ASEE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

2017 ASEE International Forum:
Columbus , Ohio Jun 28 Paper ID #20736

# SCUPI Derby – A New Approach to "Introduction to Mechanical Design"

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## Abstract

The sophomore class of "Introduction to Mechanical Design" in SCUPI is rather unique in the sense that it pairs a traditional mechanical design class with an English writing class that is centered on technical writing. To the best knowledge of the authors, this has never been experimented in other institutes. To provide the best learning experience for our students and to take advantage of the MakerSpace (a new facility that was recently set up in SCUPI), the idea of a SCUPI Derby, which was modeled after the well-known US Boy Scouts' Pinewood Derby [1], was assigned to our students as the final project. What is different from the Pinewood Derby is that the model car of our project would be made from 3D printing instead of elaborating on a pinewood block. To prepare our students for this challenging task, SolidWorks has been used as the main design tool. Not only the concept of concurrent engineering was introduced in the early stage of the class, but also the technology about rapid prototyping has been emphasized throughout the semester. Basic concepts of fluid mechanics and vehicle dynamics were also supplemented in the regular classroom discussion of mechanical design. In addition, research skills aimed at helping students search for information that could lead to better composition of their project report as well as improved design of their model car were discussed in the technical writing part.

The experience that our students gained from this class would be invaluable for their future career. This could be seen from the excitement and energy they displayed on the day of the SCUPI Derby as well as the sophomore conference. They witnessed how a well-thought design could be realized and turned into a wonderful product in life. It gives them the first taste of the design realization as well as the true meaning of engineering.

## 1. Background

The Sichuan University-Pittsburgh Institute (SCUPI) is one of the recently established joint education programs between China and US. Currently it offers three undergraduate programs in Mechanical Engineering, Industrial Engineering, and Materials Science and Engineering. It is in its second year of operation. One hundred students recruited in its first year are now sophomores. Since the program is aimed at preparing students to meet the challenges of globalization, all courses offered are taught in English. In addition, it breaks away from the

traditional model of classroom instruction to adopt more of a studio approach that centers on active-learning, problem-solving, and team work.

## 2. Introduction

Introduction to Mechanical Design is a required course for all sophomores. It is intended to introduce students to all related topics in design. To this end, a solid background in engineering graphics is required. While the course is quite common for all engineering programs, what makes it special is that it has been paired with an English writing class that is centered on technical writing. Most engineering programs in the States have tried pairing a lab course with the writing class. To the best knowledge of the authors, our class has never been experimented in other institutes. Because of the newly added component, the credit for the course has been increased to four instead of three for the traditional classes. To provide the best learning experience for our students, the instructors for both components of the class have to work closely as a team. The newly added writing part to the course posed a number of challenges. The first challenge was to manage the time. Both the content instructor and the writing instructor had to share the time for the class on the same schedule. It was agreed that the main class was the Mechanical Design part and which should be preserved for its primacy. Thus, the writing instructor came to class every other week for one hour. To compensate for not attending classes as often, the writing instructor made use of writing groups. These groups of 5 or 6 students would meet for 45 minutes once per week.

Another issue was the coordination of grades. The students would receive only one grade for the class, comprised of the grades for the main course and its writing component. We decided that the main course would account for 80% of the total grade while the writing component would account for 20%. In addition, in order to communicate the value of both parts of the course, we established the policy that students had to achieve a passing grade in both components of the course in order to pass the overall course.

## 3. New Approach and Classroom Implementation

### a. Mechanical Design

For the Mechanical Design part of the course, engineering graphics is first introduced. In SCUPI, SolidWorks has been chosen as the main graphics tool [2]. Students learned how to use the tool to create solid parts and assemblies using various functions provided within. They also learned how to produce engineering drawing for the part and assembly they created. Concepts about design such as concurrent engineering as well as manufacturing processes like injection molding and fast prototyping are also introduced. To engage students in the classroom discussion, extra-credit problems were offered from time to time to challenge students. These problems were related to other classes (such as Statics and Calculus II) that students were taking concurrently. For which they were asked to use tools provided in the SolidWorks to find alternative solutions. This approach not only engaged students in classroom discussion, but also sharpen their problem-solving skills. While students got most of their practice of the modeling tool through homework assignments, to integrate all the knowledge they learned from the class, they were also challenged with a final project. While the homework was an individual effort, the project required team work. Students were divided into 24 groups with four students in each

group. The project assigned to the students involved designing and building a model car using 3D printing. Since the model car had to be functional (the evaluation of its performance will be discussed in the assessment section), additional information about 3D printing and basic concepts of fluid mechanics (such as flow resistance and drag) and vehicle dynamics (friction and rolling resistance) were also discussed in class to prepare students for the project. The project was assigned to our students around mid-term so that they would have sufficient time to complete it before the end of the semester.

**a.1 3D Printing**

3D printing, which is also known as additive manufacturing (AM) [3], refers to processes used to build a three-dimensional object by adding successive layers of material under computer control**.** The recent development of low-cost 3D printers makes this prototyping technology popular in the education field. 3D printing could act as a bridge between theory and practice and allow students to turn their concepts into reality. The students who can physically examine their projects, will be more likely to enthusiastically participate in the classes. Also, their abilities of spatial imagination are effectively stimulated. In our project, 3D printers were used to produce every part of the model cars designed by the students.

3D printing practice was conducted in the school's MakerSpace, which is a place for our students to practice and explore their passions by using raw materials, tools, technology, repurposed items, and imagination. The MakerSpace in SCUPI was setup in April 2016 and was equipped with 3D printers, 3D scanners, processing units, robot components, unmanned aerial vehicles, and more. The 3D printers in SCUPI are desktop 3D printers (UP Box) made by Tiertime (Fig. 1(a)). They were supplied with proprietary software. These printers use Fused Deposition Modeling (FDM) technology to build parts using production-grade thermoplastics (Fig. 1(b)). Acrylonitrile butadiene styrene (ABS) was used for our student's projects since it has a greater strength and heat resistance compared to polylactic acid (PLA).

To help students understand 3D printing and its related knowledge, the following practices were organized for our students,

1. 3D printing introduction
   First, an introduction to 3D printing was presented in class. This introduction covered the definition, history of the general process, typical 3D printer structure, and industrial applications of additive manufacturing. This introduction was fundamental and critical for the subsequent steps.

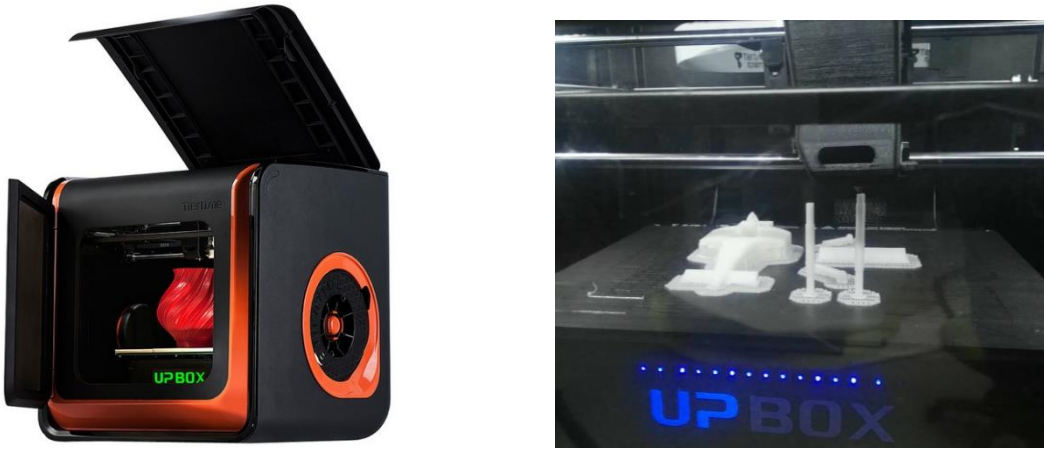
2. 3D printer hands-on operation
   This practice was focused on students' hands-on operation. Based on the availability of 3D printers in SCUPI (three were used for students' practice and one was reserved as a backup), the 24 teams of students were divided into three major groups: A, B and C. Then they were assigned to use A, B and C printer accordingly. In a 3-week period, students were given 6 opportunities to use their assigned printers for 6 to 8 hours in each given opportunity. For better management, students were asked to reserve their 3D printer in advance using a commercial scheduling tool, Doodle. Students learned the following general procedure in operating a 3D printer;

a) Save their model in .stl format
b) Power on and initialize printer
c) Load ABS wire
d) Calibrate the plate and set the nozzle height
e) Import their .stl file and adjust model
f) Set the printing parameters
g) Printing

3. Post-processing of printed parts
When the printing job completes, some post-processing work needs to be done (Fig. 2(a)). The MakerSpace provides hand-held tools such as drilling tools, saws and grinding tools etc. for students to remove the redundant material and polish the surface of the parts. In the end, students were also asked to paint their cars as the overall appearance is one of the evaluation criteria (Fig. 2(b)).

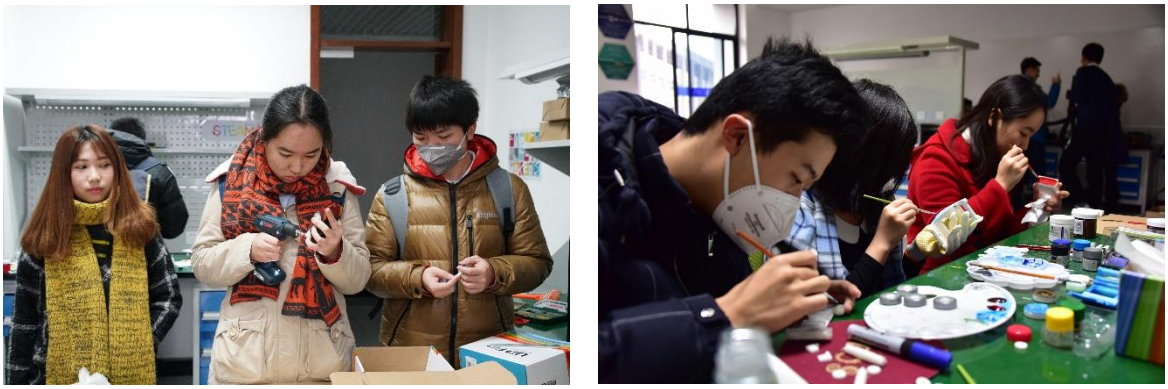
4. Design iteration and troubleshooting
The creation of a physical object using a 3D printer often requires a few tries to get it right, especially for complex objects. Sometimes the flaw is in the design itself, sometimes it is an improper setting of printing parameter that results in parts that lack the strength or precision needed to work properly. In this practice, students not only can have a better understanding of design optimization, but also learn about product defect analysis and find a feasible solution. This problem-solving skill will be useful for the later printing. For example, for the problem of warping, the solution included preheating the platform, calibrating the print bed, adjusting the advance of the temperature, and cooling the air.

Safety issues were greatly emphasized before and during students' practice. Teaching assistants and lab assistants were always on duty to help students.




(a) (b)

Fig. 1: 3D printing technology, (a) a desktop 3D printer, (b) parts manufactured by 3D printing.



(a) (b)

Fig. 2: Students' practice in MakerSpace, (a) post-processing, (b) finishing touch of final project.

**b. Technical Writing**

For the technical writing part, instruction came primarily through the weekly assignments for writing groups. As mentioned earlier, the instructor visited class every two weeks, but the writing groups met weekly. Every week, the instructor posted the new assignment on QQ, a social media platform easily accessed by mobile phones. Students had the responsibility of reading and completing assignments prior to their meetings. Within the meetings, students covered the assignment, and instructions were provided to direct the discussions. One student, selected on a rotating basis, had the responsibility of leading the group and ensuring that the task was completed.

A graduate teaching assistant or the writing instructor would monitor each group. These monitors served as resources when questions arose, and they also helped to keep the groups on track. Some of the students struggled with the leadership role, and wanted either the monitors or other students to take command of the groups. However, this would place too much of a burden on too few students, and it would miss the opportunity to develop basic leadership abilities. Additionally, the opportunities for students to practice and develop their language skills in the specific context of leading a group were also beneficial. As such, the rotation of the leadership role was continued on a weekly basis.

The nature of the assignments involved specific skills and a professional context. The original intent was to use Task-Based Teaching (TBT) [4]. In a course that already demanded a high degree of autonomy, the TBT aspect proved a bit confusing to some. Many of them were puzzled by the background or scenarios provided for the assignments. Thus, assignments were switched to a more traditional and direct style. Instead of a professional context, the assignments related only to the writing task at hand. The assignments included how to write abstracts, how to effectively incorporate figures and tables into writing, quoting and paraphrasing, citing sources, and so on.

Two major papers that were related to the students' final project went through three drafts, including an outline with a complete list of sources. Students could choose their own topic for the papers. If they had difficulty to decide one, the instructors would provide a list of suggested topics

for them. These included, for example, effects of tire thread pattern on the car performance, drag reduction using streamlined body, best practice in lubrication, … etc. The students struggled with the research, as it was almost entirely in the target language of English. They were also unfamiliar with how to use databases, which were also in the target language. Staging and pacing the work using outlines and drafts was important to keeping them on track. But it was not enough. The students still struggled to complete their first paper. Thus, students were required to produce a writing plan with the outlines for their second paper. This proved helpful, and a number of students commented on the benefits of the act of planning out how much they would write per week or per day, or which sections they would write and when. Even when they did not fulfil their own plans, they had a sense of what they had done and what remained, and how they should arrange their time and the task accordingly.

## 4. Assessment

### a. Mechanical Design

The assessment of student's performance in Mechanical Design part includes homework, exams, and final project. Particularly their performance in the final project was evaluated in three parts; design appeal, project presentation, and actual race (i.e., the SCUPI Derby). The design criteria and competition rules of the SCUPI Derby were provided to students near the mid-term so that they would have sufficient time to work on the project. On top of the design limitations set for the model car (such as its size, material, and minimum number of parts), additional challenge came from the actual condition of the race track. The race track used for the competition was made domestically and was available on the market for other similar events. It had several holes in the center of the track which consequently became road hazards that students needed to take into account when they designed their car. Since 3D printing could take considerable time to print model parts, the time management of the project became another important lesson for our students.

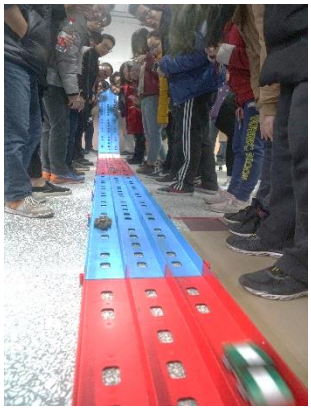
While the design appeal was peer-evaluated (Fig. 3(a) and (b)), the race was evaluated by the distance the car travelled from the inclined track as well as the time it took to reach the final destination (Fig. 3 (c) and (d)). On the day of the SCUPI Derby, students were excited and energized. Before the derby, all model cars were displayed for peer-evaluation. They witnessed how a well-thought design could be realized and turned into a wonderful product in life. We believe the experience that our students gained from this class will be invaluable for their future career. It gives them the first taste of the design realization as well as the true meaning of engineering.

### b. Technical Writing

At the end of the course, students presented their papers in a Sophomore Conference. Not all students could receive prime slots for the slide show presentations. A competition was held one week prior to the main event. The competition placed students in several large groups, and these groups selected a winner for the large group based on performance. Criteria for performance evaluation were provided, including quality of language, organization, delivery, and slides. Winners delivered their slide shows at the conference, while others modified their presentations into a poster format.

(a)

(b)



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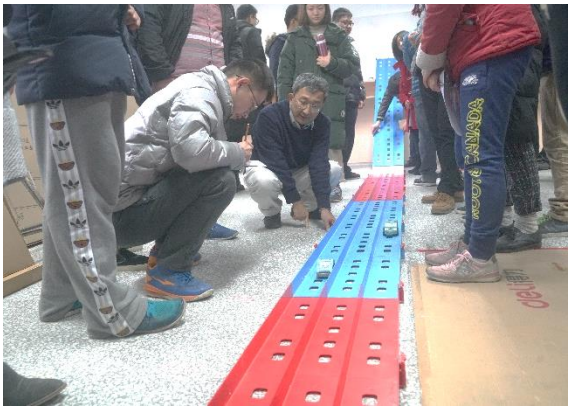
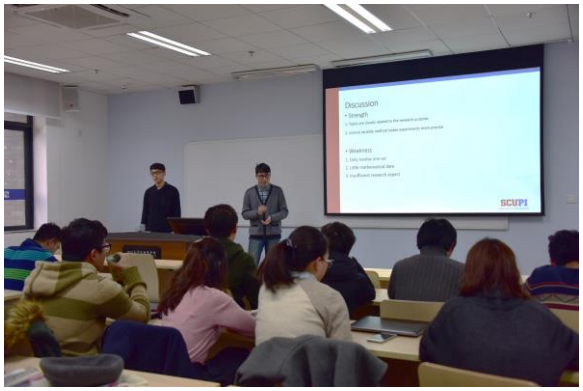


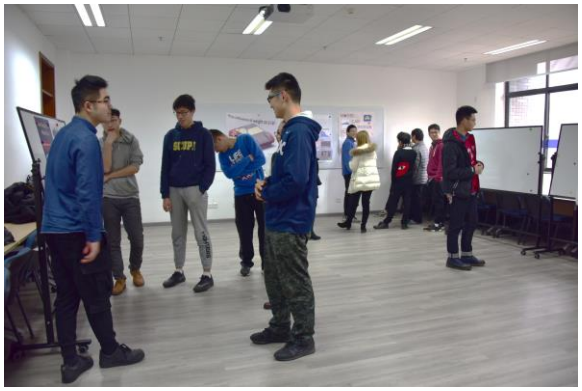
(d)

Fig. 3: Final project, (a) display of model cars, (b) peer-evaluation, (c) and (d) SCUPI Derby.

This conference experience is crucial for students' future career. They got a taste of what a professional conference looks like. Not only did they learn how to present their ideas and findings, but also how to defend them. Earlier exposure to this setting better prepares them for future success.




(a)



(b)

Fig. 4: Sophomore conference, (a) slide show presentation, (b) poster section.

## 5. Conclusion

Although this was the first time that we experimented with this approach, we were successful to motivate and engage students. More importantly we have demonstrated that a careful design class project can be both fun and educational! Many students in their course evaluations indicated that they enjoyed the challenge of the final project and learned a great deal through the project. The hands-on experience with 3D printing let them realize what impact this technology may have on future manufacturing. However, we also felt there was room for improvement, particularly the best teaching strategy for students in this joint institute or similar institutions. Frankly, Chinese students (and many Asian students as well) are more used to the traditional teaching method. While they like the new approach such as Flipped Classroom [5], they were reluctant to embrace it because of their inherent cultural background. The first year in our joint institute is perhaps the most challenging year of our students in their curriculum as they try to adjust themselves to a total English-speaking environment as well as new teaching approach. After experiencing the new approach in their first year, they have been gradually opening up to it. It may still take some time for them to feel completely comfortable.

In review, the major challenges we faced include coordinating the time, the grades, the assignments, and the writing groups. An unexpected surprise was training the graduate teaching assistants, in that we did not expect it to be as extensive. Instead of simply guiding them on grading assignments, we ended up having norming sessions to prevent disparities in grading. They needed to be frequently advised on how to manage student questions about grades. The teaching assistants were essential to the success of our class, and thus their training is important. Adjusting the assignments; improving the student management of the drafting process; training the TAs; and then managing a competition and subsequent conference are the improvements that we look forward to implementing next time.

We feel strongly that our pairing of Mechanical Design and Technical Writing in the sophomore class of Introduction to Mechanical Design is a good move for institutes with special emphasis on manufacturing technology. This would engage students in creative thinking and a team work environment in an early stage of their career. Along the way, they also learn how to conduct research and express their ideas freely. We will continue to monitor and assess the progress of our students as well as the success of our program.

**Acknowledgment**
This course was taught in Fall 2016 jointly by A. Evans and F. C. Lai with the assistance from D. Liang. F. C. Lai was on his sabbatical leave from the University of Oklahoma. He would like to express his sincere gratitude for the great hospitality that he received from the faculty and staff of SCUPI.

**Bibliography**

1. Boy Scouts of America, http://www.pinewoodderby.org/about, Mar. 14, 2017
2. Howard, W. E. and Musto, J. C. (2015), *Introduction to Solid Modeling Using SolidWorks 2015*, McGraw Hill.

3. Gibson, I., Rosen, D. and Stucker, B. (2015), *Additive Manufacturing Technologies, 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing,* 2nd ed., Springer.

4. Willis, D. and Willis, J. (2007), *Doing Task-Based Teaching*, Oxford University Press.

5. Bergmann, J. and Sams, A. (2012), *Flip Your Classroom: Reach Every Student in Every Class Every Day*, International Society for Technology in Education.