AC 2009-2416: INTRODUCING A TWO-SEMESTER RESEARCH COURSE IN THE FRESHMAN YEAR

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Introducing a Two-Semester Research Course in the Freshman Year

Abstract

Engineering schools have been using capstone projects to introduce the students to 'real world' applications and break the barrier between theory and practice. It is usually in the form of a two-semester course where the students use the first semester to develop the soft skills needed for the project in terms of project management and communication. Also the first semester is used for research and design. The second semester is used for building and testing of the final product. This approach showed success in meeting the objectives. However, there is a usual complaint from the students about the time spent in developing the soft skills during the first semester which affects the actual starting of the project. To overcome that, some schools introduce small projects in lower level courses (freshman through junior year). These projects support the material of the courses by introducing a practical application. They also help the students to develop the soft skills needed before they reach the senior year. This approach also showed success in several engineering programs.

In the present work, a research two-semester course is introduced in the freshman year. The course is a small-scale model of the senior capstone project. The main objective of the course is to improve student retention and to recruit more students to one of the engineering clubs. The focus of the course is to introduce students to the project management skills. The major difference between this course and the senior capstone project course is the technical level of the students. To overcome that, the theoretical part of the project was assigned to a sophomore level course where these students have the needed technical skills for the project. The course was offered as a one-hour lecture for the first semester and three-hour laboratory during the second semester. The outline of the course is designed to provide the students with enough guidance and allow them to have space for creativity and to develop problem-solving skills. The project assigned for the course was redesigning and building an off road vehicle for the SAE mini-Baja competition. The vehicle was originally designed and built by a senior project team during the previous year. The theoretical part of the project in terms of load and stress analysis was assigned to a Mechanics of Materials course. A senior project team was also designing and building a new vehicle in the same year, which provides another source of technical information for the freshman students enrolled in the course. At the end of the course, the students successfully completed the project and competed in the SAE mini-Baja in summer 2008. The paper describes the objectives and the structure of the course and the project stages through the two semesters. It also discusses the tools used to guide the students through the project such as weekly meeting, design review sessions, peer evaluation, and design and budget reports.

Introduction

Engineering is building equipment, this how freshman students view it. As they start their engineering education, they need to develop a solid foundation in mathematics and sciences before reaching core engineering courses. At this stage, some students are not mature enough to understand that, and they may think that engineering is not for them. This may be true for some students who can not survive basic mathematics and sciences courses. However, those who are searching for hands-on experience can be retained in the program if they can be exposed to a simplified version of the engineering projects. Parker et al[1] described two introduction to engineering courses that were offered in the freshman year. Each course had a four-week design project where the students worked in teams and used their skills to design and build a simple product. Soft skills such as writing and oral presentations were included in the course. Assessment data showed that these courses improved the student's retention and succeeded to meet their objectives.

Design projects, in general, have been effective tools to increase students' interest in the course and cross the barrier between theory and practice. Traditionally, projects are introduced in the senior year (senior capstone project), because at this level the students have enough technical and management skills, and they are ready to tackle open ended problems[2]. Duesing et al[3] discussed an effective approach to provide continued guidance to the students during the senior capstone project. In their approach couple of formal meeting (design reviews) were held during the course of the project where the students have to defend their decision and get approval from the faculty members who act as customers for the project. These meetings were held before each major stage in the project. The author showed the success of the method through several industry-sponsored projects. Miller et al[4] presented a description for a two-semester capstone course for multidisciplinary industrial projects. More recently, another multidisciplinary engineering team of seniors developed an internet controlled robot for teaching robotics courses during the capstone project, Mokhtar et al[5].

Design project of several sizes have been used to support the content of engineering courses. For example, Hamid et. Al[6] used a design project in a Mechanics of Solids and Mechanisms and Machine Dynamics course. For Heat Transfer, Newell and Shedd[7]presented a comparison between project-based and traditional lecture-based teaching in a heat transfer course. Jones et al[8] designed a project-based Advanced Thermal Systems course for undergraduate and graduate students. Mokhtar and Carroll[9] discussed the use of design project in three Thermo-Fluid courses. In these projects the students were asked to design, build, and test systems to meet technical and non-technical constraints. Mokhtar et al[10,11] presented the use of projects in a Machine Design course and the implementation of project-based learning in the Mechanical Engineering program.

Motivations and goals

In a survey for graduates from the Mechanical Engineering program, most of them indicated that the senior capstone project was the best experience they had in the program, Dusing et al[12]. They indicated that they had the opportunity to design, build and test a product and integrate all their skills toward the success of this project. They also work in multidisciplinary teams. Starting from this level of energy, which is at the end of the tunnel, a similar experience can be designed for freshman students. With the correct project outcome and the appropriate guidance, freshman students can get through a capstone-like course where they work in teams and use their skills to design, build, and test a product. To add more excitement, the final project will be entered in national competition where the freshman team will compete against seniors.

The project has three main goals:

1. Expose the students to a hands-on engineering experience in the freshman year.
2. Introduce soft skills such as writing, oral presentation and project management.
3. Introduce the students to critical thinking and engineering problem solving (EPS) techniques.

Course objectives

Four objectives were selected to meet the research course goals. The objectives are designed to address both technical and communication skills. Technical skills include problem solving techniques, project management, and literature survey. Communication skills include technical writing, oral presentations, professional technical meetings, and team work.

The course objectives include the following:

1. Perform and document research activities in a professional manner
    a. Perform literature searches
    b. Maintain a journal denoting all research activities
    c. Create a master research plan for future research direction
2. Summarize the research project's past, present, and future goals
3. Complete research related tasks in a timely fashion with limited faculty supervision
    a. Create a plan for specific research activities
    b. Update and document progress on research activities
    c. Perform open-ended tasks as assigned by the instructor
4. Participate as an effective team member on the project
    a. Attend all weekly meetings
    b. Share information and ideas with the team
    c. Complete all assigned tasks
    d. Document all research activities

Course outline

For the freshman research course, a simplified version of the senior capstone was designed to serve the above goals. The team met with the faculty advisor for one hour each week for the first semester. In the spring semester, a three-hour lab was used. Research and design were the main tasks of the first semester and one hour a week was sufficient. Figure 1 shows an outline of the course. The course graded activities are shown in Figure 2. A large percentage of the points was assigned to active participation in the project.

The design review, where the students meet with their faculty advisor and other faculty who are experts in vehicle design, took place at the end of the design stage. In this meeting, the students defend their design decision with supporting technical data, reviewed by the faculty before the meeting. At the end of the meeting the design is approved and the students are ready to move to the subsequent stages. Each student must keep a journal documenting his daily activities as related to the research project. The journal contains the student's assignments, ideas, new research directions, original works, and general observations as the team progress though the research project. As a team, two reports are required: budget report and final design documents. In the budget report, all the expenses of the parts used in the construction are included. Also an estimate of the manufacturing process is required where the students keep track of all the number of hours they put in the project and get an industrial rate per hour worked. Peer evaluation is another activity in the course where each student is asked to complete a short survey evaluating each one in the team, including himself. The objective is to allow the students to practice the evaluation process used to gauge the contribution of each team member. A small percentage of the grade is left for the course instructor to add his subjective grade for each team member based on observation.

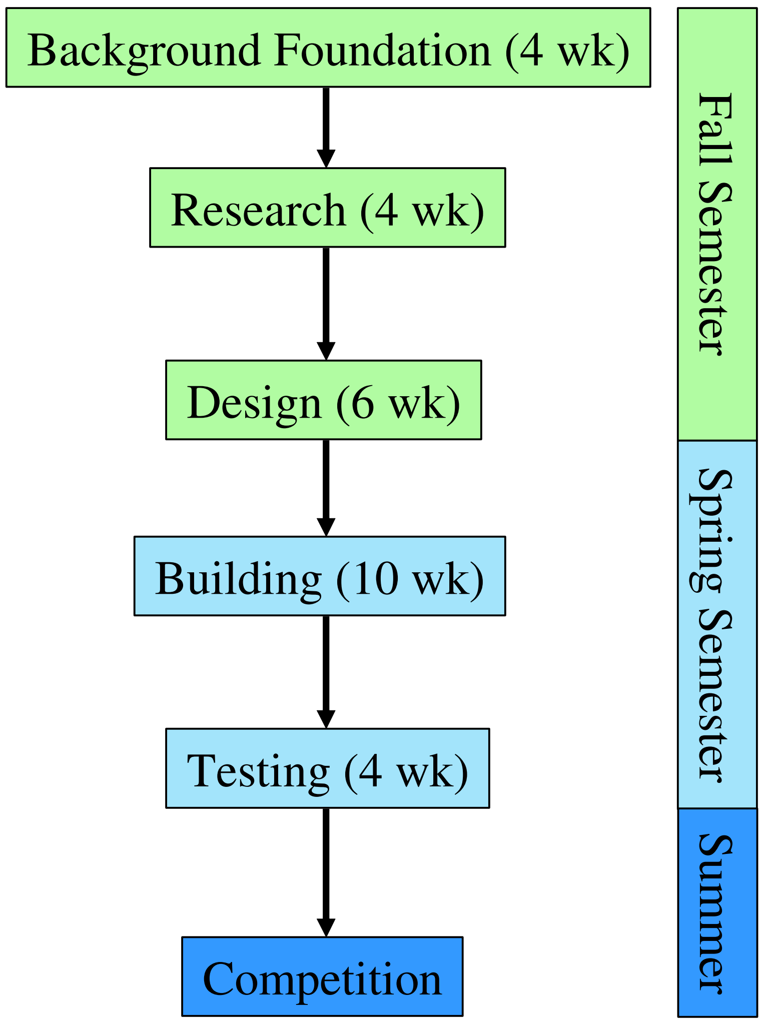

Figure 1: The research course layout

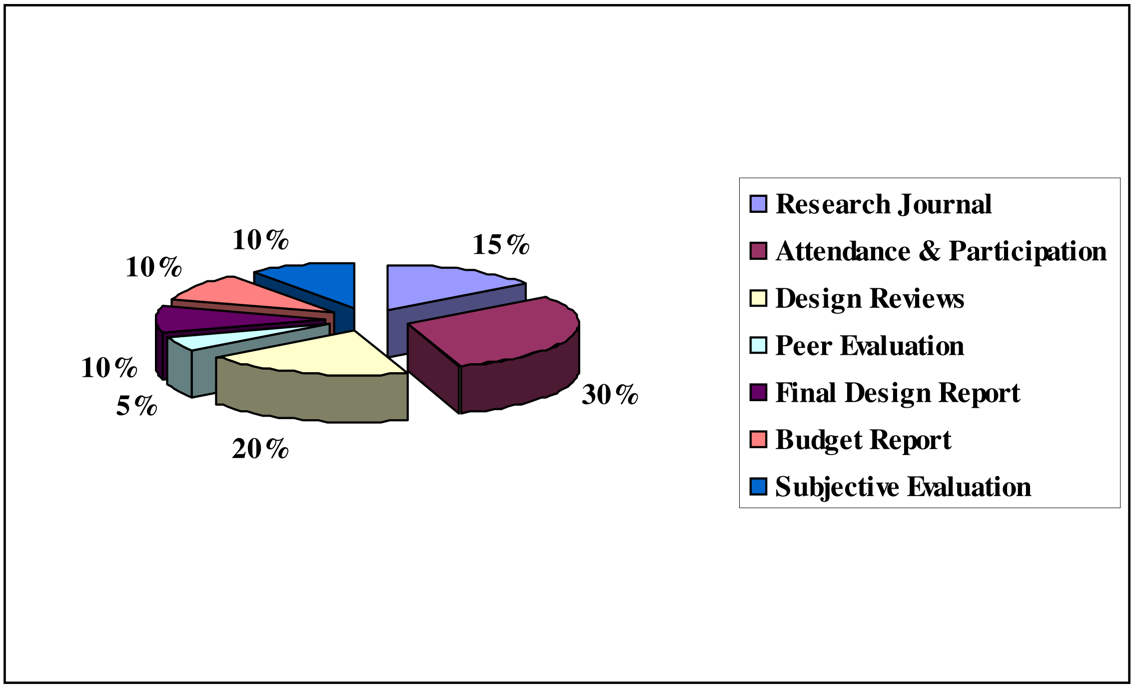

Figure 2: Distribution of the course graded activities

Project scope

The selected project for the course is the SAE Mini Baja. The competition rules allow the same vehicle to enter the race in the following year after a significant redesign. A team of seniors designed and built a Mini Baja one year before offering this course. It was a perfect opportunity to assign this project to the research course where the students can start from an actual design and improve it. Also having the vehicle in hand limits the expenses of the project. Figure 3 shows a photo of the vehicle which was built by the seniors in the previous year.

The course instructor assigned two main goals for the vehicle redesign:

- Reduce the current weight from 720 lb to 500 lb
- Increase the vehicle top speed from 21 mph to 30 mph

The students had to work with a budget of $2000 and re-used as much as they could from the original vehicle.

Background foundation

The technical skills needed for project included CAD, mechanical and stress analysis, background in vehicle dynamics and design, and manufacturing processes. For a team of freshman students, this list of skills was a major challenge. Most of the team members were enrolled in CAD and manufacturing process courses which were offered during the Fall semester. For the vehicle background, the course instructor used the first couple of meetings to introduce vehicle performance and design tools with one of the text books which has an applied approach, Gillsepie[13]. This part of the course was a mix between lectures and directed reading where each student was asked to prepare a 10 to 15 minute presentation to cover one of the topics. Topics also included the SAE rules for the competition. To provide the students with additional sources, especially for the stress analysis, the same project was assigned in a sophomore Mechanics of Material course. In this course, the project requirements were limited to full stress analysis of the rear of the vehicle. Another supporting source for information was a senior capstone project team who was building a new vehicle for the same competition. This second source assisted the students, especially with part ordering.

Figure 3: A photo of the Mini Baja vehicle designed and built by a senior team in the previous year

Vehicle design

After nearly one month of research and evaluation of the vehicle, the students decided to limit the modifications to a redesign of the following list of parts:

- The rear part of the frame
- Power train
- Front and rear suspension
- Steering system

Figure 4 shows a photo of the vehicle that was built in the pervious year. The task for the project was to redesign and build all the parts behind the driver. Figures 5 and 6 show the new design for the rear part of the frame and the power train. The main approach was to reduce number of elements and keep the same frame strength. The power train was simplified using chains instead of a gear box and the differential was removed. The same engine was used which is one of the SAE rules for the competition.

Figure 4: A photo of the previous year Mini Baja vehicle showing the frame rear part and the power train

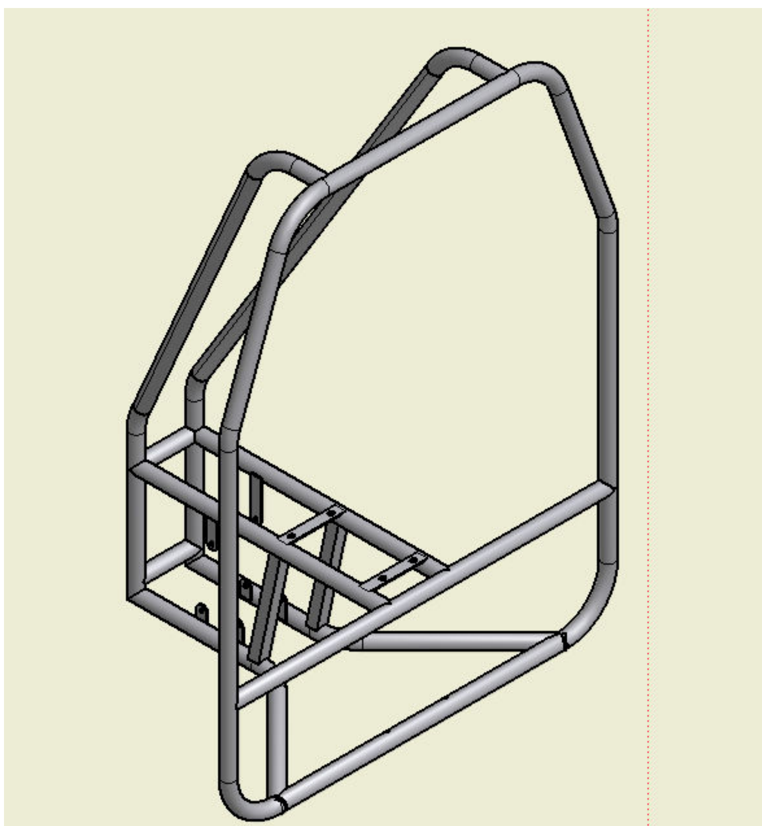

Figure 5: CAD drawing for the new rear part of the frame

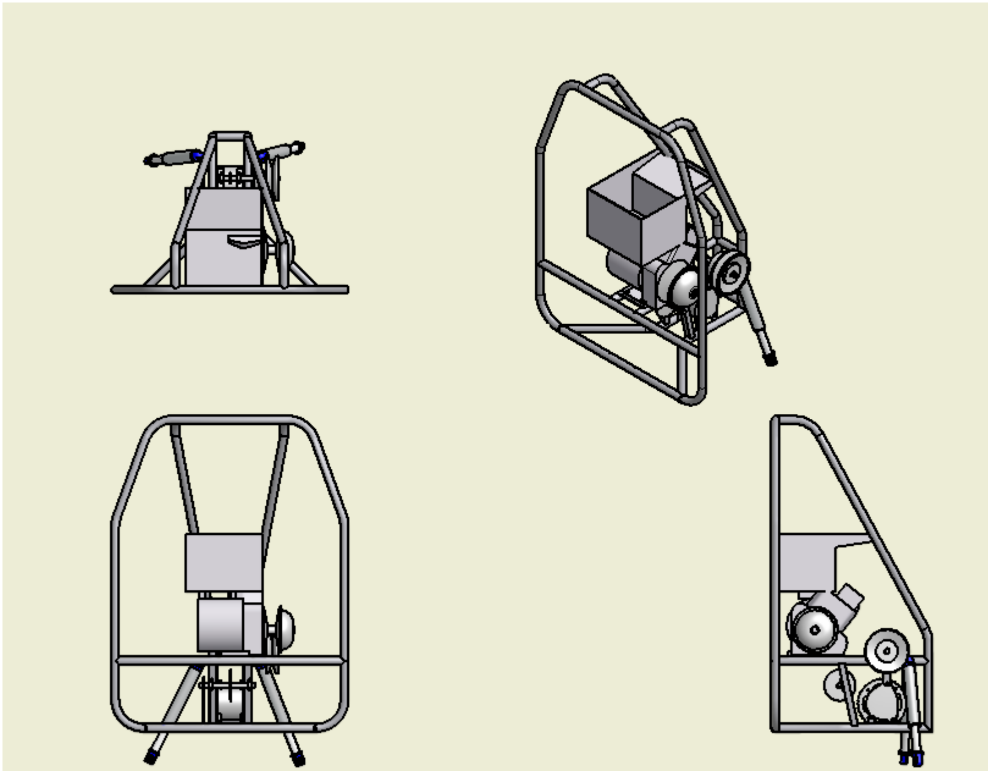

Figure 6: Several views for the rear part of the frame with the power train assembly

Vehicle building

Near to the end of the fall semester, the students scheduled a design review meeting and presented their design in front of a group of faculty. A design package was prepared by the team and delivered to the faculty for review 48 hours before the meeting. The meeting lasted for almost three hours where all the team members participated in the presentation and one of the students was responsible for recording the comments and recommendations.

The construction phase started in the spring semester. The team put together a building plan with a list of subgroups to work in each subsystem. The team was asked to disassemble the vehicle in an organized way to keep track of all the parts. After cutting off the rear part of the vehicle, the students started installing the new members of the frame. Figure 7 shows one of the team members during welding of the new frame parts. The engine and the rest of the power train were then installed as shown in Figure 8. The new suspension was added to the assembly at the end as shown in Figure 9.

The construction phase was an enjoyable and educational part of the project for all the team members. With the limited time, they had to coordinate with each other for ordering parts, matching dimensions between parts built by different students, and best use of the team skills. The power train layout was a hard and advanced part for the team and help was provided in all the steps by the faculty advisor and the machine shop engineer. Also having a couple of students on the team who were involved in similar projects in their high school helped a lot.

Figure 7: Welding the frame

Figure 8: A view of the power train

Figure 9: The new rear part of the vehicle with the suspension, power train, and new frame.

Vehicle testing

The team planned and performed full testing of the vehicle to check its durability for the race. In a simulated track, the team subjected the vehicle to similar race conditions in terms of rough terrain and high jumps. Figure 10 shows the vehicle during one of the tests. The vehicle broke a couple of times and the design was improved. Testing was another educational opportunity to learn the actual engineering problem solving process.

Figure 10: A photo of the new vehicle during the testing.

Competition

The competition included two reports; a design report and a budget report which had to be submitted a couple of weeks prior to the race. Figure 11 shows part of the budget report. As shown, the team had to keep track of all the expenses of the parts and include a labor estimate for each part. Before the race, the team had to pass a technical inspection performed by experts and give a presentation outlining the main features in the design. The race included several events to test various aspects of the vehicle such as acceleration, rock climbing, maneuverability, and a four-hour endurance race. The team had to perform several changes to the vehicle during the race to pass the inspection. Several parts failed during the events of the race and the team fixed them on site. The competition was a great educational environment for the team and the main lesson they learned was; there is more than one approach to solve the same problem. They had the chance to talk to other teams and exchange ideas. Figure 12 shows a photo of the vehicle during the race.

Sect #	Item	Description	Subassembly Costs	
			Material	Labor
1	Engine		$121.50	$35.00
2	Transmission		$423.00	$52.50
3	Drive Train		$1,649.00	$105.00
4	Steering		$190.00	$0.00
5	Suspension		$1,192.18	$749.20
6	Frame		$52.20	$1,603.04
7	Body		$35.44	$0.15
8	Brakes		$337.21	$105.00
9	Safety Equipment		$42.47	$0.00
10	Electrical Equipment		$102.00	$70.00
11	Fasteners		$281.31	
12	Miscellaneous		$90.69	$175.00
13	TEN Event		$0.00	$0.00
14	ILL Event		$670.00	$17.50
15	MTL Event		$0.00	$0.00
		TEN Total:	$ 4,517.00	$ 2,894.89
		ILL Total:	$ 5,187.00	$ 2,912.39
		MTL Total:	$ 4,517.00	$ 2,894.89

Figure 11: Part of the budget report.

Figure 12: A photo of the vehicle during the race

Assessment

Figure 13 shows student feedback for several project activities and their evaluation for the skills they gained from the project. All except the design review were above 70%. The design review was not successful from the student point of view because it was held at the end of the fall semester. They had to go through a lot of modification for the design after that. From the instructor point of view, it was a successful activity in terms of educational objectives. Guidance for the project was provided during the other stages of the project. Figure 14 shows the average of the students' grades in the course activities. Together with the student's feedback they show the success of the trial of having a research project in the freshman year. Some lessons were learned during the process and minor refinements are needed before the next run of the course.

Summary and conclusion

A research project course was introduced in the freshman year. The SAE Mini Baja competition was used as the project. It included design, build and testing the vehicle. The several stages of the course and the project were outlined and assessed. The project showed more interest from the students in the engineering program and in the vehicle option. Some lessons were learned from the offering. Overall the course results are promising and proved that with enough guidance and a well designed project outcome, a research project course can be run even in the freshman year.

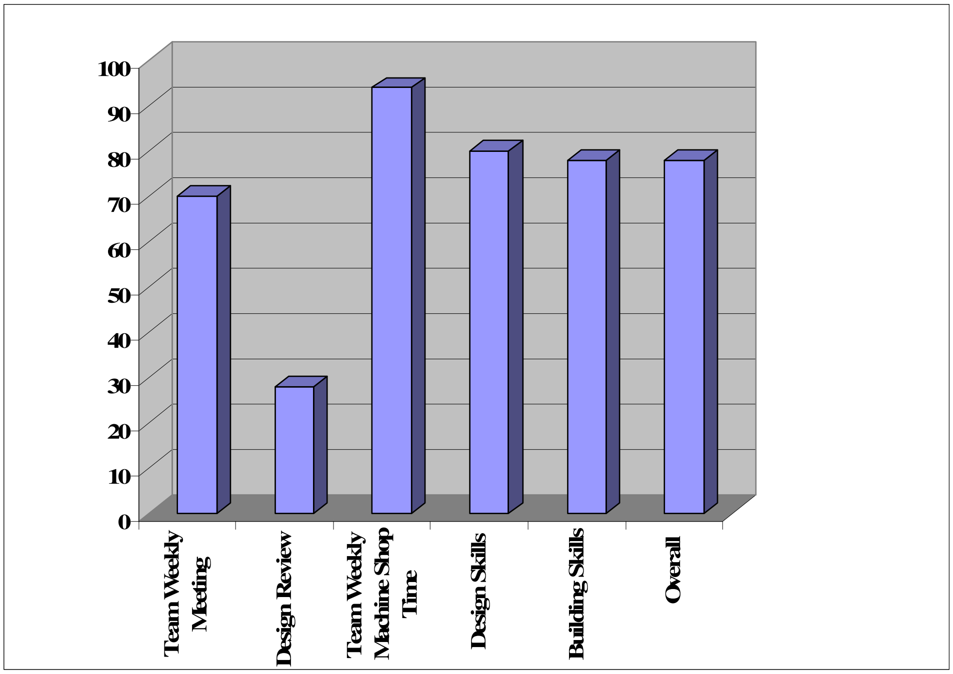

Figure 13: Results from the student feedback survey

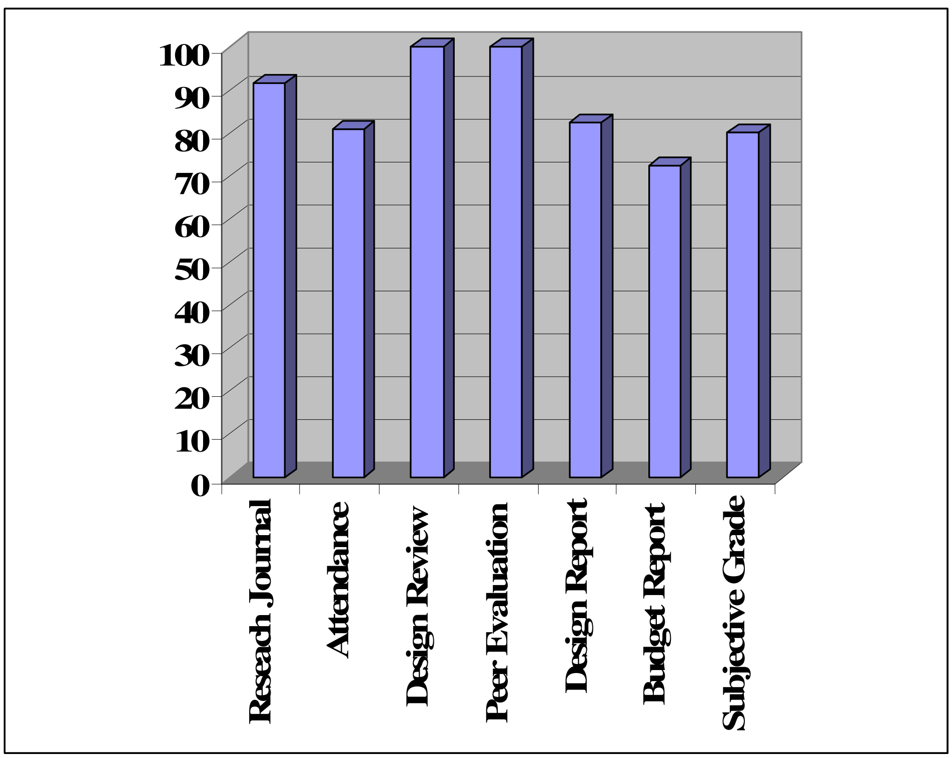

Figure 14: Students' grades in the several class activities

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