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Virtual Reality Training Integrated Curriculum: An Aircraft Maintenance Technology (AMT) Education Perspective*

THASHIKA D. RUPASINGHE
Department of Industrial Engineering, Clemson University, South Carolina 29634, USA. E-mail: rthashi@clemson.edu

MARY E. KURZ
Department of Industrial Engineering, Clemson University, South Carolina 29634, USA. E-mail: mkurz@clemson.edu

CARL WASHBURN
Greenville Technical College, South Carolina 29607, USA. E-mail: carl.washburn@gvltec.edu

ANAND K. GRAMOPADHYE
Department of Industrial Engineering, Clemson University, South Carolina 29634, USA. E-mail: agramop@clemson.edu

This paper presents results from a 3-year National Science Foundation: Advanced Technology Education (NSF: ATE) funded initiative to enhance curriculum and student learning via integration of Virtual Reality (VR) technology-based simulators. An Aircraft Maintenance Technology (AMT) curriculum is the backbone of training and educating maintenance technicians for the aviation industry to function in safe operating conditions. As a part of this research effort, the ViSIns Laboratory (Virtual Simulated Inspection Laboratory) was established at Greenville Technical College, South Carolina, USA; to reduce the gap between high-end technology requirement in the hangar (work environment) and the classroom. Using Bloom's Taxonomy in the cognitive domain, learning objectives of six course modules were refined to create more meaningful student outcomes and mapped to reflect expected student proficiency and goals. The pedagogical material development was extended to integrate two Non-Destructive Inspection (NDI) simulators (borescope and eddy current) in classroom activities and learning as interactive 3D knowledge objects. We present results on student learning using the VR augmentation on different sub-domains of cognition. Our results indicate that VR simulators are effective 3D learning objects which can be used for enhancing deliverables of the AMT education. This study further contributes to engineering education, aircraft maintenance technology education improvement and the use of VR-based simulators in technology driven training environments.

Keywords: curriculum; education; technology; training; and virtual reality

1. Motivation

In recent years, intense growth in air traffic, the economic crisis and the need to replace retiring experienced aircraft maintenance technicians has become crucial. Aircraft Maintenance Technology (AMT) programs form the backbone of training and education of maintenance technicians, allowing the aviation industry to function in safe operating conditions. According to recent airplane crash investigations, maintenance failures have been found to be one of the major causes of catastrophic crashes [1]; further illustrating the national need for qualified aircraft maintenance technicians. Modern aircraft fleets are composed of a variety of aircraft types, complicating the training missions of AMT programs.

Aircraft maintenance technicians who are cross-trained on complex wide-bodied aircrafts and have been exposed to complex inspection scenarios would have experience matching the demands imposed by the aviation industry. However, most newly graduated aircraft maintenance technicians have not been exposed to comprehensive maintenance training procedures due to the inability of the AMT programs to realistically mimic complex aircraft maintenance environments. Most institutions neither possess the hangar environment to house wide-bodied aircrafts nor the financial resources to acquire and maintain state-of-the-art training equipment [2].

This paper reports on the development and evaluation phases of a successful 3-year NSF ATE funded initiative to narrow the gap between advanced educational/training and the requirements of high-end hangar environments. Our research effort focuses on developing Virtual Reality-based (VR) interactive three-dimensional (3D) objects to enhance student learning, and hence advance AMT curricula.

2. Objective

Our study has three broad objectives. The main objective is to introduce a student-centered, perso-

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nalized, training environment integrating VR-based simulators into the existing AMT curriculum at Greenville Technical College, in Greenville South Carolina. The second is to increase student involvement, content interactivity, and motivation by bringing these 3D knowledge objects into a problem based learning (PBL) environment while maintaining overall course outcomes of the AMT education. The third is to refine current course objectives, assessment tools and assessment methodology to effectively monitor the progress and to evaluate the overall outcomes and deliverables of the system.

The skills and competencies acquired by an AMT student depends strongly on both theoretical content and hours of applied training [3]. AMT institutions face problems acquiring high-end training devices for many tasks, including Non-Destructive Inspection (NDI). Moreover, they face challenges in providing many hours of training for the AMT students.

Our approach is to resolve this issue by introducing VR-based simulators which are low fidelity in nature, less expensive, portable and easily integrated into the existing curriculum as 3D knowledge objects to benefit distance and traditional learning. This approach enables the students to 'play' around with the simulated devices for extended periods of time, increasing student exposure while limiting institutional concerns regarding the acquisition, storage and maintenance of the actual devices.

'The Importance of Play' [4] describes 'play' as an intellectual activity which helps develop cognitive functions. In the AMT context, the students can freely use these VR-based simulators to explore different inspection scenarios, exposing themselves to signatures of different types of defects in an aircraft with or without the guidance of an instructor. This approach facilitates the students to share the benefits of a more personalized learning environment created at the trainee's finger tips beyond traditional classroom learning [5].

The paper has following threads of discussion: first we outline a brief introduction about AMT education and the current system at Greenville Technical College, South Carolina. Then we describe the use of VR technology-based education tools generally used in the field of AMT and how our approach has enhanced the curriculum at Greenville Technical College. Course objective refinement using Bloom's taxonomy, sample pedagogical materials, and assessment tools are presented. Experimental designs are illustrated using subjects, VR simulators and experimental procedures with the results of a pilot study. Finally, we present the results of the main experiments, statistical analysis, conclusions and directions for future research.

3. Introduction

AMT education is the heart of training Aircraft Maintenance Technicians. In the state of South Carolina, there are three institutions with AMT programs, with Greenville Technical College being one. The college's AMT program has been used as a test bed for previous National Science Foundation (NSF) and Federal Aviation administration (FAA) funded initiatives [6]. The ViSIns Laboratory established as a part of Greenville Technical College's AMT program seeks to develop effective VR technology-based training devices to be used in an integrated curriculum setting. For this study, we have focused on six AMT courses currently taught at Greenville Technical College. These courses provide introductory as well as advanced training for students pursuing Airframe or Power-plant certifications. We have identified these six course modules due to their integration of Non-Destructive Inspection (NDI) techniques and technology requirements wherein the augmentation of VR-based 3D knowledge objects may increase student learning.

NDI procedures are considered one of the main inspection techniques used by cross-trained aircraft technicians [3], potentially utilizing different techniques that require different tools and mechanics. Widely used Non-Destructive Testing (NDT) techniques include borescope inspection, eddy current, dye penetrant, ultrasound, and magnetic particle inspection. In this research effort we have developed a virtual borescope [7] and a virtual eddy current simulator and evaluated the outcome of integrating these as pedagogical tools.

Figure 1 depicts the AMT courses selected for the

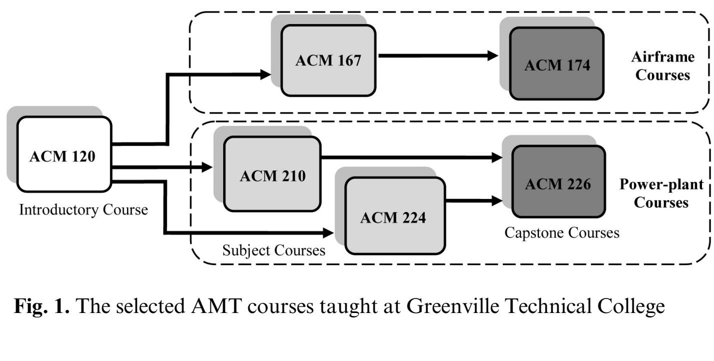

Fig. 1. The selected AMT courses taught at Greenville Technical College

study and how the airframe and power-plant certificate programs are integrated in the curriculum [8].

The AMT curriculum, coursework and hours of inspection required to complete each certification program are continuously monitored by the Federal Aviation Administration (FAA) in accordance with Federal Aviation Regulations (FAR). The NDI technique embedded course modules (Fig. 1) begin with the introductory course ACM 120 (Materials & Corrosion Control). The other courses are ACM 167 (Landing Gear Systems), ACM 174 (Airframe Inspection) for airframe certificate program, ACM 210 (Reciprocating Engine Overhaul), ACM 224 (Turbine engine Overhaul) and ACM 226 (Engine Inspections) for power-plant certification [9]. In the airframe certification program, students learn about the structural integrity of aircraft and perform a variety of maintenance and repairs to the sheet metal and composite aircraft structures. In the power-plant certification program, students are trained to work on aircraft engine components, scheduled maintenance, repairs and inspections [3]. At present the primary means to deliver a course is through classroom lectures and group laboratory sessions, which are utilized to provide hands-on experience.

3.1 Virtual reality as an education tool

According to Morgan (1997) [10], 'if a picture is worth thousand words, then an interactive 3D model is worth a thousand pictures'. Virtual reality (VR) concepts have emerged from basic 2D images to head-mounted audio-visual displays, 6-D position sensors, tactile interfaces, to high immersive, interactive virtual worlds in a variety of applications including entertainment, medicine, military and aviation training, industrial designs, and education [11]. Bricken (1990) [12] states some possible reasons for VR to be a fascinating application in education. These include its capability to offer unique experiences that are consistent with instructional strategies, hands-on learning, and conceptual visualization, while operating within the limits of system functionality. Moreover, virtual reality environments (VRE) have unique contributions to learning scientific visualization, instructions, sensory-motor performance, and for training [13]. If this is the case, it is worth investigating how learning occurs and how VR can foster this process each step of the way. The foremost items to be present in successful learning process according to most cited literature are attention or focus, meaningful representation of information [14], multiple mappings of information [15], and reflective learning. Research also shows that VR enables innovative, powerful types of collaborative learning irrespective of the reduced social interaction as compared to traditional learning environments such as laboratories [16]. In recent years more emphasis is given to evaluate VR as formal pedagogical method [16- 20]. These studies have investigated VR augmentation in the classroom and have shown promise in improving learning capabilities.

A few studies have explored the effect of VR technology in the aviation world, specifically looking at it as an inspection training tool [5]. Some research efforts focused on only two-dimensional sectional images of aircraft structures, which do not provide a holistic view of the complex maintenance/ inspection environment. To address these limitations, technology incorporating interactive 3D objects have been proposed as a solution and integrated as potential curriculum applications. Preliminary results of our research efforts were published in these articles [8–9, 21].

3.1.1 The borescope simulator and the eddy current simulator

We developed a virtual borescope simulator and an eddy current simulator to train novice aircraft inspection technicians in good practices in borescope/ eddy current inspection [7]. The first step of the development process was to carry out a detailed hierarchical task analysis to determine each task and activity that goes into the actual inspection procedures [22–23]. The tasks were performed by level III certified inspectors from the industry; each step of the inspection process was recorded and coded to create specification for the computer models. A detailed description of the VR technology-based simulators can be found in [7]. In order to mimic a more realistic tactile (haptic) interface we tested a haptic box (Fig. 2: left) and Novint Falcon® haptic device (Fig. 2: right) for borescope inspection.

For the eddy current VR simulator, to create a more realistic human-computer interface and to complement the actual eddy current simulator, we have utilized the Phantom Omni® as the tactile feedback device (Fig. 3).

Actual borescope and eddy current simulators cost thousands of dollars, while the VR simulators with state-of-the-art tactile feedback cost less than $2000 in total. These less costly, portable and flexible devices can easily serve as training tools for underprivileged AMT schools which cannot afford to invest in the former. The validation process of the graphical output, signatures of the defects and the inspection procedures generated by the simulators were monitored and refined in an interactive manner before creating with the final prototypes. Figure 4 depicts how the simulator development is integrated into the overall curriculum development process [24].

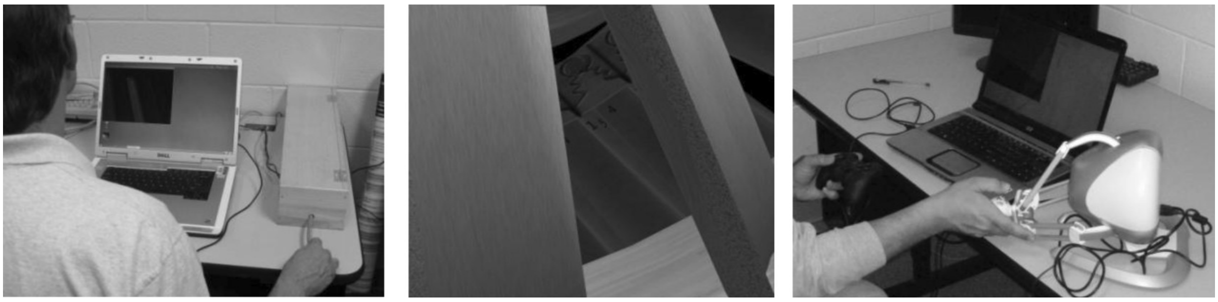

Fig. 2. User interaction with the borescope simulator haptic box (left), graphical output (middle) and User interaction with Novint Falcon® (right).

Fig. 3. User interaction with the actual eddy current simulator (left), graphical output (middle) and User interaction with Phantom Omni® (right).

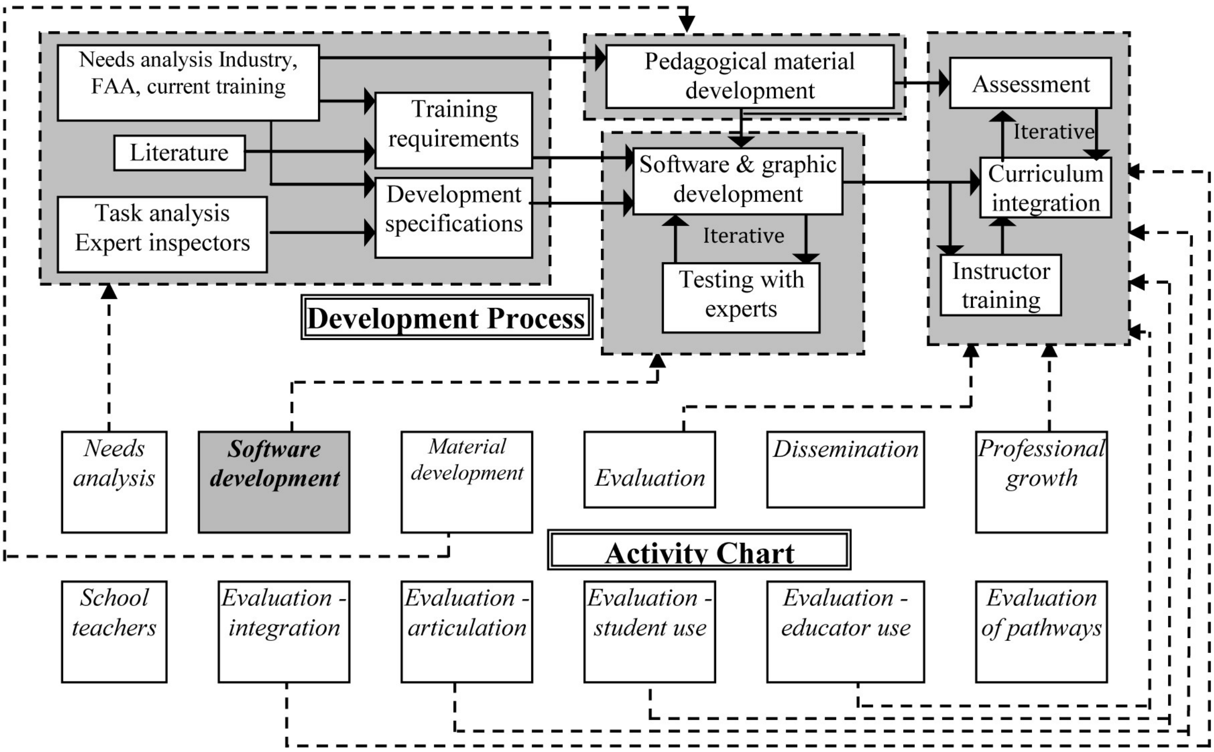

Fig. 4. Development Process Mapped with Activities.

4. Curriculum enhancement

Pedagogical material was developed using an integrated assessment paradigm (Fig. 4) and completed simultaneously with the simulator development. In the first step of this multi-phased study, student learning objectives of the aforementioned six courses were refined and analyzed using Bloom's Taxonomy for the cognitive domain to create more meaningful outcomes [9]. We developed lesson plans, lab exercises, quizzes, unit exams, laboratory manuals, video materials, grading rubrics, and other assessment aids which complemented the VR-based simulators [9]. Feedback received by the AMT field practitioners, certified level III inspectors, instructors from regional AMT institutions and through exploring curriculum/ assessment literature [25–28] specifically within the AMT context assisted the pedagogical material development.

4.1 Bloom's taxonomy to refine course objectives

We utilize Bloom's Taxonomy to refine the course objectives and to identify the possible cognitive relations between each sub-category in the respective course objective. Bloom's Taxonomy is an accepted form of pedagogical evaluation method by the FAA [2, 29]. The taxonomy describes educational objectives as belonging to one of three domains: affective, psychomotor or cognitive. In this phase we explore the cognitive domain of Bloom's taxonomy in the AMT education. The cognitive domain has been explored previously in the following fields: engineering education, psychology, biology, and medical education, while only a handful of studies have used AMT as a testbed [2, 30]. In the AMT curriculum, we were able to identify three stages for each level of cognition [6]. Table 1 shows identified stages for knowledge and application subdomains in the cognitive domain [21].

A detailed analysis has been carried out to establish course objectives via guidelines stipulated by the FAA and in the CFR (Code of Federal Regulations), recognizing the advantages of using current assessment tools and appraisal forms available for performance measurements. Using Bloom's Taxonomy, course objectives were further categorized into sub-levels and thereby the appropriate skill level. Table 2 depicts a sample course objective refinement for one of the selected course modules (ACM 167) [21]. Once the course objectives were modified to create more meaningful outcomes, specifications for simulator development, required level of teaching, and evidence collection of assessment tools (to measure the progress of the learning outcomes) were created [2].

Table 1: Bloom's Taxonomy cognitive sub domain analysis of course objectives

ACM 210: Reciprocating engine Overhaul				
Category	**Description of the objective**	**Skill level**	**Course Objective**	**Summative/ Formative Assessment**
Knowledge	• **Recall** the instructions.	Kno-1	**210-IA**	Quiz IA, Quiz IB
	• **Select** statements that apply to radial and opposed engine construction.	Kno-2		WA 210-IA Workbook section 2A
	• **Identify and understand** the service manuals, aircraft reciprocating engines, relevant tools, equipment and forms.	Kno-2	**210-IB**	Unit I Exam , Unit II Exam,Final Exam Quiz IIA
	• **Understand** the operating instructions, service manuals, tools, equipment and forms.	Kno-3	**210-IIA**	
Comprehension	• **Describe** reciprocating construction features.	Com-1	**210-IA**	
	• **Describe** reciprocating engine requirements and configurations.	Com-1		
	• **Explain** reciprocating engine theory.	Com-2		
	• **Explain** inspection and repair procedures for a 14-cylinder or larger engine.	Com-2		
	• **Explain** requirements for overhaul.	Com-2	**210-IB**	
	• **Use** overhaul procedures.	Com-3		
Application	• **Inspect** and **Repair** Reciprocating Engines.	App-1	**210-IA**	
	• **Disassemble**, clean, inspect, repair, overhaul and reassemble the engine.	App-2	**210-IB**	
Analysis	• **Examine** the components.	App-3	**210-IA, 210-IB** **210-IIA**	
Synthesis	N/A			
Evaluation	• **Make a judgment** about what components to be inspected with appropriate NDI method.	Eval-1	**210-IA,** **210-IB** **210-IIA**	Quiz IA, Quiz IB WA 210-IA Workbook section 2A
	• **Perform** engine installation, inspections, checks, service and repairs.	Eval-2	**210-IIA**	Unit I Exam , Unit II Exam, Final Exam
	• **Perform** engine operational checks.	Eval-3		Quiz IIA

Table 2: (ACM 210: Reciprocating Engine Overhaul) Bloom's Taxonomy Analysis

Cognitive Sub Domain	Skill Level	Description
Knowledge	Kno-A	Basic knowledge of general principles or practices.
	Kno-B	Knowledge of general principles, practices and operational concepts.
	Kno-C	High level of knowledge of principles, practices and operational concepts.
Application	App-A	No practical application.
	App-B	Limited practical application.
	App-C	High degree of practical application.

Fig. 5. Microsoft Excel® based course management system.

4.2 Tracking student performance

In order to measure the degree of success of each course outcome, each question in a typical assessment tool (unit exam/ final exam) is mapped to each course objective and the respective cognitive subdomain. This enables the researchers to monitor the progress of each student and the augmented curriculum's capacity to meet the overall outcomes. A Microsoft Excel® based course management system (Fig. 5) has been developed using Visual Basic for Application (VBA) to assist the instructors in maintaining and modifying the tracking sheets [9].

Figure 6 shows several screenshots of the tracking tools designed for ACM 120. In ACM 120, the refined course objectives using Bloom's taxonomy were presented using subject matter knowledge codes / course objectives [3]. These outcomes are matched with each question number of a particular assessment tool and the grid (middle) was created. When a particular student scores zero on a question, it is marked on this grid. The graph (right) is created for each course learning objective, with one bar for each related assessment instrument. This graph presents the percentage of students who have answered each question correctly whereby the related outcome is achieved [9]. For example; in Fig. 6 (right), out of the five questions depicted here; questions 1, 2, and 5 were missed by a few students and questions 3 and 4 were answered correctly by all the students.

5. Methodology

In methodology section, we present a detailed description of the results of the pilot study, students and their demographics, design of experiments, apparatus and assessment tools and the survey instruments.

5.1 Pilot study

Evaluations of the augmented curriculum initiated with a pilot study, with 10 students selected from the Greenville Technical College's AMT program (nine male students and one female student). These stu-

Fig. 6. Student performance tracking sheets.

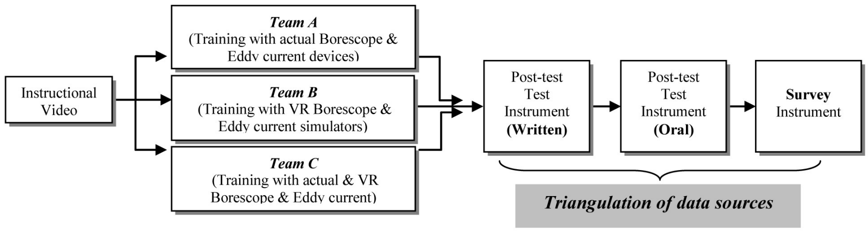

Fig. 7. Abstract description of the experimental procedure.

dents were selected from the ACM 120 class (the youngest participant's age was 20 years and the oldest was 63) with the participants divided into two groups, one being the control (*Team A*) and the other being the treatment group (*Team B*). We used the students' GPA (Graduate Point Average) as a pre-test, dividing them into two groups using stratified random sampling technique. We paired the students who displayed similar performance levels and created the two groups using random assignment [27]. The post test results of the pilot study indicate that the VR augmentation was beneficial and the treatment group outperformed the control ($p<0.05$). The survey results further elicited that students were excited about the VR simulations and learning objects [8].

5.2 Main experiments

The main experiments subject group consists of three student cohorts of 39 students from the AMT program (38 male students and one female student). We categorized these students into three groups with 13 students each; control cohort (*Team A*), Treatment cohort I (*Team B*) and Treatment cohort II (*Team C*).The age of the students ranged from 20 to 44 years. *Team A* and *B* were considered as a between subject design of experiment and *Team C* was constructed as a within subject design to minimize the error associated with the analysis. Using the same procedure utilized for the pilot test, we used the current cumulative GPA of each student as the measure for the pre-test and through random assignment paired students with similar GPAs to each cohort.

5.3 Experimental procedure

An abstract description of the experimental procedure is presented in Fig. 7. The process begins by showing a pre-recorded video for each student with the instructions and brief description of NDI in a webinar format by their instructor (using Echo 360® distance learning multimedia). Then each student group is sent to the respective station (A, B or C) for training on with the appropriate device / simulator. Each student received more than 30 minutes of training on each device (borescope / eddy scope) and the experiments were carried out for two days. In an actual classroom setting, the students were only given group lab sessions and often students are unable to touch or play around with the actual devices. However, we allowed the students to receive training using the actual devices and compared their performance against the training received by the VR simulators. The training procedure utilized PBL scenarios, different tasks involved in the inspection process, methods for detecting defects, corrosion and signatures which are prominent in complex inspection settings and good practices in using each NDI tool.

5.4 Test instrument and surveys

Student performance is measured by two instruments (one written exam and one oral exam) composed of questions from each sub-domain of the Bloom's taxonomy. This enables us to compare / contrast performance of each student group with respect to each sub-domain. When developing the test instruments (written and oral), we have referred to the instructors, industry practitioners and students to identify possible questions and hence maintained the *content validity*.

The written examination consisted of two-tiered multiple choice questions, 'fill in the blanks', and a few essay questions in which the students had to describe, and apply concepts and procedures learned. The oral examination was form of a free response interview, where students were given several inspection scenarios and they had to describe how they would resolve the issues using the most appropriate NDI tool. These questions were aimed at testing higher levels of Bloom's taxonomy on each inspection device / simulator.

The survey instrument consisted of 12 questions using a Likert scale responses with 1 being strongly disagree and 5 being strongly agree, designed to elicit student opinion about the training they received. The survey questions are categorized into questions examining the behavior, functionality and constraints of the inspection tools [31– 33] and analysis of the human interactions with the tool / simulator in a given inspection scenario. The reliability of the survey instrument was measured by computing Cronbach's alpha to ensure *internal consistency*. Each question scored a value greater than 0.8, hence we conclude the survey has adequate internal consistency.

6. Results

The written examination answer scripts were first coded (excluding the name, age and other demographic information) to ensure the anonymity and were graded by the instructors at Greenville Technical College. The oral examination data was transcribed and were quantified according to predefined scales. The scales/rubrics were compiled by following instructors' advice and the AMT curriculum grading policies.

In Fig. 8, the written and oral examination results are depicted for the two inspections, for the three student cohorts (*Team A: 1, Team B: 2 and Team C: 3*). In each box plot, on the left written examination scores are represented and to the right the oral examination scores are presented. It is noted that for *Team C* (group 3), in both inspection scenarios, the median is high and the inter quartile range is minimum, whereas *Team A* and *B* show different results. Especially for oral examinations, this observation is quite visible for both inspection scenarios (except for oral exam score: Team A).

Survey results are analyzed, and depicted in Table 3. Mean and the standard deviation of the responses presented with the percentage of the responses for each Likert scale. The nature/ context of each question is given in the first column and using Wilcoxon Signed Rank test, we evaluated whether there exists a statistically significance difference between the hypothesized mean of 3 (neutral) and the student responses. For all 12 questions, both inspection scenarios showed a statistically significant difference ($p<0.05$) through Wilcoxon Signed Rank test and students had positive feedback on VR augmentation and training.

6.1 Statistical analysis

For the main experiments, we used 39 students and each student cohort had 13 students. In considera-

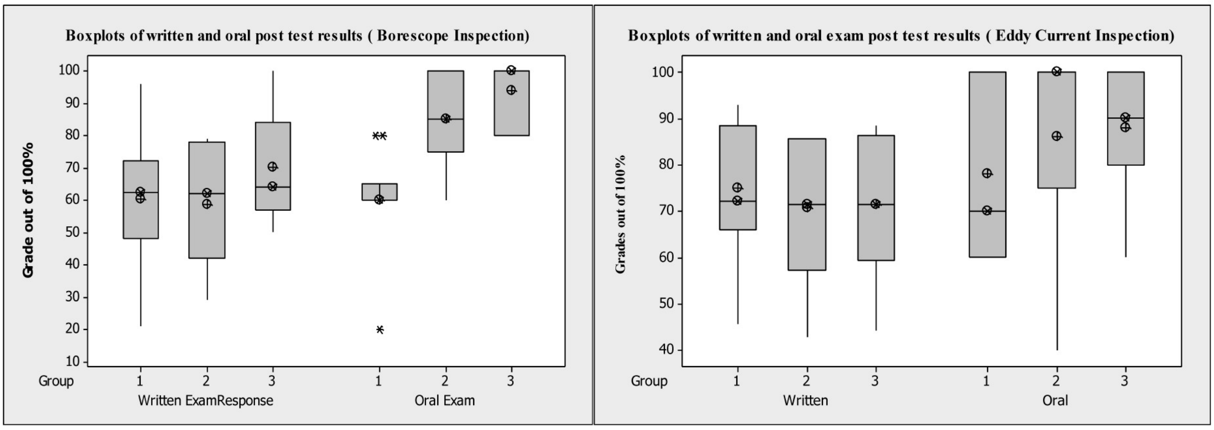

Fig. 8. Box-plots of Written and Oral exam results of the three cohorts for Borescope Inspection (left) and Eddy current Inspection (right) (*Team A: 1, Team B: 2 and Team C: 3*).

Table 3: Survey Results on VR Borescope & Eddy current Simulators (AVG: Average and SD: Standard Deviation)

	VR Borescope Simulator							**VR Eddy current Simulator**						
	% of responses for Likert Scale							**% of responses for Likert Scale**						
Survey Question	**1**	**2**	**3**	**4**	**5**	**AVG**	**SD**	**1**	**2**	**3**	**4**	**5**	**AVG**	**SD**
Q1. Usability	0	0	0	20	80	4.80	0.40	0	0	0	30	70	4.70	0.46
Q2. Expectations	0	0	0	20	80	4.80	0.40	0	0	0	20	80	4.80	0.40
Q3. Easiness	0	0	0	20	80	4.80	0.40	0	0	0	10	90	4.90	0.30
Q4. Adequacy	0	0	0	10	90	4.90	0.30	0	0	0	0	100	5.00	0.00
Q5. Variety of Skills	0	0	0	30	70	4.70	0.46	0	0	0	20	100	4.80	0.40
Q6. Complicated	70	30	0	0	0	1.30	0.46	50	20	20	10	0	1.90	1.04
Q7. Required skills?	20	40	40	0	0	2.20	0.75	20	20	10	30	20	3.10	1.45
Q8. Useful	0	0	0	40	60	4.60	0.49	0	0	0	10	90	4.90	0.30
Q9. Incorrect procedures	30	60	10	0	0	1.80	0.60	60	30	10	0	0	1.50	0.67
Q10.Unrealistic	50	50	0	0	0	1.50	0.50	70	30	0	0	0	1.30	0.46
Q11. Feedback	60	30	10	0	0	1.50	0.67	50	40	10	0	0	1.60	0.66
Q12. On-the-Job training	0	0	0	20	80	4.80	0.40	0	0	0	10	90	4.90	0.30

Table 4: Summary of the Results of Mann-Whitney test (M-W) and two-sample t-test (2-t test)

Student cohort Comparison	Written post test				Oral post test			
	p values		Significance		*p* values		Significance	
	M-W	2-t test	M-W	2-t test	M-W	2-t test	M-W	2-t test
Borescope Inspection								
Team A & Team B	0.762	0.828	**No Difference**	No Difference	0.003	0.004	**Significant**	Significant
Team A & Team C	0.003	0.002	**Significant**	Significant	0.000	0.001	**Significant**	Significant
Team B & Team C	0.007	0.867	**Significant**	No Difference	0.003	0.004	**Significant**	Significant
Eddy Current Inspection								
Team A & Team B	0.384	0.828	**No Difference**	No Difference	0.043	0.065	**Significant**	No Difference
Team A & Team C	0.496	0.052	**No Difference**	No Difference	0.005	0.008	**Significant**	Significant
Team B & Team C	0.791	0.867	**No Difference**	No Difference	0.010	0.058	**Significant**	No Difference

tion of the small sample sizes, we used a non-parametric statistical test (Mann-Whitney test) and compared the results with a parametric method (two-sample t-test) to draw conclusions. Table 4 depicts the summary of the results of the statistical analysis.

From Table 4, it is found that for borescope inspection there was a statistically significant difference in control and treatment II for the written and oral post tests. This was verified by the parametric and the non-parametric method as well. For the oral examination scores for treatment I and II both outperformed the control cohort. Whenever the results of the two methods (Mann-Whitney test and two-sample t-test) contradict; we compared the variance of each cohort and checked whether the 'equal variance' assumption is met or not. Since the assumption was violated we accept the results of the non-parametric analysis and the final results are boldfaced in Table 4.

For eddy current inspection, we were unable to demonstrate a statistically significance difference between the written examination scores of the control and the treatment cohort II; however for oral examinations both statistical analysis tests found significant differences. One interesting observation was that the control and treatment I were not statistically significantly different in nature, meaning the training received by students via the VR simulators was not worse than the actual device-based training.

The scores obtained for each category of questions representing the sub-domains of the Bloom's taxonomy were also found to be interesting. The higher levels of cognition (application, analysis and evaluation) scores for treatment I and II were significantly different ($p<0.05$) as opposed to the control. This observation is consistent for both written and oral examinations across the two inspection methods.

7. Conclusions

This study reports on a successful implementation of educational materials and integration of virtual reality (VR) technology-based simulators for a leading AMT curriculum in South Carolina, USA. Our main objective is to introduce a student-centered, personalized training environment integrating VR-based simulators to the existing AMT curriculum. We used Bloom's taxonomy as a pedagogical evaluation method and course materials and assessment tools were developed while analyzing different levels of cognition. Using detailed experimental procedures involving current students of the AMT program and a thorough statistical analysis, we find that VR-based simulator involvement to be advantageous and beneficial. Especially for the oral examinations (questions targeted the deeper knowledge and understanding) students of the treatment cohorts outperformed the control ($p<0.05$).

In conclusion, the primary aim of this research was the development of pedagogical materials, assessment tools and training simulators and integration of these to enhance student learning in AMT curriculum. The results of this study indicate improvement in student learning through additional simulator training.

Future research directions include investigation of other learning theories applicable to AMT, measures for increasing student retention and web-based delivery of educational materials specifically to train future aircraft technicians. More comprehensive training transfer studies can be used as future work to measure the quality and the exact benefits VR training aids not only for the context of the AMT curriculum, but for engineering education in general.

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Carl Washburn: Assistant Dean Transportation division Greenville Technical College. Earned his BS from Embry Riddle Aeronautical University, FAA certified Airframe and Powerplant Mechanic since Feb 1990, designated maintenance examiner since March 2004. Over 30 years experience in the aerospace industry.

Mary E. Kurz: Associate Professor of Industrial Engineering at Clemson, has research and teaching interests focused on deterministic operations research and metaheuristics. She holds a PhD in Systems and Industrial Engineering from The University of Arizona, minoring in Mathematics, as well as the MS and BS (with Honors, magna cum laude) in Systems Engineering from The University of Arizona. She teaches on facility layout and location and metaheuristics for graduate students and deterministic operations research and decision support systems for undergraduates. She was the recipient of the IIE Operations Research Division's 2005 Award for Excellence in the Teaching of Operations Research. She is a member of INFORMS and ASEE and is a senior member of IIE. She also serves as an ABET Program Evaluator. Her research has been supported by industry and NSF, resulting in over 40 archival journal and refereed conference proceedings.

Anand K. Gramopadhye: Professor and chair of Industrial Engineering, Clemson University received his MS and PhD from University at Buffalo (SUNY). His research focuses on solving human-machine design problems and modeling human performance in technologically complex systems such as healthcare, aviation, and manufacturing. He has more than 200 publications in these areas, and his research has been funded by NIH, NASA, NSF, FAA, DOE, and private companies. Currently, he is pursuing cutting-edge research on the role of visualization and virtual reality in aviation maintenance, hybrid inspection and job-aiding, technology to support STEM education and process design issues. He has been recognized by the NAE through the Frontiers in engineering program, and he has received the Clemson University's collaboration award and the McQueen Quattlebaum award, which recognizes faculty for their outstanding research. He is the editor-in-chief of the International Journal of Industrial Ergonomics and on the editorial board for several other journals.

Thashika D. Rupasinghe is a doctoral student of Industrial Engineering at Clemson University, South Carolina. She received BS from University of Kelaniya, Sri Lanka and MS degree from Clemson University. Her research thrusts include modeling systems using metaheuristics and financial engineering applications. She is also pursuing research on engineering education, virtual reality-based training, and student retention.