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The effect of a new teaching methodology on learning performances of automotive - mechatronics students

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Abstract

In this study a new methodology for teaching of Automotive Mechatronics course is proposed. The students who have taken the course were divided into two groups: the first, for classical mode of teaching and the other for the new model of instruction. The performance of the students were measured by pre-test and post-test. The results show that, handing out the class material beforehand and having the students learn by practicing in the laboratory, increase the students' interest and success when compared to those being taught the theory, in class and having completed the experiments in the lab afterwards.

Keywords: Automotive; mechatronics; education; method.

1. Introduction

In US nationwide shortage of skilled mechanics is 60000. Studies by the US Bureau of Labor Statistics indicate that the automotive industry will need at least 35000 new mechanics every year for the next decade to address the level of the demand [Peckham, 2003]. Besides, the developments in the automotive industry have enforced the continuous improvement of abilities of the workforce in this area. The workers are expected to be adaptable to the new developments which strives the need for continuing efficiency in teaching of automotive technologies. An industrially-supported course program was developed by the support of American Society for Engineering Education, Mentor Graphics, Cascade Design Automation and Hewlett Packard Corporations [Ainslie, 1994]. The first week of the course included description of Integrated Circuit design tools and methodologies through presentations, tours and lab experience of using engineering workstations, instructed by engineers and managers from Delco Electronics. The second week of the course was aimed at designing one of four Integrated Circuits based on the specifications for typical automotive applications. The ability of all groups to complete design creation, schematic capture, logic simulation, module compilation and initial IC layout has been observed to be extremely satisfactory. Additionally the course has been measured to be very pleasing by participants. Reliability education usually requires forty five hours of theoretical presentation in the class, and fifteen hours of practical training in the laboratory [Marcos, 2001]. The material for this type of education is usually too extensive and the laboratory work

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lacks behind the preplanned program. The situation has been resolved by initially providing the students with the circuits and eliminating the design part which requires extensive amount of time. The students were asked to complete the reliability analysis task which is the main intent of the course. Another measure has been incorporation of a software tool to aid reliability analysis. The tool allows easy data input to a windows environment, which allows the user to select every standard characteristics for a component and provide a verbose for a contribution of each component to the system failure. The modification of the teaching material has been found to improve the students' understanding of reliability calculations. Trainees from Motorola were exposed to the movements of a 4000-pound connecting rod forging hammer with instructions to move a molten bar being relayed in a voice-masking ambient noise environment. Late actions might result in damage to equipment, not to mention the spraying of harmful; molten metal. The effect of Virtual Reality in training future factory workers on manufacturing lines which use human operators in the supervision of industrial robots has been carried out by Motorola, in conjunction with Adams Consulting Group in the US. The production line of Motorola's Pager Robotic Assembly Line was recreated in VR for both desktop and immersive presentation to test subjects. When comparing the performance of those trainees who had exposure to the VR set-up with those who trained using real equipment in the laboratory, VR trainees learn faster and make fewer errors (Adams, 1996). Another VR study has been conducted at Ford's Vulcan Forge in Dearborn, Michigan where safety is of paramount importance (UK VR Forum, 1999a). Workers are exposed to the movements of a 4000-pound connecting-rod forging hammer, with instructions to move a molten bar being relayed in a voice-masking ambient noise environment where late actions could result in damage to equipment in addition to the danger of spraying of harmful molten metal. The operators' are expected to perform this function for many hours at a time. The hammer and local forge environment was reproduced to display to the trainees using immersive VR technologies. Although the subject pool had been small (three trainees only), the two who have been trained via VR (over a 2-day period) were found to be 20% more efficient than the one who has been exposed to conventional training using an off-line hammer. A pilot study emphasizes the need for additional sensory stimulation, including plant noises, the voice of a trainer and a pneumatic cylinder system to deliver realistic impact forces to the VR user. An introductory course in mechatronics to serve senior undergraduate and graduate students has been developed at University of Detroit Mercy [Krishnan 99]. The course has been taught by a team of three faculty two from Computer and Electronics and one from Mechanical Engineering. The class included many more Mechanical Engineering students than Electrical Engineering students due to the course conflicted with another popular EE Technical Elective. 50% of the course was spent for laboratory activities. Grading was based on both individual and group achievements. Incorporation of project-based activities to understand the theoretical depth of the course, increases the success as measured by an assessment questionnaire at the end of the course program. Increasing global concern over air pollution and greenhouse gases by vehicle emissions led the advancement of Electric Vehicle research [Hendrix, 2004]. Designing a curriculum for students from both physics and automotive mechanics classes resulted in collaboration, sharing their expertise and talents. The dynamics of diversity merits the success of the program by encompassing theory and mechanics. The project encouraged the students to involve in vocational technology and vice-versa, providing each group of students a greater overall comprehension of the EV project. The students were asked to assemble 48V single and dual motor electric modular-teaching vehicles by meeting once or twice a week to learn theory and applications prior to assembling the vehicles. After mastering the laboratory and shop floor safety, students investigated basic electricity and magnetism by both in lab experience and on computer integrated tools. Afterwards, students were divided into the groups of their choice to complete the wiring of control panel and assembling the cart body. It is observed that, the initial apprehension of the physics students was alleviated by eager help of the auto-tech students. Then on, after a few sessions, they were observed to be enthusiastic about meeting and working on the project. Advanced automotive power systems demands for higher fuel economy, performance, reliability, and reduced emissions resulted in an increasing demand for electrification of ancillaries and engine augmentation, developing into electrical vehicles and hybrid electric vehicles nowadays [Emadi, 2004]. The emerging research and technology application opportunities in automotive industry, has been incorporated as multidisciplinary projects into the Inter-professional Projects Program at Illinois Institute of Technology, Chicago. Teams of 5 to 15 students from all academic levels and from across IIT's professional programs were challenged to complete semester-long undergraduate projects based on real-world topics. One of the latest project was to study the effects of automobile system electrification, mainly through HEVs. Two subgroups are formed one administrative to search for the legal aspects of the circulation of HEVS on the streets and the other technical group; to focus on the design, simulation and optimization issues during the development of the vehicle.

By the end of the course, students were not only to develop hybrid vehicles but also were able to determine optimum design and control strategy to give the greatest fuel economy. Due to requirement of massive investment in training of CAD-related software, the high number of people to synchronize hardware updates, software releases and training throughout these corporations, companies established centers with well-equipped classrooms dedicated to specialized education and training from on site instructors as well as for distance learning. It was expected that using the latest communication and instructional technologies, web based material, along with occasional visits of instructor to centralized locations would have increased the interest in distance learning. From the company perspective, in most industries broad implementation of a major new technology requires massive investment in training. Very often the companies sponsor courses provided by contracts with universities or specialized firms. However CAD-experts and CAD-superusers usually educate themselves due to the lack of job related educated and training offerings. The spread of virtual environments spread by CAD resulted in decisions at all levels including nonusers of CAD whose job CAD substantially impacts. The lack of training and education of nonusers, especially managers constitute the integral part of the difficulties in taking full advantage of CAD. Due to the increasing demand in training and education with respect to CAD, American Society of Mechanical Engineers has been consistently recommending a curriculum that includes knowledge of CAD and the use of CAD related software. Education and training has been brought together by the effort of industry throughout programs such as PACE (Partners for the advancement of CAD/CAM/CAE Education) at General Motors [Field, 2004]. Through such programs, corporations supply up-to-date technology and training materials while universities provide instruction in subjects such as three dimensional solid modeling, basic assembly of components and collaborative team design. Such coordinated efforts help to set realistic level of expectations for CAD software. Due to the growing impact of CanBus, all over automotive industry, a curriculum design for fieldbus skills has been vital for education of IT Engineers [Marino 2004]. After several years of thesis supervision, a curriculum has been designed at University of Vigo, Spain. Two languages LoTo and SDL were chosen. For making analysis and simulation purposes, two relevant European fieldbuses were selected. PROFIBUS and WorldFIP, FPGA chips (Field Programmable Gate Array) were included for the design and implementation of nodes. Reconfigurable embedded systems, is adaptable to several fieldbus standards. Tornado tool, which runs of the Works real-time operating system, manufactured by Windriver System has been selected to design and implement the emulation nodes of the fieldbus.

Growing complexity of automation systems, in several areas including automotive industry, resulted in a growth in industrial communication networks or fieldbuses [Marifio, 2005]. It is essential to incorporate the starter and training system into the curriculum of technical programs. To provide the students with the practical knowledge about different fieldbus protocols available in the market, a course program to teach CAN (Controlled Area Network) has been developed to include the design of different nodes that constitute a starter and training industrial network. The starter and training CAN network included one monitoring station (protocol analyzer), one control module, one device based on microcontroller 8751, one device based on reconfigurable circuit (FPGA) Field Programmable Gate Array) and several Input/Output devices based on the integrated circuit P82C150 SL10-CAN. The education setup allows the students to make simple communication practices, including analysis and studying of all the frames and messages transmitted on the bus in a specific control application. One practical example was to control the speed of a direct current motor by using a potentiometer placed in a remote node. The network includes a monitoring station, a control module, and two I/O devices one for the motor and the other for the potentiometer. The student commands to the speed of the motor through the control unit by manipulating the potentiometer while observing the protocol on the monitoring station.

Due to the increasing demand in skilled personnel having expertise in new Automotive technologies, Automotive Mechatronics course has been incorporated into the curriculum of Mechatronics Education. This research is focused on the effect of the teaching method, on knowledge acquisition of students from Automotive Mechatronics course. The paper is organized as to to describe the method in section 2, followed by the discussion of the results in section 3. The work is completed by the final section of conclusions.

2. Method

The research has been carried out at the Department of Mechatronics Education students throughout a semester long Automotive Mechatronics course. Among the students of Automotive Mechatronics course, 30 were selected for testing purposes. The students had no prior knowledge of Automotive Mechatronics. Two subgroups of 15 in each were formed randomly and named, control group and experimental group, respectively. All of the subjects were asked to complete a pretest to measure their level of knowledge in the field of Automotive Mechatronics. By the end of the coursework, they were asked to complete a test to measure their degree of capacity in the field of Automotive Mechatronics. Pretest and final test questions were kept the same and multiple choice.

The Automotive Mechatronics course was taught in two different ways to each group. Classical teaching method was used for the control group. The course of the control group included, teaching the theoretical concepts in class and afterwards practicing the material in the laboratory. On the other hand, teaching of the Automotive Mechatronics concepts to the experimental group has been conducted, completely in the laboratory environment. The course material was handed out to experimental group beforehand and the course of education included, solely hands on practice in the laboratory. The lab applications were prepared in a way to comply with the theoretical course material and were handed out at the beginning along with the theoretical package.

The theoretical concepts included,(1) Engine and vehicle mechanics, (2) Types of engines, wiring and subsystems, (3) Power transmission systems, (4) The basics of automotive technology, (5) Fundamentals of electrical engineering, (6) Electronic components and basic electronic circuits, (7) Applied automotive electronics, (8) Automotive digital electronics, (9) BUS systems, (10) Electronic power transmission and gear systems and (11) Vehicle dynamics. The laboratory practice topics included (1) Engine education set (Combined fuel ignition and powertrain system); gas injection, ignition, power-train, (2) Common rail Diesel engine injection and ignition systems; ignition system, injection system, vehicle loading, failure analysis, (3) Ignition system for gasoline engines; injection system, ignition system, vehicle loading, failure analysis, (4) ABS-ASR vehicle safety systems; operational fundamentals of ABS and ASR system, failure analysis, diagnostics, (5) Vehicle lighting system. Long and short head lights, mechanical measurement sensors, (6) Airbag system components, operational principles.

The lab work of both groups were conducted within the same laboratory environment which includes the following equipment;

1. Motronic system
2. Common rail ignition and fuel injection system
3. Gas engine fuel injection and ignition system
4. ABS-ASR set
5. Automotive Electronics Set
6. Airbag system

Lab exercises were conducted on Lucas Nuller, ignition, fuel injection (Figure 1), motronics and automotive safety systems (Figure. 2) developed for both gasoline and diesel engine systems.

Each educational set is controlled by a software program (Figure 3). The system allows for both simulation and realtime education of the system.

Figure 1. Motronic Education Set

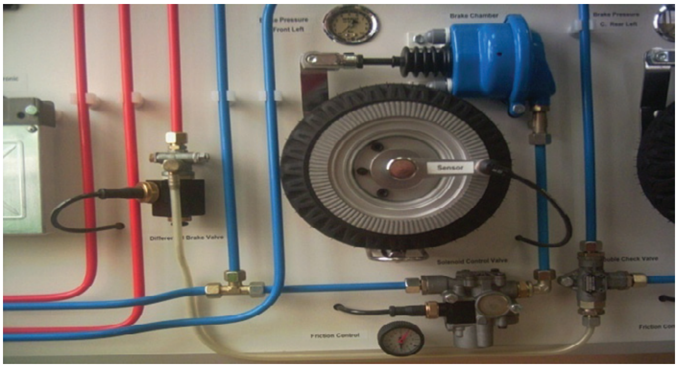

Figure 2. ABS – ASR Education Set.

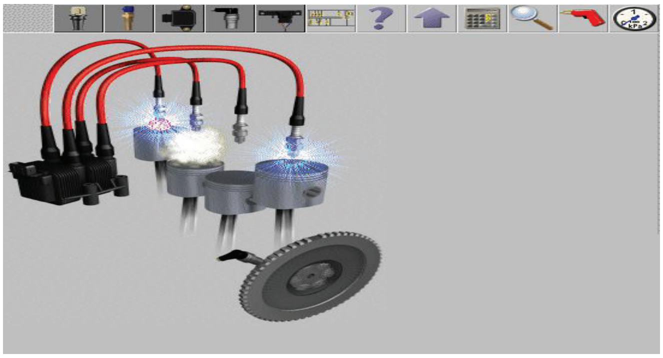

Figure 3. Education Software Interface

Theoretical handout included visual and written documents similar to the knowledge provided by the simulation interface of the software along with the theoretical knowledge.

The degree of capacity of the students in the filed of Automotive Mechatronics was measured by applying a pretest and a final test. The questions were kept the same for both tests. The pretest and final tests were conducted at the beginning and at the end of the semesters, respectively. The results were analyzed by a statistical program. The results of the pretest and final tests for each groups were analyzed both, within each group and across, the groups, to be able demonstrate, overall performance along with the advantage of the proposed method. The results were anaysed for nonrelative and relative measurements, by applying MannWhitney-U and Wilcoxon non-parametric tests, respectively.

3. Results

3.1. The pretest results of the Control and Experimental Group

The results of the pretest to measure the capacity of both control and experimental groups in the field of Automotive Mechatronics was analysed by Mann Whitney-U test and are shown in Table 1. According to the anaysis, there’s no significant difference between average values of the control and experimental groups (U= 109,5, p › 0,5). When the mean rank was observed, the scores of the students in both groups were found to be similar. According to the results of the pre-test, both groups demonstrate a similar capacity in the field of Automotive Mechatronics.

Table 1. Results of the Pretest for Both Groups

Test Groups	N	Mean Rank	Sum. of Ranks	Mann-Whitney U	P
Experiment Group	15	15,70	235,50	109,500	0,902(a)
Control Group	15	15,30	229,50		

a. Not corrected for ties. b. Grouping Variable: group

3.2. The Comparison of Pretest and Final Tests for the Experimental Group

The degree of a meaningful difference between the performance of experimental group in pretest and final test was measured by Wilcoxon non-parametric method [Table 2]. The results of the analysis indicate that, there is a significant difference between the scores of the pre-test and the post-test of the students participating in the research (z=3,415; p ‹ 0,05). When the mean rank and the total of the scores of the difference are observed, it can be seen that the difference is for the advantage of positive ranks, (that is to be the post-test). According to the results, the proposed educational model for Automotive Mechatronics, demonstrates a significant improvement on the capabilities of the experimental group.

Table 2. Wilcoxon Signed Ranks Test for the Comparison of Pre-test and Post-test Results for the Experimental Group

	N	Mean Rank	Summary of Ranks	z	p
Negative Rank	0 (a)	0,00	0,00		
Positive Rank	15 (b)	8,00	120,00	-3,415 (a)	0,001
Ties	0 (c)				
Total	15				

(a) Post-test < Pre-test (a) Based on negative ranks

(b) Post-test < Pre-test (b) Wilcoxon Signed Ranks Test

(c) Post-test < Pre-test

3.3. The Comparison of Pretest and Final Test for the Control Group

The degree of a meaningful result between the pretest and final test results of the control group is measured by Wilcoxon non-parametric method [Table 3]. The results of the analysis indicate that, there's a significant difference between the scores of the pre-test and the post-test of the control group (z=3,331; p ‹ 0,05). When the mean and sum of the ranks are considered, this difference is in favor of the final test. When the order average and the total of the scores of difference are taken in consideration, it can be seen that this observed difference is for the advantage of positive order, (that is to be the post-test). According to the results, the capabilities of the control group is improved throughout the course of Automotive Mechatronics.

Table 3. Wilcoxon Signed Ranks Test for the Comparison of Pre-test and Post-test Results for the Control Group

	N	Mean Rank	Summary of Ranks	z	p
Negative Rank	1 (a)	1,50	1,50		
Positive Rank	14 (b)	8,46	118,50	-3,331 (a)	0,001
Ties	0 (c)				
Total	15				

a. Post-test < Pre-test a. Based on negative ranks

b. Post-test < Pre-test b. Wilcoxon Signed Ranks Test

c. Post-test < Pre-test

3.4. The final test results of the Control and Experimental Groups

Mann Whitney U test results for the final test of both groups are shown in Table 4. According to the test results, there's a significant difference between the results of the group, which followed an independent-practice oriented course of education when compared with the group which followed a classical course of education (U= 37,50, p < 0,05). This result indicates that the students oriented in an independent-practical course, were able to increase their capacity in the field of Automotive Mechatronics more when compared to those who followed a classical in class course of education. When the mean ranks were considered, the scores of the students from the experimental group are better than those from the control group. According to the post-test results, the experimental group is more successful than the control group.

Table 4. Results of the Post-Test for Both Groups

Student Group	N	Mean Rank	Summary of Ranks	Mann-Whitney U	P
Experimental Group	15	20,50	307,50	37,500	0,00(a)
Control Group	15	10,50	157,50		

a. Not corrected for ties. b. Grouping Variable: group

4. Conclusions

Traditionally, Automotive Mechatronics course has been conducted classically by teaching the theory through inclass presentations and afterwards having the students practice the pre-prepared exercises in the laboratory. As an alternative to the classical method a new model is developed which suggests, providing the students with both theoretical notes and laboratory exercises beforehand and conducting the course solely in the laboratory by having them to complete the exercises. The effect of the model on learning capabilities of the students was explored throughout the course of education and measured by pre-tests and post-tests. The results of the proposed model were compared to that of classical mode of teaching. Generally, the pre-test and final-test results suggest that the Automotive Mechatronics course improved the capabilities of the students in the field of Automotive Mechatronics. Moreover, the proposed methodology improved the capabilities of the students more when compared to those taught by the classical method.

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