Comparison of Virtual Reality Versus Reality: Effects on Student Learning Using Virtual Technology on Nanotechnology Education

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Abstract

Throughout the years instructors have had to solve and resolve the dilemma of how to teach. With each group of students new challenges appear forcing institutions to adapt while still maintaining a high standard. As nanotechnology has been growing both as a science and as an industry it has become necessary for universities to search for means to teach it effectively. While some institutions can afford the expensive equipment needed to teach nanotechnology others cannot. The need for practical experience in this field causes problems for institutions with restricted resources. Virtual reality (VR) has the potential to help overcome these barriers while still providing an education that pushes for excellence. This paper will delve into the educational effects of virtual reality on student learning. It analyzes the potential benefits and hazards of utilizing VR in teaching as well as summarizes a teaching module being developed at Utah Valley University (UVU) for the purpose of furthering nanotechnology education by combining VR labs with in-class teaching.

Introduction

Nanotechnology is defined by the National Nanotechnology Initiative (NNI) as " ...the understanding and control of matter at the nanoscale, at dimensions between approximately 1 and 100 nanometers" [1]. Nanotechnology has a long history, dating back to the roman period, however many of the advancements are quite modern with the first lecture on nanotechnology occuring in 1959. More recent advancements include the creation of the scanning tunnelling microscope, the discovery of the carbon nanotube, and the creation of dip-pen nanolithography [2]. With constant discoveries being made in nanotechnology it has become ever-more important for students entering the field to have an education that prepares them for the challenges that come with being on the front lines of discovery.

One, if not the most, difficult task placed on the shoulders of instructors is creating a curriculum that adequately addresses the needs of industry, students, and their own institution. Throughout the years many studies have been created looking at various methods. One promising method is virtual reality. Virtual reality is the immersing of a person in a computer generated environment. It does so by replacing a person's sight, hearing, and sometimes touch with a virtual world via headset and controllers. The truly unique and powerful aspect of VR comes from this alternate world as it is not bound by the same restrictions as reality. Because of this, VR as the ability to visualize abstract concepts, or concepts that are normally difficult to depict such as molecular bonding or the nanoscale. That is not to say that VR doesn't have weaknesses; due to VR's technical limitations true realism is still years away. Furthermore, the temptation to utilize VR too much can come at the cost of education [3].

In order to test the potential of virtual reality UVU put together a team of researchers whose purpose was to develop a lab that implemented VR into existing curriculum. The lab was designed to complement in-class lectures and allow for students to participate in lab experiences all while mitigating costs without negatively impacting student learning. This paper is a report on that effort. It will begin with a summary of the VR lab, its creation and implementation. Then the impact of the VR lab on student learning shall be addressed.

Creation of Virtual Reality Lab

The VR lab is a collection of individual modules that are meant to go hand-in-hand with in-class education. Currently there are three virtual modules: photolithography, scanning electron microscope (SEM), and plasma etching, with the potential for more being developed. The first step to creating these labs was the creation of the real-world, in-class materials. These materials include lectures, slide presentations, diagrams, and homework given to students. Figure 1 is an example of some diagrams used to teach students about nanotechnology. Following that, educators also created photolithography, SEM, and plasma etching labs using real-world materials and processes. It was only after these initial steps were completed that UVU's research team began development on the virtual modules.

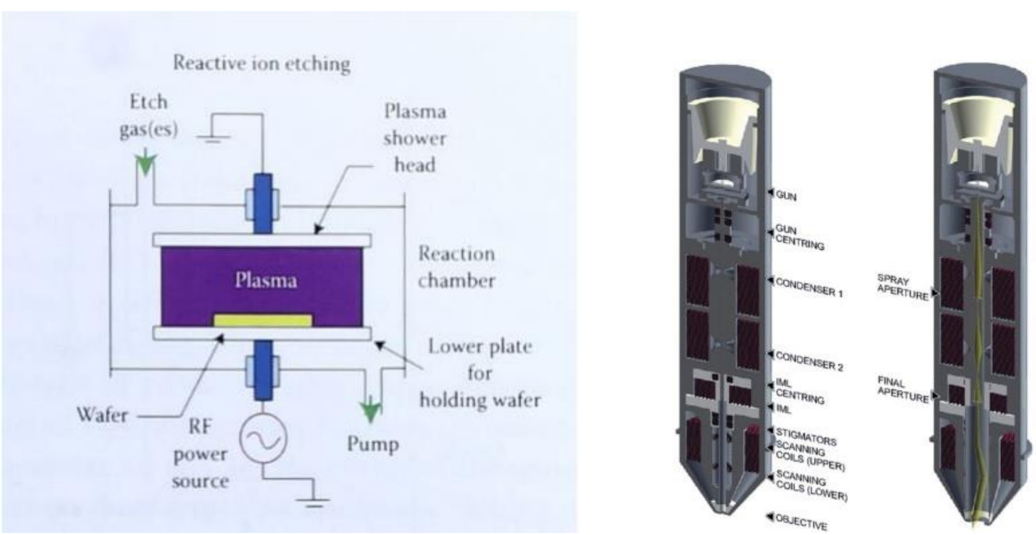

Fig 1: Left: Diagram of RF generated plasma chamber, Right: CAD model of SEM column

Each VR module was created following the same principles and guidelines. First, the team creating the virtual simulations were instructed in the real-world labs. They performed and documented the same experiences the students will perform. Next, they took their recordings and created 3D models of the lab machinery, environment, and other needed materials using the industry standard for 3D: Autodesk Maya (Maya). The modeling process started with block, or very low detail, models in order to properly scale the objects with the user as well as provide a basic layout of each lab module. Afterwards, the models were improved upon until they were a close approximation of their real-world counterparts. The next step was to finish each model with texture and color; some were completed using Allegorithmic Substance Painter (Substance) while others were done using Maya (see Fig 2).

Fig 2 Left: Block layout of a prototype lab, Right: Etching machine in Substance

At this point the assets were imported into the game engine Unity 3D (Unity). Researchers utilized two plugins to Unity in order to bring the simulation to VR: SteamVR and Virtual Reality Toolkit (VRTK), which contains a library of premade assets for use in VR development. The simulations were completed through combination of Unity, VRTK, and the C# coding language (see Fig 3).

Fig 3 Above: Completed photolithography room, Below: Completed etching room

Implementation of Virtual Reality

These virtual labs will be included as companions to existing curriculum. Students will first be instructed in the classroom regarding the purpose of the various labs and their use in nanotechnology. Once they have a basic understanding they will enter VR and perform the same physical actions that they would do in a real-world lab. For example: in the VR etching lab students are taken though the full etching experient, starting with preparing a wafer and the machine, all the way to the actual etching and storage of the wafer (see Fig 4).

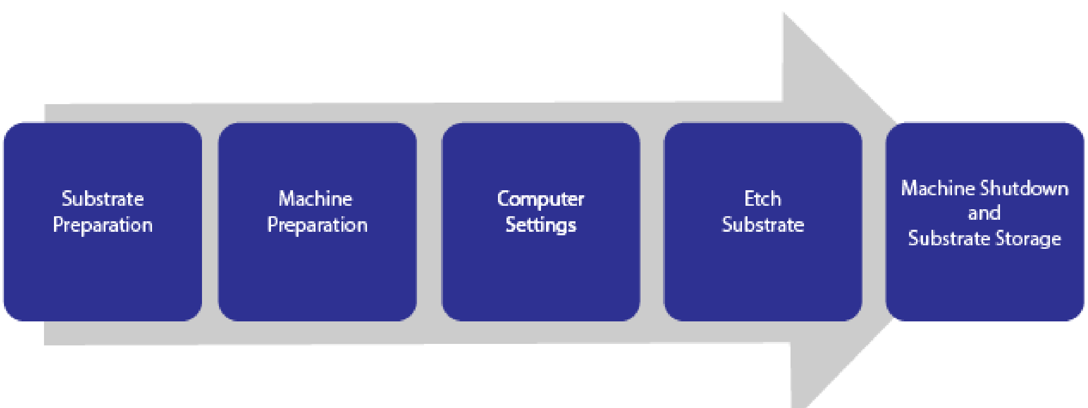

Fig 4: Steps for etching a wafer in the VR lab

The labs have a time limit of fifteen minutes but most complete them in about ten minutes. Students are graded on their ability to safely and correctly follow the experiment, and, upon proving their abilities, will be allowed to do the exact same experiments in a real-world lab.

Virtual Reality and Student Learning in Nanotechnology

Higher educational courses are always under a microscope. Instructors are constantly evaluated for their effectiveness, and students are being measured for their ability. There have been near countless studies into the effectiveness of teaching, each one evaluating what works and what doesn’t [4]. Instructors at UVU took these studies into account while building the curriculum for teaching nanotechnology. Many of the studies pointed out the many different ways to teach and learn. If such teaching and learning styles don’t align it is harder for students to understand the material and become the type of nano-engineers that the industry needs. Lectures, slides, diagrams, and other presentations assist in student learning but they don’t cover all types of learning styles. Furthermore, as class size increases it becomes harder for instructors to provide the one-on-one interactions that many students need to excel. Class size can also make it difficult for each student to have access to lab experience, especially in the more time consuming processes involved in nano-manufacturing, like photolithography.

Virtual reality has the potential to help overcome some of the problems caused by lecture-based teaching by providing more means and opportunities for students to learn. Different methods of learning allow each student to learn in ways that fit them. Bell and Folger provided an in depth study about the strengths VR has in relation to different learning styles [5]. When it comes to nanotechnology education, VR’s greatest strength lies in allowing students to physically interact with the processes without the risks inherent in nanotechnology. Students are able to pick up samples, closely examine the changes that occur to them during the nano-manufacturing process, and take charge of their lab experience by being active participants. Furthermore, VR also provides a means to visualize phenomena otherwise impossible to see. By allowing students to look inside the machines as they run, VR enables them to see truly the remarkable. They can watch as electrons bombard samples in the SEM lab, or see the subtle changes that happens to wafers during the photolithography process (see Fig 5).

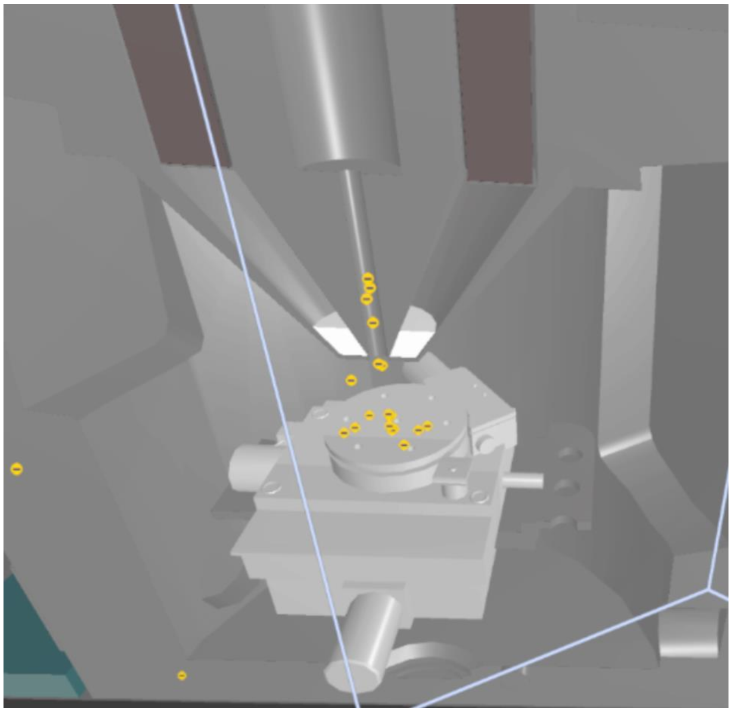

Fig 5: VR view of electrons in SEM

Finally, students are able to be in control of their learning experience as there is no need for instructors to closely monitor them to prevent costly mistakes. Thus, students are able to experiment, not just perform safe, routine procedures. As they do so they gain more opportunities to learn the ins and outs of nanotechnology, how it truly works, and what is most effective. By nurturing their natural curiosity, instructors can help students grow into more capable nano-engineers. Students are not the only ones who gain from this freedom. Now that instructors need no longer keep a close eye on their students they can spend more time in other areas of study.

The second area VR helps improve is cost. The tools and supplies needed to run nanotechnology experiments quickly run into the thousands of dollars as upkeep and mistakes can be quite costly: 100mm wafer samples are ~$100 per five wafers [6], a manual mask aligner costs $50,000 - $200,000, ect. VR, on the other hand, is comparatively cheap. A standard headset is around $600 and VR ready computers are about $2,000 [7] (see Fig 6). When taking these costs into consideration it can be hard for some institutions to implement real-life nanotechnology experiments. But with VR’s price it will be easier for those same institutions to teach their students, resulting in more nano-engineers for the industry.

Fig 6: Left: HTC Vive bundle, Right: Mask Aligner

The final aspect where VR shines is in the amount of time it takes for students to perform nanotechnology experiments. Most students accomplished the VR photolithography lab in ten minutes, whereas the same experiment in real-life can take up to an hour. SEM and etching both follow similar results with VR experiments taking less than half the time of real-world experiments. By allowing more students more opportunities to learn the number of graduates who will be ready for the field will further increase.

VR’s weaknesses stem from two areas: first, the limitations of technology, and second, the novelty of the idea. While the technology for virtual reality has come a long way in recent years it is still far away from being truly realistic. It is possible to approximate, but affordable headsets don’t have the resolution to support full detail, and most computers don’t have the power to process true realism. This is easiest to see when trying to read text as the resolution of the headset makes most fonts illegible unless they are blown up to exceedingly great proportions. Thus preventing many instructional, or reading, aspects of learning from being used in VR, such as slides or manuals. Technological issues don’t just stay in the virtual world either. Since VR operates by completely cutting off the user from the real world there are other hazards to consider. Students unfamiliar with VR had to be taught about the “play area”, which is an area in the VR world that represents a clear, real-world, space where they can walk and interact with the virtual equipment unimpeded (see Fig 7). If this instruction was neglected some students would attempt to run, which, at best, could unplug the headset from the computer, and, at worst, would result in them running headfirst into a wall.

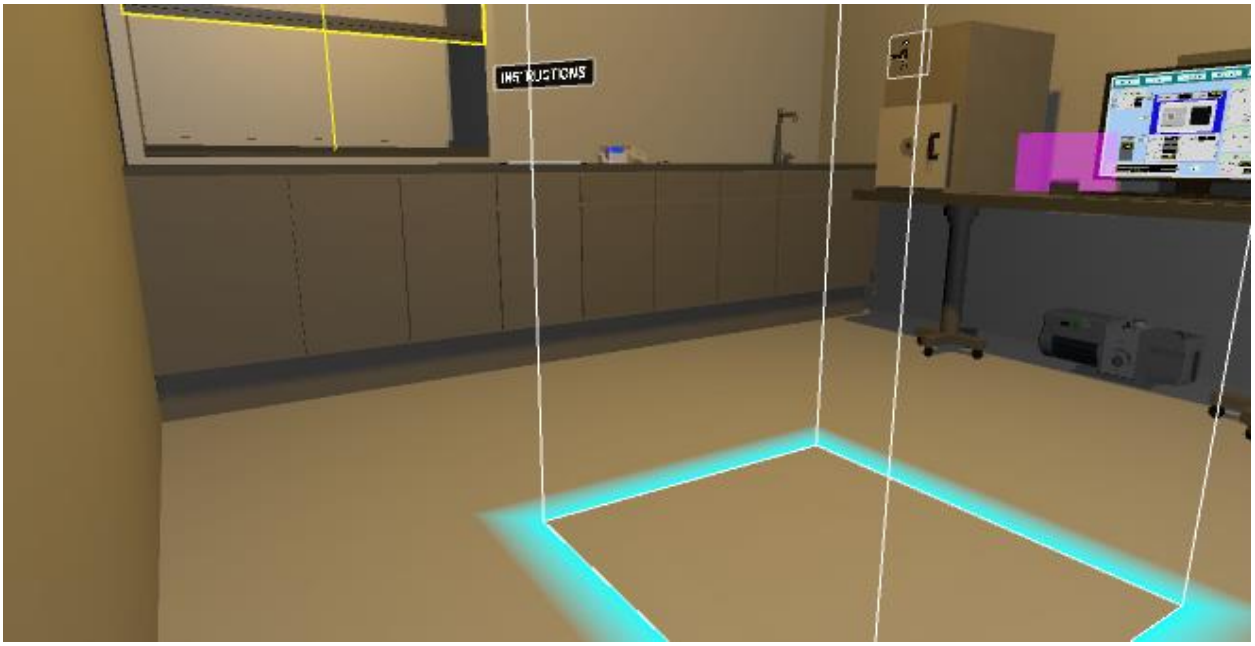

Fig 7: Play area, outlined by the light blue square, in the etching room. (Size of play area is dependent on the settings chosen during VR setup)

Further cause of alarm came from others walking around the student currently immersed in VR. If they were not careful the student could accidentally walk into or hit them. Finally, due to VR's unique approach to teaching the VR environment itself can become a distraction. Many students upon first entering the simulation spend time exploring and looking at their surroundings, the more extravagant the virtual world was, the more time students wasted. Distractions weren't limited to just visuals either: many students would spend time throwing the virtual equipment, such as photoresist bottles, across the room as they attempted to learn the rules of the virtual world.

Initial Student Interaction

In order to test the effects of VR on training, students were asked to participate in a brief study. Due to the timeline, there were only a handful of students who were able to participate, and most of them were new students to the Engineering program who had little to no experience with nanotechnology. Two students completed both a pre- and post-survey about their experiences, one who used the VR course before using the machines and one started using the machine directly without the benefit of VR. Others participated, but did not complete both surveys and so were not included.

The student who completed the VR first before using the machinery reported that they benefited from the VR training before actually using the machine and that they felt familiar with the machine. The student who went straight to using the machine mentioned that they did not feel prepared prior to using the machinery. They also specifically mentioned that they were afraid they might break something. While the numbers are quite small to draw any general conclusions, these statements are encouraging and give us a sense that further research in this area should be done to help create a better understanding of the benefits of VR technology in teaching.

Conclusion

Virtual reality has the potential to greatly add to traditional methods of student learning, but it is not a replacement. It's best used in conjunction with standard methods of teaching so that they can build upon one another. Thus allowing the weaknesses of each to be covered by the strengths of the other. This is the model that UVU researches have chosen to follow. First, students are instructed in class via lecture and other standard methods of teaching. Then they take what they have learned and attempt a virtual simulation of various nanotechnology processes. Finally, once they have proven that they understand the material and can correctly perform the experiments they are given the opportunity to perform the same experiments they learned in VR in a real-world lab.

References

[1] "What is Nanotechnology?" *What is Nanotechnology? | Nano*. [Online]. Available: https://www.nano.gov/nanotech-101/what/definition. [Accessed: Dec. 28, 2018].
[2] "Nanotechnology Timeline," *Nanotechnology Timeline | Nano.* [Online]. Available: https://www.nano.gov/timeline. [Accessed: Dec. 28, 2018].
[3] J. Parong, "Learning Science in Immersive Virtual Reality," *Journal of Educational Psycology*, vol. 110, no. 6, Aug, 2018, [Online]. Available http://eds.a.ebscohost.com/eds/detail/detail?vid=0&sid=ff2ec3e5-713b-4476-b106-e9ec04288c99%40sessionmgr4006&bdata=JnNpdGU9ZWRzLWxpdmU%3d#db=pdh&AN=2018-03101-001 [Accessed: Jan. 8, 2019]
[4] R. M. Felder, "Reaching The Second Tier: Learning And Teaching Styles In College Science Education," *Journal of College Science Teaching*, vol. 23, no. 5, 1993 [Online]. Available: https://www.engr.ncsu.edu/stem-resources/legacy-articles/education/. [Accessed Jan. 10, 2019] provides a model of learning and teaching styles that has been cited by numerous sources as they look for more effective means of teaching.
[5] J. T. Bell and H. S. Fogler, "The Investigation and Application of Virtual Reality as an Educational Tool," June, 1995. [Online]. Available: https://www.cs.uic.edu/~jbell//Professional/publications.htm [Accessed: Dec. 21, 2018].
[6] UniversityWafer.com. [Online]. Available: https://order.universitywafer.com/default.aspx?cat=Silicon&gclid=CjwKCAiAmO3gBRBBEiwA8d0Q4uOB1ErkvT_nwFFOH0s1oec9T_r_MOzs18k96_tDVQ9V91elq1xWLRoCcYIQAvD_BwE [Accessed: Jan. 10, 2019]

[7] “The ultimate VR headset buyer's guide,” TheVerge.com. [Online]. Available: https://www.theverge.com/a/best-vr-headset-oculus-rift-samsung-gear-htc-vive-virtual-reality#highendoption. [Accessed: Jan. 10, 2019].