

Using a Request for Proposal (RFP) Methodology to Enhance Engineering Design Courses

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Abstract

This paper presents a novel teaching technique that uses a “Request for Proposal” (RFP) as a design tool to add practical real-world engineering design experience in upper level electrical and computer engineering courses. Design examples and student survey responses from a Computer Architecture and Computer Networks course are described.

RFPs are used in government and industry for nearly all engineering development contracts. The RFP specifications used in the courses are adapted from actual equipment specifications used in the procurement of major system development, such as a redundant air traffic control computer system and a digital telephony switch.

Teams are chosen by the instructor and, as far as practical, contain equal numbers of Computer Science, EE students, graduates, and undergraduates.

The major benefits of the RFP methodology and the significant award (exemption from the final exam) are:

- Generating an extremely high level of interest, which is a key to learning.
- Developing lively and interactive project presentations, since each team has worked on the same design problem.
- Learning to integrate cost as a design constraint.
- Gaining redundancy and reliability expertise because the RFP specifications required them.
- Learning how to bid solutions to complex real-world problems
- Learning the competitive procurement methodology.

The paper discusses the various real-world design specifications that are used and the modifications to the specifications required to make the solutions feasible for a course exercise. Summaries of student evaluation scores, evaluation comments, and examples of student results are included. The author demonstrates the value of this technique from a motivational, as well as technical, perspective.

Background

Request for proposal (RFP) is the method used for nearly all major and most minor competitive design procurements. Nearly all engineering graduates will be involved in responding to, or preparing RFP's. An RFP usually has strict rules, such as submission deadlines, page limits, and required content. The RFP is composed of a statement of work (SOW) that describes the program or results required and numerous ancillary requirements such as equal opportunity employment requirements, technical reporting requirements, financial reporting requirements, prior experience, costs, and management plan. The RFP discussed in this paper is primarily concerned with the SOW and the costs required to achieve the work proposed.

Examples of very large programs bid using RFPs are the space shuttle, United States Air Force (USAF) aircraft procurements, and United States Navy ships. Examples of medium sized programs bid by RFP, and responded to by the author, are computers for the USAF, telephony switches, U.S. Postal sorting equipment, and air traffic control systems for the United States. RFP's would be used for small bids such as wiring of a building, design of a high fidelity system for an office or any thousands of projects that require a technical solution to be designed and developed.

The information in this paper is derived from two classes, Computer Architecture¹ and Computer Networks². The details can be found from the websites:

- <http://coen.boisestate.edu/jhartman/ee434/ee434.htm>
- <http://coen.boisestate.edu/jhartman/EE432/432.htm>.

Both classes are taught to seniors or graduate students in Electrical and Computer Engineering (ECE), or Computer Science (CS). They are top-level survey courses, which cover a large variety of topics, which unfortunately prohibits in-depth treatment of these topics. All of the students have taken a microprocessor course as a pre-requisite.

The instructor for the course is the author and has spent 25 years in industry prior to joining the Electrical and Computer Engineering faculty. While in industry, he led large teams of engineers in the design and development of complex computer-controlled systems. These proposal teams consisted of up to 50 engineers that responded to a variety of government RFP's and won over 2 billion dollars worth of contracts. Although many of these RFPs in these courses are from the author's personal experience, an RFP can be developed using any existing system as a basis. The problems invented for the course worked as well as those that were derived from actual RFPs.

Class Objectives

The RFP methodology is used in the courses to provide design content that covers many aspects of the courses.

The secondary objectives are to introduce reliability, robustness of design, and cost as a design constraint. This is achieved by putting cost and reliability as evaluation factors and introducing modules on those topics in the course. The non-technical objectives include development of teamwork, presentation training, writing skills, and learning RFP response techniques.

Class Organization

The instructor selects the teams. This is similar to the real world situation, where the manager selects the team. The teams are balanced as far as practical with equal numbers of graduate students, undergraduates, ECE majors, CS majors, and overall talent.

To stimulate competitive spirit and to simulate the winning of an RFP competition, a significant prize is needed. The solution is to have the winning team not have to take the final exam. Each member receives credit for a good grade on the final. To insure that team members are rewarded in proportion to their efforts, each member evaluates themselves and their team members, as suggested by Felder³. The evaluations are used to raise or lower the team grade.

The exact evaluation criteria were specific to the class project, but typically are:

- 60% for technical content
- 30% for cost
- 10% for reliability and redundancy which exceeds the specification

As in a real RFP situation, questions could be asked in class (bidders briefing) or submitted in writing. The answers, to the written questions, are then posted with the questions on the class websites. This avoids giving an advantage to teams that test or tryout ideas on the instructor (procurement officer). If they have a unique idea, they need to ask enough questions to make sure it meets the RFP requirements, and bid it. If they ask too detailed a question then the other groups could benefit. How to ask questions on an RFP is part of a winning strategy.

The list of class projects is shown in table 1 with the modifications required to accommodate a class project. Typically the modifications include listing a number of components and prices that

Project	Source	Modifications
Air Traffic Control System	FAA Mode-Select Air Traffic Control System	Bid only hardware. A large major parts list is provided.
Architecture Office Network	Invented	Routers and bridges could be made up from tables, computers restricted to HP and Micron PCs, cabling restricted to 5 choices and price/ ft of cable provided
Sensor System Network	EPA Research System	Components restricted to a large list provided, subcontracts for data services restricted to 3 providers
Gaming Terminal and System	Video Lottery Technologies Specification	Cache and memory design using modifiable memory components
Critical Inventory Control System.	Invented	Components restricted to a large list provided. Data entry devices specified.

Table 1. List of various projects and the modifications applied.

must be used in the projects. This avoids the project becoming a cost look-up exercise instead of a design exercise. For example, in some cases the memory was specified as \$X/ Megabyte. The best design and lowest cost, would be one that reduced memory size, not one that found inexpensive memory parts on the Internet. In all cases the software development was assumed, but not bid.

Results

The RFP methodology met the objectives and is a successful teaching methodology. The results are divided into two sections: motivation and design.

Class selection data, class evaluations, questionnaire data, and anecdotal results demonstrate the motivational benefits.

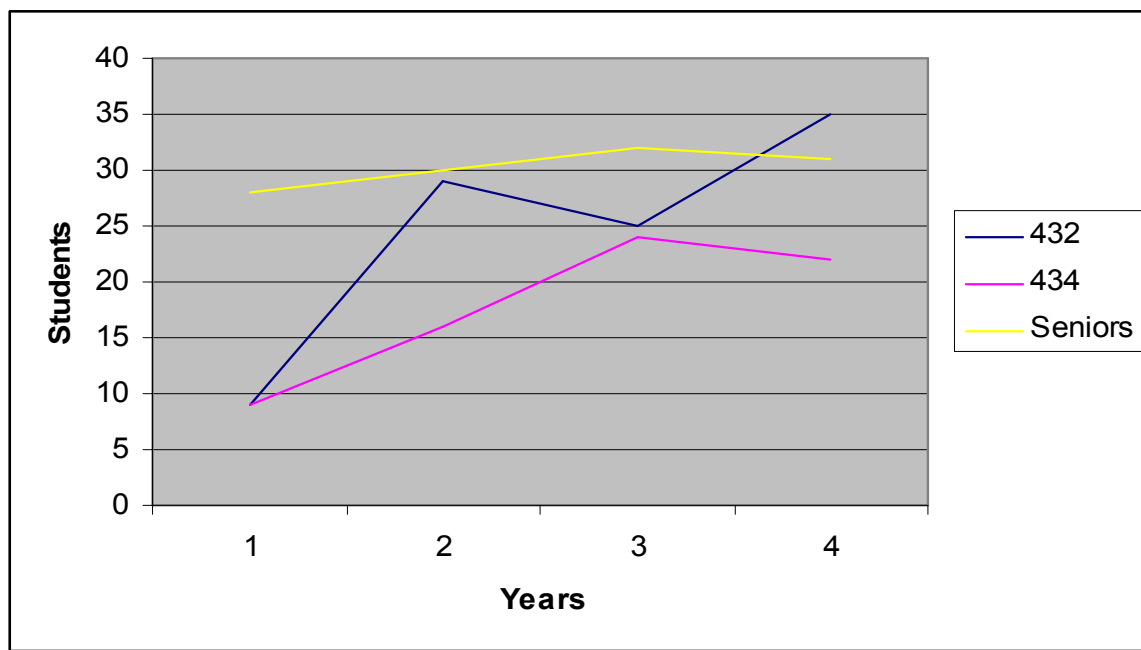


Figure 1. Class growth versus time compared to student growth versus time

A measure of the effectiveness of elective classes is their selection by students. Students compare notes and discuss their classes, thus the growth in class size compared to the growth in the department is a measure of student acceptance. The increase in class size, shown in figure 1, is substantially greater than the increase in student enrollment in the department. The student evaluations (not graphed) show excellent ratings for the course. These positive measurements could be attributed course characteristics other than the RFP, since there is not a specific evaluation category for the RFP project.

To determine the contribution of the RFP, to the increases in class size and ratings, a class evaluation questionnaire was sent to the students. One of the questions asks them to rank the educational value of the four components of the course, homework, project, tests, and lectures. The average scores for categories are plotted in figure 2. The data shows the students value the project as highly as the homework and more than the lectures as a learning tool. The responses to the other questions indicated that students overwhelmingly thought the RFP contest was fair and

very useful. The few negative comments were on the lack of detail in the SOW and the limited choice of design components.

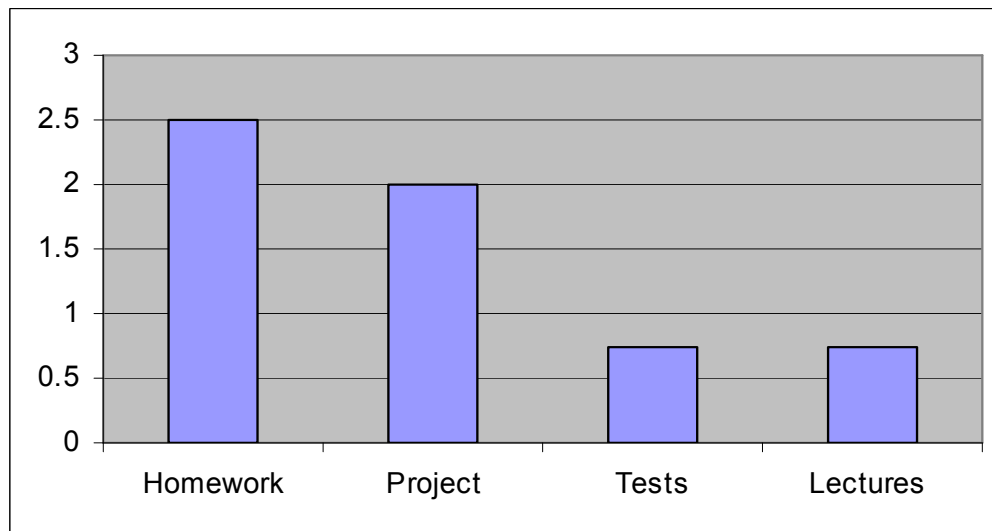


Figure 2. Responses to the value of components of the computer networks course.

In addition to the quantifiable measurements, there are other indications of the motivational effects. Well over 50% of the teams gave a name to their team such as J²Q System Engineering and Manchester Data Consultants. They also gave themselves titles such as chief engineer, CEO, technician, etc. A few groups even developed letterheads and business cards that they handed out during their presentation. The names, titles, and letterheads, along with business attire for the presentation were done without any direction from the instructor. The intangible and measured results indicate the high level of motivation that the competitive RFP process provides.

The student teams' designs were excellent and in most cases provided solutions that compared favorably to the actual solutions. A detailed example of a RFP design solution has been previously report ⁴. A solution to the problem on an architectural office is shown in figure 3. The detail in this diagram was matched with a write up that included discussion of the types of wiring selected, the data bandwidth, the protocols used, and the costs of the entire system.

The concepts the students learn and put into practice are:

- A system level approach to design
- Inclusion of redundancy and reliability in the design
- Cost effective design techniques
- Logical presentation of results
- RFP response techniques

Because every team presents their proposal to the entire class, they can compare many alternate solutions to the same problem.

The typical errors that occur are:

- Overkill in design by adding the finest parts and many extra features. This may result in high technical scores, but very low cost scores.

- Single points of failure. In good designs of any system, parts will fail. If multiple parts exist in a system, then it should be designed to gradually degrade instead of shutting down on a single failure. As an example, in the diagram of figure 3, there are two stackable switches that control the data flow in the office. Printers and computers are attached to both switches, so if one switch fails, the office still has ½ the capacity. A typical error would be to hook all the printers to one router and the computers to the other, therefore if either switch failed, the entire office would not function.

These errors have been used as feedback to improve the course material.

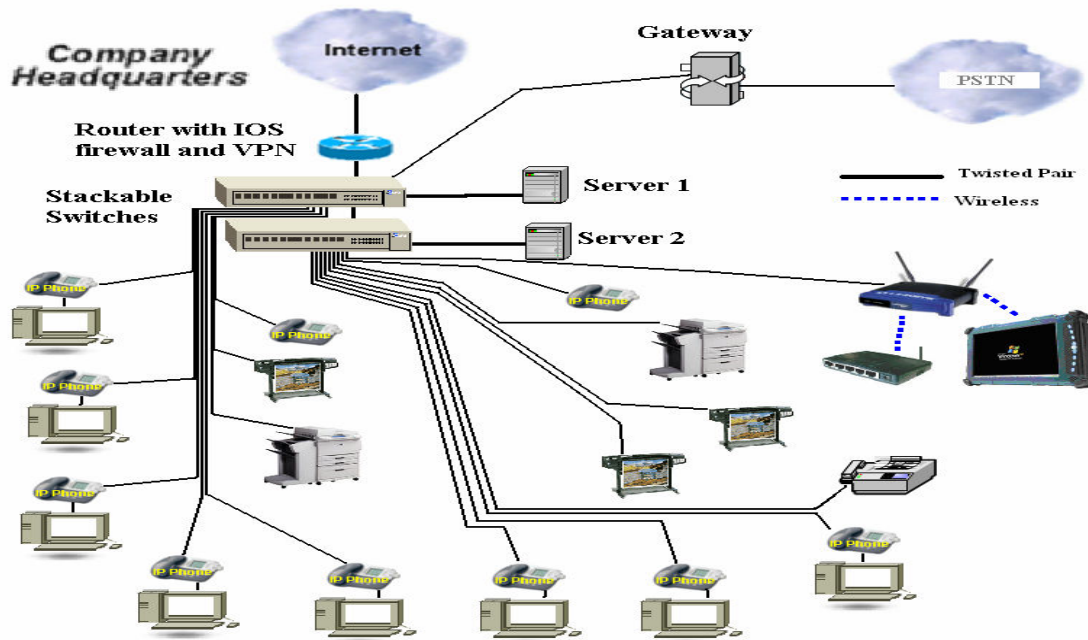


Figure 3. Architectural Office Block Diagram

Benefits

The major benefits of the RFP method and the significant award (no final) are:

- Generating an extremely high level of interest, which is a key to learning.
- Developing lively and interactive project presentations, since each team has worked on the same design problem.
- Learning to integrate cost as a design constraint.
- Gaining redundancy and reliability expertise because specifications required them.
- Learning how to bid solutions to complex real-world problems
- Learning the competitive procurement methodology.

Summary

RFP techniques are used for nearly all procurements of technical designs and development. This technique has been used to introduce capstone design projects in computer networks and computer architecture courses. The RFP problem is based on real world problems with some

modifications to accommodate a one-semester course. The use of this technique has been shown to provide a high level of motivation for the student teams. The RFP methodology provides training in design of systems, cost trade offs, presentations, teamwork and in the RFP process itself.

Bibliography

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