Reality in the Nuclear Industry: Augmented, Mixed and Virtual

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Yaël-Alexandra J. Monereau was born in Brooklyn, New York. She received her B.S. degree in construction management from Southern Polytechnic State University and since then she has taken leave from a B.S. in Mechanical Engineering Technology and is presently teaching at a Harmon STEM School in Tampa, FL. Recently, teaming up with Prewitt Solutions, LLC., Yaël hopes to help develop STEM education amongst the generations. From 2011 to 2013, she worked as a Product Analyst at Genuine Parts Company-Rayloc. Within the Genuine Parts Company-Rayloc division she teamed up with another engineer to headline the Disc Brake Pads portion of the business. Presently, she co-founded Elyape Consulting, LLLP., which specializes in infancy start-ups, with a higher priority given to local non-profits. Her research interests include augmented reality, construction, energy, user-computer interface, virtual reality, and virtual augmentation. Ms. Monereau, is an active member of the Associated General Contractors (AGC), American Society for Engineering Education (ASEE), American Society of Mechanical Engineers (ASME), the National Society of Black Engineers (NSBE), and the Society of Automotive Engineers (SAE). Through her tenure within these organizations she has served on the Board of Directors for NSBE, as well as multiple leadership roles throughout her undergraduate career with AGC and ASME.

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Abstract— **In the Nuclear Engineering industry problem-solving and critical-thinking prior to entering into high risk situations are amongst the top skills needed by employees. Employers expect workers to possess these traits. However, traditional methods of education are becoming outdated in comparison to the continuous development of technology. It is widely known that when a learner is presented the opportunity to experience or visualize work, portions of the brain are engaged that allow for the user to be more receptive and to retain more information. Training using virtual augmentation in classrooms and simulation labs would prove beneficial to not only enhance learning outcomes but also to improve the efficiency of instruction. In the engineering community we are challenged with processing large amounts of data quickly and this requirement can be met by frustration and confusion. Within the area of Probabilistic Risk Assessment (PRA) the focus is on the outcome and ensuring the path taken leads to a favorable conclusion. Currently, PRA is a study of numerical computations to predict the future resultants. This method does not necessarily prepare one for real-world failures. The goal of this work is to show how PRA combined with virtual augmentation methods can be used to improve the effectiveness of calculations and training.**

Index Terms— **Augmented Reality (AR), Computer-Assisted Instruction, Electronic Learning (E-Learning), Implementation in Engineering Practices, Nuclear Engineering, Probabilistic Risk Assessment (PRA), Risk Management, Simulation, Software Design, Virtual Augmentation, Virtual Reality (VR), User-Computer Interface**

1. Introduction

The value of people is increased or decreased based on knowledge, this information may be obtained through multiple facets. Taking an in-depth look at the multiple Implementations in Engineering Practices that are being introduced across the various industries, there are some very strong differences in delivery methods; however the similarities far out-weigh the variances. Utilizing Augmented Reality (AR) and Virtual Reality (VR) environments in addition to traditional teaching practices allows for a comprehensive view to what can only be experienced through doing. Simulation type teaching is built on the premise of, "I hear and I forget. I see and I remember. I do and I understand." Confucius (551 BC - 479 BC) [1].

It is imperative to remember that electronic learning (e-learning) is not only limited to streaming a lecture over the internet for students. Through simulation a risk management plan goes from being hypothetical to being realistic without including the element of actual harm or hazardous situations. A Level 1 PRA models the various plant responses to an event that challenges plant operation. The plant response paths are called *accident sequences* [2]. If there was a way to introduce a learner to the accident sequences through an immersion teaching method, the importance is impressed upon all those involved and presents itself in a more favorable outcome.

2. Background

When a learner is presented the opportunity to complete or visualize the work, there are portions of the brain engaged that allows for the user to be more receptive to retention. In order to tap into the more active learning areas of one's mind, it is important to revitalize the method of delivery. In Figure 1, the study reflects that the retention curve excels what can be expected by only providing one method of implementation.

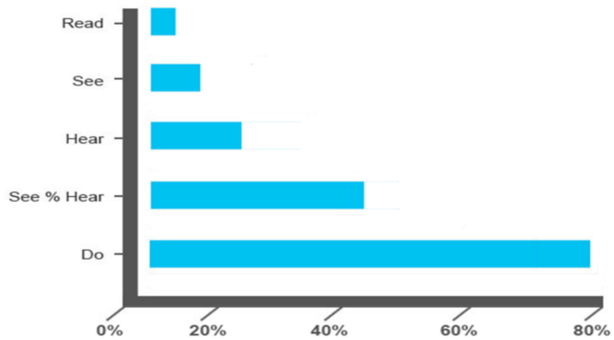

Figure 1 Students Remember [3]

Information from the study shows the act of reading about vs. the act of seeing an action respectively is far less than hearing about an action. The percentage of information retained increases by approximately 40% if you physically perform an action versus only seeing and hearing it.

In the field of Nuclear Engineering, PRA is taught and managed through traditional teaching practices, such as, Fault Trees and Event Diagrams, which are the crucial foundation for event scenario layouts. However, they only allow users to see the 2D version of the path and daydream about the positive or more importantly negative consequences of their decisions. The use of PRA from the Nuclear Regulatory Commission (NRC) is to estimate risk by computing real numbers to determine what can go wrong, how likely is it, and what are its consequences. Thus, PRA provides insights into the strengths and weaknesses of the design and operation of a nuclear power plant [2].

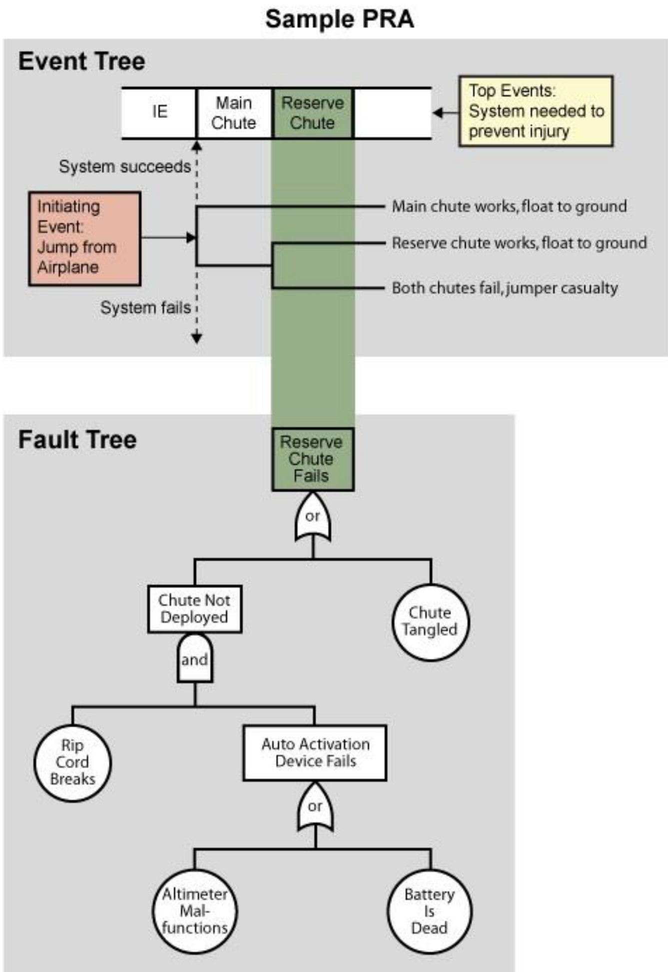

Figure 2 Complete Sample PRA Event and Fault Tree [2]

In reviewing the current teaching methods in engineering, researchers such as Davies studied the inherent correlation between information presentation and reception on behalf of the end-user. As Davies details in "Student engagement with simulations: a case study", simulations can be defined as computationally correct representations of a situation which offer the user control over the outcome of the program. Motivation for this study was a desire to understand the characteristics of simulations that support learning: the attributes, qualities, and circumstances of their use that lead to an improvement in a student's understanding. To investigate this issue a qualitative study of student engagement with simulations was conducted. [4]

As a result of this inquiry a two-year study developed. Davies continued his efforts by having his students complete quantitative and qualitative surveys during the Heat Transfer course offering. His results are displayed in Table 1 and Table 2. Addressing the issues of self-imposed study skills and then reviewing the current teaching practices, Davies was able to extrapolate a reasonable amount of data to justify his study.

Final survey questions which address issues of study skills

Question	Strongly agree		Agree		Neutral		Disagree		Strongly disagree	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
Using the simulations helped my understanding of the subject	0	1	9	8	4	4	0	0	0	0
I was able to review content at my own pace	0	4	11	5	0	3	2	1	0	0
I enjoyed using the simulations	2	2	3	5	6	5	2	1	0	0
I plan on using the simulations to help my revision	1	0	4	1	6	5	2	5	0	2
I would like to see other subjects in Materials Engineering use simulations	1	6	3	4	8	3	0	0	0	0
I used the simulations outside the formal class times	2	1	1	1	9	9	0	1	1	1

Table 1 Final survey questions which address issues of study skills [4]

Final survey questions which address issues of 'higher' learning skills

Question	Strongly agree		Agree		Neutral		Disagree		Strongly disagree	
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001
I was able to transfer my experience with the plate simulation to the casting simulation	1	2	4	8	4	1	3	0	0	0
The relationship between the simulations and the analysis methods was clear	1	0	2	5	5	8	4	0	1	0
I found I was able to predict the effect of my actions on the outcome of the simulation	2	2	6	7	4	3	1	1	0	0
I found talking to my friends about the simulations helped my learning	1	4	9	7	3	1	0	0	0	0

Table 2 Final survey questions which address issues of 'higher' learning skills [4]

3. Objectives

The offering of Simulation Based Training (SBT) provides a more holistic user-computer interface. Some goals with integrating AR, VR, or simulations with the traditional learning methods is to provide novices and veterans the visual stimulation needed to make informed decisions consistently and witness the detrimental fallouts.

For the type of nuclear plant currently operating in the United States, a PRA can estimate three levels of risk.

- A Level 1 PRA estimates the frequency of accidents that cause damage to the nuclear reactor core. This is commonly called core damage frequency (CDF).
- A Level 2 PRA, which starts with the Level 1 core damage accidents, estimates the frequency of accidents that release radioactivity from the nuclear power plant.
- A Level 3 PRA, which starts with the Level 2 radioactivity release accidents, estimates the consequences in terms of injury to the public and damage to the environment [2].

4. Current Methods

A review of the current methods of AR versus VR environments prove to show strong potential in application. Dependent on the goal of your assignment, it may just be more beneficial to use one versus the other or even in unison. The end-design has to be taken into consideration in the pre-planning phase to help the computer programmer in developing a software design that truly

can be used as a vital integration in Computer-assisted instruction and not just a haphazard alternative. This integration requires a 360 degree review of all objectives and goals.
AR-based systems, shown in Figure 3, support information visualization through augmenting virtual objects onto the real world. VR-based designs, as shown in Figure 4, provide very intuitive interaction with the end users in terms of visualization and the interfacing with downstream processes [5].

Figure 3 Student sketching a wine bar in a VR Environment [5]

Figure 4 Users interacting with a Thermography Reading on a Virtual Object created in an AR Environment [5]

Use of SBT combined with the Project Team Builder (PTB)[1] Simulator is used in the field of Industrial Engineering.

In 1987, Grieshop listed some of the benefits of games and simulations:

1. Emphasize questioning over answering on the part of players.
2. Provide opportunities to examine critically the assumptions and implications that underlie various decisions.
3. Expose the nature of problems and possible solution paths.
4. Create an environment for learning that generates discovery learning.
5. Promote skills in communicating, role-taking, problem solving, leading, and decision-making.

[1] The Project Team Builder software tool combines an interactive, dynamic case study and a simple yet effective Project Management System…The PTB provides an environment for hands-on experience in project scheduling, resource and budget planning, risk management and project control. [1]

6. Increase the motivation and interest in a subject matter [1].

When using simulation based training to teach someone the consequences of what happens when a PRA is done incorrectly, one must consider the audience. The "audience" may change at different phases of the planning or implementation process. Simulation environments can be used with any audience, without the inherent risk of danger.

The implementation of Lean Practices and principles allows many professionals to consider the end goals of a project not only in the final output, but also in the input stages. The authors of "Implementation of Lean Engineering Practices" go on to explain two of the key tenants of Lean principles as:

1. Respect for People – Seeing employees as the most important and valuable resource is critical for creating a high-performance working environment.
2. Value – It is important to capture the value defined by internal and external customer stakeholders, the external customer being the one who defines the final value of the deliverable [6].

SBT shows great promise, in particular, its contribution to the implementation of Lean Management Practices ("Lean Enablers") among project team members and stakeholders in two different industries in order to lead to better project outcomes in terms of time, performance, cost, and stakeholders' approval [6].

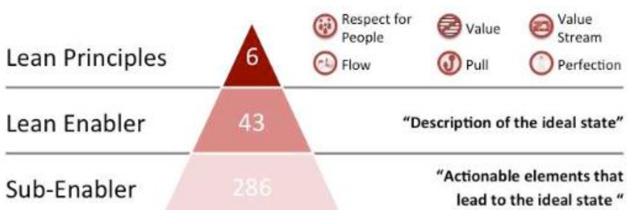

Figure 5 Lean Principals, Lean Enablers and Sub-Enablers [6]

When people are placed as the first priority in a training or education program, the focus is on learning habits. It is desirable to build a program that is adapted to the learning style of a broad audience. By reviewing The Learning Pyramids and many years of implementation it has been discovered that totally immersing someone in a subject ensures they not only learn but also retain the most information.

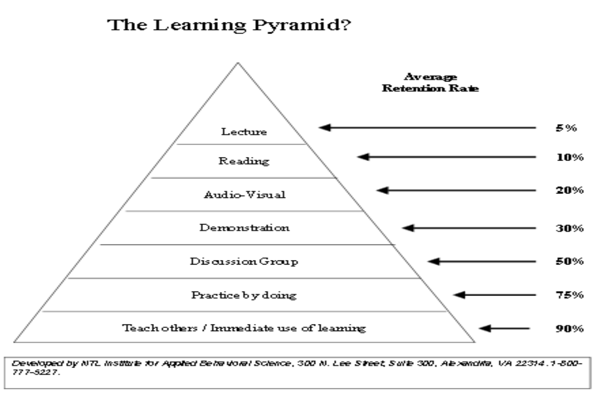

Figure 6 The Learning Pyramid [3]

In Figure 7 and Figure 8 problem-solvers are using a to-scale walk-through projection to assist them in assessing the needs of the differing facilities. For Figure 7 the importance is on the air-flow through and over the space of the equipment within the plant. This can be extremely useful in temperature dependent portions of edifices.

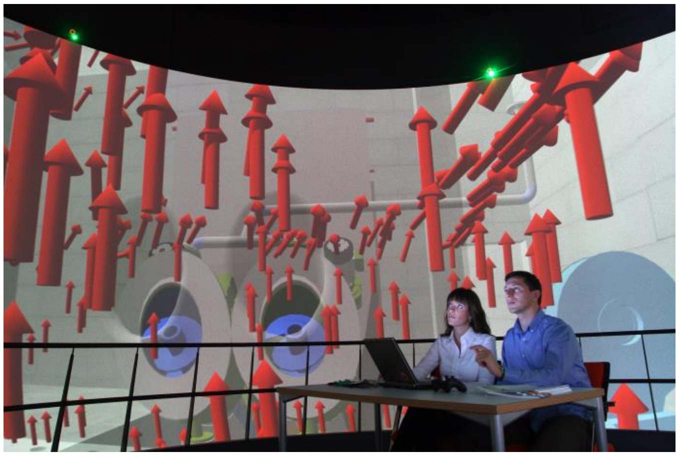

Figure 7 Digital Engineering for Safe and Reliable Systems [7]

Shown in Figure 8, the reviewer has access to life-size projections of pipes and other system components, if someone is creating an Event or Fault Tree being able to visualize the failure can help the PRA Analyst in making a detailed tree and effectively do a Root Cause Analysis (RCA) without unnecessary guess work.

Figure 8 Virtual Reality for Factory and Plant Engineering [7]

5S is a cyclical methodology: sort, set in order, shine, standardize, and sustain the cycle.

$$Lean = process - waste + flow$$
$$5s = work\ area - extra\ stuff + visual\ order$$ [8]

Equation 1 5S Reasoning for LEAN Practice

5. Relevant Prospective Technologies

Augmented and Virtual Reality are presently being used in the learning and research stages in the Medical fields and have shown enormous amounts of yielding tremendous outcomes. As the world of AR and VR crosses more and more thresholds, cross-industry discoveries have increased as a result of a more inclusive educational focus.

Many studies have shown the strides in medical sciences, highlighting the amount of abilities learned through avidly participating in the learning.

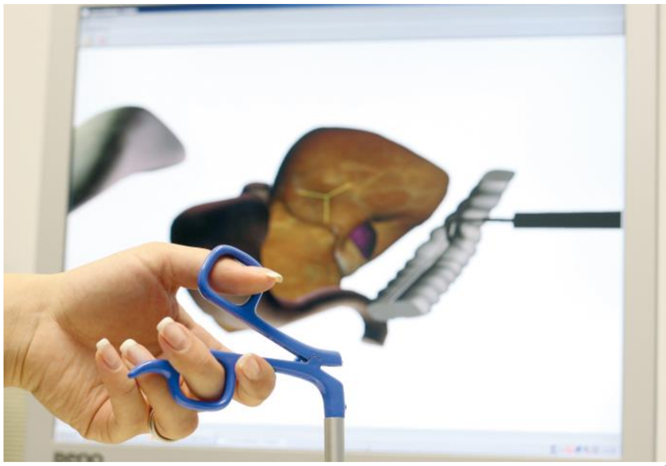

Figure 9 Mixed Reality used in the Medical Field [7]

Even though the results from the medical field are growing exponentially, there are great leaps in fields even more closely related to the Nuclear Engineering realm. For example in Mining Engineering, a "Virtual Reality Laboratory" consists of a 360-degree screen [of an excavation site] with 12 projectors on top. Shown in Figure 10, users stand in the space wearing 3D glasses [9].

Figure 10 Virtual Mining at the UNSW Australia Engineering [9]

In further efforts combining LEAN practices, AR, and VR, with ideas such as Risk in Early Design (RED), the end result is continuous improvement. Risk in Early Design (RED) method as the backbone of the graduate level Function Based Risk Assessment course to teach an interdisciplinary group of engineers how to use traditional PRA techniques such as failure modes and effects analysis (FMEA), fault trees, and event trees in conceptual product design. The innovative use of specific engineering taxonomies and knowledge-based failure data representation allows RED to identify product risks armed only with product function. [10]

6. Future Goals of This Work

$$AR + VR + PRA = Redefined\ Teaching\ and\ Learning\ Practices$$

Equation 2 Redefining the Impact of PRA

The goal of this research in the future is to improve the user-computer interface used in training so that a person can learn valuable outcomes to better prepare them in making educated PRAs. By taking the accident sequences and making them life-size without the inherent risk that comes from "on-the job training," end-users are better equipped to make informed decisions. As the Nuclear Engineering field makes strides towards the future, it should look to improving e-learning experiences and adopt the advancements in the technologies used by a variety of other industries.

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8. Appendix

Supplemental Examples:

a) By utilizing the Quick Response Code (QR Code) found in Figure 11 factory worker is able to accurately fill a customer's order from the beginning to the end of production line. The properly distributed barcodes work in conjunction with the QR Codes in the factory to maximize the effectiveness of computer support before and after the training phases.

Figure 11 Virtual and Augmented Reality for Production [7]

b) As demonstrated in the Figure 12 the user of the Virtual War Room is absorbed in a simulation that allows the participant to experience training environments and see the realistic results, practiced with everyday body movements.

Figure 12 The Virtual War Room, a product of the Mixed Reality (MxR) Lab [11]

c) Dr. Daniela Faas received a doctoral degree in mechanical engineering and human-computer interaction from Iowa State in May 2010. Her dissertation, "A Hybrid Method of Haptic Feedback to Support Virtual Product Assembly" [12].

Figure 13 Faas Utilizes the Virtual Reality Applications Center [12]

Supplemental Videos:

a) New strides are being made in teaching techniques as seen in "Virtual Reality Technology for Cerebral Palsy [13]", a study being conducted through a partnership of the University of California, Los Angeles (UCLA), the University of Southern California (USC), and the Cerebral Palsy International Research Foundation (CPIRF).
b) Companies like Marxent Labs, who is an AR Vendor, sell the benefits of AR to production companies for infusion in their marketing efforts. They not only look to assist the commercial market, but also the educational market with technologies as displayed in "Augmented Reality 3-D Brain Interactive Model [14]. The value of showing the inner workings of the human body or industrial systems is insurmountable.
c) In the "Reality City of the Future [15]" Morris May and Ryan Pulliam display the benefits from usage of AR in city planning.