We Came, We Saw, We Changed Some Things: Engineering Educators Talk About Extending Oklahoma University's "Sooner City" Program to their Own Institutions

Norman Dennis, Jon Fricker, Paul Palazolo, Anna Phillips

The University of Arkansas/Purdue University/The University of Memphis

Abstract

In August of 1999, Oklahoma University hosted an NSF-sponsored workshop for 29 engineering educators to present initial findings from their interdisciplinary "Sooner City Project" and collect feedback and ideas from the participants. The authors of this presentation represent four participants from three different universities who discuss pedagogical issues and instructional modifications made in their own engineering classes following what was learned at "Sooner City".

I. Introduction

As Jon Fricker from Purdue is finding out, you don't have to revise the entire curriculum to begin integrating design within a Civil Engineering program. He presents examples in which pairs of professors can exploit natural relationships between certain courses to make the undergraduate student's experience more unified.

Norm Dennis has revised an existing semester long scenario-based design problem in his foundation engineering class at The University of Arkansas to include portions of the "Sooner City" geotechnical subsurface database. His students use this database extensively in planning a field and laboratory investigation program to characterize soil properties needed for the design of their facility.

Paul Palazolo has customized the computational and project elements from "Sooner City" into his undergraduate Civil Engineering Computation course at The University of Memphis with extension of the authenticity of the programming to relate to actual engineering audiences.

Anna Phillips from The University of Memphis relates a technical writing instructor's viewpoint about Oklahoma's "just-in-time" instruction with modifications to include multidisciplinary technical writing and spreadsheet design in her multidisciplinary Engineering Communications courses and the Civil Engineering introductory engineering classes.

These educators have a shared purpose of applying "Sooner City's" innovative instructional methods in their own classes, and their research findings report that these methods appeal to students because they offer a direct and explicit link to the work they will do as "real engineers". Together, they hope to encourage other engineering educators to experiment with these ideas in their own classes, and in doing so, integrate new approaches to traditional problems

II. Background

In August of 1999, Oklahoma University hosted an NSF-sponsored workshop for 29 engineering educators to present initial findings from their interdisciplinary "Sooner City Project" and collect feedback and ideas from the participants. The Sooner City Project is an innovative and customized system of engineering education that was implemented initially by The School of Civil Engineering and Environmental Science (CEES) at The University of Oklahoma (OU) in the fall semester of 1998[1,2]. What makes this program unique in engineering education is that it seeks a multi-year system of constructivist-based education that actively promotes interdisciplinary and multidisciplinary learning as focused on the primary task of engineering design. To summarize, incoming freshmen work in groups and are assigned a section of a virtual landscape and this section serves as the working platform for all design elements in the program. For example, as the students learn about surveying or fluid dynamics in their class work, they apply these concepts directly to projects linked to their section of the virtual landscape. As the knowledge base of the students increase, the design problems evolve to reflect this increased learning and the interaction between the needs and requirements of the constituents involved in the virtual environment. At the same time, students are exposed to interdisciplinary and multidisciplinary relationships that offer different perspectives based on different goals across the curriculum[1,2,3,4].

One of the primary goals of the Sooner City Project is to produce engineering graduates who possess higher levels of critical thinking and problem solving abilities, and it is hoped that these graduates will use these skills in open-ended design projects throughout their engineering careers.[3,4]

While Oklahoma University has opted for a full-scale implementation of this curricular design, we believe it is possible to use some of their same goals and objectives based around the same constructivist-based theory of learning on a more limited (and less expensive) basis in other universities.[3] The authors of this presentation represent four participants from three different universities who discuss pedagogical issues and instructional modifications made in their own engineering classes following what was learned at "Sooner City".

III. Using Sooner City Curricular Concepts at Purdue

At Purdue University, a prominent issue is design in the CE curriculum: how much design is there, what form does it take, and how should it be documented in reporting to ABET? Most faculty, indicating that almost all courses in the CE undergraduate curriculum had at least some "design" content, had already completed a preliminary survey. A key question regarding design in the curriculum is to what extent is design *integrated* through the curriculum? The Civil Engineering faculty at Purdue proposed that two or three courses that have overlapping or sequential content could be coordinated by their respective instructors to include an ongoing integrated design project.

One of the courses chosen to implement the Sooner City lessons was a *Transportation Planning* course, a "dual level" course with 18 students, eight of whom were undergraduates. A semester-long project would be a case study of an actual city in Indiana. The project would be done by groups of three students. Data would be collected, models would be applied, and alternative proposed projects would be tested for their impacts on the travel patterns in the study area's road network. The impacts of each alternative would be measured in terms of its benefits -- among other things, reduced travel time and travel distance -- to the travelers in the study area. The "alternatives analysis" would not be completed in CE566, however, because the costs of each alternative would also need to be estimated, then compared against its benefits. The skills necessary to complete the project would be developed in *Transportation Systems Evaluation*, a course that most of the students would be taking in the following semester.

The linkage and redevelopment of the project from an existing project required a significant level of effort on the part of the faculty member. The resulting reports that were written by the student groups were shared with the firms that contributed the software that the students needed to carry out their modeling activities. The results were presented, with appropriate caveats, to interested officials in the study area. The faculty member has now provided the results of his students' work with the instructor in the following course. The follow-up course has accepted the work with appreciation for the opportunity to inject a fresh and realistic element into the course. The cost estimation task fits well with the procedures that are already taught in the course and it will emphasize the interrelationships between the various phases of a complete transportation study.

For years, the CE curriculum at Purdue has relied on a capstone design course to tie together whatever design experiences the undergraduate student happened to have acquired as he/she took courses in the program. Until recently, these design experiences were isolated and independent. The Sooner City model is providing an example of how a meaningful and integrated design experience need not wait for a massive overhaul of an undergraduate curriculum, but can be approached step by step. All it takes is a broader view, some communication, and some cooperation.

IV. Using Sooner City Tools at The University of Arkansas

Elements of the Geotechnical Website, developed by the Sooner City project, were incorporated into a senior-level design course at the University of Arkansas. The selected course was

Foundation Engineering, which is a required course in the Civil Engineering program. In accomplishing the major objectives of this course, students are required to produce an unconstrained site layout, plan a subsurface exploration program for their site, interpret raw field and laboratory soils data to extract design parameters and, finally, to complete designs for shallow and deep foundations as well as earth retaining structures. All of the objectives are accomplished through the execution of a semester long-scenario based design problem which requires the students to work in teams to complete each phase of the project. In addition to the actual design computations, each team submits a series of engineering reports to a client, documenting their findings and giving a recommendation for each phase. The scenario changes from semester to semester, but its essence is to complete the geotechnical portion of a design for a major commercial facility such as a hospital complex or shopping mall. The facility is to be constructed on a real 100+-acre parcel of undeveloped land owned by the university.

The first phase of the project requires students to actually walk the land to establish the requirement for utilities, internal and external road construction, any hydraulic improvements, and to actually site their buildings. Coupled with the first phase of the project is the requirement to plan a subsurface exploration program for the site. This program includes drilling and sampling as well as prescribing the necessary laboratory and field tests. Historically, the subsurface exploration phase of this project has been a real struggle for the students because the concept of integrating drilling with sample collection and laboratory testing is very abstract to them. They have seen pictures of drill rigs. They know what the sampling and testing equipment looks like and how it works. They have price lists from local consultants for sampling and testing. However, their ability to put all the pieces together in a coherent fashion to produce an executable program, within budget, was lacking. Even with general rules regarding spacing and depth of borings, the student teams found it difficult to determine the minimum required exploration program necessary to adequately characterize their site.

The Sooner City geotechnical website, http://www.soonercity.ou.edu/geotech/, was viewed as a tool that would solve all of the cognitive problems related to subsurface exploration. The site allows students or groups of students to create a virtual subsurface exploration program complete with the results of laboratory and field-testing, but requires them to work within a budget. There are two levels of access to the website, one for students and one for professors. The professor must first create a project by specifying the student access codes, the number of groups to work on the project and the physical layout of the project site. The website uses real subsurface data, compiled during the extensive subsurface investigations to characterize the National Geotechnical Experimentation Sites, (NGES), as the basis for forming a subsurface profile for a virtual site. The professor specifies which NGES site to use and the physical dimensions over which that site's data are to be mapped. Students access the project by supplying the appropriate access codes and group numbers. When students enter the website, they are confronted with a screen image similar to that shown in Figure 1. By clicking on any location within the site map, they are able to establish a new boring location and then select the type or types of tests they would like to conduct at each boring location. The costs of boring, sampling and testing are tallied so students know the cost of their program before they elect to purchase it. Physical data from testing cannot be viewed by the student group until they actually purchase the sampling and testing program. Only then can they determine if they have created an exploration program that provides enough data to adequately characterize their site.

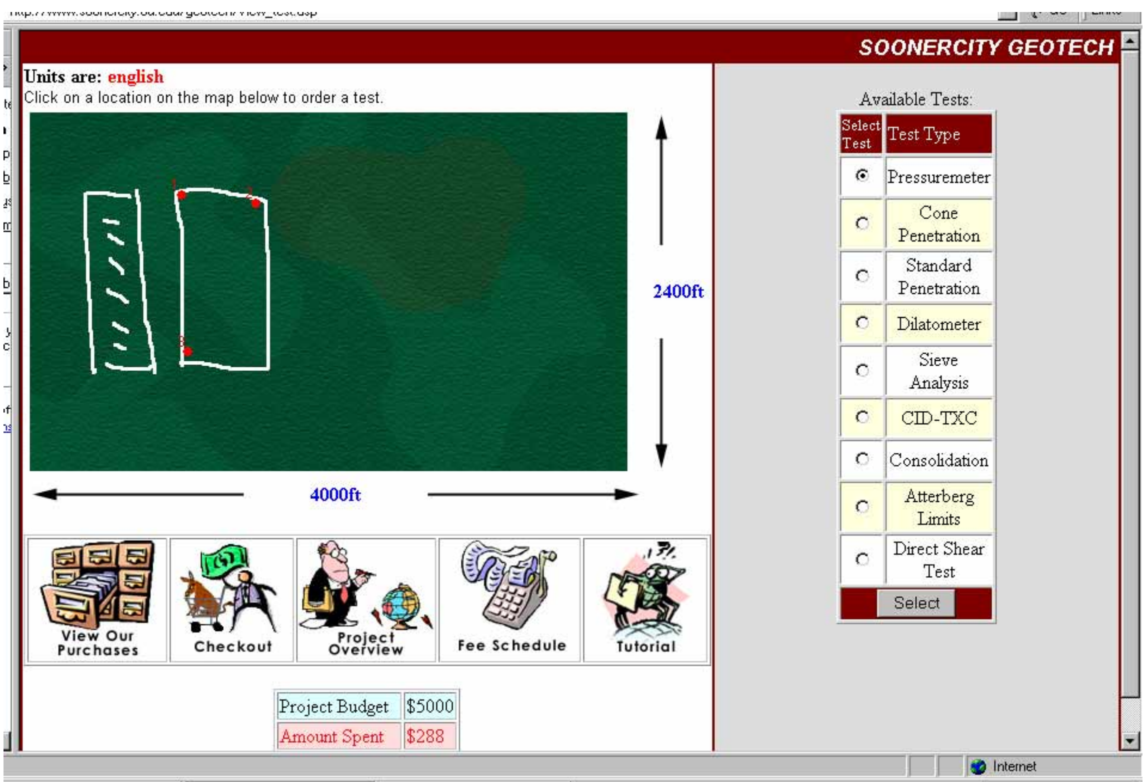

Figure 1. Screen image of the Sooner City Geotechnical Website, illustrating a virtual site plan with boring locations, schedule of tests and costs.

Initially, the plan for the semester long-course project was to map the virtual information from Sooner City to the physical 100 acre site in Arkansas and require the students to generate all of their design parameters from the Sooner City website. Unfortunately, this plan proved to be an unworkable solution to the subsurface exploration problem for several reasons. First, the website is a work in progress and many of the features that will be present ultimately are not active now. For example, there is no help section or tutorial available yet. Second, data from only one of the six NGES sites is entered into the database in sufficient quantity to make it an effective virtual site. Third, the physical NGES sites are relatively small and mapping them to large parcels of virtual land dilutes the data to the point that unrealistic soil profiles could be created. Finally, the soil conditions at the real site in Arkansas do not match those available at the virtual site.

After a failed first attempt to use the Sooner City website, a backup plan was developed that consisted of creating a virtual project of much smaller scope which would allow the student teams to practice their planning skills before tackling the real physical project. The project site consisted of a building with defined column loads and a parking lot. Student teams were given a $5000 budget and required to produce an acceptable subsurface characterization of their site within budget. While it was not the intention of the instructor, this assignment actually turned into a competition among teams to see who could create the most complete exploration and testing program for the least cost. Once this assignment was completed, the students were armed with a list of available price lists for drilling, sampling and testing from local geotechnical firms, and given the open-ended assignment of creating the exploration and testing program for their site.

The benefits of using this website for practice before undertaking the real thing were immediately apparent when the students submitted their exploration plans for the real project site in Arkansas. The most striking improvement to the project reports was the fact that students focused on justifying to their clients why they needed lots of information in some areas and only limited information in others, rather than simply describing the testing and sampling equipment as they had done in the past. They were extremely cognizant of budgetary constraints and tended to remember things like including mobilization costs and the incremental cost of taking a sample when a lab test was specified. Their perspective on this assignment had completely changed from simply regurgitating information they read in their texts to focusing on the real problem of collecting sufficient information to do their jobs as design engineers. It was clear that the students had moved up the hierarchal ladder from “knowledge” to “application” in Bloom’s taxonomy of learning.

Like any first-time endeavor, the use of this website as a teaching tool required some experimentation and tweaking. However, the time invested in creating this homework assignment was minimal and the benefits derived were significant, so from a cost-benefit standpoint the use of the Sooner City website was a real winner for this course.

V. Using Sooner City Concepts at The University of Memphis

Since 1994, the introductory sequence in Civil Engineering at the University of Memphis has culminated with a final course in computation. Originally, this was a typical programming course utilizing FORTRAN as the language of choice. Three years ago, the course moved to VISUAL BASIC as the language of choice but the problems and projects utilized in the course did not change significantly. As a result of the experience of the information gathered at the Sooner City presentation, the course projects and problems were modified to reflect a closer connection to actual engineering projects.

The number of projects was reduced from three to two and the demands on the students were broadened to include more extensive communications and an enhanced design requirement. The goals of the course were also extended to include:

- introductory material in simple statistics
- introductory material in numerical methods
- collection and utilization of actual field data in the design process
- utilization of simulation within the design process

The first project involved the preliminary design of a method for moving pedestrian traffic safely across a street with a high volume of vehicular traffic. The students were required to collect data on both the pedestrian and vehicular traffic and to make an analysis of the statistical patterns of each. From these patterns, the students were given very simple traffic control devices to consider modifying the behavior of the vehicular traffic and allowed to come up with their own devices to modify the behavior of the pedestrian traffic. Student teams were required to do a design analysis and select the solution that increased the safety of both the pedestrian and the vehicular traffic. A formal written presentation was required that had the students acting as consultants to the municipality and to the organization (the university) where the problem was occurring. This problem was based on an actual problem occurring just outside of the Engineering building at The University of Memphis. The students were given the background information and allowed to discover the plans that the university had developed, which incorporates the Sooner City principle of direct links between engineering content and authentic engineering situations.

The second project utilized computation to look at alternatives to the treatment scheme for a new industry locating in the region. A small stream was selected as the receiving body of water and the conditions in the stream were presented. Through a series of exercises, the students were introduced to the concept of modeling (Streeter-Phelps) and allowed to consider alternative treatment schemes for an industrial site discharging into the watercourse. The modeling was then complicated by the seasonal variability of the receiving stream. The student teams represented different interests: the local government, an environmental group, and the industry. Each of the teams was required to develop alternative solutions (simple treatment plans) for the industry reflecting the bias of their constituency. From these presentations, each of the student teams then made another analysis of the problem and presented a final design based on the needs of all three constituents

Each of the projects used was based on a problem that has occurred in the immediate region of the university campus. Although simplified to reflect the knowledge and skill base of the students, each is reflective of typical problems of the region. The students themselves are a part of the traffic problem and have first hand knowledge of the hazards of crossing the street in question. The stream modeling and industrial discharge problem was more difficult to incorporate, as the students did not have a first hand connection to that problem.

Since the students had no programming experience entering the course, there was a disconnect between the skill requirements for the projects and the skills that they had. Each programming assignment was directed at a skill that they would be able to use later in their project analysis. At times this required the students to make significant leaps in their programming skills and there were some students who found it difficult to make these leaps. The utilization of the extension of the students' previous work in EXCEL did make this easier but the problems of teaching programming were consistent with the problems that had been encountered earlier in teaching other programming languages. The significant difference was the realization of the students that by utilizing a program, the analysis of a design problem could be reduced considerably.

For each analysis tool, the students were first shown how to make the analysis using hand and spreadsheet methods. Then the automation of the tool was developed using typical programming constructs. Student teams were then required to make the analysis using the automated method. The project analysis required a number of alternatives to be evaluated thereby expanding the computation time requirement. The more programming tools that the teams used, the more alternatives they were able to analyze in the time required. As student teams began to be more successful through the use of programs, they passed this attitude on to other student teams.

The implementation of "Sooner City" type problems made this class both easier and harder for both the instructor and the students. The removal of emphasis on "toy" problems made the development of programming skills more difficult while the focus of doing something "real" made the utilization of a program for analysis much easier for the students to accept. The problems inherent in actual data, such as the traffic and stream condition data, caused a disquiet in the students who had been used to much more clear cut information. The multiplicity of viewpoints in the stream-modeling problem also caused some disquiet. The students did appreciate being involved in problems that were closer to what they could expect in practice.

VI. Communications lessons from Sooner City at The University of Memphis

The final example of curricular modifications from Sooner City's model relate to the communicative and multidisciplinary aspects of engineering education. The University of Memphis's College of Engineering has supported a multi-disciplinary team-teaching approach to freshman engineering courses for several years, and the Sooner City Project offered new opportunities to implement technical writing with intra-disciplinary applications. One example comes from a required communications course taught by English instructors within the engineering college. This course focuses on improving students' technical writing and technical communication skills, and the workshop at Oklahoma provided a good model for multiperspectives in communication based around one central example. As each section of Sooner City's virtual world is constructed, it involves different fields of engineering in different ways—this example provides engineering communication students multiple ways to view the example and also provides the authenticity of potential real-life applications. Mechanical engineering students are able to work in conjunction with civil engineering students and electrical engineering students, and this has resulted in improved communication within the classroom and increased students' awareness of how different fields of engineering apply outside the classroom as well.

Another link between Sooner City's multi-disciplinary focus and The University of Memphis's goal of increased communicative levels of engineering students relates to the timing and planning of curricular delivery styles and methods.

For example, the team-taught Freshman Introduction to Engineering course has implemented a type of "just-in-time" learning similar to the Sooner City Program. This involves basing an entire assignment around a design goal and attempts to develop and link multi-disciplinary skills in the fields of technical writing, computer applications, and engineering design.

The freshman engineering sequence at The University of Memphis shares the same goals as the Sooner City Project with regard to higher thinking skills, but while Sooner City uses virtual computer-based applications, UM students receive hands-on training and practice to complement computer applications. For example, the idea of "just-in-time" learning means presenting the material to students just before they need to use it, and this is possible because the freshman course is team-taught by an engineering instructor and a technical writing instructor. As the engineering instructor introduces the design process for a simulated beam-building competition, he teaches the conceptual skills required to design via computer-based spreadsheet applications, and then links the spreadsheet data to lab applications in determining proper amounts of materials to build the beam. At the same time, the technical writing instructor teaches elements of a technical report and presentation that would accompany this type of design in authentic engineering situations.

The intent in both team-teaching this course and designing “just-in-time” delivery is that linking these three skills early in the curriculum will concurrently promote higher thinking skills with increased writing and communication skills as demonstrated in advanced design. And while the program currently includes writing, computer applications, and engineering design links, it is planned to integrate calculus, physics, and possibly engineering graphics instruction into this course design so students can see the interaction between the disciplines as they apply directly to the engineering concepts they are building.

VII. Discussion/Recommendation

While these excerpts represent a small fraction of the changes that have taken place in engineering classrooms across the country as a result of Sooner City’s pioneering work, it is hoped that they might inspire other engineering educators to implement some of these cognitively-based, authentically-structured, student-centered methodologies in their own classrooms. Each of the authors is happy to discuss any of his/her modifications in more detail upon request, and e-mail addresses are included in the biographical sketches below.

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NORMAN DENNIS
Norman D. Dennis, Jr., P.E., is an Associate Professor in the Department of Civil Engineering at the University of Arkansas-Fayetteville. His research interests are related to the deformation characteristics of soils used in transportation applications and the use of geographical information systems in the geotechnical arena. Dennis has been actively engaged in faculty development activities for over a decade. He is the director for one of ASCE's ExCEEd teaching workshops and sits on the ASCE Faculty Development Committee. Dennis holds BS and MS degrees in Civil Engineering from the University of Missouri-Rolla, an MBA from Boston University, and a Ph.D. from the University of Texas-Austin. NDD@uark.edu

JON FRICKER
Jon Fricker is Professor of Civil Engineering at Purdue University in West Lafayette, Indiana. He teaches courses such as Introduction to Transportation Engineering, Transportation Planning, Introduction to the Comprehensive Urban Planning Process, and Public Mass Transportation on a regular basis. Besides his full research agenda and activity in numerous technical committees, Prof. Fricker is a member of the Institute of Transportation Engineers' Transportation Education Council.fricker@purdue.edu

PAUL PALAZOLO
Paul J. Palazolo is the Assistant Dean for the College of Engineering at the University of Memphis. He is also a member of the development and teaching team for the introductory sequence of classes in the Civil Engineering department. Dr. Palazolo is a registered engineering in the State of Tennessee and in actively involved in educational research in engineering. Dr. Palazolo received his B.S. and M.S. in Civil Engineering from Memphis State University and a Ph.D. from the Georgia Institute of Technology.ppalazol@memphis.edu

ANNA PHILLIPS
Anna Phillips is Director of Technical Communications at The University of Memphis in Memphis, Tennessee, and she's also an active instructor and researcher in the Civil Engineering Foundation sequence. As a technical writing instructor with a background in educational psychology, her contribution to this project is based on the team-teaming collaborative environment associated with the Sooner City Project customized to expand the areas of technical communication for undergraduate engineering students.anna1231@aol.com