminate geographical barriers while providing increased convenience, flexibility, currency of material, student retention, individualized learning, and feedback over traditional classrooms [177, 178, 179]. Traditionally, learning environments are defined in terms of time, place, and space. Three further dimensions: technology, interaction, and control are included. Table 4.1 contains definitions of each dimension and examples that clarify how a VLE differs from traditional classroom education on each of them.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Definition</th>
<th>Comparison between VLE and Traditional Classroom Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>Time of learning.</td>
<td>VLE learners determine the time and pace of instruction and not constrained to timings fixed as in classroom.</td>
</tr>
<tr>
<td>Place</td>
<td>Physical location of learning.</td>
<td>VLE participants are free from geographical constraints and use the networked resources through the internet compared to face-to-face learning in a classroom.</td>
</tr>
<tr>
<td>Space</td>
<td>Collection of resources available to the learner.</td>
<td>A large number of varied resources are available through the internet while in classroom learning, secondary resources should be provided.</td>
</tr>
<tr>
<td>Technology</td>
<td>Collection of tools to deliver learning resources</td>
<td>Text, hypertext, graphics, streaming audio and video, computer animations and simulations, embedded tests, and dynamic content are some examples of delivery technology in VLEs.</td>
</tr>
<tr>
<td>Interaction</td>
<td>Exchange of educational ideas among learners and between learners and instructors</td>
<td>VLEs rely on information and communication technology to create the venue of knowledge transfer and learning progress.</td>
</tr>
<tr>
<td>Control</td>
<td>The extent to which the learner can control the presentations of instructions for learning.</td>
<td>VLEs provide higher flexibility control rather than in traditional classroom instruction.</td>
</tr>
</tbody>
</table>

Table 4.1 Dimensions of Learning Environments

The important advantages of the virtual reality environment over other computer based design tools are that it enables the user to interact with the simulation to conceptualize relations that are not apparent from a less dynamic representation, and to visualize models that are difficult to understand in other ways. The interactive nature of virtual environments made it a natural extension to the 3-D graphics that
enable students to visualize real life structures before actually building them. New desktop VR technologies now make it possible for industrial teacher educators and the teachers they train to introduce their students to virtual environments as learning tools without complex technical skills or expensive hardware and software. Specifically, two desktop VR technologies offer exciting potential for the classroom:

(a) Virtual worlds created with VRML-type templates

(b) Virtual reality movies that allow learners to enter and interact with panoramic scenes and/or virtual objects.

The goal of VR is to place the user in a three dimensional environment that can be directly manipulated, so the user perceives interaction with the environment rather than the computer [180]. Users must perceive that they are occupying the same space as virtual objects. VR attains its power by captivating the user’s attention to induce a sense of immersion. Desktop VR [181] is used to build animated interactive 3D graphics virtual worlds with desktop displays and without head tracking. Experience suggests that proper 3D cues and interactive animation aid immersion, and that the act of controlling the animation can draw the user into the 3D world. In other words, immersion should not be equated with the use of head-mounted displays: mental and emotional immersion does take place, independent of visual or perceptual immersion [182].

The major challenge for a learning environment is to meet as many needs and expectations as possible. This starts with the graphical presentation of the learning environment and includes the navigation, clearness of the structure of content and the learning method. By means of new graphic software and techniques it is now possible to digitalize a flat picture and display it as a three dimensional structure. A learning style can be defined as ‘the complex manner in which, and the conditions under which, learners most efficiently and most effectively perceive, process, store and recall what they are attempting to learn’ [183]. The underlying hypothesis of this project is that by giving a learner the opportunity to learn with instructional content that matches their preferences, a significant improvement on performance, understanding and motivation is expected in comparison to a static environment. VLEs require all participants to interact extensively with computers. In such a learning environment, individuals who are comfortable with technology and who have positive attitudes toward it should thrive due to low levels of anxiety and likely
excitement with the learning environment. In other words, they are computer-based systems that permeate every aspect of the students' learning experience.

Using this technology, instructors can create an industry environment such as a machine shop, a medical laboratory, an auto repair shop or assembly plant, an airport, a pharmacy, a hospital, or a construction site, or can allow their students to participate in existing environments already available. These virtual worlds are presented over the Internet through the services of a hosting organization's server. Learners enter, explore, learn, train, and interact in the worlds by means of an avatar, a computer-generated character or body double selected to represent the learners within the virtual environment [184,185]. For industry and technical educators who wish to take their students into realistic learning environments, VR movies can open potentially powerful doors. Complex equipment, hard-to-reach locations, dangerous environments, and multi-factor on-the-job decision situations are common in most fields of industry training; all may become more accessible and meaningful via desktop VR movies.

In these virtual environments, students can experience and learn by taking control of their own decisions and actions, just as they would in real-world environments. They can discover, practice, and apply technical skills, information and principles; and can realistically experience results and consequences of various actions without unwanted physical or financial risks. VR is also valuable when the experience of actually creating a simulated environment is important to learning [186,187]. Creating their own virtual worlds has been shown to enable some students to master content and to project their understanding of what they have learned [188,189]. This advantage of the technology has been cited by developers and researchers from such diverse fields as firefighting, anti-terrorism training, nuclear decommissioning, crane driving and safety, aircraft inspection and maintenance, automotive spray painting and pedestrian safety for children [190, 191, 192, 193, 194, 195]. A visual learner is one who grasps and retains information best when it is presented in a visual fashion. Learning tools such as graphs, charts, and Power Point presentations are traditionally geared towards visual learners.

Internet-based interactive and adaptive learning environments to train students in the areas of construction methods, equipment and processes are explored. New training programs integrating innovative techniques, such as virtual reality using Virtual Reality Modeling Language (VRML), make it possible to display detailed
customer-specific plant situations virtually and to recreate different learning scenarios. VRML building instructions must include precise sizes and distances to control the size and placement of shapes built within VRML’s three-dimensional space. The implementation of three-dimensional virtual representations makes it possible to view electrical plants that are otherwise difficult to explore because of time constraints, cost, natural hazards, or access restrictions. The major advantage of three-dimensional representation of objects and complex systems can be seen, namely it delivers new possibilities in a graphical presentation of information. In addition to learning a skill or piece of knowledge, the user will also be called upon to use that skill or knowledge in order to overcome certain challenges.

Ethics training becomes much more realistic and engaging for the learner through the virtual experience. This develops a more complete understanding of the ethical issues within the particular professional field. Ethics are an important part of all businesses in the 21st century when corporate social responsibility is such a major concern. In the same way that policies and strategies can be given a “trial run” through the use of 3D training simulations, ethical decisions and stances can be subjected to the same scrutiny. Learners can experience complex and challenging ethical dilemmas and observe the potential outcomes of various responses in a safe and structured environment. This ensures better results in practice and provides employees a clear line of appropriate and inappropriate behaviors in the workplace. In short, 3D learning and training can be disseminated in a variety of different ways; how it reaches the end user is ultimately up to the discretion of the organization and their particular training needs.

4.6 VRML in Virtual Training

With model-describing languages like VRML, industries are now looking for ways to distribute digital models of their designs electronically, potentially eliminating the need for distribution via printed construction drawings and specifications. VRML developments have been made in areas such as virtual prototyping systems, product evaluation systems, simulation of assembly sequences, and machine monitoring and control. Intelligently constructed VRML representations of steel structures can be done in an object-like fashion. Virtual prototype of facilities and their layout could benefit the potential users and experts to interactively evaluate its goodness prior to a real deployment. There is evidence that the use of virtual
reality may provide some benefits in improving safety and reducing risk in the physical work environment.

Facility layout and machine operation training by itself is quite time consuming, costly and dangerous, which need to be conducted quickly and correctly in the first time. Therefore, underlying physics and psychology factors must be considered during designing a work space to realize safe, comfortable and efficient manufacturing. A virtual machine is a software emulation of a real machine. A virtual machine has an instruction set, just like a physical machine. Frequently mechanical and aerospace students don’t have enough exposure to the use of manufacturing equipment in their manufacturing class. By creating three dimensional machine and components; not only can the students rotate and examine the part from different angles but also operate or run the virtual model. By imparting the concept of each part of the machine, the students can easily pick up skills needed to enable them to design something that can be practically machined.

Just like the product prototype plays important role in the manufacturing industry, facilities and their layout need also a “prototype” for the potential users and experts to evaluate its goodness prior to a real deployment. A VRML Prototype is used to create a Beam object that provides a simple way to specify thousands of different types of beams with only a beam designation and position. The prototype encapsulates the details of the implementation of the Beam object. Similarly, an assembly of parts, such as a beam with clip angles bolts, holes, and welds, might have many other instances of it in other locations in a structure.

Object-like VRML representations make it easier to update models or to extend the implementation of the object without having to change the model. Useful construction equipment and materials are developed with their behaviors that can interact with each other and their environment. Steel structures are characterized by a variety of basic structural elements including beams, columns, plates, and pipes. With the exception of plates, basic structural elements are typically much longer than their overall cross section dimensions. Complex structures, such as trusses, are built from a combination of basic structural elements. Mechanical and chemical process equipment is often built from a combination of basic structural elements as well. For manufactures and operators of complex systems, plants and machines, this method can permit effective training and fast familiarization with operation, control and
process sequences. In short, if a picture is worth a thousand words then a VRML model is worth a thousand pictures.

Not only is VRML a picture, but it is also dynamic 3-D environment that interacts with the user. However, VRML is not the only way to publish 3-D but it is one of the cheapest and easiest methods. The entire model is displayed only after it has been completely downloaded and processed by the VRML browser. With a VRML model of a steel structure any project participant can view it wherever they are and whenever they need to. All that is required is a computer and a web browser with a freely available VRML plug-in. No proprietary software, including the originating steel-related software package, is required. Construction managers in remote locations can use VRML models in their decision-making processes. A subcontractor without access to any steel CAD software packages can view the VRML models just as easily as the project manager. VRML can also be used to show tourists what buildings or areas of interest look like without them physically having to travel there or see pictures of it.

The first basic operation is the identification of a certain object. The VR browser is not a complete GUI, e.g., point-and-click operation is not a responsibility of the browser. The browser reacts on user actions other than navigation only if they are initially and explicitly described. A particular sensor has to be attached to a particular object before the user is able to interact with that object. The next step is the composition of the response. What does the user want to achieve selecting this object: text, graphics, image, and spatial analysis, and attribute information, data about the selected object or about other objects? In this approach, the decision on the type of sensor, the target object and the resulting event (CGI script or Javascript, has to be taken by the CGI script during the dynamic creation of the document.

VRML files are text files that contain information regarding the objects and linkages between the objects in a virtual world. It can be applied to a number of areas including web-based entertainment, 3-D user interfaces to remote web resources, 3-D collaborative environments, and interactive simulations for education, virtual museums, virtual retail spaces, and more. The ability to animate, play sound and video within the virtual world allows users to interact with the virtual world. The control and enhancement of the virtual world with scripts allows the development of dynamic and sensory-rich virtual environments on the Internet [196]. These features of VRML can be beneficially utilized to build teaching aids that supplement
classroom instruction. When creating the virtual elements it is important to represent
the models as realistically as possible. Very complex elements are formed into groups
of object in order to accelerate the application operation and to minimize the data
loading time.

VRML allows us to build a virtual model of either real equipment or an entire
system, depicting it from all sides. VRML also makes it possible to manipulate heavy
equipment otherwise impossible to move or visit up close [197]. Using VRML many
aspects and physical rules from reality can be easily adapted into the virtual platform.
For example, the objects have their own visual attributes, namely their definite
geometry, they are made from different materials and they are also light sensitive. It is
possible to touch, per mouse click, the objects and move or rotate them. The user is
able to cause an action which can trigger off another event in the virtual environment.
The student has the opportunity to learn and to see all of the specific functions of the
different parts. The trainee’s experience is enhanced by viewing the actions through
the best angle suggested by the trainer. A trainee may change the view if he/she so
desires. The use of visualization tools also promotes interest and curiosity towards a
manufacturing course.

The VRML prototype mechanism (PROTO) adds extensibility to VRML for
creating new geometric nodes similar to the built-in VRML geometric primitives.
This is the primary basis for developing application-specific VRML nodes to model
information. The advantage of using the prototype mechanism is that the VRML
necessary to model a steel structure can be in terms related to steel such as length,
width, depth, and section dimensions rather than only the coordinates that define the
faces of a part. VRML PROTOs can be used to model a complex steel structure.
There are also several efforts to use VRML to visualize constructed facilities modeled
with Industry Foundation Classes [198], however, the VRML that is generated only
uses the default VRML geometric primitives and does not seek to create new IFC-
related VRML nodes.

A PROTO is used to represent all members of a manufacturing model
regardless of whether is it a beam, column, clip angle, or gusset plate. The main input
parameters for the PROTO are its cross section, length, and features. A cross section
is specified by its dimensions and optional parameters such as a cardinal point, offset
values, and a flag to indicate if the cross section is mirrored. All the PROTO nodes
describe the geometry of an object and contain no information about their position
and orientation. An assembly is a collection of located parts and joint systems, for example a beam, clip angles, and bolts or a column, base plate, and weld.

The EXTERNPROTO section provides the interface definition and the URL of where the actual implementation of the PROTO can be found. By keeping the implementation of the PROTO separate from its use, the implementation can be changed without having to change any of the VRML files that use it. However, if the interface definition changes, for example by adding a new input parameter, then the VRML files that use the PROTO must be modified to account for the new interface definition.

Any VRML node can have a user-defined name using DEF. Once a node is defined then multiple instances of it can be used with the USE construct. Using DEF and USE provides for reusing geometry and other VRML nodes, greatly reducing the size of a VRML file and speeds it’s processing by the VRML browser. Reusing geometric nodes is much more efficient than explicitly creating the geometry for an object that already exists. Typically in a steel structure there are multiple identical parts, features, joints, and assemblies. In the VRML file, DEF and USE can be used to reuse identical entities. Usually there are many identical clip angles, each with their location.

In a simple framed structure, multiple instances of an assembly of parts, features, and joint systems, could appear in several locations. Both the clip angle and assembly could be defined with DEF and reused in other parts of the VRML scene graph. In this way, the VRML for a large structure can be developed with the maximum degree of reuse of existing components. There are other ways for parts to be reused. For example, consider a structure made up of parts that all have the same cross section yet all have different lengths. Since length is an input parameter for a part, normally only parts with the same length and cross section can be reused. However, if a part is generated with a unit length and nested in a VRML Transform node with its scale value set to the length, and then the part can be reused.

### 4.7 Virtual Reality in Industrial Training (VRIT)

The system design of VRIT is to bridge the gap between the training site and the actual industry site by bringing the complexities of the industry site to the training site through advanced Internet-based computing technologies. The application building tool allows embedding the VRML application in a hypermedia context. The
linking of parts of a VRML model to entries in an HTML based list or table is supported as well as the access to additional information. The system is used as an instructional tool for to set up an industry (a steel plant where steel beams are constructed using raw steel blocks). A factory constructing steel beams and columns is simulated for training purpose by setting up a website to disseminate design data as VRML models and HTML text to the design client. One should plan at the beginning of the design process the order in which the various parts are to be displayed. The user-friendly structure of a module makes the navigation much easier. It is also possible, depending on the student’s need, to either jump between the modules or to choose the sequential way through the sections.

The dynamic virtual models can promote and support professor led motivational lectures as well as self-directed experiential learning activities. The conceptual principle adopted here for an example, is to reinforce students understanding of the behavior of concrete beams with the aid of simple structure such as simply supported beam with a point load on center of the beam.

The factory operates in a dynamic environment where equipment and materials are being moved, attached together, or taken apart. A crane lifts a load of steel beams from the back of a flatbed truck and places them on the site. Then the crane lifts one beam into place where it is attached to a steel structure. Cutting of edges and drilling the blocks for joining them are also modeled. Modeling the behavior of industry equipment and materials in VRML presents many challenges. Those include developing useful 3D geometric models of construction equipment, keeping track of the dynamic state of the construction site to avoid collisions between equipment and materials, moving materials between equipment and/or the environment, and controlling the position and orientation of equipment and materials from external data sources or within a VRML browser. From the VRML model, the database will be queried to access other non-geometric information about the construction project.

The visual interface has been implemented in web-based client-server architecture. The client-side user interface is a HTML webpage. On the server side, a CGI script invoked by the client reads the needed and returns a VRML file that can be displayed immediately in the user’s web browser. There are minimum requirements necessary to display the resulting VRML models. Most important is the amount of memory on the client computer. At least 256 MB of memory is recommended.
Without sufficient memory, larger VRML models will not display. The speed at which the VRML model is initially displayed is also dependent on the client computer’s processor speed. The rate at which the VRML model is updated when interacting with it is dependent on the client computer’s graphics processor. At least a 32 MB graphics processor is recommended. The system architecture is shown in figure 4.2.

![System Architecture of VRIT](image)

**Figure 4.2 System Architecture of VRIT**

Components of a factory and the construction process of steel beams are modeled by VRML. The standard units needed to set up a factory are stored in a database. SQL Server 2005 is used as the backend tool. .NET platform is used to present the models to the users. The components are themselves 3D models which are associated with a scenario that governs its appearance and behavior in a virtual scene. These scenarios specify what actions are performed by objects either at specific points in time or as a result of user actions or interactions with other objects. They are independent reusable VR objects constructed according to some specific patterns.

This project Virtual Reality Industry Training (VRIT) comprises of three parts. The first part shows a model of a factory and the second part displays the construction process of steel beams and columns from raw steel blocks which can be presented to the subcontractors from a parent company. The VRML data model of the factory follows the standard 3D graphics concept of a Scene Graph. A scene graph always has a root node that represents all of the information. All parts of the world
can be accessed from here. As figure 4.3 illustrates, the world is then broken into three distinct parts:

- Meta data information
- Renderable data
- Node templates

Metadata contains basic information about the scene that does not necessarily effect the rendering. Renderable data is what affects the output of the system. It consists of nodes and fields. Fields describe attribute information of the node, but in themselves contain attributes. This describes the type of data represented, the name of the field, it's value and the type of access provided to the field. Node definitions are a way of providing a set of abstractions to make the file size smaller and to make content more readable and manageable. Node templates do not provide actual renderable data. These templates collect information. These templates can then be used within the renderable data, and when they do a copy is made of the template and turned into a concrete form.

Figure 4.3 UML Structure of the VRML abstract data model of a factory

The web site for the project consists of several frames. These frames feature the project title, and index to the model set, a link to a record of related issues, a main
graphic display, and related notes. The construction details of a factory and its model is shown in Figure 4.6. Models designed for the construction of a factory are fabricated together to setup a factory. The information provided in the database is also simultaneously presented.

a. Factory office  
b. Crane  
c. Drilling Machine  
d. Lathe  
e. Generator  
f. Shed  
g. Rest Room  
h. Compound with gates and lights.  
i. Flatbed  
j. Truck

Two VR models are shown in figure 4.4 and 4.5. Using translation feature, the VR worlds are positioned in the appropriate places in the factory.
Combined with Javascript, operators could be trained using a virtual machine before using the real machine. Therefore saving training cost, machine cost, freeing up the real machine for the real work and ensuring the operators’ fitness to operate the real machine. VRML as a visualization tool can enable engineers to develop better manufacturing processes. The CAD model is not easily accessible to the manufacturing engineers usually in a factory. A visualization tool is necessary to view the end product which may help them in their job.
The second part of VRIT consists of 3D model construction of steel beams starting from the initial stage of collection of raw steel blocks. Each stage is designed individually as given below in figure 4.7 – 4.12.

a. Collection of raw steel blocks  
b. Preparing their edges by welding  
c. Joining three pieces of steel to form a column  
d. Drill holes in relevant areas in the steel column  
e. Join the different columns to construct a steel beam.

These steps are also provided in a database maintained in SQL Server 2005. As the models are presented, the textual information is also displayed from the database. The presentation of these constructs to the user is done through aspx web pages.
The method described appears to be valid for conducting internet based virtual training on new machining technology and transferring the experience gained from virtual to real environment to improve the training efficiency and reduce risks. VR modeling with VRML helps to improve the industry training without taking the users
to the training site. This is a low cost development tool for visualizing the virtual construction. This technology allows the trainees to explore a 3D visualization of the industry that has to be constructed, thus enabling them to understand more effectively through interactivity. The presented experimental scenarios can provide a rewarding learning experience that is otherwise difficult to obtain.

Figure 4.9 VRIT - Column Preparation

Figure 4.10 VRIT – Drilling Holes in Steel Column
The web-based virtual factory based on simulated data demonstrates an effective method of allowing students to acquire knowledge through a virtually designed environment. A web-based virtual learning environment to teach industrial continuous improvement techniques has been discussed. This highlights the use of real industrial data in building a simulation environment so that students can appreciate a realistic training scenario without accessing the actual plant or loosing the interaction of learning underlying engineering knowledge. The website serves as a
platform independent feature which also facilitates collaboration in the learning process, where students learn through discussion and competition. Upon acquiring the proper knowledge using the simulated data, the students will move onto a synthetic process, which can be treated as a real time system with connections to the machinery. Further this environment can be used as an effective predictor of the process optimization, and will eventually have the ability to connect to real online systems.

Ways need to be investigated to display digital media in full-size on the job site, with robust technology that is accessible and manageable by the personnel who need to use it. There is a need for intuitive, natural movement between models, drawings, and text on the World Wide Web. Transitions between perspective views, orthographic views, alpha-numeric, and tabular data must take place seamlessly when integrating these media into the description of a complex building design. It is not enough to have links and anchors between models, images, and text in various frames. Rather, ways should be investigated to develop an overarching spatial interface to access these various types of data.

The ability of the 3D training to take the learner out of a passive role and turn the learning experience into a user-centered and fun experience cannot be underestimated as a highly effective design and delivery method. 3D training simulations are carefully engineered training tools that utilize the experience of interactivity and fun into order to maximize the pedagogical advantage of the tools. In other words, the existence of “fun” in these tools is not intended just to sweeten a bitter draught; it is actually an integral part of the training design that fundamentally makes the training more effective. These methods have proven so reliable in promoting and facilitating learning that most modern instructional design directly implements a core 3D learning element in some way or another 3D learning is so effective, it’s fast becoming the industry standard behind the scenes.

The Gartner Group argues that “access to the Internet and e-learning will make the universal goal of educating the general population and the workforce more achievable. This will impact some aspect of business for every enterprise and will influence culture and society, workforce diversity, application complexity and developmental spending. They recommend that

“Enterprises assess the impact of these trends on their business and define a strategy and timeline to adapt, at a minimum, e-learning or, optimally, to exploit and leverage it.” [199]. The need to develop a more realistic factory environment which includes
for example the input and output of real data will benefit especially part-time students from industries to gain hands-on experiences within classes.

The need for a realistic environment training tool is increasing. An intelligent interactive learning environment which reproduces the actual scenario of an industry could be a solution to the difficulties of contemporary engineering education. In reality, virtually all industries could effectively put 3D learning to use in order to facilitate superior training and secure a competitive advantage through greater efficiency. As the future of globalized industry becomes increasingly competitive, those organizations which are able to efficiently leverage the full value from employees will be the organizations which succeed in the long term, and 3D learning is a key way to achieve exactly such an outcome.