Using Virtual Reality Welding to Improve Manufacturing Process Education

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Abstract

Virtual reality welding systems increasingly are being used to train welders in industry. One such system is being used to introduce entry level industrial distribution undergraduate students to welding processes in preparation for hands on real welding in labs. The same system is also used for upper level manufacturing and mechanical engineering technology students to extend their knowledge of the systems and techniques, as well as to teach them about the effects of welding parameters on quality. In order to improve the lab experience, a survey was taken regarding the student anticipation of the experience, and the results are shared and discussed. Suggestions for the improvement of the lab experience for the students using this system are made.

Introduction and Background

Virtual reality (VR) is an interactive computer-generated experience taking place within a simulated environment that incorporates mainly auditory and visual sensory feedback [1]. Typically via a worn headset, a VR system 'immerses' the user in a computer-generated graphical user interface (GUI) that can be interacted with. Though it is most widely used in the entertainment industry, in gaming and videos for example, VR is increasingly being used for education and training. This is because a real workspace can be simulated with which the users can interact for educational and training purposes without the typical risks involved and at much lower costs; it further has the advantages of scalability and flexibility.

Over the years VR has found wide application in 2-year technical colleges and 4-year universities to train students in the effective use of manufacturing process equipment, especially welding processes. Due to its inherent benefits, welding equipment manufacturers themselves have taken on creating the market for welding simulators leveraging a VR interface. It is expected that student training using VR welding simulators reduce the costs involved in terms of time, consumables, infrastructure and other resources, as well as the environmental impact. Though there is no equal substitute for a real welding experience, faculty using VR simulators to prepare their students in for welding processes, and then supervising them on the real welding exercises have reported improved performance, both in terms of the familiarity/startup-time involved and the weld quality themselves [2]. Further, the effectiveness of VR welding simulators based on the task difficulty have been evaluated by numerous researchers who have found that both fully virtual and VR-integrated into real world training programs were appropriate weld training, at the low and medium task difficulty levels, while at the highest level of difficulty, the VR system was no longer solely sufficient for training [3]. Another study observed that the students trained using 50% virtual reality had training outcomes that surpassed those of traditionally trained students across four distinctive weld qualifications, and that the VR-integrated group demonstrated significantly higher levels of team interaction, which led to increased team-based learning [4]. Skill and competency assessment as well as their tracking over time for each user/student is another beneficial application of such technological capability, besides being able to distinguish novice vs. experienced students well as their relative performance across task difficulty levels [5, 6].

Class and Lab Description

MMET 201 Manufacturing and Materials is a service course taught every semester to non-majors in the Industrial Distribution (ID) program at Texas A&M University. The ID curriculum was recently revised; MMET 201 was developed to replace two materials courses and a dedicated manufacturing course in the previous degree plan. The new course is 4 hours of credit, which includes 3 hours of lecture and a 2 hour lab each week. There are 14 sections of 16 students in a regular semester and two sections of 16 students in a summer semester. The lab activities cover a range of manufacturing processes and material testing techniques. Due to the large number of students passing through the lab, and the large quantity of topics to be covered, faculty were forced to limit the welding experience to two lab sessions. Some of the activities include making a fillet weld on a T joint and making a butt weld. To better prepare the students going into the actual welding lab, and to better accommodate the large number of students in the overall course, the lab session was designed to include the use of a virtual reality welding system for instruction. In order to begin the assessment of the implementation of the system, a survey was deployed to former students in the course to gather impressions and indicators for course improvement.

Virtual Reality Welding System

The VRTEX 360 system by Lincoln Electric as shown in Figure 1 was used for the lab activity. The system can emulate gas metal arc welding (GMAW) and shielded metal arc welding (SMAW). There are smaller systems from Lincoln Electric and other companies which yield similar experiences. For GMAW simulation, the system provides a wire feed style welding gun model with a realistically weighted cable attached to the machine to let the operator become used to the weight of the gun and the cables while making the weld.

Figure 1 The VRTEX 360 system by Lincoln [7]

The VRTEX 360 system uses an actual welding hood, but instead of having an operational lens, the hood is fitted with internal, adjustable eye pieces which allow the user to “see” a VR weld coupon and a torch. A selectable background provides more realism for the wearer.

Figure 2 Internal view of the adjustable hood from Lincoln [8]

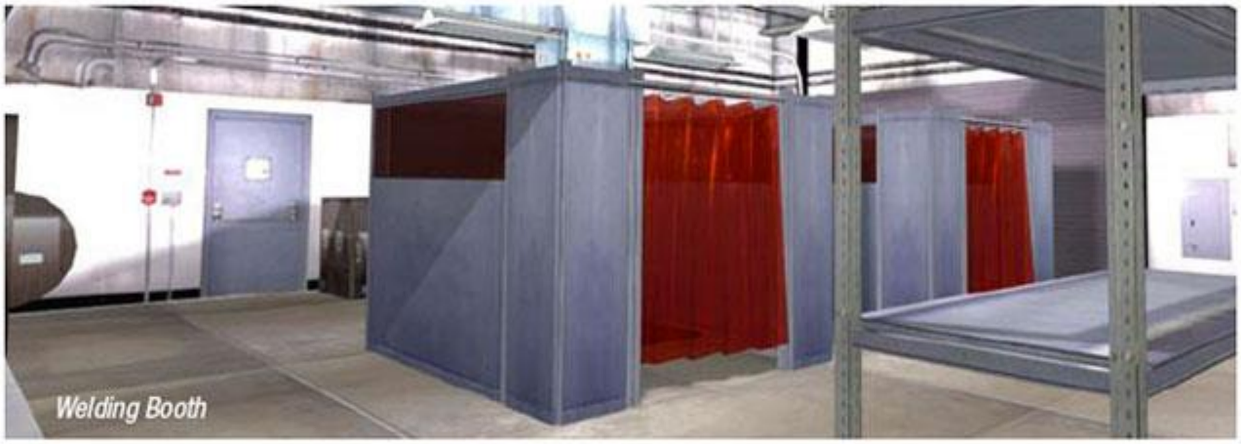

Figure 3 One of the backgrounds as viewed through the hood by the VR, from Lincoln [8]

Feedback can be provided to the operator through the use of visual cues, which can indicate travel speed, direction of the arc, and arc length. The instructor can see the same images on a screen, or can watch a plot of the weld parameters as the weld is being made, and watch another plot indicating virtual quality problems such as porosity and undercutting as they are made. IMAGE Audio feedback helps the operator learn to listen for the sounds which indicate the proper or improper arc lengths. The instructor can advise the operator how to make changes in travel speed or arc length that would improve the weld quality. The images can be shown on an auxiliary screen so that the other students can observe and learn from their classmate's experience.

Using VR for GAT training

The VRTEX 360 system was used to train the graduate teaching assistants (GATs) on the welding process and machine set up before they went into the lab to make actual welds. The instructor had trained GATs for several years prior without access to this system. He noticed that the GATs were able to make good quality welds much faster in the real welding lab with the prior training on the VR welding system, even when taking into account the same number of weld beads made. A future study reviewing the actual weld samples will be undertaken to verify this observation. This assumption was encouraging as the waste of material and consumables used during training could be lessened, reducing cost and environmental impact. This also enabled the GATs to use the VR machine on their own to practice, without having the instructor in the lab at all times. They were able to check out the coupons to use on the VR machine on their own schedule.

Using VR for lab instruction

Due to the time constraints of the lab, students in the lab sessions were divided into two groups. The first group trained on the VR welding system, making T joint welds on the virtual machine. A student making a VR fillet weld is shown in Figure 4. Also shown in the auxiliary screen displaying the live assessment of the weld to other students in the lab. The students then went to the lab to make the actual welds with the GMAW welding process. The second group welded first, and then used the virtual reality welding system. The goal again was to give the students additional welding time, even though virtual, that could not be afforded due to the high demand for the lab. Additional benefits were reduced cost for the lab. More VR welding means less gas used, reduced metal expense, and less environmental impact. Future work will include exploring this group's experience compared to the first group. Inspection of the welds will also be incorporated in a future study.

Figure 4 Student using the VR welding system in lab

Survey of students with results

In order to improve the welding experience this semester, faculty sent out a Qualtrics survey to students from previous semesters asking them to reflect on their experience with the virtual reality welding system, using a Likert scale for assessment.

Before answering the first two questions, the students were requested to recall their impressions after using the virtual reality welding system, but before entering the welding lab to make a real weld. The first question was: "How confident were you that you could make a real weld after using the virtual reality welding system?" The results are shown in Figure X. The results showed that 33.87% of the students ranked the answer as very confident or somewhat confident, while 30.65% were neutral.

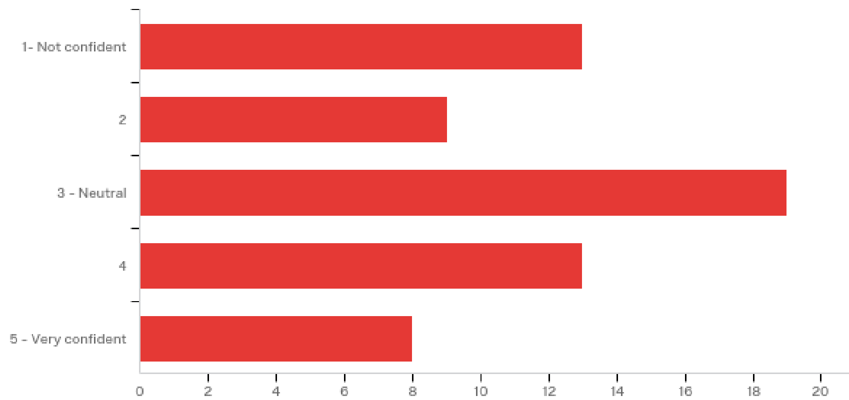

Figure 5 Responses from the pre-welding question regarding preparation for welding

Based on the student comments discussed later, it is very likely that the students would have benefitted from having more exposure to the VR welding system. Students who had previous welding experience were not identified as part of this group, which also might have skewed the answer negatively.

The second question was, "How confident were you that you would be able to weld safely?" The results showed that 66.66% of the respondents indicated that they were very confident or somewhat confident in the ability to weld safely after receiving the training on the VR welding system.

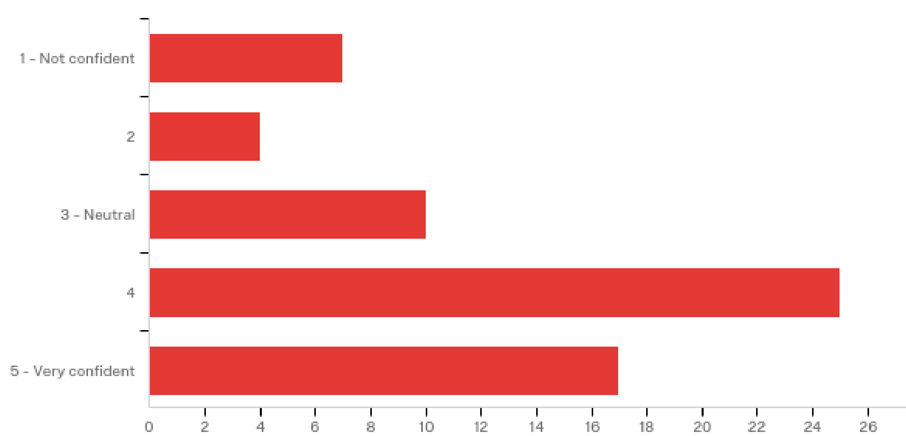

Figure 6 Responses for the pre-welding question regarding safety

Next the students were requested to think about their impressions after they completed the real welding activity. They were then asked, "Did you feel that the virtual welding system training actually improved your welding ability?"

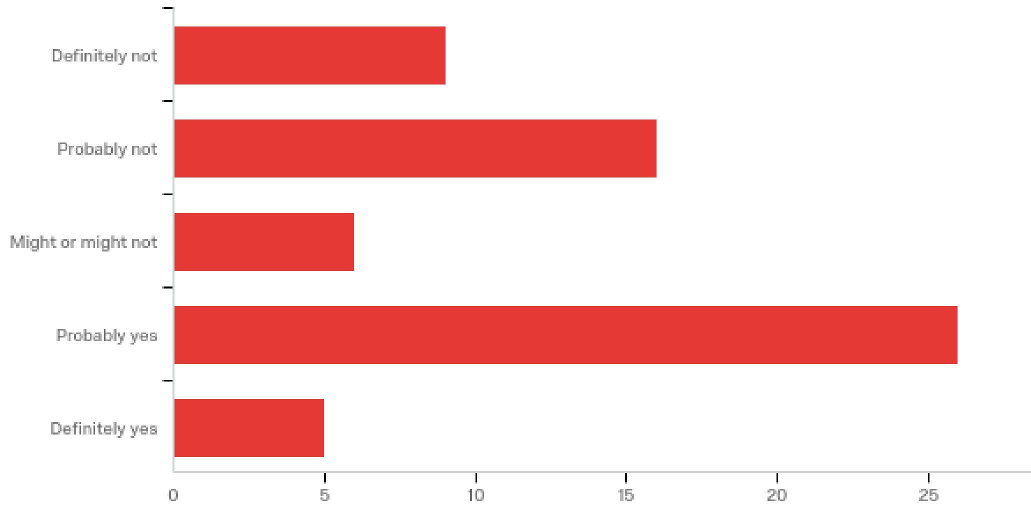

Figure 7 Responses for the post-welding question regarding benefit of the VR welding

Fifty percent of the respondents selected definitely yes or probably yes, while 9.68% were neutral. Again, there is no knowledge if previous welding experience affected these results.

Comments from students and discussion

The students were also given the opportunity to provide comments on the use of the virtual reality welding system. Some of these responses provided valuable feedback on opportunities to improve the overall experience. For example, it was evident from one student comment that the GATs did not all know how to adjust the virtual reality welding hood. This small issue had a significant negative impact on that student's experience, and it can be surmised on others as well. GATs will be properly trained in the future on how to adjust the helmet to the students, and an instructional sign will be posted next to the machine.

Several students who already had welding experience expressed unhappiness with the virtual reality welding experience. Interestingly, this was already observed in previous student interactions by one of the authors. A student stated, "The virtual welding is nothing like actual welding. There was nothing that I gained from that experience. It made me hate the welding process which I have done outside of class prior to taking the course. My welding experience was not made better by doing virtual welding." This might be attributed to the emphasis on specific motions with the VR welding system to make a successful weld. If the student had learned other techniques, then he or she might not like learning a different method. This might be addressed by emphasizing that the system trains for a known successful method and does restrict the parameters intentionally to ensure a quality weld.

A number of the students enjoyed the experience and found it helpful. “I was initially scared of beginning the welding labs. But the virtual reality weld lab eased me into how easy it can be and now I really enjoyed all the welding practice we did.”

“Practicing the motions beforehand definitely had an impact on how I approached the real thing. However, I ultimately started off welding for real improperly, and it had to be corrected. I was going way too fast, something which I feel the simulated welding did not cover well.” This should have been addressed by the visual cues which provide immediate feedback on the welder controlled parameters such as travel speed, work angle, and contact tube to work distance. Additional sessions with the VR welding system would help with this. As another student noted, “It was definitely preferable to no preparation but I still feel like maybe two sessions with the virtual thing would have helped me feel more prepared.”

Additionally, the same VR welding system was also used to educate and train upper level manufacturing and mechanical engineering technology students to extend their knowledge and skills in welding processes. Specifically, students who had prior experience on the VR welding simulator showed benefits in terms of better welding quality, especially for more difficult tasks. The results from this study will be detailed in a subsequent paper.

Conclusions and Future Work

This was the first real attempt to assess the course improvement achieved through the use of a virtual reality welding system to enhance and improve the welding lab experience. There is more opportunity to improve, and future studies will be undertaken to learn other ways to make the experience more productive for the students. Immediate changes in addition to those mentioned previously will be:

1. Utilizing media available from Lincoln, and linking it to the course management system website

2. Creating a video, handouts and/or online training for the local machine set up, and discuss the specific lab activities and outcomes.

3. Ensuring that GATs are properly trained in the future on how to adjust the helmet to the students, and posting an instructional sign next to the machine.

4. Trying to separate the experience into two lab sessions so that students can try the virtual welder on more than one occasion. This may be a challenge with the constraints of the number of students and limited lab time, and will require some realignment of lab activities.

It is important to note that the virtual reality welding system has always been intended to augment, rather than replace the hands-on experience of the students. This goal is not changing, but the instructors desire a way to teach the students more efficiently, and allow them to have more welding experience at a reduced cost and lessened environmental impact.

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Biographies

Dr. Angie Hill Price is an Associate Professor in the Manufacturing and Mechanical Engineering Technology program at Texas A&M University. She received her Ph.D. in Interdisciplinary Engineering from Texas A&M. She has worked in industry as a welding engineer in the US and Mexico. Her research interests include welding quality and corrosion, materials selection, and engineering education.

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