Missouri University of Science and Technology
Scholars' Mine

Opportunities for Undergraduate Research Experience Program

Student Research & Creative Works

01 May 1994

An Assessment of the "AN/EX" Structural Engineering Teaching Laboratory

Gregory E. Effland

Follow this and additional works at: https://scholarsmine.mst.edu/oure

Recommended Citation

Effland, Gregory E., "An Assessment of the "AN/EX" Structural Engineering Teaching Laboratory" (1994). *Opportunities for Undergraduate Research Experience Program*. 29.
https://scholarsmine.mst.edu/oure/29

This Report is brought to you for free and open access by Scholars' Mine. It has been accepted for inclusion in Opportunities for Undergraduate Research Experience Program by an authorized administrator of Scholars' Mine. This work is protected by U. S. Copyright Law. Unauthorized use including reproduction for redistribution requires the permission of the copyright holder. For more information, please contact scholarsmine@mst.edu.

AN ASSESSMENT OF THE "AN/EX" STRUCTURAL ENGINEERING TEACHING LABORATORY

Gregory E. Effland

Department of Civil Engineering

ABSTRACT

An innovation in teaching structural analysis, the "AN/EX" Structural Model Laboratory, has been implemented into the civil engineering curriculum at UMR. The purpose of the AN/EX innovation is to give the students a "hands-on" lab in structural engineering that will help correct some of the deficiencies currently found in engineering design education. In an effort to determine the effectiveness of the "AN/EX" Laboratory at correcting some of the education deficiencies, a rigorous, semester long assessment was conducted. This assessment included an attitude assessment and an ability assessment. The methods and results of both assessments are provided in this report.

INTRODUCTION

Over the past few years, many engineering disciplines have discussed the need for innovations in the engineering curriculum. Practicing engineers and professors alike have been suggesting that the methods for teaching design need to be reformed [1]. Many articles have been published that discuss what and how engineering students should be taught [2,3,4,5,6]. Most of the articles imply that the current trends in education tend to provide the students with the skills necessary to understand the theory, but not with the skills that are necessary for the application of that theory. At the University of Missouri-Rolla (UMR), the "AN/EX Structural Model Laboratory," an innovation in teaching structural analysis, has been implemented into the civil engineering curriculum to help solve some of the deficiencies in engineering design education [7].

ENGINEERING DESIGN EDUCATION

"Industry needs, and will continue to need better designers [8]." In the words of John Dixon, Mechanical Engineering Professor at the University of Massachusetts, "Engineering design education is not successful; ... Industry continues to be dissatisfied with the design education of engineering students [9]." Even ABET annual reports show design deficiencies have been prominent [10]. Many different methods for fixing deficiencies in engineering education have been tried. Each of these methods works best in a specific environment that is dependent on what is being taught and what deficiencies are trying to be corrected. Independent of the method used for correcting education deficiencies, the main emphasis should be on providing the best education possible to the design engineers of tomorrow.

TEACHING STRUCTURAL ANALYSIS AT UMR USING "AN/EX"

The AN/EX facility consists of four basic components. These components include:

1. **Computer**
2. **Test Bed**, which provides an environment for the students to perform physical experiments.
3. **M-STRUDL**, a professional-level structural analysis software package [11].
4. **Specially designed AN/EX software**, which helps teach M-STRUDL, runs an analysis through M-STRUDL, handles data acquisition tasks required by students when performing experiments, and provides graphs and tables correlating the computer analysis to the physical experiment.

The main goal of AN/EX is to solve as many of the deficiencies in engineering design education as possible. Some of the key skills required in engineering design education, that AN/EX is intended to provide, include:

1. **Computer Skills.** With the increasing use of computers in the engineering process, it is clear that engineering students must be prepared in the use of computers [12].
2. **Judgment Skills.** With the increasing use of commercial software packages in engineering, it is becoming even more important that the engineers can make rational judgments about the validity of the computer output.
3. **Nontechnical Skills.** Skills such as writing, speaking, and organization are included in this group. Education of these skills better prepares engineers to adjust for and understand changing conditions that will affect "technology development in the global marketplace of the future [13]."
4. **Synthesis/Design Skills.** With the numerous variations and special considerations included in each project in industry, it is apparent how just knowing the theory behind the solution is not always sufficient. The ability to synthesize or create solutions to unique problems is critical for design engineers. Synthesis involves the use of parts of many techniques to solve a single problem.

OBJECTIVE OF ASSESSMENT

To determine if AN/EX corrected any deficiencies in engineering design education, a semester long, rigorous assessment of the impact of AN/EX on the abilities and attitudes of civil engineering undergraduates in an introductory structural analysis course at UMR was completed.

"AN/EX" ASSESSMENT

Assessment Methodology

To determine the impact of AN/EX in the introductory structural analysis class, a rigorous, semester long assessment was completed. This assessment consisted of an ability assessment and an attitude assessment. The assessment was applied to a sixty student class. First the class was randomly divided into two groups, equal in prior academic performance. The only difference between the two groups in this course was the lab session that they attended.

Group A performed a semester long open ended design project that required the use of the AN/EX Laboratory. Group A was divided into working teams of 3-4 students. Their design project consisted of the design, construction, testing, and presentation of a balsa wood tower.

Group B attended weekly "guided" problem sessions. Each week, students from Group B were randomly chosen to present homework solutions on the chalkboard during their problem session. The students were graded in terms of technical merit (i.e., accuracy) and presentation quality (i.e., explanation and response to questions). For both groups their "lab" counted towards 20% of their final grade. The assessment methodology is graphically presented in figure 1 on the next page.

Attitude Assessment Methodology

The attitude assessment consisted of two questionnaires, one, immediately after dividing the class into two lab groups and the other at the end of the semester. These two questionnaires were used to evaluate the student attitudes towards the class, the lab groups, etc. The first questionnaire consisted of seven questions regarding such topics as structural engineering, graduate school, feelings about their assigned lab group, etc. The second questionnaire consisted of the original seven questions and an additional three questions regarding the lab. Figure 2 illustrates the questions on the two questionnaires.

Ability Assessment Methodology

Both Lab Group A and B took the same exams throughout the semester. These exams consisted of 80% classical structural analysis and M-STRUDL problems along with 20% nontraditional "synthesis" problems. The nontraditional, synthesis oriented problems had multiple constraints and a single solution. To solve these problems, the students had to draw upon knowledge from prerequisite coursework, such as statics and mechanics of materials. These problems required an overall understanding of structural analysis concepts instead of a direct step-by-step solution method. Figure 3 shows the synthesis problems from the second and third exam.

After the semester was completed, the exam scores were compiled and statistically analyzed. The exam scores were analyzed in the following categories:

1. Overall Grade
2. M-STRUDL portion of the overall grade
3. Classical structural analysis portion of the overall grade
4. Synthesis portion of the overall grade

Each group's exam statistics were analyzed to determine the mean, standard deviation and coefficient of variation. The normal distributions of these statistics were converted to a standardized normal distribution. Then, based on a level of significance of 1 percent and the null hypothesis that the two groups were equal (B=A), the statistics were evaluated by means of a two-tailed probability test to determine if there was a statistically significant difference between the two groups.

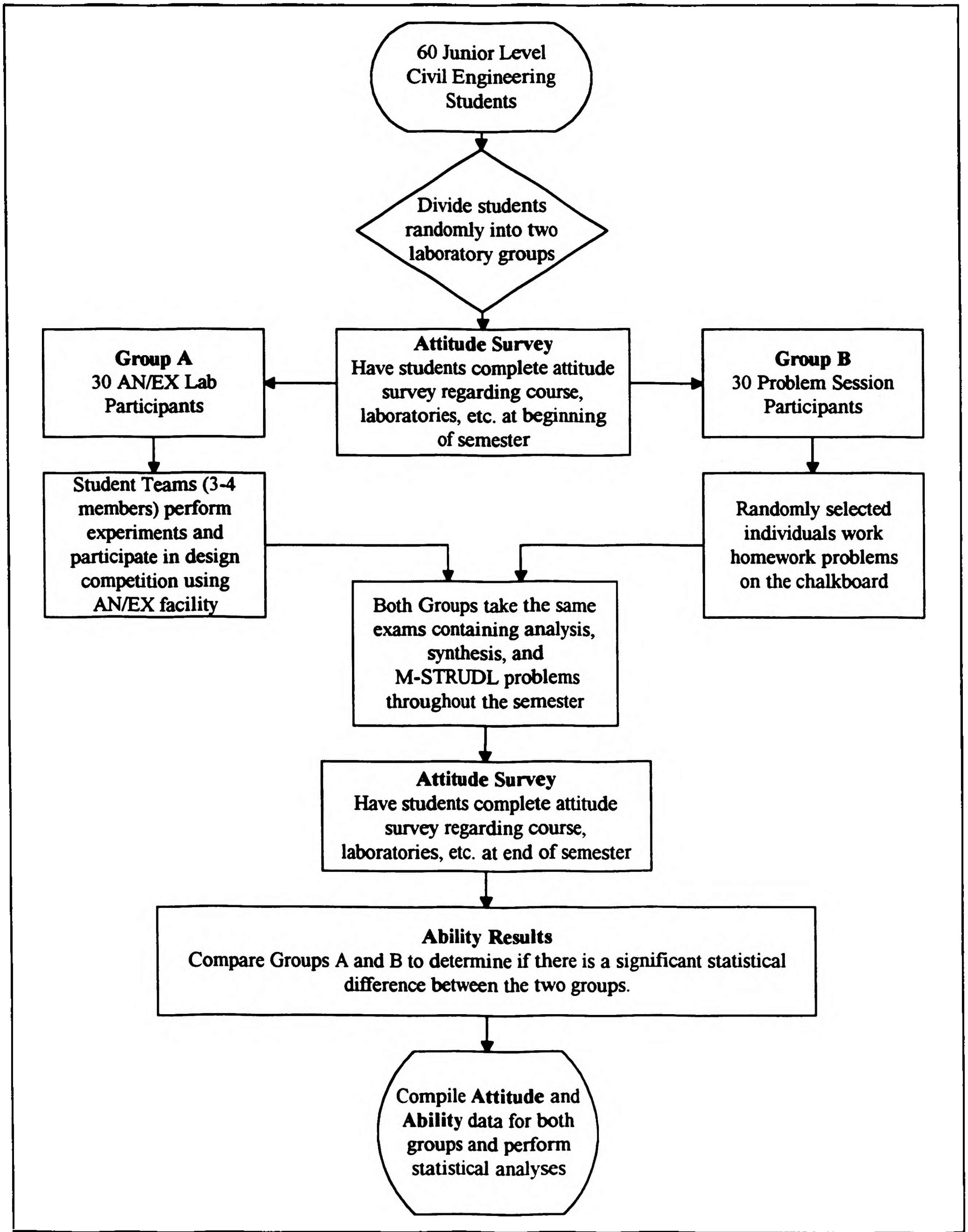


Figure 1. Assessment of AN/EX in an Introductory Structural Analysis Course.

CE-218 STRUCTURAL ANALYSIS
Student Opinion Questionnaire

Note: This questionnaire is anonymous and will have absolutely NO effect on your course grade. Your thoughtful responses will be appreciated.

Group:
________ Design project using ANEX (Group A)
________ Problem Solving Sessions (Group B)

Your Current Overall GPA: _____/4.0

Your Average Grade in Statics
and Mechanics of Materials: _____/4.0

1. I plan to emphasize structural engineering in my BSCE degree.
2. I plan to go to graduate school and specialize in structural engineering.
3. I am satisfied with the laboratory group to which I have been randomly assigned.
4. My current feeling is that the design project using ANEX is a good emphasis for the laboratory portion of this course.
5. My current feeling is that problem solving sessions are a good emphasis for the laboratory portion of this course.
6. Learning how to use a structural analysis software package such as M-STRUDL is a valuable part of my engineering education.
7. I am comfortable with engineering problems that require trial-and-error procedures and judgment calls in order to solve.

Questions added to second questionnaire

8. The laboratory component of this course had a positive influence on my attitude toward structural engineering.
9. The laboratory component of this course had a positive influence on my ability to solve structural engineering problems.
10. Using the ANEX Lab to perform hands-on experiments would help me to learn structural engineering.

****Note:** The questions were rated between 0 and 4 by the students, with 0 representing *Strongly Disagree* and 4 representing *Strongly Agree*.

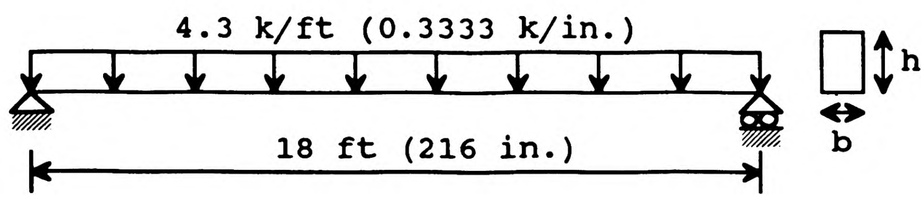
Figure 2. Attitude Questionnaires

Exam 2.

An 18-ft (216 in.) long simply supported beam is to be designed to carry a uniformly distributed load of 4 k/ft, which include the weight of the beam. The beam material has the following properties: compressive and tensile normal allowable stresses of 4 ksi, shear allowable stress of 1.5 ksi, elastic modulus of 4,000 ksi, and shear modulus of 1,600 ksi. The beam is to have a rectangular cross section of width b and height h. Using the above material properties and loading, estimate b and h in order to satisfy the following:

(1) the total weight of the beam is minimum,
(2) the midspan deflection due to shear and bending ($\Delta_V+\Delta_M$) is minimum,
(3) the ratio of shear deflection to bending moment deflection (Δ_V/Δ_M) at midspan is not to exceed 1.5%,
(4) and none of the allowable stresses are exceeded.

<u>Note that</u>:
(i) the shape factor of a rectangular cross section used for the computation of shear deflection is k = 1.2,
(ii) the internal normal stresses in a beam due to bending moments are $\sigma = \frac{My}{I}$
(iii) and the internal shear stresses in a beam due to shear forces are $\tau = \frac{VQ}{Ib}$



Exam 3.

A 10 ft (120 in.) long cantilever beam is to be designed to carry a uniformly distributed load of 48 k/ft, which includes the weight of the beam. The beam material has the following properties: tensile normal allowable stress of 2.5 ksi, compressive normal allowable stress of 5 ksi, shear allowable stress of 0.5 ksi, and elastic modulus of 3,000 ksi. In order to minimize the volume of construction material, the beam is to be designed to have two different rectangular cross sections, of width b and height h, along its length.

(1) Using the above material properties and loading, estimate the values for b and h and the location of the cross section transition.
(2) Given the beam design in part (a), compute the maximum deflection due to bending effects only using <u>the virtual work method</u>.

<u>Note that</u>:
(i) the internal normal stresses in a beam due to bending moments are $\sigma = \frac{My}{I}$
(ii) the internal shear stresses in a beam due to shear forces are $\tau = \frac{VQ}{Ib}$

Figure 3. Synthesis Problems Used in Introductory Structural Analysis Class.

Results of Assessment

Ability Assessment Results

From the statistical analysis, the groups were determined to be statistically equivalent in all exam categories *except the synthesis problems*. The results of the two-tailed test are presented in table I.

TABLE I. ABILITY ASSESSMENT RESULTS

Exam	Category	z value	Significance (Yes/No)
Exam 2	Overall	-0.26	NO
	M-STRUDL Problems	-1.24	NO
	Analysis Problems	0.855	NO
	Synthesis Problems	-2.6	YES
Exam 3	Overall	-0.807	NO
	Analysis Problems	1.13	NO
	Synthesis Problems	-3.54	YES

Note: A absolute value of z greater than 2.576 was required to show a 1 percent level of significance. All z values in this table assume Group B = Group A. Negative Values represent that Group A did better in those categories.

Attitude Assessment Results

The results of the attitude assessment are shown in Table II.

TABLE II. ATTITUDE ASSESSMENT RESULTS

Question	z from First Questionnaire	Significance (Yes/No)	z from Second Questionnaire	Significance (Yes/No)
1	-1.23	NO	0.81	NO
2	-1.74	NO	-0.217	NO
3	-0.788	NO	-1.2	NO
4	1.24	NO	-2.05	NO
5	2.13	NO	3.61	YES
6	3.03	YES	1.23	NO
7	-0.9	NO	-2.47	NO
8	N/A	N/A	-5.14	YES
9	N/A	N/A	-0.09	NO
10	N/A	N/A	-0.14	NO

Note: A absolute value of z greater than 2.576 was required to show a 1 percent level of significance. All z values in this table assume Group B = Group A. Negative Values represent that Group A rated those questions better.

CONCLUSIONS

The statistical difference between the exam score for the synthesis problems showed that the AN/EX Laboratory did indeed make an impact on the learning of the design process in the introductory structural analysis class. Due to the larger z value of the exam 3 synthesis problem (3.54 as compared to 2.6), it could easily be inferred that the amount of the exposure to AN/EX is directly proportional to the increase of knowledge in the design process. According to the attitude results, Group A felt stronger than Group B about the laboratory having a positive influence on their attitudes toward structural engineering. The AN/EX Lab improved student performance in the area of synthesis/design problems.

ACKNOWLEDGMENTS

I would like to thank Dr. Richard Behr and Dr. A. Belarbi for providing the research opportunity and assisting in the assessment of AN/EX. I would also like to thank the National Science Foundation for funding the AN/EX Project and the University of Missouri Research Board for funding the assessment of AN/EX.

REFERENCES

[1] J. C. Liebman, "Designing the Design Engineer," *Journal of Professional Issues in Engineering*, July, 1989.

[2] J. S. Russell and B. G. McCullouch, "Civil Engineering Education: Case Study Approach," *Journal of Professional Issues in Engineering*, April, 1990.

[3] P. Tarricone, "Education at a Crossroads," *Civil Engineering / ASCE*, Oct., 1990.

[4] D. W. Gentry, "Educating Engineers for the Next Century," Proceedings -- 1990 SPE Annual Technical Conference and Exhibition, New Orleans, LA, Sept. 23-26, 1990.

[5] R. B. Corotis and R. H. Scanlan, "Future of Civil Engineering Profession and Role of Education," *Journal of Professional Issues in Engineering*, April, 1989.

[6] J. R. Dixon, "Engineering Design Science: New Goals for Engineering Education," *Mechanical Engineering*, March, 1991.

[7] R. A. Behr and D. S. Vollenweider, *ANEX Laboratory Manual*, Department of Civil Engineering, University of Missouri-Rolla, Rolla, MO 65401; 1992.

[8] L. M. Nicolai, "Designing a Better Engineer," *Aerospace America*, April, 1992.

[9] J. R. Dixon, "Engineering Design Science: The State of Education," *Mechanical Engineering*, Feb., 1991.

[10] J. B. Jones, "Design at the Frontiers of Engineering Education," Proceedings -- 1991 Frontiers in Education Conference.

[11] *User's Manual for M-STRUDL and CAST Utility*, Computer Aided Structural Technology, Inc., P.O. Box 7326, Fremont, CA 94537-7326; 1986.

[12] K. H. Law, W. J. Rasdorf, M. Karamouz, and O. Y. Abudayyeh, "Computing in Civil Engineering Curricula: Needs and Issues," *Journal of Professional Issues in Engineering*, April, 1990.

[13] R. W. Eck, "Developing a Civil Engineer for the 21st Century," *Journal of Professional Issues in Engineering*, April, 1990.