AC 2009-1737: PREPARATION FOR AN INNOVATIVE COURSE SEQUENCE IN STATICS AND SOLID MECHANICS

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Preparation for Innovative Statics and Solid Mechanics Course Sequence

Abstract

Grand Valley State University has a strong partnership with local industry. We strive to match our curriculum to their needs while maintaining high educational standards. The contents of present mechanics courses and their sequence in curriculum do not suit the needs of all the students of different programs and the employers. The present sequence of in-class semesters and mandatory co-op semesters is such that students have solid mechanics competency after the first co-op experience while machine design course which is last in the sequence is taught concurrently with the first part of senior design projects. The present sequence is therefore less beneficial to the students in terms of co-op experience and the senior project.

This paper presents initiatives taken to address these issues and discusses the details of the proposed scheme. Initially, the issues were identified from all the stakeholders' inputs. And then our approach has been evolved with three main components. Each one addresses some of the issues. First component is to develop an innovative course in statics and solid mechanics which will be the first course in the sequence. There is a paradigm shift in the way the mechanics and design topics will be taught. In that course, principles of statics, solid mechanics and machine elements are taught together in a concise way. With this background students are anticipated to complete their first co-op semester successfully. The introduction of the major changes in the first course has altered the course contents in the subsequent courses. The follow-on course will have a more rigorous mechanics study with introduction to finite element analysis tools. The second component of the approach is to introduce a new course on Finite Element Analysis. The third component of the approach is to reorganize the sequence of the course throughout the curriculum.

The proposed plan of study is also presented. Expected benefits from the endeavor are discussed. Brainstorming and discussions preceded the preparations. This paper also presents challenges of textbooks, scheduling and resource allocations. The paper concludes with the discussion of the future work. In summary this paper presents identification of issues, innovation, approach taken, and the necessary preparations. The main objective of the paper is to disseminate the innovative approach and seek the constructive comments from the engineering educators.

Introduction

The School of Engineering at Grand Valley State University is surrounded by several auto suppliers and furniture manufacturers. Over the years, our engineering school has developed a strong partnership with the local industry. Co-op is mandatory in our undergraduate program and we provide well trained co-op students to the industry. All of our capstone projects are sponsored by the local industry. It is therefore imperative that we strive to keep our curricula up to date, so that they reflect local industry's needs and our students remain competent in the fast changing environment of technology and businesses. Our engineering program emphasizes teaching and applied research. Therefore, our faculty is continuously engaged in pedagogical research and its implementation and it is active in disseminating the results to engineering educators.

As a part of our continuous evaluation of our curriculum, we realized that the present mechanics course contents and their sequence in the curriculum are not well suit for the needs of all the students of different programs and the co-op employers. Several employers have indicated that they wanted students to have better grasp of mechanics and with broader background in machine elements before they go for their first co-op semester. Our analysis identified few important issues: students from certain programs do not sufficiently benefit from the solid mechanics sequence, the time gap between the first and second course in the mechanics sequence is too long, and students are not adequately prepared early enough for the co-ops.

This study describes the present state of the statics and solid mechanics courses, investigates related issues, and showcases an innovative approach taken to address those issues. There is a paradigm shift in our philosophy about the way the mechanics and design topics will be taught. Preparation of these courses is underway and will be implemented beginning in Fall 2009. This study also describes challenges faced during the preparations which are also presented.

Many techniques are being used in teaching statics. Techniques which use visual aids from everyday life appeal to those who are visually oriented [1, 2]. In the presently proposed course, machine elements are to be used to teach statics and solid mechanics. If we believe that if mechanics is taught with direct applications to the mechanical systems, instructions will be more effective. Rearranging of topics in statics and solid mechanics and changes in the timing of these courses in the curriculum are not new. However, there is a wide diversity of university backgrounds, course sequence and structure, students' and local industry's needs, pedagogical objectives and approaches, etc.
The main objective of the paper is to disseminate the innovative approach and seek the constructive comments from the engineering educators.

The paper is divided into the following sections:

- Background of the solid mechanics courses and co-op semesters
- Discussion on the issues regarding the present curriculum
- Inputs from stakeholders
- Approach
- Benefits from the proposed changes
- Challenges faced in the process
- Future Work needed to complete the process

Background

We offer three courses in the statics, solid mechanics and machine design area at the undergraduate level, but a Finite Element Analysis (FEA) course is not offered at this time.

Table 1 Present Solid Mechanics Courses

Title	**Topics in our courses**	**Equivalent Traditional Courses**
EGR 209 Statics and Solid Mechanics	Statics Stresses and strains in axial and torsional loadings.	• Statics • First two chapters from Solid Mechanics
EGR 309 Machine Design I	Stresses in bending and combined loading, Stress transformation, Beam deflection, Early part of course : Static and Fatigue failure theories	• Solid Mechanics.
EGR 409 Machine Design II	Second part of Machine Design: Design or Selection of machine elements: gears, springs, pulleys, welds, joint etc	• Machine design course

We have four emphasis areas of engineering, called engineering programs. Required mechanics courses are different for each engineering program as shown in Table 3.

Table 2 Solid Mechanics Requirements for different engineering areas

Program	**EGR 209**	**EGR 309**	**EGR 409**
Mechanical Engineering (ME)	Required	Required	Required
Product Design and Manufacturing (PDM)	Required	Required	Optional
Electrical Engineering (EE)	Required	----	----
Computer Engineering (CE)	----	----	----

As mentioned earlier, co-op is mandatory in our undergraduate program and the co-ops alternate every other semester. The sequence of the mechanics courses is interspersed with co-op semesters as shown in Table 2. Because of the co-op arrangement, spring/summer semesters are regular semesters in the curriculum.

Table 3 Typical Present Study Plan (with relevant courses)

Year	Fall Semester	Winter Semester	Spring/Summer Semester
Freshman	*First Semester* EGR101 CAD/CAM	*Second Semester* EGR103 Analysis	------- No courses
Sophomore	*Third semester* **EGR 209**	*Fourth Semester*	Co-op I
Junior	*Fifth semester*	Co-op II	*Sixth semester* **EGR 309**
Senior	Co-op III	*Seventh semester* **EGR 409** Capstone Project I	*Eighth semester* Capstone Project II

EGR101 CAD/CAM is required for all the programs in the first semester. In this course students are exposed to machine elements in the classroom as during a course project. The content of this course is broad but the coverage is shallow due to the very nature of the course. Besides EGR103, there is no problem solving engineering course in the freshman year. When our students work in the industry as a part of the co-op program, they use FEA tools.

Most faculty members serve as advisors to the students who are on co-op in the local industries, visiting these students and their employers. One of the major objectives is to assess students' preparedness with respect to the employers' requirements. We receive feedback from the employers, one of our major stakeholders, about the students' preparedness and our curriculum.

Issues

Contents and timing of the mechanics courses have created several issues. They were identified from perspectives of the programs, students, instructors, capstone projects and the employers. Issues regarding the contents of the solid mechanics courses and their timings are presented in what follows.

Employers and Co-op Semesters:

Before the first co-op semester, presently only EGR 209 is completed. Considering the present content of EGR 209 (Table 1), the topics covered are not adequate for the first co-op experience. EGR 409 is offered after the third and last co-op semester. In either case the employers are not benefited adequately.

Most companies that carry out mechanical analysis use FEA tools. Our students start using FEA software on their first or second co-op assignments without any formal academic introduction to this very powerful tool.

Students and Programs:

Present content of the EGR 209 is designed with the implicit assumption that the students will take EGR 309 afterwards. EGR 209 is the only course required for the Electrical Engineering

(EE) program. Exposure to the solid mechanics and machine element area is minimal and inadequate for EE students. EGR 409 is not a required course in the Product Design and Manufacturing (PDM) program. These students lack experience of the design and selection of machine elements which is carried out in EGR 409.

Instructors:

Presently there is a huge gap of 4 semesters between the EGR 209 and EGR 309. Retention of the knowledge gained in EGR 209 until EGR 309 is poor for many students. Instructors must review fundamental statics concepts and definition of stress and strain before continuing to cover new material. These reviews take away valuable time that could be utilized for other topics.

We are concerned that students who use FEA tools in their co-op experience without a proper course in the subject tend to become fascinated with the colorful outputs from FEA without having the ability to view the results critically as they are not trained in the fundamental principles

Capstone Projects:

There are also some issues of the sequencing of the courses in the curriculum. In the present setup machine elements topics are covered in EGR 409 concurrently with the capstone senior projects and after the entire three-semester co-op experience is completed. In this scenario EGR 409 loses its impact because it is too late in the curriculum. The present sequence is therefore less beneficial to the students in terms of co-op experience and the senior project.

Inputs

A survey of the employers and input gathered from discussions with them indicated that they wanted students to be better prepared with, among other things, a grasp of solid mechanics and with a broader background in machine elements before they go for the first co-op. An ability to select basic off-the-shelf machine components was also desirable. .

Many employers also indicated that they wanted students to be familiar with the FEA tools and should be able to use them more effectively. An addition of an FEA course also has been frequently demanded.

Approach

Our approach has three main components. Each one addresses some of the above mentioned issues.

First Part of the Approach: First Course in Mechanics, EGR 209:

The first component of the approach is to develop an innovative course, EGR 209 in statics and solid mechanics while keeping some of the above mentioned issues in mind. The course will be called “Machines and Mechanics”. The title and the course description will be changed to more accurately reflect the direction this course will take while being developed. Some of the salient features and philosophy are presented in what follows.

- Common machine elements will be introduced with standard systems and nomenclature at the beginning of the course. Examples: Welds, Bolts, Chains, Belts, Gears, Bearings etc.
- Concepts of statics and solid mechanics will never be abstract entities. They will be introduced in the context of relevant machine elements. For example:
  - Moments and force will be introduced in terms of torque and forces on gears
  - Formulas for calculating gear forces will be presented without the geometrical details. These details will be deferred to the EGR 409 Machine Design course.
  - Concepts of equal and opposite forces on the contacting components will be introduced at the same time gears are introduced as mentioned above.
- If possible, design or selection of the machine elements will follow immediately after the concepts are introduced. For example:
  - After introducing the concept of moments and forces using gears, gear selection from the standard catalog will be taught. Again the details will be deferred to EGR 409 Machine Design course.
  - When reactions are calculated at the bearing location, bearings will be selected from a standard catalogue.
- Because of the very nature of this course, detailed theory will not be covered in the course.
- Many theoretical details will be deferred until EGR 309 or EGR 409. For example:
  - Derivation of bending stresses
  - Shear stresses in beams
  - Deflection of beams
- Emphasis will be on the grasping the bigger picture in terms of application and problem solving skills.

Objectives: At the end of the course, we anticipate that the student will learn…

1. Forces, moments and their origins in mechanical system - Assessment Method : Quizzes
2. Identification and description of components of an engineering components: gears, belts and chains, bearings, shafts etc. Assessment Method: Quizzes and Project
3. The basics and applications of equilibrium and force analysis. Assessment Method: Tests, Quizzes, assignments and project
4. The basics and applications of stress, strain, material properties, structures under common applied loads. Assessment Method: Quizzes and tests
5. Determination of stresses in the structures and the structural components: welds, bolts, shaft, frames etc. Assessment Method: Tests, Quizzes, assignments and project
6. Selection methods for basic off-the-shelf machine components. Assessment Method: Project

Second Course in Mechanics, EGR 309:

This course will become a statics and solid mechanics course with detailed underlying theoretical details. Since students have completed EGR 209 *Machines and Mechanics*, they can better understand the theory because of the early exposure to the application and visualization of the concept. Static and fatigue failure theories, which are not usually taught in a solid mechanics course, will be moved to EGR 409. (Table 1).

This course has a lab component, which will be used for FEA tutorials. The tutorials will be used as tools in teaching the solid mechanics concepts and for back-of-the-envelop calculations vis-à-vis FEA results. The underlying FEA theory is deferred to a separate course on FEA, which is developed and described below. However, it is anticipated that the students will be proficient in preprocessing techniques. The familiarity with the commercial software will provide them a head start in the new FEA course. Most importantly, it will also be emphasized that proficiency in the commercial software is a useful and essential skill but it is unrelated to the mastery of FEA.

Second Part of the Approach: FEA Course, EGR 329:

The second part of the approach is to introduce a new course EGR 329 Finite Element Analysis (FEA). We already have added introductory FEA material to EGR 309 [3] to better prepare our students to use FEA tools properly. However, Mechanical Engineering students need more theoretical background in this area. All phases of FE analysis will be covered e.g. geometry creation, modeling techniques, element types and their selection, material specification, problem solution and postprocessing of results using commercially available software. A focus will be placed on the behavior of FE, planning of the analysis, errors and mistakes, checking and critique of FE results. Throughout the course, the importance of understanding fundamental FEA techniques will be emphasized for becoming an expert engineer, as opposed to a mere well trained user of commercial FEA softwares.

Third Part of the Approach: Reorganization of the course sequence:

The third part of the approach is to reorganize the sequence of the course throughout the curriculum. The proposed plan of study is presented in Table 4.

Table 4 Proposed Study Plan

Fall Semester	**Winter Semester**	**Spring/Summer Semester**
First Semester EGR101 CAD/CAM	*Second Semester* **EGR 209**	No course -----------
Third semester **EGR 309**	*Fourth Semester*	**Co-op I**
Fifth semester **EGR 329 FEA**	Co-op II	*Sixth semester* **EGR 409**
Co-op III	*Seventh semester* EGR485 Capstone Project I	*Eighth semester* EGR486 Capstone Project II

EGR 309 is moved such that it directly follows EGR 209. This arrangement will provide valuable engineering education for the students before their first co-op employment semester.

EGR 329 FEA course is placed before the second co-op semester. EGR 409 is also moved before the third co-op semester. This also allows students to complete the machine design sequence before the capstone project.

Benefits and Anticipated Outcomes

It is anticipated that the proposed changes will address all the issues mentioned earlier. Specific benefits of the proposed changes include:

- Because of the changed content of EGR 209, students of all the programs will be better prepared in, among other things, solid mechanics skills with a broader background in machine elements before they go for the first co-op.
- The EGR 209 - EGR 309 arrangement will provide valuable engineering education for the ME and PDM students before their first co-op employment semester.
- We expect that the introduction of EGR 209 will help strengthen problem-solving skills and it will be one of the problems solving engineering course in the freshman year.
- It is anticipated that the introduction of EGR 209 in the freshman will reduce loss of talented students who do not feel sufficiently challenged by engineering courses in the freshman year.
- Students will be better prepared in FEA theory before they use this tool in the co-op semester. They will also be better prepared for their capstone design projects.
- Moving EGR 409 before the third co-op semester will allow students to complete the machine design sequence before the capstone project.

Challenges

Textbooks: Whenever a nontraditional course is offered, finding a textbook has always been a problem. A course pack containing instructor's notes is usually developed. One very good solution is to create a custom made textbook. McGraw Hill provides this facility. Different chapters or sections from different books can be selected and put into a single book. We are going to choose this type of a textbook. The book will be available only at the university book store in paperback form, and it is expected to be relatively inexpensive.

Scheduling and Resources: A resource analysis was carried out for the revised curriculum considering the current loading of both the ME and PDM faculty. The aggregate impact on teaching load was found to be a single lecture shift from the fall to the winter semester for both faculty groups combined, without any net increase in the faculty load, or need for additional new resources. Moreover, the new schedule is anticipated to provide expanded access and opportunities for early remediation for courses that normally impact secondary admission, such as EGR 209.

Assessment and Future Work

We are planning to improve the proposed change continuously based on the lessons learned at the end of every semester. Assessment of each part of the approach will be performed.

First part of the approach: Since all the students will be going through the proposed curriculum, it will not be possible to compare current and past students' performance in EGR 209. Because of the students' early exposure to the applications and visualization thereof in EGR 209, performance in EGR 309 and EGR 409 will be compared to the past performances.

Second and third parts of the approach: EGR 329 Finite Element Analysis will be offered for the first time as an independent course in FEA. Its impact will be judged by the employers' and students' surveys conducted after every co-op semester. Instructors' feed back is important in terms of pacing of the teaching, fine tuning the course content and changing the teaching method based on student's response and performance in the tests.

As stated earlier, the main objective of the paper is to disseminate the innovative approach and seek the constructive comments from engineering educators. A follow up paper will be written on initial findings after two or three semesters.

Bibliography

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[3] Chaphalkar, P., Maletta, M., "Development of Finite Element Analysis Lab Module in the Second Course of Solid Mechanics", ASME Congress at Seattle, WA, 2007

It helped me a lot in my course when the actual course material was hard to understand and useless. Simple put, this book got me an 'A'. Read more.Â This is the best book there is for introductory solid mechanics. The material is explained in a nice clear manner, and there is very little that is non-essential. This book inspired my interest in solid mechanics and now I am a researcher in solid mechanics. Read more. 4 people found this helpful. Meriam Kraige Engineering Mechanics Statics 7th Edition book dynstab1/Demonoid Mechanical Engineers' Handbook, Materials and Engineering Mechanics. 1,042 PagesÂ·2015Â·12.03 MBÂ·88,008 Downloads.Â advanced topics are dealt with in a companion volume - Mechanics of Materials 2. Each chapter contains Mechanics of Materials 2, Third Edition : The Mechanics of Elastic and Plastic Deformation of Solids and Structural Materials. 561 PagesÂ·1997Â·24.08 MBÂ·7,659 DownloadsÂ·New! to difficulty and furnished with answers at the end.Â 1,119 PagesÂ·2009Â·9.24 MBÂ·11,983 Downloads. Engineering Mechanics - Statics Chapter 2 The beam is to be hoisted using two chains Meriam Kraige Engineering Mechanics Statics 6th Edition book. The object of the course Mechanics may be defined as that science that describe and develop the conditions of equilibrium or of the motion of the material bodies under the action of the forces. Mechanics can be divided in three large parts, function of the studied object: mechanics of the no deformable bodies (mechanics of the rigid bodies), mechanics of the deformable bodies (strength of the materials, elasticity, building analysis) and fluid mechanics.Â These notions will be named as basic notions and they will be defined for each part of mechanics. In Statics we shall use three notions: the force, the moment of the force about a point and the moment of the force about an axis. Statics and Mechanics of Materials, 5th Edition. 5th Edition.Â YES! Now is the time to redefine your true self using Sladerâ€™s Engineering Mechanics: Statics answers. Shed the societal and cultural narratives holding you back and let step-by-step Engineering Mechanics: Statics textbook solutions reorient your old paradigms. NOW is the time to make today the first day of the rest of your life. Unlock your Engineering Mechanics: Statics PDF (Profound Dynamic Fulfillment) today. Journal (0000). A finite volume solid mechanics toolbox for openfoam. 3.Â Open-source software is, of course, not without its weaknesses: it requires a certain level of system administration experience and technical expertise in order to manage and develop content; in addition, there are often no ofcial code reviews or quality assurance processes in place, instead relying on users and developers to perform these verications, checks and subsequent xes.Â The denition of the engineering stress Ïƒs for a number of popular solid constitutive laws (Mechanical Law in the class structure) that are suitable for linear geometry (small strains and rotations) are given in Table I; the corresponding mechanical parameters are described in Appendix A, Table X. Linear (Hookean) elastic.