A Project-based Pedagogy in Teaching Robotic Mechanisms: Design a Remote Control All-Terrain Vehicle out of a Junky Car Chassis

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Abstract – In this paper we will share our strategies for improving student engagement through a course design project in teaching robotic mechanisms at Embry-Riddle Aeronautical University (ERAU). In this project, students designed and constructed a remote control driving and steering system for a discarded all-terrain vehicle (ATV) chassis. This unique project-based learning experience has exposed students to practical issues in designing motion and motion transfer systems for wheeled vehicle. Through progress reports and weekly group presentations, we kept track of the project progress and helped them find and solve critical issues in time. Students successfully constructed a fully functional remote control ATV. The project was developed within the latest engineering education initiative CDIO (Conceive-Design-Implement-Operate) framework. The framework is intended to transform the focus of engineering education from the teaching of theory to building foundation for practice. At the conceive stage, students defined customer needs and developed conceptual design plan while being aware of the Design constraints. At the Design stage, students completed the part selection and the CAD drawings based on the conceptual design. During the Implement stage, learning activities shifted to manufacturing, installation, and testing. At the Operate stage, students should deliver the developed product to customers and provide maintenance and improvement if necessary. Due to the time constraint, students did not complete the Operate stage in this project. In conclusion, this teaching practice has successfully demonstrated that the project-based learning developed within the CDIO framework is very effective in engaging students in learning and improving their skills in design, teamwork, and communications.

Keywords: robotics mechanism, project-based learning, CDIO, mechanical engineering education

I. INTRODUCTION

Instructional Needs

Since its inception in 2004, the mechanical engineering (ME) program at Embry-Riddle Aeronautical University (ERAU) has grown steadily strong by attracting young talents with its unique hands-on learning focused curricula. The ME program offers three tracks including Robotic Systems, High Performance Vehicle, and the recent added Clean Energy Systems. ME 306 Robotic Mechanism is a junior level track course for students on the Robotics System track and an elective for those on the other two tracks. Since all students on the Robotics track will design an autonomous vehicle during their senior year and compete at a variety of collegiate robotics competitions sponsored by Association for Unmanned Vehicle System International (AUVSI), one of the goals of ME 306 is to familiarize students with common mechanisms used in all autonomous vehicles they will design later, especially the motion and the power transfer system.

In order to prepare students well for the motion and motion transfer system design, we introduced the project-based pedagogy in the ME 306 curriculum that required students to design and install a remote control driving and steering

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system on an all-terrain-vehicle (ATV) chassis. The traditional curriculum may only require students to size the motor and select the motion transfer mechanism without considering any practical issues such as the space constraint. This project, however, exposed students to every stage of the motion and the motion transfer system design including motor sizing and motor mounting, motion transfer mechanism selection and mounting, the battery system design, and the remote control unit design. The final product of the project is a functional driving and steering system which enables a remote control ATV.

Motivation for Pedagogical Change

Although students taught in a traditional pedagogic setting can become proficient in solving well-defined problems, their problem solving skills are challenged when they encounter practical problems which are usually not well defined. For example, when given the ground vehicle wheel size, the speed requirement, and ground surface conditions, students may know how to calculate the required torque of a driving motor. When they need to select a motor for the actual ground vehicle, however, they cannot make a decision as they do not know how to select one from a variety of similar motors. This issue may be caused by the difference between problems in academic settings and in engineering practice [1]. Most academia oriented problems are presented with clear connections with required concepts and may only require thinking from one perspective, while practical issues do not indicate associated concepts and need to be examined from different perspectives, which requires students to apply concepts and skills learned from different subjects. Such disconnection between academia and engineering practice prevents students' problem solving skill development for their future engineering career.

We have applied the project-based pedagogy intensively in ME program to reduce such disconnection. This vision stems out of teaching practices of our experienced faculty, and has echoed the recent engineering educational initiative: the CDIO (Conceive-Design-Implement-Operate) Initiative, a framework for educating next generation of engineers [2]. The CDIO Initiative is intended to reform current engineering education which does not place enough emphasis on students' skills such as design, teamwork, and communications [3]. As an institutional collaborator of the CDIO Initiative, ERAU has adopted its open curriculum development architecture model in engineering education and intends to equip students with skills to allow them to "Conceive-Design-Implement-Operate complex, value-added engineering products, processes, and systems in a modern, team-based environment" [3].

The project-based pedagogy in ME 306 is developed within the CDIO framework. At the Conceive stage, students need to define customer needs and develop conceptual design plan while being aware of the design constraints. At the Design stage, students should focus on the design such as the part selection and the CAD drawings. During the Implement stage, learning activities will shift to manufacturing, installation and testing. At the final stage, Operate, students should deliver the developed product to customers and provide maintenance and improvement if necessary. Due to the time constraint, we only went through the CDI (Conceive-Design-Implement) stages.

The paper is organized as follows. The development of this new pedagogy will be explained in Section 2 including the pedagogical goals, project selection and technical milestones. The implementation of this new pedagogy at each stage of CDIO will be presented in Section 3. Key findings and lessons learned from implementing this pedagogy will be included in Section 4.

II. DEVELOPMENT OF THE NEW PEDAGOGY

Pedagogical Goals

Since ME 306 is the track course for students on the Robotic Systems track, the goals of this course have been determined as follows:

1. Familiarize students with common mechanisms used in robotic systems such as motor and motion control systems, motion transfer devices, vehicle suspensions and drivetrains, and steering.
2. Equip students with in-depth knowledge of motion and motion transfer system used in robotics system.
3. Have students develop a systems perspective.
4. Have students develop skills required to work in team such as project management and solve problems cooperatively.
5. Have students improve their technical communication skills, both written and oral.

The instruction materials and learning activities were designed to meet these goals.

Project Selection and Design Tasks

This project idea originated from a discarded ATV chassis. The autonomous ground vehicle group at ERAU purchased an ATV chassis (see Figure 1) and planned to use it in the Intelligent Ground Vehicle Competition (IGVC). But it was found out that the vehicle was not suitable for IGVC due to its large turning radius. As we were also looking for a project for ME 306, we decided to develop a project based on this chassis which already integrated suspensions and the steering system. Considering driving and steering system designs are important mechanical design tasks, we decided to have students taking ME 306 develop a remote control driving and steering system for this ATV chassis.

Figure 1 The ATV Chassis Used in the ME 306 Project

The remote control driving and steering system should meet the requirements listed in Table 1.

Table 1 Design Requirements

1.	Select a driving motor such that the vehicle can achieve maximum speed of 5 mph.
2.	Mount the motor and design the motion transfer system to drive the rear wheels.
3.	Select a steering motor to enable steering on all possible ground surfaces including dirt, tile, and the carpet.
4.	Mount the steering motor and design the motion transfer system.
5.	Design the remote control unit such that both the driving and steering can be operated by a RC controller.
6.	Design and install the battery system to power the driving motor and the steering motor. The run time should be no less than 30 minutes.
7.	Each team should not spend over $1,000.

There were nineteen students taking this course during the spring semester 2011. They should complete the project within nine weeks. In order to maintain a good group dynamics for effective teamwork, these students were divided into two teams: the driving team and the steering team. Each team had three subgroups responsible for general design and motor sizing, motor mounting, and motor speed control unit design, respectively. As a result, there were two to four students on each subgroup. Although we were not suggested by any compelling evidence on optimal group size, we found a group of such size can usually work effectively and productively.

The class had two lectures of 75 minutes each week. When the project begun, on the second lecture time, only half an hour was for the regular lecturing while the rest of the class was for team updates. Each subgroup gave a presentation to update their progress during the past week and report critical issues they encountered. Each subgroup was also required to submit a written report to complement their presentation.

III. Implementation of the New Pedagogy

This section will discuss the implementation of this pedagogy in each stage of CDIO. As explained earlier, due to the time constraint, the final stage, *Operate*, was not implemented.

Conceive

At this conceive stage, students from each team need to define customer needs and work out a conceptual design plan. By reviewing the design tasks, students brainstormed issues such as the motor torque requirement, the space constraint, and costs. For example, the general design requirements and associated reasoning were summarized in Table 2.

Table 2 Minimum Design Requirements of Driving System

Requirement	Reasoning
Max vehicle speed ≤10 mph, preferably 5mph	Speeds higher than 10 mph will be unsafe for an autonomous vehicle
The vehicle must have an effective run time of 30 minutes.	For future development as an autonomous vehicle.
Chain must be able to withstand the forces produced by the motor and sprockets.	A robust design is desired
Chain and sprockets must be able to mount on vehicle without major changes to the existing vehicle	Major changes are not feasible due to time and budget constraints

Based on the steering torque requirement, the steering team calculated desired motor torque. The steering motor mounting group listed required steps to accomplish the task:

1. Measure the distances of the front sub-frame assembly area.
2. Discuss possible options of mounting the motor to the ATV.
3. Finalize mounting option
4. Find a distance to place the motor away from the steering shaft through mock-design.
5. Use these dimensions to design a mounting system that would allow space for a sprocket and chain set.
6. Design mounting brackets and plate
7. Manufacture brackets and plate
8. Attach brackets to the frame and plate to the motor and brackets
9. Assemble steering motor components including the controller, motor and sprocket/chain set.
10. Initial testing phase
11. Modification of ATV steering shaft and collar
12. Final test resulted in the ATV steering left and right

Design

Motor sizing was a critical task for each team. The driving motor team summarized their findings in Table 3 while the steering team can only find one motor providing the required torque within the budget.

The motor mounting groups took different approach during the design stage. Since one student in the driving team is proficient in CAD, he took the lead and created the design in CAD as shown Figure 2. Through this approach, they were clear about the dimensions, which facilitated their selection of the gear transmission. Although the steering team did not have expertise to generate similar CAD design within the short time frame, they followed the step generated during Conceive stage and created the CAD for each assembly (see Figure 3) instead of the whole steering part.

Since the two motors should share one battery system, the student in charge of battery selection worked with both teams to find the power requirement. By comparing four types of rechargeable high power batteries including lead-acid, Li polymer, $LiFePO_4$, Li titanate, the student chose the AGM (Absorbed glass mat) deep cycle battery, a type of lead-acid battery, because of its high power density and rapid discharge rate.

The remote control unit design group from each team also worked together to determine the requirement of remote control transmitter and receiver. Such design experience exposed students to a system perspective to solve the problem.

Table 3 Driving Motor Options

D&D 170-512-0005 DC Motor ***$250*** • 24 - 72 VDC • 7/8" single-shaft base • 6.7" Dia x 8.5" Long • Actual Weight 38 lbs CONTINUOUS RATING: 48 Volts • 3100 rpm • 45 amps armature • 9.5 amps field • 2.3 HP PEAK RATING: • 4500 rpm • 350 amps armature • 20 amps field • 8.5HP	**ME0909 DC Motor** **$380** • Power:6.3HP continuous • Voltage: 12 - 48 Volts • Speed:3,984rpm at 48V • Size:6.88"OD,6.29" long • Shaft:7/8"x 1-5/8", 3/16" key • Weight: 24.1 Lbs.	**ME0708 DC Motor** **$425** • Power • 6.44 HP continuous • Voltage • 24-48 Volts • Speed • 3360 rpm at 48V Unloaded • Size • 8" OD, 5.5" long (w/o shaft) • Shaft • 7/8"x 1-5/8", 3/16" key • Weight • 30 lbs.

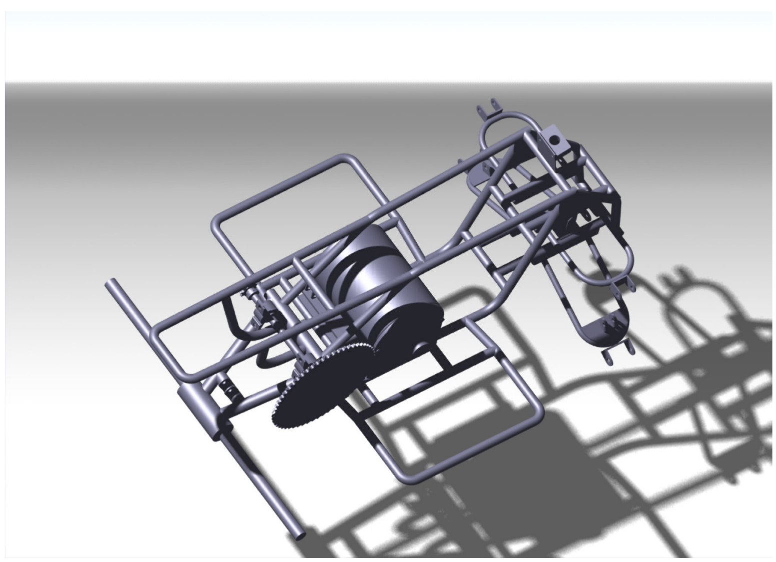

Figure 2 The CAD Drawing of the Driving Motor Assembly

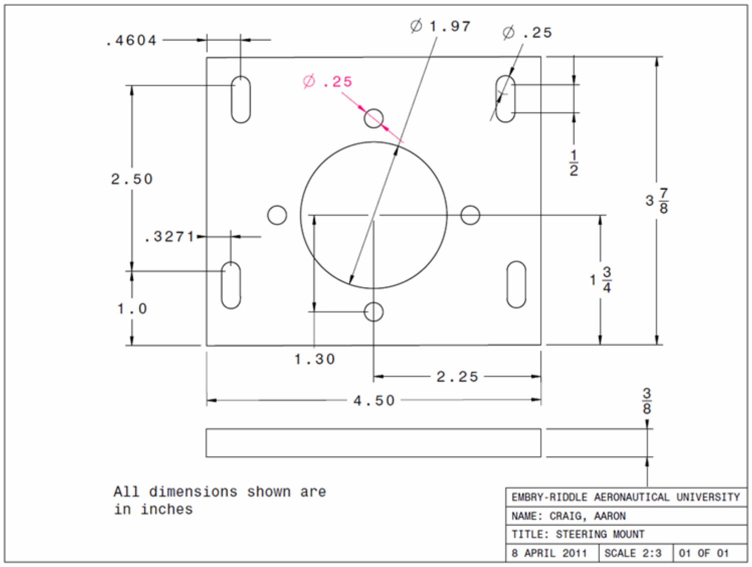

Figure 3 Steering Motor Mounting Plate

Implement

During the Conceive and Design stages, each subgroup was giving presentation every week and submitted a written report to update the progress. Therefore, each group could receive immediate response from other team members and the instructor to solve critical issues. In this project management approach, the project was carried on the right track. After nine weeks of hard work, both teams successfully completed the project. Figure 4 shows the steering motor mount assembly, and Figure 5 is the final product with a functional remote control driving and steering system. All the requirements listed in Table 1 have been met.

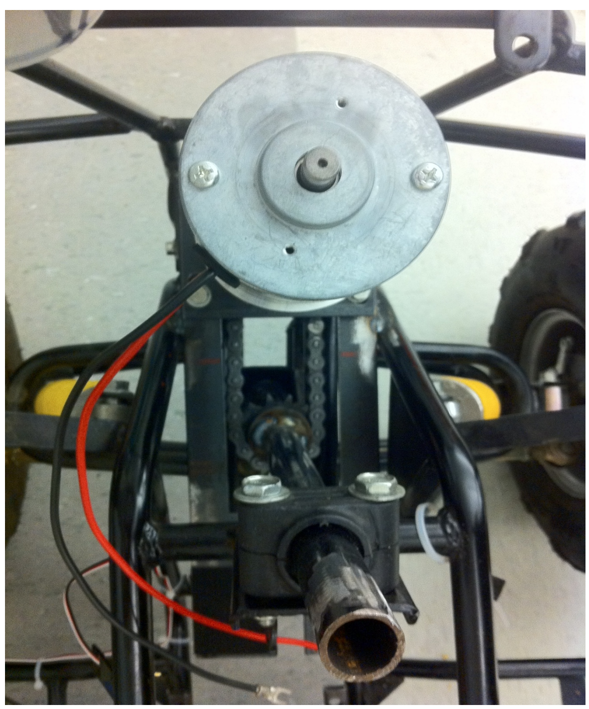

Figure 4 Steering Mount Assembly

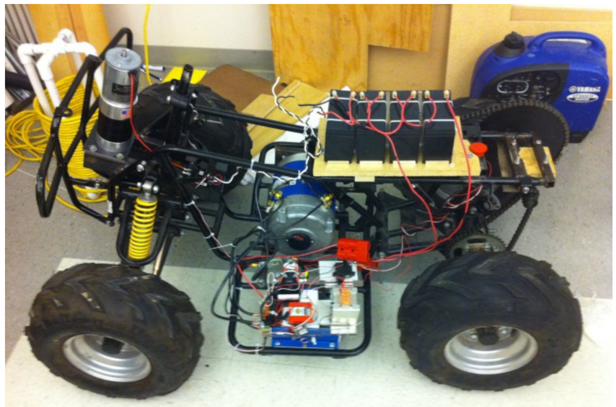

Figure 5 A Remote Control Driving and Steering System on an ATV Chassis

IV. KEY FINDINGS AND LESSONS LEARNED

Students' Comments

From the students' comments on final project and the end-of-course evaluations, 85% of students expressed their appreciation of this project-based pedagogy. They really enjoyed the learning experience. The completion of the project has given them a great sense of success and achievement. The dissatisfaction of the other 15% came from their insufficient involvement due to their lack of experience with cars. Students who had worked on cars took over the majority of work while left those inexperienced students less chance to contribute. This issue may be fixed by properly assigning groups such that each subgroup will not be dominated by experienced students.

Logistics is a major challenge which was not encountered in traditional curriculum. Since the project required a large amount of manufacturing, some of their work was delayed due to the busy schedule of the machine shop. The technical documents from the manufacturers also caused some design confusion, which gave students a good lesson that technical communication is so important for customers.

Although procrastination occurred in some groups, in general most sub-groups worked efficiently and completed the task in time.

Costs

Although the project was a success, the cost was a major hurdle to implement this pedagogy on a regular basis. The two teams spent $1,666 in total. Although the parts used in the project can be re-used in similar projects or other courses such as mechatronics and control systems, a high cost may not be avoidable. Therefore, design a low-cost project will help continuously implement this pedagogy.

Time

Although the project was completed in time, students did not have enough time to improve their design. The majority design focused on functions while safety issues were not well addressed. As seen from Figure 5, the placement of batteries is a big safety issue. Probably a small scale project would fit a semester-long curriculum, so the students will have enough time to improve the design to address critical issues in practice.

V SUMMARY AND CONCLUSION

The project-based pedagogy implemented in ME 306 at ERAU has been introduced, along with findings and lessons learned from this practice. This pedagogy was developed within the CDIO framework which intends to produce next generation of engineers characterized by the capabilities to Conceive, Design, Implement, and Operate complex, value-added engineering products, processes, and systems in modern team-based environment. In general, students enjoyed the project-based learning experience and had successfully accomplished the tasks. The effectiveness of the pedagogy needs to be evaluated by continuous implementation.

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