Field Session at Colorado School of Mines
A Capstone Applied Mathematics/Computer Science Course

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Each student at the Colorado School of Mines completes "Field Session" as one of the graduation requirements. In Chemical Engineering, the students do unit operations labs, in Petroleum Engineering, they get hands on experience in petroleum extraction, in Civil Engineering, they learn to survey, and in Mining Engineering, they actually work in the school's experimental mine. In the Department of Mathematical and Computer Sciences, the students tackle mathematics or computer problems. This six hour course is taken at the conclusion of the junior year. The only prerequisite is the completion of a programming course. Field session is designed so that students will apply the knowledge and skills which they have learned in their three years of study to the solution of a real problem for a real client. Getting the scope of the problem is often difficult for the students as they have never dealt with a problem which took all of their time for this long a period. Students are expected to treat this course as a forty hour per week job for the six week session although many students spend more than the forty hours per week. Communication skills, both oral and written, are a major part of the course. The students must apply their knowledge, be able to work in teams, communicate, manage a project and their time, and think independently.

Securing Projects: The projects may come from either faculty members or off campus contacts which may be interested in sponsoring such a project. Early in the Spring semester, the instructor will request such input. Usually there are more requests for projects than there are students to work on them. Some students have contacts for summer jobs which they want to use for field session, but this experience must be more than just a summer job. Each such request is handled on a case by case basis to insure students get the full benefit of completing a design project.

Characteristics of Projects: Each project must be clearly defined and doable in a six week time frame. The project needs a clear beginning and end, but it may be part of a larger problem. Clients are important as they simulate what happens in the real world and are more likely to give students problems which are open-ended. Students must produce a product which satisfies the client. That experience of not having a correct answer is valuable. Also, working with a client to define the scope of the problem aids the student in setting up a strategy to satisfy the requirements. The client must guarantee that appropriate resources are readily available. If a student needs additional help, he must be able to obtain it easily. Students are amazingly resourceful when they have a clear cut goal. It is difficult to make-up problems which are as realistic as cliented projects. Letting students choose the project which they want to do is more likely to bring satisfaction to the student and the client.

Student Criteria for "good" projects: Some students like to work on projects which give them a chance to learn a skill they want to learn. Others like projects which are theoretical, for example, one project involved doing fractal analysis for oil well drilling. Some projects involve games. Some projects are desirable because of a well-known or well-liked client. Summer jobs develop out of some projects. Teams which enjoy working together can have a synergetic effect on the output.

Schedule: On the first day, students meet in the morning to hear the ground rules, survey the various projects, to form teams and choose the project on which they want to work. In the afternoon, students meet with their client and begin work on their projects. They write a preliminary description of the problem to be solved. On the second morning, all students meet again to present their preliminary requirements to the entire class. The class offers suggestions and comments. Each team meets with the instructor to review the scope of their problem. Then the work begins. In general, teams work on their own during the week and then meet on Friday to present their weekly progress report. These weekly meetings enable the students to get an idea about all of the project areas. Some students determined last year that there was an area of software development in which they were not interested. Others found new areas of interest.

Some field trips to local firms to determine career opportunities are planned. Once students get involved with their project, they are usually anxious to see it to conclusion and are not thrilled about having too many speakers or field trips.

Reporting Requirements: Each team presents a ten minute oral report each week which gives a brief overview of accomplishments of the past week and plans for the next week. Weekly written reports must include the following:

- Team's goals for the week
- Accomplishments during the week
- Problems encountered and their solutions
- Remaining goals
- Plans for the following week
- Time sheets - which detail how students used their time
- Plan for entire project and progress towards goals

Presentations were graded for grammar and spelling as well as style. The students were given the list of requirements for written reports at the first meeting so on the first Friday some teams just turned in a list of the required contents without attention to the narrative. As the session progressed, the students' writing steadily improved. The importance of good communication skills was stressed throughout. The students had already participated in the CSM Engineering Problems Introductory Course Sequence (EPICS) program so they had some experience with written and oral reports. After five weeks of reporting, the students had formed the basis for their final report. With the constant feedback they received, they were able to produce an excellent final report.

The final reports included:

- Client report with:
    - the product
    - an overview of the project
    - results of the project

- current status
- lessons learned
- management of the team
- comments
- Users and programmers manuals for computing projects
- The product or solution to the problem
- Copies of the five weekly progress reports

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Evaluations: There were three levels of evaluations. They included peer evaluations by the students, client evaluations of the projects, and student evaluations of field session. All students completed peer evaluations of their team members' contribution in which they rated their peers in eleven areas. There were no negative replies to this survey**.** After the 1996 field session, all teams received excellent evaluations by their clients. In the student evaluations of the field session, some of the comments were:

- Field session is a good thing. First, it encourages and actually demands team work.
- The team worked very well together, everyone speaking freely and criticizing when appropriate. We broke down things well and worked well together.
- One thing which would have made it better would have been getting paid. I liked not being hawked over while working on the project. It was nice to have to set your own schedule and objectives for today, tomorrow, and next week.
- I liked being able to choose a project from a big list and to get to do one from my minor field.
- Our team had good rapport. We took and gave criticism well when it was necessary.
- This was by far the most effective team I have ever worked on. There were no slackers and everyone gave 120% effort.
- Having the instructor available at all times helped.

Two sample project descriptions submitted:

Computational Modeling for Electromagnetic Scattering from Rough Surfaces

This project is concerned with the application of wavelet decomposition methods to analyze integral equations which arise in electromagnetic scattering. The specific application is to the scattering from rough surfaces, and in particular, from very rough surfaces. The wavelet application is not the conventional one. Limited research results which treat the application of wavelets to integral equations have been confined to the spatial domain. Here wavelets work well for smooth spatial variability, but break down when variability is rapid. This is exactly the problem with rough surfaces. This project proposes to apply wavelet methods in the Fourier transform space or k-domain to these problems.

There is even less known about the specific application of wavelets to electromagnetic scattering problems. The efficient computational solution of the latter has broad implications and extensive applications in industry and government. In summary, the project consists of the formulation of rigorous equations in transform space and their solution using k-space wavelets. The aim is to provide an efficient and novel technique to solve complicated electromagnetic scattering problems. The latter have applications to the laboratory investigation of controlled electromagnetic scattering experiments from materials, substrates, and other electromagnetic devices. The first phase of the project calls for the development of both Mathematica and Matlab code to compute the amplitudes of the scattered field from elementary surfaces where the results can be compared with known analytical forms. The required mathematical background includes Linear Algebra, Wavelet Theory, basic notions of applied mathematics, programming in C or Fortran as well as basic knowledge of Matlab, Mathematica , and Unix.

Results: *The students surpassed all expectations in this project and research has continued through the next year.*

Simulation of the Scanning Electron Microscope

The problem is to develop a PC-based program which would provide an animated simulation for the interactions of the electrons from a electron beam with a wide variety of specimens in a scanning electron microscope (SEM), a variety of different interactions can occur and these interactions can occur at differing positions within the specimen. One of the major concerns is the size and shape of the interaction volume. This is a critical feature in determining the fine scale chemical composition of a multiphase specimen, especially the compositions close to the interface between two phases. One of the major ways to study the size and shape of the interaction volume is using Monte Carlo simulations of the electron. In the Monte Carlo method, the detailed history of an electron trajectory is calculated in a stepwise fashion. This program would be helpful in teaching and also in doing atomic scale chemical analysis at interfaces with the scanning electron microscope.

Results: *The team successfully developed the simulation. In order to do so, they had to learn how to do graphics plus the Monte Carlo method. The students had some interesting discussions on the geometry and trigonometry involved also. The product is being used in classes and research.*

In conclusion: The students' evaluations indicate that they enjoyed working in teams and acquiring new knowledge. In this age of technological change, the best preparation which we can give students is preparing them for life-long learning. In field session, students learned to solve problems and find the resources essential to bring their projects to a successful completion.

BARBARA BLAKE BATH is Associate Professor of Mathematical and Computer Sciences at Colorado School of Mines. She coordinates the undergraduate curriculum and has been active in the curriculum reform effort at the school for the past three years. She taught the course described in this paper in Spring, 1996. Her BA and MA are from the University of Kansas and her PhD is from American University, Washington, DC.