AC 2009-1240: PEDAGOGICAL MATERIAL DEVELOPMENT AND CURRICULUM ASSESSMENT TO ENHANCE NONDESTRUCTIVE INSPECTION IN AIRCRAFT MAINTENANCE TECHNOLOGY (AMT)

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Abstract

This paper presents results from curriculum enhancements implemented at an Aircraft Maintenance Technology (AMT) program to improve the learning process of students through creation of educational materials, assessment tools and curriculum redesign. Using Bloom's Taxonomy in cognitive and psychomotor domains, course objectives were refined to create more meaningful student outcomes. These were mapped to reflect the expected student proficiency and goals as advised by regulatory agencies. These include the guidelines stipulated by the FAA (Federal Aviation Administration). We identified course objectives for six course modules currently taught in an aircraft maintenance program at a 2-year technical college: ACM 120 (Materials & Corrosion Control), ACM 167(Landing Gear Systems), ACM 174 (Airframe Inspection), ACM 210 (Reciprocating Engine Overhaul), ACM 224 (Turbine engine Overhaul), and ACM 226 (Engine Inspections). For these modules, each objective was analyzed under Bloom's Taxonomy's sub-domains. These include knowledge, comprehension, application, analysis, synthesis and evaluation under the broad cognitive domain and initiation, manipulation, precision, articulation and naturalization under the psychomotor domain. Through an iterative process, course objectives were refined for the six course modules and objectives were transformed to outcomes. The curriculum material development process was extended to identify new non-destructive inspection (NDI) simulators to be incorporated in classroom activities and learning processes. These interactive 3D knowledge objects based simulators are expected to be integrated in the AMT curriculum to improve the learning outcomes. A thorough statistical analysis will be carried out to evaluate the student outcomes through the enhanced curriculum. A novel Excel based decision support system, which will be used for the curriculum design and as an assessment tool/template using Visual Basic for Application (VBA) is proposed as future work.

1. Introduction

The Aircraft Maintenance Technology (AMT) curriculum is the backbone of training and educating maintenance technicians for the aviation industry to function in safe operating conditions. In complex environmental conditions due to growth in air traffic, economy and population, the competencies and skills required by the aircraft technicians is significant[10]. Therefore, it is the responsibility of training institution and AMT curriculum to find means to enhance student learning to satisfy this national need[10].

The purpose of this NSF ATE funded 3-year study is to develop pedagogical materials, assessment tools and training aids using virtual reality (VR) technology to be used in AMT programs. The study focuses on Greenville Technical College's AMT program. This 2- year technical college is equipped with state-of-the-art technology facilities, a hangar with multiple aircrafts and an educational environment designed to produce cross-trained aircraft maintenance technicians who are capable of working with complex aircraft systems.

1.1. Aircraft Maintenance Technology (AMT) Programs

Due to the close integration of AMT curriculum with the high-end technology, the AMT programs require improved educational environments to realistically create scenarios of complex maintenance environments[5]. However, not all institutions can afford to invest in expensive training aids, wide-bodied aircrafts and stimulus materials. Therefore, implementing educational materials integrated with technology aids that are less expensive, portable and effective can be considered as an efficient solution.

ViSIns Laboratory (Virtual Simulated Inspection) was established in Greenville Technical College as a part of this ongoing research effort to diminish the gap between high-end technology requirement in hangar and the classroom environment. The primary aim of the research is to evaluate the feasibility of implementing technology-based solutions using low fidelity simulators and their integration into the classroom curriculum and impact on student outcomes.

1.2. Non- Destructive Inspection (NDI)

NDI is one of the important inspection techniques used by a cross-trained maintenance technician to conduct complex inspection tasks. The general procedure is to carry out inspection without disassembling the component to detect irregularities and defects. This method is widely used for inspecting airframe structure and engine components. Some of these techniques of NDI include borescope inspection, eddy current, liquid or dye penetrant, magnetic particles, X- ray and ultrasound inspection[2].

In this study the proposed interactive three dimensional (3D) training simulators are developed based on these different NDT (Non- Destructive Testing) methods. Figure 1 presents some apparatus and typical applications of these devices in the aviation maintenance field.

Borescope Eddy Current Liquid Penetrant Ultrasound

Figure 1: Non-destructive inspection techniques

For this study, emphasis was given to develop the virtual borescope simulator and to evaluate its integration as a training aid in the AMT curriculum. In the subsequent phases, rest of the simulators are to be developed. A thorough analysis has been carried out to identify different course modules which introduce the students to these NDI methods and the levels of teaching required to enhance the overall learning.

1.3. AMT Curriculum and Pedagogical Materials

The structure and the content of the course materials and the number of hours of inspection a student needs to accumulate is governed by Federal Aviation Administration (FAA) and FAA Federal Aviation Regulation (FAR) part 147. All AMT programs and schools are FAA certified by FAR part 147.5 and the levels in which the students learn the course materials are categorized into three teaching levels[2].

We have selected six course modules currently taught in the two certification programs of Greenville Technical College, consisting of one introductory course, three subject courses and two capstone courses. These are depicted in Figure 2 with each NDI technique relevant to particular course module.

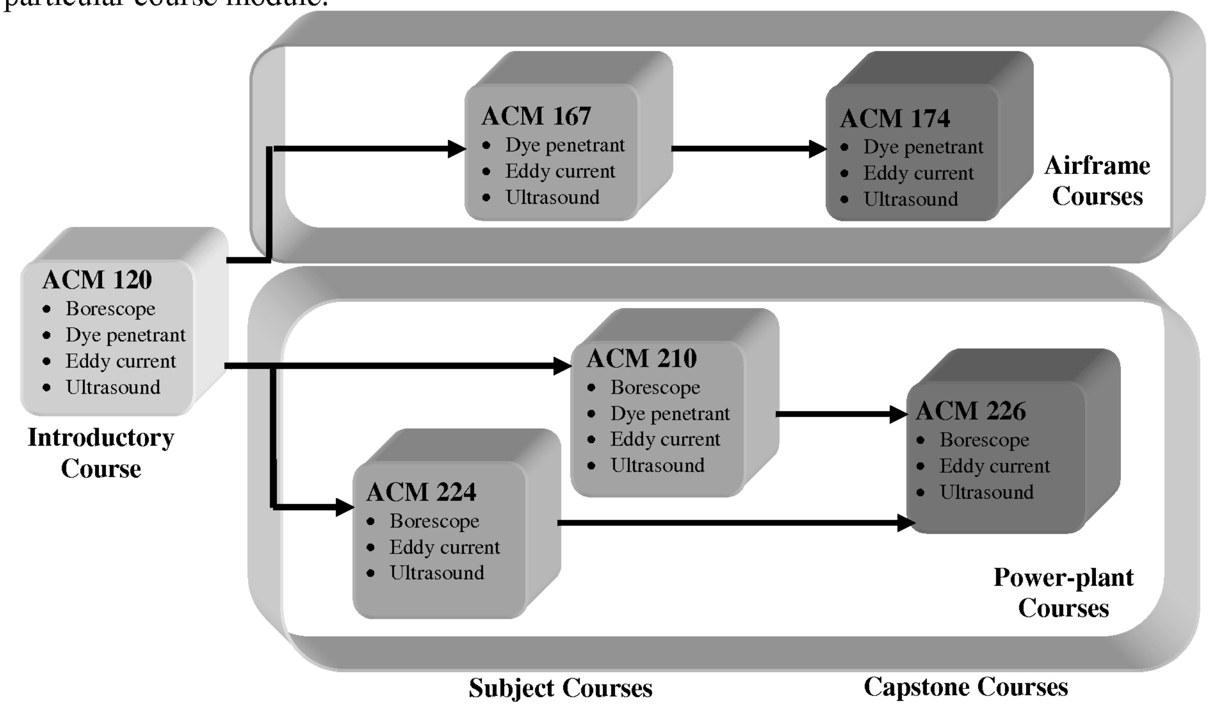

Figure 2: The Selected Courses With Non-Destructive Inspection Techniques

The introductory course ACM 120(Materials & Corrosion Control) provides the initial exposure to the NDI techniques and is reinforced in ACM 167(Landing Gear Systems), ACM 210 (Reciprocating Engine Overhaul), and ACM 224 (Turbine engine Overhaul). The two capstone courses ACM 174 (Airframe Inspection) and ACM 226 (Engine Inspections) provide more advanced knowledge of the inspection techniques and the two certificate programs (Airframe and Power-plant) originate from the introductory course.

The airframe certification program focuses on teaching the students the structural integrity of aircraft and performing a variety of maintenance and repairs to the sheet metal and composite aircraft structures. In power-plant certification program, the students are trained to work on aircraft engine components, perform scheduled maintenance, repairs and inspections[2]. The primary course delivery method is through classroom lectures. Laboratory sessions are incorporated into the curriculum to enhance student learning by providing hands-on experience. The assessment tools consist of projects, unit exams, quizzes and final exams. The proficiency of the materials is determined by the final grade.

2. Pedagogical Material Development

Pedagogical material development was carried out using an integrated assessment paradigm. The primary deliverables include lesson plans, exercises, quizzes, exams, laboratory manuals, video materials, grading rubrics, and other assessment aids. The student learning objectives of the aforementioned courses were refined and analyzed using Bloom's Taxonomy for the cognitive domain to create more meaningful outcomes.

The newly developed course plans, exercises, quizzes, exams and laboratory manuals are expected to be incorporated in each course module to match appropriate level of teaching. The 3D simulators allow instructors to create various inspection and maintenance scenarios by manipulating various parameters to mimic the mechanic in the aircraft maintenance hangar environment.

2.1. Bloom's Taxonomy for Mapping Cognitive Behavior

The educational material development process was initiated with identification of course modules to be evaluated with the NDI simulators and subsequently refining the course objectives to incorporate the new training simulators. Within the renewal process of the integrated assessment plan, steps have been taken to establish the curriculum goals. A detailed analysis has been carried out to establish the course objectives via guidelines stipulated in the FAA, FARS and CFR (Code of Federal Regulations). Special attention was given to identify the current assessment tools and appraisal forms available for performance measurements and these documents were used for developing the proposed assessment tools (Figure 3).

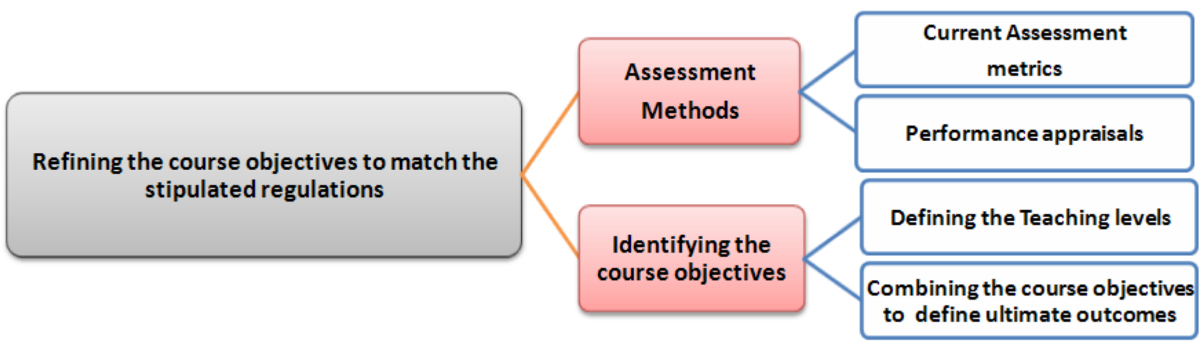

Figure 3: Pedagogical Material Development

The iterative refinement process of the course objectives was carried out for all six courses. Using Bloom's Taxonomy for cognitive domain, those objectives were transformed to outcomes. Each objective was analyzed under the sub domains of the knowledge, comprehension, application, analysis, synthesis and evaluation of the cognitive domain[1]. Separate analysis has been carried out within the psychomotor domains[3] on the selected AMT course modules. The sub-domains considered under psychomotor domain were imitation, manipulation, precision, articulation and naturalization.

The current curriculum assessment metrics were identified to reflect the measurements of the outcomes. Through a detailed review of the existing assessment materials, new metrics were proposed to enhance the measurement of cognitive skills. Table 1 summarizes two courses, ACM 120 and ACM 167 and the application of Bloom's taxonomy for mapping the course objectives to different levels of cognition. This analysis has been carried out for the remaining four courses along with separate analysis for psychomotor domains.

Table 1: Application of Bloom's taxonomy for ACM 120 and ACM 167

	Category	Description of the objective	Assessment	Metric PA 120	Teaching level
ACM 120	Knowledge	• **Recall** and list the nondestructive testing methods • **Recall** the instructions • **Recognize** the component with appropriate nondestructive testing methods	Quizzes Unit Exams Final Exam	IIIB IIIC	Level 1 Level 2
	Comprehension	• **Identify** and **list** the nondestructive testing methods • **Explain** the nondestructive testing and understand the meaning of NDI • **Translation** of problem to one's own words • **Interpretation** of instructions			
	Application	• **Apply** the concept of NDI			
	Analysis	• **Distinguishes** between facts and inferences • Logical fallacies of **reasoning** • **Examine** the components		IIIC	
	Synthesis	N/A			
	Evaluation	• **Make** a judgment about what components to be inspected with appropriate NDI method		IIIB IIIC	Level 1 Level 2
	Category	**Description of the objective**	**Assessment**	**Metric PA 167**	**Teaching level**
ACM 167	Knowledge	• **Recognize** the operational retractable landing gear, manufacturer's service manuals and ground support equipment • **Recall** instructions to disassemble brake master cylinder • **Recognize** the instructions to maintain and service a hydraulic brake system • **Recall** aircraft wheel and tire assembly, and manufacturer's service instructions	Quizzes Unit Exams Final Exam	IIA IB IIB IIC IID	Level 3
	Comprehension	• **Identify** and list the nondestructive testing methods • **Explain** the nondestructive testing and understand the meaning of NDI • **Translate** the problem to one's own words • **Interpretation** of instructions			
	Application	• **Apply** the concept of NDI • **Use** appropriate NDI methods to find defects			

	Analysis	• **Distinguishes** between facts and inferences • **Examine** the components • **Discriminate** the defects			
	Synthesis	**N/A**			
	Evaluation	• **Choose** the most appropriate method • **Make** a judgment about what components to be inspected with appropriate NDI method • **Select** the correct NDI technique		**IIA** **IB** **IIB** **IIC** **IID**	**Level 3**

2.2. Assessment Tools

Figure 4 presents a sample quiz developed for ACM 120 with relevant objectives, directions and rubrics.

ACM 120: Materials and Corrosion Control

Written Appraisal PA 120-IIIB: NDT Methods

Name: ________________________Date: ________ Score ___/10 Pass/Fail______

Objective: Given a selection of metal types or aircraft components, the student will **identify** and **list** the nondestructive testing methods for each. At least 70% of the metals or aircraft components will be matched with the appropriate nondestructive testing methods.

Directions: The instructor will demonstrate and discuss the appropriate **NDI** methods used for each type metal/component. Students are encouraged to utilize these methods in a practice environment. When practice time is completed, each student identifies the nondestructive methods used for inspecting the **metals** listed below.

Rubrics: The minimum score to pass is 7 out of 10 correct. Each question carries equal points.

Metal to be Inspected	NDI Method
[1]. Engine tubular mount	
[2]. Wing rib (installed in the aircraft)	
[3]. Reciprocating engine accessory drive gear (removed)	
[4]. Bonded floor structure	
[5]. Aircraft wheel assembly	
[6]. Plexiglas windows	
[7]. Nose landing gear strut scissors link assembly	
[8]. Turbine engine compressor section (engine assembled)	
[9]. Propeller hub	
[10]. Ceramic part	

Figure 4: A Sample Quiz of ACM 120

The other assessment tools include unit exams, mini projects, in- class assignments, exercises and Computer Based Testing (CBT) inspection scenarios. On the completion of the refinement process of course objectives, the teaching levels and the lessons were identified to integrate the respective NDI simulators. Through psychomotor domain analysis, the relevant skills required to perform inspection were recorded as part of the need analysis study to obtain baseline metrics and evaluation tools for the simulator development.

2.3. Tracking Student Performance

The pedagogical material and assessment tool development includes concurrent development of Microsoft Excel® based tracking sheets to monitor the progress of student performance. For a specific assessment tool for each student, the course objectives are matched with each question to evaluate whether the student has achieved the expected outcomes. This enables the instructors to continuously maintain content validity[9] and to incorporate new methods of teaching if they haven't achieved a particular outcome. Figure 5 shows few screenshots of the tracking tools designed for ACM 120. In ACM 120, the refined course objectives were presented using subject matter knowledge[2] and were numbered accordingly. These outcomes are matched with each question number and the grid (left) was created. When a particular student scores zero on a question, it is marked on this grid and graph (right) is created to depict the results. This graph presents the percentage of students who have got each answer correct whereby the respective outcome is achieved.

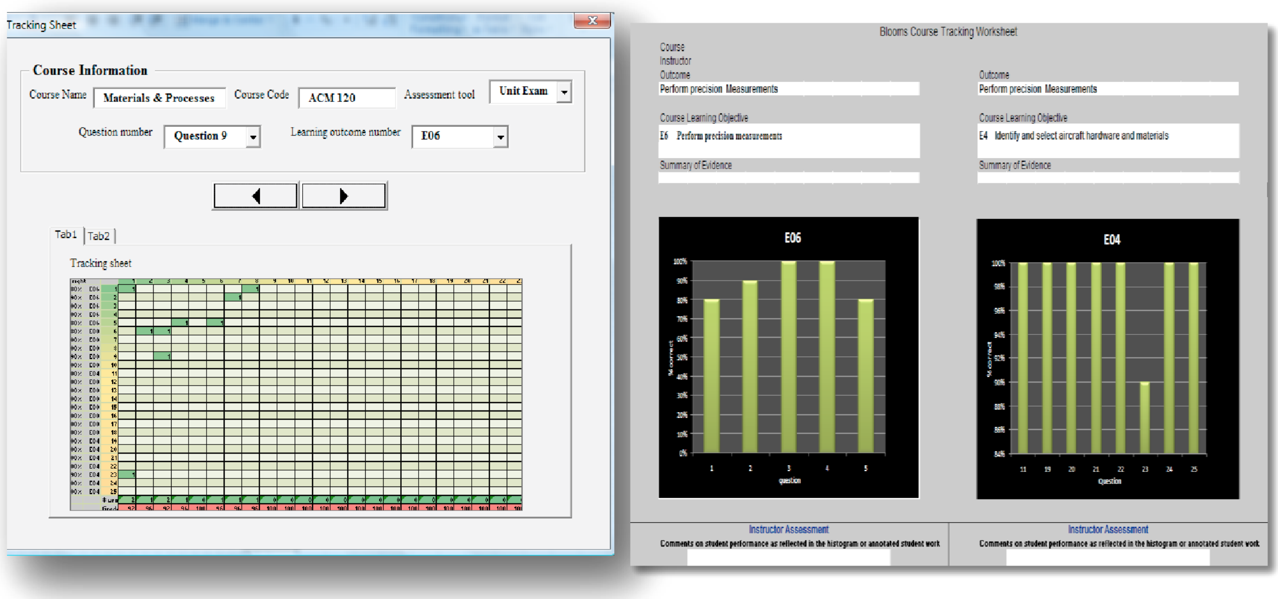

Figure 5: Tracking sheets for ACM 120

2.4. Microsoft Excel® Based Decision Support System

Along with the pedagogical material development, a novel Excel-based decision support system has been proposed to minimize the work load of the instructors. This system is used for creating the tracking sheets and generating relevant information and reports. Figures 6 and 7 presents few screen shots of the interfaces developed using Visual Basic for Application (VBA).

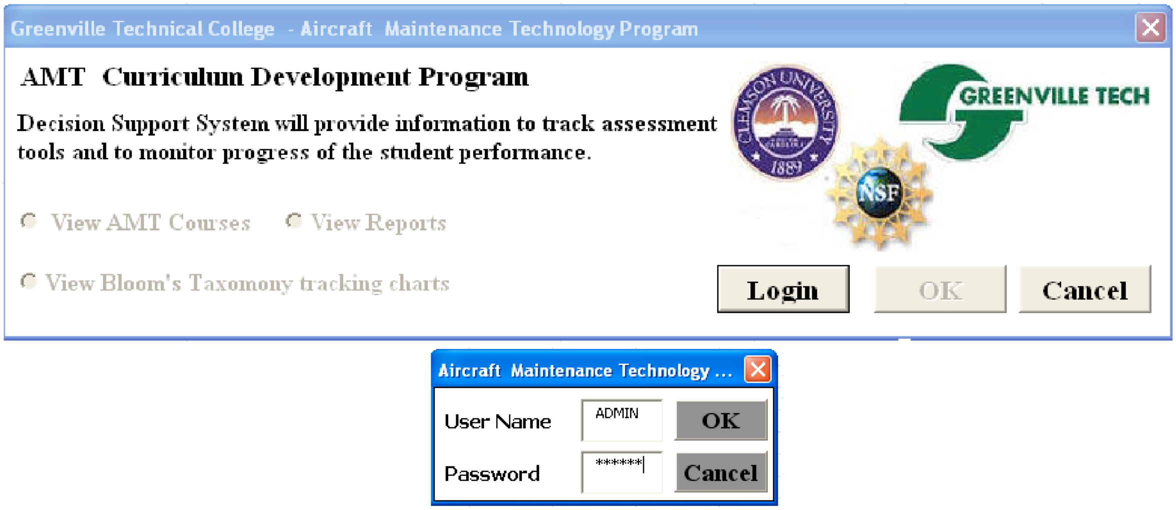

Figure 6: AMT Decision Support System- Main Interfaces

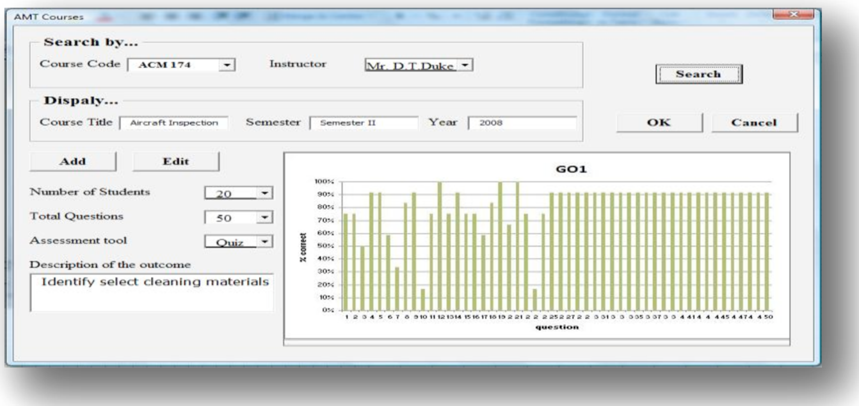

Figure 7: AMT Decision Support System – View Reports

3. Experimental Design of the First Phase

In order to evaluate the first phase of the study, we carried out a descriptive design as well as an experimental design[8]. In the descriptive design, we used a survey consisting open ended questions and selected response questions. The experimental design was carried out in the form of a randomized controlled trial, with stratified random sampling technique. The experimental design was constructed to determine if there was an improvement in student learning with borescope simulator training and instructional methods as opposed to conventional instructional procedures.

3.1. Participants

10 students were selected from ACM 120 consisting of nine male students and one female student (age range was from 20 to 63 years). The participants were divided into two groups using stratified random sampling technique. One group was identified as the control (Team B) and the other as the treatment group (Team A). We used the students' GPA (Graduate Point Average) as

a pre-test and paired the students who displayed similar performance levels. The two groups were created using random assignment by assigning one participant of the pair to the control group and the other to the treatment[7].

3.2. Procedure

The two groups were initially given a brief lecture on non-destructive testing (NDT) and the use of borescope simulator in NDI by the course instructor. For a detailed description of the borescope simulator development, please refer to Vembar et al (2008)[11]. In order to evaluate the differences between the two groups, an assessment instrument was designed as a form of a quiz. This assessment tool consisted of four sections, three sections representing the three levels of Bloom's taxonomy (knowledge, comprehension and application). The sub domain synthesis was not included since it was not applicable to the AMT curriculum. The last section consisted of a survey to elicit subjective responses from the students related to their perception of the curriculum redesign, new assessment tools and teaching approaches. On completion of the lecture, the control group was given a post-test quiz to evaluate their performance while the study group received simulator training before attempting the quiz.

3.3. Validation of the Assessment Tools

In order to ensure the validity of the assessment tools, we carried out construct validity and content validity at each step of the development. Continuous review process has been carried out by a panel of experienced instructors to enforce the content validity of the pedagogical materials and the assessment tools. Furthermore, in post-test analysis, when decoding the answers of open-ended questions, inter-coder agreement ratings were maximized.

4. Experimental Results and Statistical Analysis

Results of the post test were analyzed based on the responses given to each section. Each section had a maximum of 6 points and a minimum of four questions. Quantitative techniques were used for analyzing the first three sections and qualitative methods were utilized to interpret the last section. Table 2 provides a summary of the descriptive statistics of the data collected.

Table 3: Post-test scores of two student groups

Student Group	Statistic	Levels of Bloom's Taxonomy		
		Knowledge	Comprehension	Application
A (Treatment)	Average	4.4	5.76	4.6
	St. deviation	0.89	0.34	1.34
B(Control)	Average	3.9	4.6	2.80
	St. deviation	1.34	0.89	1.79

4.1. Statistical Analysis

Friedman test was used for analyzing the data. Due to the small sample size and non-normality of the data, nonparametric technique was needed for statistical analysis. The null hypothesis was there is no significant difference between the two means of the two student groups. Table 4 presents the results obtained through Friedman test (at $p < 0.05$ significance level). From Table 4, there is sufficient evidence to conclude that there exists a significant difference in the means on Sections 2 & 3 (comprehension and application) in contrast to Section 1 (knowledge).

Table 4: Statistical Analysis Using Friedman Test

	P value	Null hypothesis
Knowledge	0.157	Accept
Comprehension	0.025	Reject
Application	0.046	Reject

Figure 8 displays changes in the mean values between the two student groups. Both groups had the same score for the pre-test, which was 3.5 (GPA) and hence, share the same origin.

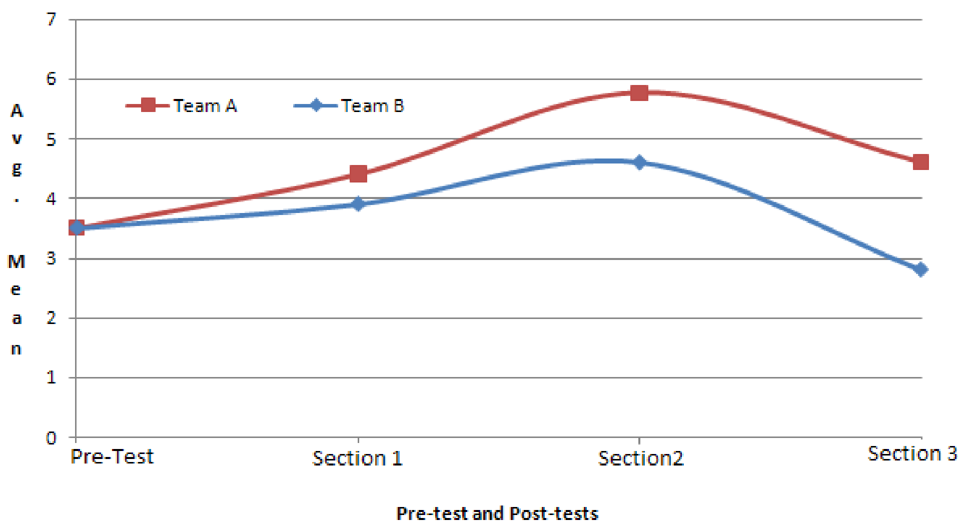

Figure 8: Average Mean vs. Pre and Post tests

4.2. Qualitative Analysis

The survey portion of the instrument consisted of three sections. Table 5 presents the structure of the questionnaire with broad categories of questions. We have used qualitative techniques to analyze the data gathered through the subjective survey and the data is summarized in Table 6.

The responses indicate a positive impression about the use of new assessment tools and educational materials. In the next phases of the study, a more comprehensive survey is proposed to capture the perception of the students and monitor the progress of curriculum integration.

Table 5: Structure of the subjective Questionnaire

	Category	Description of the Questions
Section 1	**Category A** Perception of the existing curriculum	• About conventional lecturing • What they felt about more Instructions • More hands-on experience • Exercises and lab hours
Section 2	**Category B** Training Aids	• Use of Simulators • Creating complex inspection scenarios • Applications of inspection tools
Section 3	**Category C** New Assessment Tools and Pedagogical Materials	• Perception of learning • Whether they have improved knowledge? • Whether they got feedback? • Performance tracking • Self attainment

Table 6: Analysis of the Subjective Questionnaire

Category	Nature of the Questions	Negative View	Neutral	Positive View	No Comments
A	Conventional lecturing	40%	30%	30%	0%
	More instructions	30%	20%	30%	20%
	More hands-on experience	0%	0%	100%	0%
	Exercises and lab hours	0%	10%	90%	0%
B	Use of Simulators	0%	0%	90%	10%
	Creating complex inspection scenarios	0%	0%	100%	0%
	Applications of inspection tools	0%	10%	80%	10%
C	Perception of learning	0%	20%	80%	0%
	Whether they have improved knowledge	0%	20%	70%	10%
	Whether they got feedback	0%	20%	70%	10%
	Performance tracking	0%	20%	60%	20%
	Self attainment	10%	20%	60%	10%

5. Conclusions and Future Work

According to the statistical test results of the experimental design, a significant difference in the means of the two student groups was observed. We hypothesize that this was due to the improvements in their comprehension and the application aspects. Knowledge was not affected significantly due to instructional procedure received by both student groups. It can be concluded that by providing more hands-on experience with the simulator training students enhance their learning.

Figure 9 presents the box plots of the mean, median of the two student groups with respect to the three sections discussed above. The survey data on curriculum and teaching approaches was separately analyzed and showed positive feedback about the pedagogical material development.

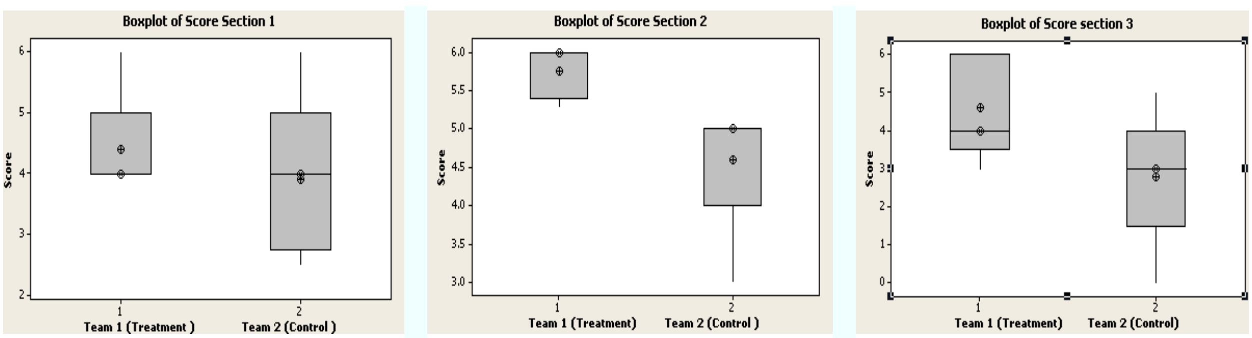

Figure 9: Box Plots of Post-tests of Two Student Groups

In conclusion, the primary aim of this research is the development of pedagogical materials, assessment tools and training simulators to enhance student learning in AMT curriculum. Preliminary results of the curriculum integration indicate improvement in student learning through additional simulator training. In the subsequent phases, remaining NDT tools (eddy current, ultrasonic and magnetic partial inspection) are expected to be integrated with the AMT curriculum. More comprehensive training transfer studies are proposed as future work with possible extensions of distributing these pedagogical materials and training aids to other AMT institutions.

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