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Andy S. Zhang
CUNY New York City College of Technology

Gaffar Gailani
CUNY New York City College of Technology

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Dr. Andy S Zhang, New York City College of Technology of CUNY

Professor Andy S. Zhang earned his master's in mechanical engineering from the City College of New York in 1987 and his Ph.D. in mechanical engineering from the Graduate Center of the City University of New York in 1995. Prior joining the Mechanical Engineering Technology department at City Tech, he served as an engineering instructor for the JUMP, an engineering training program sponsored by the New York State Department of Transportation. Professor Zhang's research area includes materials testing, composite materials, CAD/CAE, engineering animation, and mechatronics.

Dr. GAFFAR BARAKAT GAILANI, New York City College of Technology

Dr. Gailani is an assistant professor in the Dept. of Mechanical Engineering and Industrial Design Technology. Received his Ph.d in Mechanical Engineering from the City University of New York in 2009. His research work is focused on poroelasticity and its application in biomechanics. He has more than 15 journal publications and conference proceedings and one book.

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Abstract

This paper discusses the collaboration of faculty members in the mechanical engineering technology department to improve the quality of students' design work in a senior design project of the Machine Design class. A faculty member who taught Machine Design, a capstone course, collaborated with two faculty members who taught Advanced Solid Modeling, a feeder course for Machine Design. The collaboration originated from a review of students design work in the senior design project of the machine design class which indicated that many students who took three engineering graphics courses still lacked certain skills and understanding when creating their design models and working drawings. For examples, many students didn't understand the difference between working drawings and the corresponding 3D objects, and they had difficulty in creating sheet metal components and gears. This was an on-going project which started in fall 2012. Some details concerning the implementation of intradepartmental collaborative work including assessment was discussed in this paper, more will be discussed in future papers.

1. Introduction

Engineers use engineering graphics to describe their design, to exchange ideas, and to communicate with others. As an important communication tool, most engineering department commits at least two courses on engineering graphics.

The mechanical engineering technology department at the college offers three engineering graphics courses in its associate degree program. They are: Engineering Drawing, Computer-Aided Engineering Graphics, and Advanced Solid Modeling. The objective of these offering is to give students opportunities to get familiar with different types of engineering graphics from 2 dimensional (2D) to 3 dimensional (3D), and from general to mechanical engineering specific graphics in a gradual fashion so that they can develop needed drafting skills over times and apply them in senior design courses such as Machine Design.

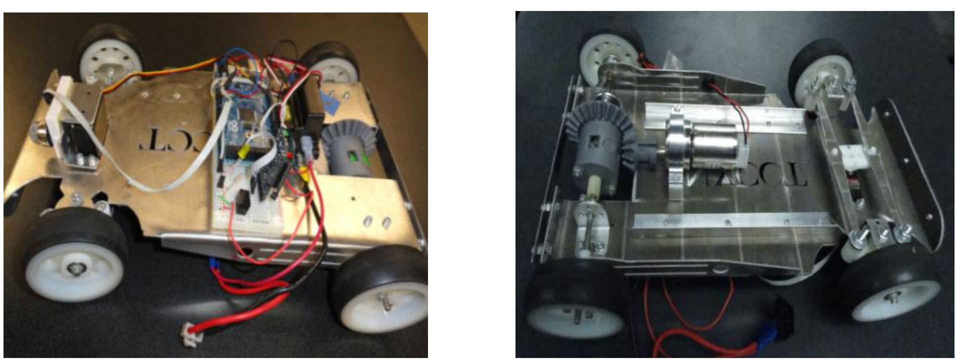
Despite the extensive offering of engineering graphics courses to the students, a review of students work in senior design projects of machine design classes revealed that students still lacked certain skills and understanding when creating their design models and working drawings. For examples, many students didn't understand the difference between working drawings and the corresponding 3D objects. They had difficulty in creating sheet metal components and gears. When designing a product with multiple components or subsystems, many students failed to take into considerations the intrinsic relations among various components. As a result, many components cannot be assembled properly. It is important for the students to realize that product design is an integral system design not the design of individual unrelated components [1-5].

In fall 2012, a team of faculty members consisting an instructor who taught the capstone course: Machine Design that has a senior design project, and two instructors, one full-time and one part-time, both were teaching the engineering graphics course called Advanced Solid Modeling started to work on a collaborative project to address the issues mentioned above. Based on the findings that many students who were enrolled in the Machine Design class did not have enough knowledge and skills in creating gears and sheet metal components, a special design project that requires students to create these components was given to students who were enrolled in the Advanced Solid Modeling class, a feeder course for machine design. In this project students were not only required to create many common mechanical components such as gears, sheet metal components, and mechanical subsystems (differential drive system and steering system), they had to considerer how assemble each component into a functional product. The faculty member who taught the Machine Design class helped the other two faculty members to implement the project. This project provided an opportunity for the students to sharpen their skills related to their future course work and relate the engineering graphics to an actual design work.

Some details concerning the implementation of intradepartmental collaborative work including assessment was discussed this paper. More will be discussed in future papers.

2. Details of the Hands-on Design Project

To help students to make connections between their engineering graphics work and actual product design work and better prepare them for senior design project, a hands-on design project was introduced at the 7th week of the Advanced Solid Modeling class. Students were required to design the RC cars which may have three mechanical components: 1) a chassis made of sheet metal, 2) a differential drive system, and 3) a steering system. To help students to visually understand the scope of the task, a RC car prototype as shown in Figure 1 was given to the student to study.



a) Top view b) Bottom View

Figure 1 A Remote Controlled RC Car Prototype.

There are over fifty components in the RC car prototype. This provided a realistic scenario to inform the students that product design requires the design and selection of many components in a systematic way in order for the product to function properly and to meet certain design specifications. The sizes and dimensions of most of the components such as the wheels, the DC motors for driving the RC car and a servo to drive the steering system were given to the students in the form of individual 3D CAD files so students don't have to create them. Students were only required design three subsystems mentioned earlier: 1) the chassis, 2) the differential drive and 3) the steering system. However when designing these subsystems, students were told to check the existing CAD files for the parts they wanted to use to make sure the information on these files were properly reflected in their design. This means that for each part the team decides to use, they have to allocate proper space for it to be installed.

To give students more options during initial brainstorming and research phase, students were given a freedom to choose three-wheel option or four-wheel option for their RC car drive train design. That means, when designing the drive train, the team can choose to have one drive motor with a differential drive system or two drive motors without the differential system.

Teaching differential system has always been a difficult task. To help students to understand the principles of a differential drive system, a prototype differential system made of 3D printer as shown in Figure 2 was presented to the students created to demonstrate how differential system works.

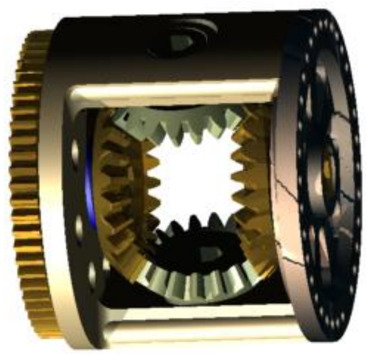


Figure 2 A Differential Drive System Prototype

3. Leveraging the Parametric CAD Package

Many parametric CAD packages have modules that enable the designer to create sheet metal components easily. Autodesk Inventor, a 3D CAD package from Autodesk Inc., also has a design module called Design Accelerator that allows users to create spur gears, bevel gear, and worm gears systems easily. Design Accelerator has become a very effective tool for us to teach gear concepts [6]. Users simply specify the diametric pitch or module, the tooth numbers, and the helical angles etc. Design Accelerator then will create a set of meshing gears automatically. The software however only provides details information about the shape and size of the teeth for each set of meshing gears. Students are still required to add details to the gears such as a hub, a keyway, and a hole based on design intent and sound engineering judgments.

When designing chassis using sheet metals, students were told to pay attention on the rigidity of the chassis by making proper flanges or adding rib reinforcements in special locations. Students were encouraged to apply industrial design knowledge make their design more aesthetically appealing to the customers. Aesthetics has become an important attribute in product design and development [7-8].

4. Learning through Reinforcement

In the mechanical engineering technology department, students were supposed to learn the concepts of geometric and dimensional tolerancing, gears and cams in a 2D based course called Computer Aided Engineering Graphics which is the pre-requisite for taking the Advanced

Solid Modeling class. As a result, when teaching Advanced Solid Modeling, the instructors took it for granted that students would be able to create gears, shafts, and chassis using Autodesk Inventor. Students would then be able to apply dimensional and geometric tolerances when converting their design into working drawings. It turned out that these concepts had to be reinforced in Advanced Solid Modeling class because many students did not have a good grasp of these engineering concepts when learning them for the first time in the Computer Aided Engineering Graphics.

The RC car design project helped the instructors who teach Advanced Solid Modeling course to realize that they need to continue to refresh students' memory about gears and tolerances through proper assignments or design projects. It also helped the students to think about the interconnections of each component and/or subsystem when design a product. Students were asked to give examples on why they had to pay attention to the interconnections of each component in the project. These examples and the follow-up discussions helped students to understand the importance of the integrated approach to product design as demonstrated in Figure 3 of the RC car design project.

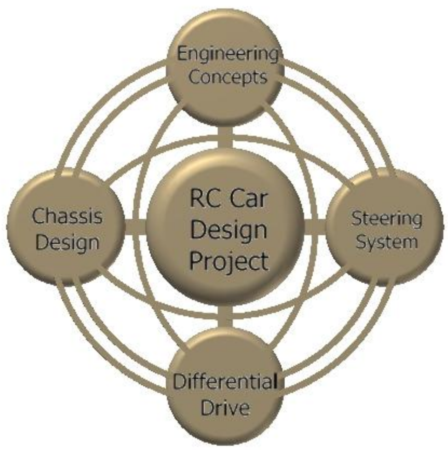


Figure 3 Elements Involved in the RC Car Design Project

For example, when performing chassis design using sheet metal, students need to consider the following: size of wheels, wheel spacing, size of differential drive, motor size, and size of steering system. Any change in chassis design affects the design of differential drive, the steering system, the motor selection, and wheel selection or vice versa. Because of the scope of the project, students were divided into teams to accomplish the design project. Effective communication among team members became critical. Each member in a team needed to understand the inter-relationship among each component and subsystem. If a student who was assigned to design the chassis failed to take into consideration of spatial requirements of other components, reflected them in his/her design, and communicated effectively with other members, there would problems down the line when putting everything together to make a final product.

5. Initial Results

At the end of the semester, most students working in groups were able to create the RC car model. Two design teams' work was presented here. Figure 4 is a computer rending of one RC car design which adopted the three-wheel option. The front two wheels can be turned using a steering system driven by a servo. The single rear wheel was supposed to be driven by a DC motor. This design avoided the use of a differential drive system. The reason to use the three-wheel option was that the team realized the difficulty to create a design of differential drive within the given time frame. As can be seen from the design, the team had not figured out how to attach the drive motor to the rear wheel.

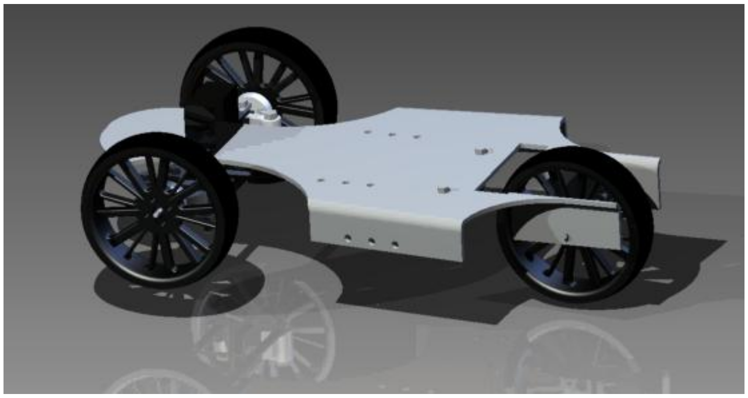


Figure 4 Computer Rendering of One RC Car Model

Figure 5 was the design by another team who adopted the four-wheel option. Since the team spent extra time outside the class to work on the project, they were enabled to finish the design project and to duplicate the design of the RC car physical prototype provided.

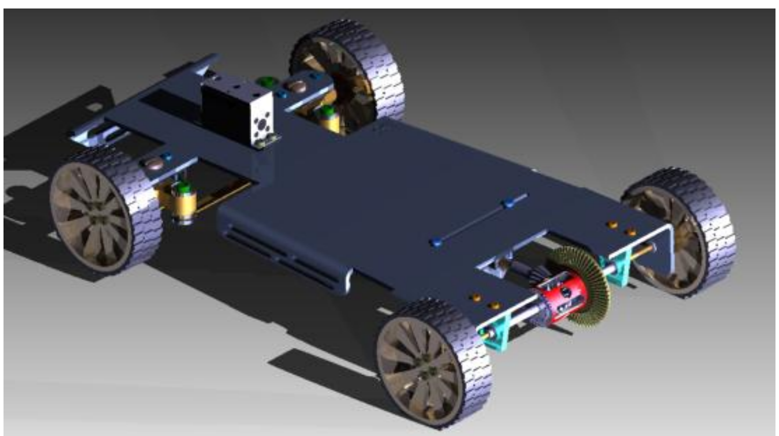


Figure 5 Computer Rendering of another RC Car Model

6. Assessment

The objective of the collaborative design project is to improve students' ability in creating better engineering graphics related to machine design or broadly speaking, product design. As a design project, there are certain performances criteria that were used to assess the learning outcomes of this project. These criteria included:

- ability to use sheet metal module to create mechanical structures with rigidity and strength consideration,
- ability to create gears, especially differential gears using Design Accelerator,
- ability to create a four-bar linkage that serves as a steering system,

- ability to take into consideration many factors related to design and use them for overall planning,
- and ability to organize and work in teams.

Formative assessment such as interactive class discussion, exit survey, and oral presentation were used. The following table showed some of the survey results.

RC Car Design Project – Q & A Worksheet

Instructions: The answers to the questions below are intended as starting point for discussion and will not be graded. Just write your first intuitive response to the questions and don't think over it…..	
Q1. What do you think is the most difficult part of this joint design project, the gear system, the robot chassis design, the steering system, or putting everything together?	A1. The gears; Not enough knowledge about gears design; Assembly and adjusting dimensions (tolerance).
Q2. Does this project give you a new perspective on what product design is about?	A2. "YES"; Team work and collaboration; It will help me in future work, it seems like real design; We learned what we can achieve with inventor.
Q3. What have you learned in this or other classes that you can apply other course you take?	A3. Math; basic design skills; gear design; design process; basics of RC car parts and their purposes.
Q4. What have you learned in this class or other classes that makes you a better problem solver?	A4. Good experience; Developing an idea that is practical for the use; Product design combines all ideas in one object.
Q5. What have you learn in this or other classes that make you a better thinker?	A5. Inventor can be helpful in every course; Group work; Time management.
Q6. What have you learn in this or other classes that make you a better communicator?	A6. We have to come out with our own idea.
Q7. What have you learn in this or other classes that make you a better team player?	A7. We divided work; Discuss ideas; Explain project to the class.
Q8. What have you learn in this or other classes that make you a better leader?	A8. Listening to others; Learning form others; Work together.
Q9. What questions or suggestions do you have?	A9. Need more time for the design that will make it better.

7. Conclusion

The collaborative work between the faculty members in Machine Design and Advanced Solid Modeling has created an initial success. It gave students a fresh experience in learning engineering graphics and helped them to relate what they learned in Advanced Solid Modeling class to their future work. The hands-on design project motivated the students. Students were anxious to make physical prototypes based on their design work.

8. Future Work

The intradepartmental collaboration to improve students' ability to apply engineering graphics in their design work will be continued. Effort will be made to bring the instructors who teach introductory courses: Engineering Drawing and Computer Aided Engineering Graphics on board to review the three engineering graphics courses together. This will enable the department to find a better way to improve them as a whole. We will require the faculty members who teach engineering graphics to continue to upgrade the knowledge in utilizing the latest CAD package so they become competent instructors to teach engineering graphics.

The work on assessment and evaluation will be tied to the continuous improvement plan for the mechanical engineering technology department for the upcoming ABET visit.

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