

AC 2010-1003: ASSESSMENT OF A COMMON FINITE ELEMENT ANALYSIS COURSE

Raghu Echempati, Kettering University

Enayat Mahajerin, Saginaw Valley State University

Anca Sala, Baker College Of Flint

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Abstract

This paper discusses the outcome of the common assessment of a sample introductory undergraduate/graduate level course on finite element analysis (FEA) taught at three different local four-year engineering colleges, namely, Baker College and Kettering University (Flint, MI), and Saginaw Valley State University (SVSU, Saginaw, MI). The assessment is based on the commonly used course topics and based on identifying the common course learning objectives (CLOs). CLOs are then mapped with ABET's program outcomes (POs). Assessment tools such as class work, home work, quizzes, tests, as well as the final exam and/or final project work with presentations are used to assess the performance of the students. The rationale for writing this paper is to understand the variation if any in students' understanding of the material on their overall performance in the class. Variation is to be expected since the student population is different (full time versus part time, graduate versus undergraduate) and the course is taught by different instructors. However, usage of common CLOs, course topics, and assessment tools used reveal that the students lack knowledge in pre-requisites and also had problems using CAE tools compared to using math tools for FEA. Finite element analysis (FEA) course typically requires pre-requisites knowledge in Statics, Mechanics of Materials and to some extent Engineering Materials, Computer Aided Modeling and Machine Design. Although many students at these colleges usually take FEA as seniors, there are a few graduate students at Kettering who take this class. Some of whom are on-campus while few others are off campus (distance learning) students. Both math and CAE tools are typically used for this course with more emphasis on finite element methods rather than finite element modeling using a CAE tool. The math tools such as MatLAB involve using matrix algebra for most part to solve the equations obtained by either direct stiffness method or by energy methods for 1D and 2D problems. CAE tools involve modeling components that involve simple or complex geometry, and solving those using SOLID EDGE/UG/ANSYS/IDEAS software. Results of assessment will be presented in the form of charts and tables and discussed in detail. A sample assessment and evaluation form will also be included in the paper.

Introduction

More and more universities are teaching basics of finite element analysis at the undergraduate level with more emphasis on theory at the graduate level. For the undergraduates though, there should be a balanced approach between basic theory coverage and more simulations using numerical computation. In this paper the experiences gained in teaching this course at three different schools under three different students and class settings is discussed. For most part, common CLOs have been identified and the assessment based on those is discussed using charts and tables. Numerous papers on this subject are available in the literature which is briefly included in the next section. Sample feedback from students is also included at the end of this paper.

Literature review

Pike¹ and Logue² used finite element analysis (FEA) tools for aiding in better understanding of Statics and Mechanics of Materials courses, respectively. Shakerin and Jensen³ discussed how the use of photoelasticity and FEM enhanced their students' understanding of mechanics of material course. Zechner⁴ developed instructional tutorial book and related multimedia CD-Rom that integrates basic finite element modeling (FEM) concepts with a tutorial approach to learning how to use a FE program, which in this case was ANSYS Workbench. Baker⁵ and Coffman⁶ developed similar exercises using ANSYS for their basic FEA courses. There are several workbooks published by Schroff Development Corporation (SDC)^{7,8} and by ANSYS Company⁹ on the use of various CAE tools for FEA, such as ANSYS. There are also several textbooks such as the one by Moaveni¹⁰ which are written based on a particular math or CAE tool. Steif and Gallagher¹¹ developed a web-based FE program as an aid in teaching deformable (Solid) mechanics course. There are several math tools and textbooks available¹²⁻²¹ in the literature that can be used to enhance the basic understanding of a typical FEA course. Other relevant literature on this subject area are also included in the bibliography²²⁻²⁴.

Common Course Learning Objectives (CLOs):

The instructors teaching this course have identified the following common course learning objectives which will facilitate using common assessment tools for this course.

1. apply the knowledge of Matrix Algebra, Statics, CAE and Mechanics of Materials courses to a basic understanding of the Finite Element Method and its engineering applications
2. understand the assumptions and model a given physical system for analysis by the Finite Element Method
3. formulate the Finite Element equations for 1-D and 2-D finite element problems
4. familiarize with the math and CAE tools used for the FEA process
5. understand the validation process to correctly interpret the results in a view to make any design changes to a component or a subsystem
6. understand the risks and limitations of FE solutions and simulations

Each CLO is given a weightage while mapping those with ABET's Program Outcomes (POs). For example, CLO 1 is assigned 70% weightage with PO (a), namely, "An ability to apply knowledge of mathematics, science and engineering", 20% with PO (e): "An ability to identify, formulate and solve engineering problems", and 10% with PO (k): "An ability to use the techniques, skills and modern engineering tools necessary for engineering practice". The total weightage for each CLO adds to 100%. Similarly, other CLOs are mapped and weighed with the appropriate POs as conceived by the instructors teaching this course. Both the CLOs and their weightage may have to be changed based on the assessment of the course once every few terms or years as needed. However, the instructors teaching this course would ideally meet at the end of every term they teach to do an assessment report that identifies and acts on the deficiencies in the course topics or its coverage. This is primarily based on the students' performance on each assessment tool (homework, class work, labs, quizzes, tests and project & project presentations).

For the finite element analysis course, the following main topics have been agreed to be covered at the three schools and used for assessment purposes. Besides these topics, each school is free to teach additional topics in order to meet their internal assessment requirements.

Common Course Topics:

Review of Statics and Solid Mechanics; Introduction to structural finite element analysis and modeling; Review of matrix algebra; Direct stiffness method and its application to 1D element problems (axially loaded bars and planar beams); Application of 1D element formulation to planar trusses and planar frames; Applications of 1D element analysis to heat conduction problems; Introduction to energy methods and their application to the solution of 1D problems; Application of 2D formulation to plane stress, plane strain and axi-symmetric problems; Course review.

Math software tools such as MATLAB[®], MathCAD^{®3} and Excel[®] are used mainly to solve the system of linear algebraic equations resulting from the finite element formulation by the stiffness method. FEA formulations involve breaking a continuum (real system) in to several smaller bodies called elements that are connected to each other by nodes to model the entire original system. This is called meshing of the model. In so doing, however, it is often impossible to match the finite element mesh with the original geometry of the object being analyzed. The model is constrained using boundary conditions. Boundary conditions for structural analysis include specifying the displacement and load at nodal locations. These are equivalent to the way the real body is constrained using supports and the way the load acts on it. Applying correct or in some situations more realistic boundary conditions to a finite element model is not an easy task and the final results of an analysis may be different if proper boundary conditions are not used. Lot of experience is needed, which is a part of teaching and learning experience for both the instructor and the students. The results of a finite element analysis are only approximate that will never match 100% with exact solutions. This is true even for the analysis of problems involving simple geometry. In addition to the modeling errors, finite element analysis involves solving the equations using numerical methods, which again yield approximate solutions. Depending up on the type of analysis performed, namely, structural, thermal, dynamic, NVH, etc., validation of results by simple models and hand calculations is necessary.

The goals in FEA are thus to (a) use correct formulations to attain results close to exact results or results from testing, and (b) to achieve convergence of the such results in the fastest time. There are other goals in terms of the development of theory and constitutive relationships to model complex geometries consisting of advanced materials (such as composites), modeling joints (for example, welds), etc. As the technology advances both in terms of computational power and theory, performing FEA has become routine in many industries that engineers with undergraduate education are able to validate and interpret the results of FEA with experimental data or with other models.

A simple structural 1D bar or beam element consists of two end nodes with zero or one or more mid-nodes. Each such element in the linear analysis is treated as an axially-loaded member or transversely-loaded beam (or a combination of these as a beam) for which stress and deflection equations are used. The unknown parameters in FEA are usually the displacements of each node

in an arbitrarily selected global coordinate system. Stress in each element is calculated using the deflection values and the material properties (modulus of elasticity and Poisson's ratio). For a detailed FEM and matrix operations procedure, the reader may refer to standard text books¹²⁻²⁰.

In addition to the above guidelines and information to be followed by the three schools mentioned in this paper, the format of the FEA course taught at SVSU is lectures with embedded interactive workshop sessions. Their course is a 3-credit, senior level and a design elective course. The additional course objectives are:

- Gain an understanding of fundamental theory and essentials of FEA
- Become proficient in efficient modeling and use commercial FEA tools

At both Baker College and at KU, the course is a 4-credit, senior level and an elective course. At KU, both on-campus and off-campus graduate students can also take this as a design elective course. Because all students need FEA in the capstone design courses the FEA course is usually offered regularly at SVSU, while it is offered only twice a year at the other two schools. The course prerequisites are differential equations and, solid mechanics, computational methods and engineering analysis. Majority of students enrolled in the FEA course are familiar with the solid mechanics, heat transfer and fluids topics and it is convenient to assign a wide variety of problems in the homework and as projects.

In the light of the above, a suitable undergraduate textbook for FEA must have the following characteristics:

Formulation is based on matrix methods or the weighted residual approach (Galerkin approach). However, the following types of books should be avoided due to their higher level of topics coverage: Highly condensed books; Books that are compilation of research results; Highly mathematical-oriented books; Books that are based on variational Calculus; Books without ample examples; Books that contain excessive computer printout of a particular commercial tool; Books that concentrate on only one topic, e.g., structural analysis or thermal problems.

While at KU and Baker College the students are open to use any CAE software like NX5, I-DEAS, etc., at SVSU, students normally use SolidEdge software²¹ in which ANSYS⁹ is embedded and the FEA processes are conducted following completion of the model.

Computer facilities

At all three schools, there are several CAE labs in which the required math and FEA software are available to the students.

Assessment Tools (at SVSU):

Homework assignments; Project assignments; Mid-term Exam; Final Exam; Presentation.

There are at least 14 in-class presentations in which students or a team of two students use the podium to use FEA and analyze a problem. The problem titles and presentation times for

individual students are provided in the course syllabus. Students are required to send a power point presentation prior to the presentation to the class and to the instructor. This requirement was added in the fall 2009 semester and seems to be an effective way of learning the FEA and to communicate the results to audience.

Grading Scheme:

Homework Assignments:	100 points
Project Assignments:	50 points
Presentation:	25 points
A Design Problem:	25 points.
Midterm Exam:	100 points
Final Exam	100 points
Total	400 points

A minimum of 280 points (%70) is needed to pass the course with a C-grade.

Assessment Tools (at Baker College and at KU)

The course is taught for approximately 10.5 weeks with one 4-hour meeting per week at Baker, while it is two 2-hour blocks per week at KU. The students at Baker attend evening classes starting at 6 pm since they work during day time. Many of these students are married and commute long distances (15 to 50 miles) to take classes at Baker. At both these colleges the assessment tools include homework, class work, math and CAE laboratories, examinations and a final project. A minimum grade of 70% is required to pass this class.

Observation from course assessment:

Course Delivery

As mentioned before, the FEA course at Kettering University is a senior level elective undergraduate/graduate (mezzanine level) course offered to full time on-campus students and to part time off-campus students by distance learning mode. The on-campus students are mostly undergraduate students (seniors or those in BS/MS program), with a few full time graduate students. Usually the graduate students get 3 to 4 weeks additional time to complete this course, and hence are expected to do additional graduate level work compared to the undergraduates. Traditionally this course is offered two times a year – as a “Live” course during the summer terms and as “On-campus only” course during the fall terms. Offering twice a year covers both the A-Section and B-Section students wishing to take this class at KU. In the “Live” mode, lectures are delivered to the on-campus students in a studio room while at the same time the lectures are videotaped (recorded) for later distribution to the off campus students. The “On-campus only” classes are taught in a traditional classroom and are not recorded. Therefore, the off campus students wishing to take this course during the fall (or in another) term are sent the pre-recorded video material under a ‘Directed Study’ option that is available to students. Copy of pre-recorded lecture material is also kept in the university library for reference to the students enrolled in the class.

The number of topics and the amount of course coverage varied depending on the available time, availability and familiarity of using particular CAE tools, and depth of students' knowledge in pre-requisite courses. Undergraduate students being a majority population in this course, usually FEM theory (with math tools) and modeling, analysis and validation by CAE tools is around 50-50 or 60-40, while for graduate students this ratio tends to be 70-30. Following are the observations & course concerns along with remedial steps taken to address the concerns of this course. At both Baker and at SVSU, the lectures are delivered only in the "Live mode".

Class room facilities and class timing issues versus learning:

For KU, the "Live" delivery of lectures in the video room posed several issues including the passive delivery mode of lectures (speaking to the camera) that made active learning a challenging issue for many students. Also attending an early morning class in passive learning mode has posed problems for some students. Additionally, the unavailability of advanced CAE tools on the video room desktop computer made learning even more difficult, although the service provided by the video unit personnel and the students' motivation and tolerance to attend those lectures to try to learn the material is commendable. The fall term classes are scheduled during mid-day in a regular lecture room or in a computer lab that provided active learning environment. Therefore the above issues for early morning lectures in summer term did not pose major difficulties for the fall term students.

Over the course of two to four years, the summer class issues have been resolved to some extent as follows:

- Pre-recorded course lectures are made available in the library for the students to watch a second time if needed.
- Streaming video technology made it easier for almost synchronous learning by the on or off campus students since the streaming video files of the lectures are posted on Blackboard within few hours after they are recorded.
- A faster computer desktop with advanced Math and CAE tools installed made it easier to engage students to watch the Math (MatLAB or Maple) or FEM demonstrations while covering theory.
- Short answer quizzes are given to hold students attention to lectures and motivation to attend classes.
- Guest lecturers from industry made the classes more active since a short quiz followed the guest lecture. (this also addresses CLO 6)
- On some days students have been engaged in the video room for only a short time to cover the theory, while the rest of the class period is spent outside the video environment in a CAE lab to do hands on exercises on matrix formulations and solution by a math tool or to do FE modeling and validation studies using an advanced CAE tool such as ANSYS/UG NX/I-DEAS. The off campus students are given instructions to do the same learning activities using their own or their work facilities. (CLOs 4, 5)
- Breaking up the two one-hour block class periods in to several shorter module sessions was considered but could not be implemented.
- During the summer 2009 term this course is completely offered in a regular CAE lab with no recording done to assess its effect on student learning. However, a few students still

had problems staying active in the early morning class. To alleviate this issue, many class work problems and short quizzes have been assigned based on the concepts covered, and on some days the class time was entirely devoted to do modeling and analysis using a math or CAE tool.

These are no major issues at the other two colleges about these problems.

Course learning issues/Action items:

Although the above mentioned room facilities and class timing issues at KU have been addressed to some extent, there are still course related problems at all three schools that some students had as follows:

- Many students continue to have problems with basic pre-requisites knowledge – Statics and Mechanics of Materials to decide which mechanics formula (axial, bending or torsion, or combined loading) to use for validation of results. Therefore, considerable amount of time is spent reviewing those while at the same time covering the FEM theory using the same examples, namely, statically determinate and indeterminate 1D and 3D bar and beam formulations and their applications to truss and frame problems. Plane stress and plane strain problems are also covered the same way while reviewing the Machine Design and stress concentration effects.
- Some students have problems understanding what type of element formulations to use for 1D (truss and frame problems), or 2D problems. This addresses the issue of a clear understanding of the degrees of freedom of each node in a model, as well as the degrees of freedom of the entire structure. Many practice problems have been discussed to address this issue.
- Many students have problems using the appropriate (displacement and load) boundary conditions to a (FEM or a CAE) model. Several worked examples from Statics and Mechanics of Materials textbooks have been discussed to see what type of boundary conditions if used in the FEM formulations (or in the CAE modeling) yield the closest answer as the mechanics textbook answers and why. In tune with this, several real life examples and scenarios have been discussed to decide what type of boundary conditions may be most appropriate to use. For example, what is the effect of clearances in a real pin joint, or a roller support, etc., on the output (nodal displacements, stresses and reaction loads)? This addresses all CLOs to a great extent.
- There were some issues with type of software used versus the renewal of license. This is particularly an issue for off-campus graduate students. To address some of the software issues, it was decided to use either ANSYS (at SVSU), or NX (at KU) and/or I-DEAS (at Baker) with NASTRAN as solver for this class.
- There are some issues with using NX for this class since the newer versions (5 to 7) have a learning curve. For example, NX3 and NX5 modeling and structural simulation modules are not quite similar. Also, neither NX3 nor NX5 appear to have proper cast tutorials based on 1D and 2D element modeling that would satisfy part of CLO 4, namely, validation of 1D and 2D FEM (MatLAB/Maple) formulations by a CAE tool. Under these circumstances, many students preferred to use NX I-DEAS or NASTRAN with some learning curve since they both have a few online practice tutorials for 1D, 2D

and 3D modeling. Also I-DEAS workbooks developed by private publishers such as S.D. Corporation (www.sdcpublications.com)²² are available at very moderate cost to students.

- Use of proper mesh size and mesh refinement for obtaining convergence is another issue that was addressed and resolved to some extent by showing them the difference between free and mapped meshing through examples from textbooks and CAE online tutorials.
- Understanding and properly using planar/axi-/cyclic symmetry boundary conditions and the associated theory is still an issue that is partially addressed by showing the worked examples and having them practice the CAE online tutorials.
- The rigor of teaching optimization/redesign, heat transfer and dynamic analyses could not be achieved due to time constraints. However, students practiced few examples using the online CAE tutorials on these topics, and analyzed the simulation results. This satisfies CLO 5 to some extent. However, more time needs to be devoted to cover dynamic analysis.
- Finally, students are provided guidelines and asked to select their own structural component for the final project. However, selection of an appropriate open-ended topic (structural component) that involves ambiguous boundary conditions and design modifications needed based on results obtained, has always been a challenge. They tend to think of components that are too simple to analyze. Therefore more guidelines have been provided on how to select an appropriate component for the project that addresses all CLOs. Where necessary, an engineering component has been selected for them to work on.

As a side note to this, few students always creatively think of a common project topic that addresses different aspects and requirements to satisfy another course(s) they take during the same term, for example, a senior capstone design course or another ME elective course such as failure considerations in design or failure analysis courses. This is a highly desirable as it provides a total learning experience for the students. This aspect should be looked in to and discussed further by the concerned faculty offering those projects to carefully define and differentiate the individual aspects and requirements of each final project so that the students can turn in a single quality report to all courses rather than individual reports for each courses. This minimizes any cheating practices that may arise due to non-coordinated projects by students trying to claim 'double credit' for the same amount of work done for more than one class.

Assessment of Course Learning Objectives (CLOs) and action plan (See Figure 1):

CLO 1:

Students used MatLAB or Excel for the most part of HW/CW/Quizzes and Tests. They used CAE tools to some extent on the Tests but more on the Final Project/practice more HW problems to assemble matrices.

CLO 2:

Still a few students had problems modeling the HW/CW/QZ/Test problems to determine whether to use 1D bar or beam elements to solve the truss or frame problems. Also problems were there in understanding plane stress versus plane strain applications. Action plan included additional discussion of these to show more examples.

CLO 3:

With modeling problems as mentioned above, the stress and deflection values go wrong. Understanding stress concentration effects and remeshing of part geometry seems to be an issue for some students. Action plan included spending more time to discuss these issues.

CLO4:

Use of proper load and boundary conditions on CAE models has always been a problem. Also use of new/upgraded CAE tools in the CAE laboratory posed a learning curve. Action plan included development of more tutorials or recommend a workbook if using UG NX or NX I-DEAS.

CLO5:

Discussed both direct stiffness method and the energy method for structural 1D elements and 2D CST, Quadrature formula. Action plan included more coverage of thermal and dynamic analysis and in more in depth.

CLO6:

It is required that all work be validated using Statics and Mechanics approach. While validating the CAE results, some students have problems with using the correct formula for computing stresses. Action plan included asking the students to review solid mechanics book or to use Internet for material they have problems with.

Figure 1 shows the average performance charts based on homework, class work, quizzes, etc. for the summer of 2008 class taught at Kettering University. The students' overall performance in the course shows a satisfactory level.

There were five homework sets, three design projects and two exams used as assessment tools at SVSU. In addition, as a part of the design activities individual students were required to present results of an assigned project to students using power points. Overall, the course went very well because it is an elective which means that students who truly want to learn FEA enroll in it. Also, FEA has a good reputation both on campus and in industry and as a result, everyone completes the homework assigned projects diligently. Relative poor results in the exams are natural and is always due to the pre-requisites including integration, matrix manipulation and also concepts of thermal, fluids and stress analysis. Overall, students believe that *“you learn too much for a 3-cr.”*

Table 1 and Figures 2, 3 and 4 attached at the end show statistical evaluation of the course taught at SVSU.

Figure 5 shows the average performance charts for the fall 2009 class taught at Baker College. Students did well with the Homework assignments and the Quizzes, but had some difficulties with the Exams (midterm and final exam). Here the extent of the problems coupled with the time constraints overwhelmed some of the students. Overall the performance was at satisfactory level.

Student feedback and suggested best practices

“FEM Learning Outcomes

There were a number of lessons to be learned from this assignment some of which are briefly described below with regards to the use of FEA. Some of the more general learning outcomes relative to FEA were:

Mesh density:

- The number of elements/nodes affect whether the solution has converged
- The engineer needs to determine what the convergence criteria will be and what tolerance is acceptable
- No effort was made to create mapped meshes or reduce the element count while retaining mesh convergence
- Mesh density is critical to obtaining a reasonable FEA simulation result

Element type

- Limitations from using assumptions such as plane-stress need to be considered since they may affect the results particularly if there are other stress components due to other loads
- Effect of higher order, lower order elements, or other elements options such as reduced integration must be understood by the engineer
- The choice of element type (HO, LO, visco-elastic, etc.) and options (plane-stress/strain, reduced integration, etc.) are also critical to obtaining a reasonable FEA simulation result
- Although higher order elements can be better suited to curved surfaces with its mid-side node, lower order elements are often suggested for plasticity which was not an aspect for this project

Boundary Conditions

- Boundary conditions can affect the results
- Since this project iteratively solved to balance the axial force, the single fixed node was not a deterrent in application for this specific problem which may normally cause local issues on other problems
- The engineer must determine the locations of interest and accurately model them so the model is not polluted

Symmetry

- The use of symmetry can affect the results if not applicable but was appropriate for assessment of the projectile body

Load Application

- The method of loading must be considered particularly if local stresses are of interest
- High stresses regions must be modeled in a more representative fashion if an area of interest
- An elastic foundation with contact elements may account for load redistribution and alter the results locally or globally

- The engineer must understand the potential load variations and the effect on the final margin of safety

Material

- The engineer must understand the environment and acceptance criteria to determine the failure modes along with appropriate use of allowable strengths and deflections to verify acceptable form, fit, and function
- The engineer must determine if some plasticity is allowed, the amount, and whether it occurs from a single load application
- The engineer must understand the potential material variations and the effect on the final margin of safety

Results Interpretation

- The engineer must have a discerning eye reviewing plots
- The engineer must understand the limitations of the FEM with regards to actual hardware
- Smooth stress gradients are not necessarily the criteria for an accurate solution
- Then engineer must understand and be able to explain the results with regards to a physical interpretation”

Over all Conclusions

In this paper some of the experiences of teaching the same course at three different engineering colleges are briefly discussed. Assessment procedure has been carried out that indicates some common problem areas in students’ prerequisites knowledge and also in the course delivery methods. Overall, it was a good experience and new methods of innovative teaching are certainly necessary to keep the motivation of the students learning of this state-of-the-art and industry-standard course.

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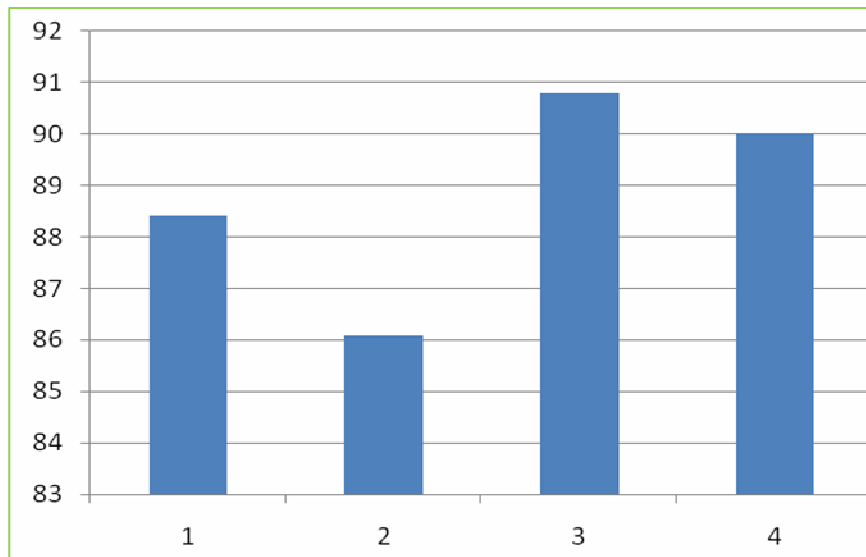


Fig. 1: Overall performance (xxx university); Number of students: 29
 Chart legend: 1: Classwork/Homework/Quizzes/Labs (40%); 2: Tests (50%); 3: Final Project (10%); 4: Overall grade (100%)

Table 1: Stats of course taught at SVSU (3 cr., Elective) Fall 2009; # of students n=15

Item	Min	Max	Mean	St. Dev.
Homework	74	100	95.8	9.2
Design	60	100	88.2	9.6
Final Exam	58.7	97.3	79.3	11.2

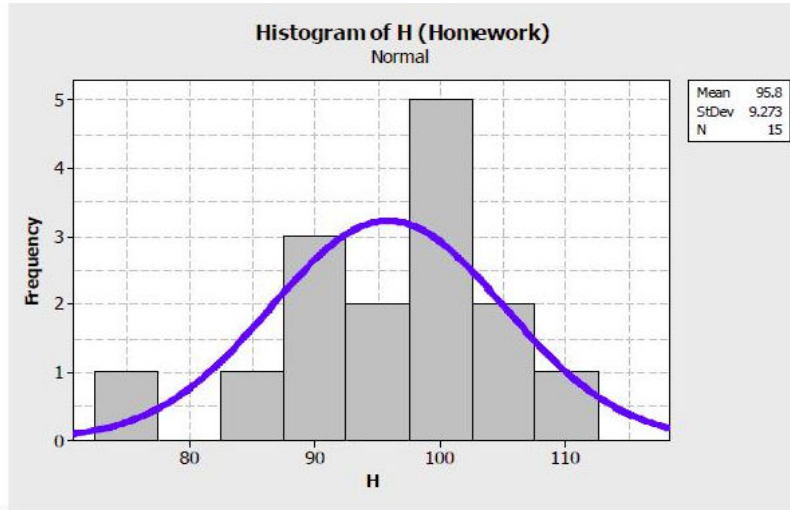


Fig. 2: Overall performance on Homework (SVSU); Number of students: 15 (Weightage: 25%)

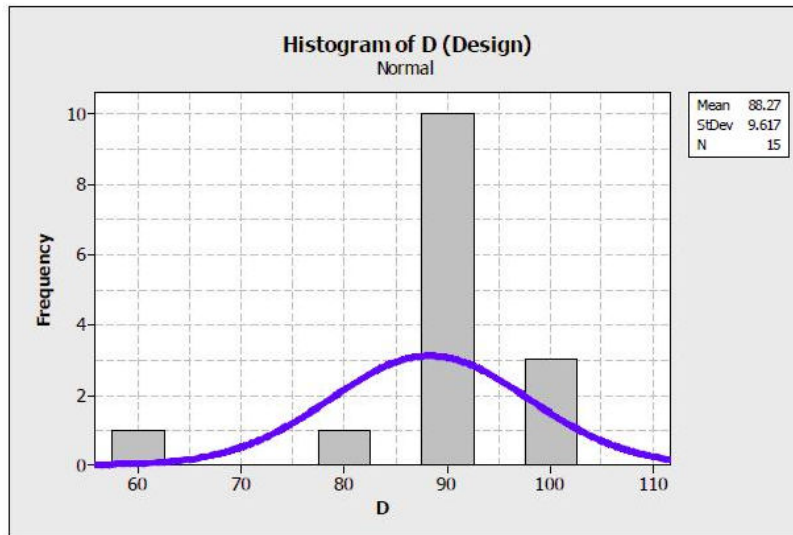


Fig. 3: Overall performance on Design (SVSU); Number of students: 15 (Weightage: 25%)

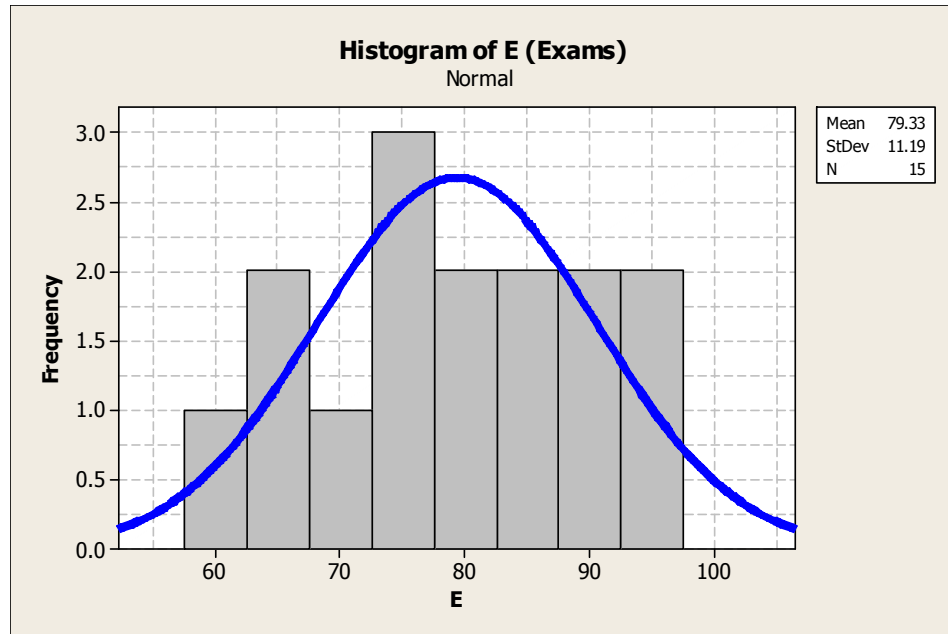


Fig. 4: Overall performance on Exams (SVSU); Number of students: 15 (Weightage: 50%)

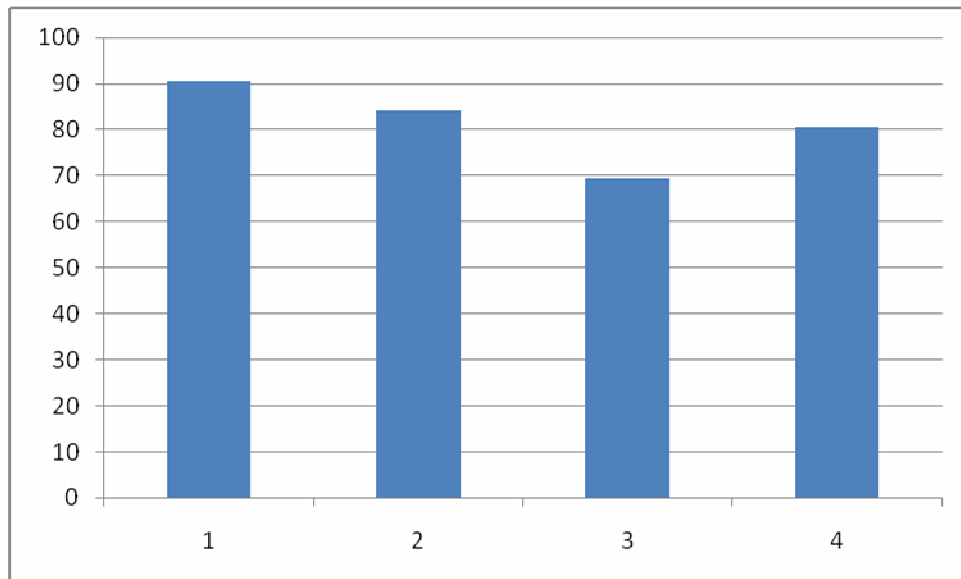


Fig. 5: Overall performance (Baker College); Number of students: 13
Chart legend: 1: Homework (40%); 2: Quizzes (10%); 3: Exams (50%); 4: Overall grade (100%)

On the next page, a sample term assessment meeting report is presented, which is based on the instructors meeting each term to review the performance of students during that term.

Sample ABET Course Assessment Form

Course Name: Introduction to Finite Element Analysis
Instructor Name: -----
Assessment Term: Summer 2008
Course coordinator: -----
Mechanics group meeting date: Fall 2008
Attendees: -----

Brief summary of assessment results:

1. Students continue to have a poor understanding of the prerequisite subjects (Statics and Solid Mechanics). That is, they have problems understanding the basics (FBD's, stress calculations, shear-moment diagrams), how to read a problem to determine the unknown(s) involved, proper use of the data, UNITS, and so-on. Help sessions were offered to classes, problem sessions have been held; attendance is sparse. Students have been given a review test on Statics and Solid Mechanics; but, their performance is not satisfactory, indicating their weak pre-req knowledge.
2. Understanding and applying correct boundary conditions is also another problem.
3. Final project report writing and documentation of results is not satisfactory.
4. There were a few seniors in the class whose attitude in learning the subject matter is not satisfactory compared to others who chose this course to enhance their knowledge in this subject area.

Recommended action items:

1. Students must take a review exam based upon the fundamentals of statics and solids. If they do not pass, they will be advised they need to attend help sessions to obtain the knowledge necessary to pass the finite element analysis course.
2. There will be no review of the material during scheduled class hours. Help is needed in the form of a graduate assistant to help with the review sessions. Furthermore, the grad assistant can help with homework problem sessions.
3. Add a daily 10 minute quiz at the beginning of each class session to motivate the students to pay careful attention to the class lectures.