AC 2007-1801: INTRODUCTION OF NANOTECHNOLOGY INTO FUNDAMENTAL ENGINEERING CLASSES: HOW TO THINK SMALL IN A GOOD WAY!

Robert Pieri, North Dakota State University

Bob Pieri is Professor of Mechanical Engineering at NDSU in Fargo, ND. He has many conference publications on engineering education and design. His primary interest areas include: Engineering Education, CADD, Design, Fracture Mechanics, Materials Science and Alternative Energy Options. Prior to joining NDSU, he taught for 10 years at the US Air Force Academy.

Ghodrat Karami, North Dakota State University

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Abstract

Calls for engineering curriculum review to increase effectiveness and relevance have been made by both industry and university communities over the past decade. When considering the fundamental engineering courses in Statics, Dynamics and Mechanics of Materials it is important that the traditions long associated with these courses do not stand in the way of improving their relevance by inclusion of technological advances. This paper will discuss an approach and propose some examples that can be utilized to introduce the latest arena of technological research, nanotechnology, into one of these foundation courses, Statics. Using constructivist theory, this paper will discuss ways to facilitate intellectual development of new college students as they reanalyze their world in ways that open connections to the submicroscopic world. This multiscale engineering approach will be set in the framework of a Statics course utilizing existing physical and intellectual resources and activities in innovative fashions to impact the thought process of undergraduate engineering students. This will be done in such a manner, through the application of creative modules, as to allow these students to easily move up or down the size continuum, tackling problems at the micro- or nano-scales as easily as "full-size" problems. The efforts will be facilitated by using the simulation capabilities of Computer Aided Design and Drafting (CADD) as well as the analysis capabilities of Finite Element Modeling (FEM).

Overview/Background

In the midst of today's global technical challenges with respect to the environment, energy, healthcare and general quality of life, the pivotal role of engineering education to prepare the next generation of problem solvers goes with out question. However, as pointed out in recent publications, [1, 2] the topics, methods and audience of this enterprise requires ongoing assessment and revision to ensure relevance, efficacy and accessibility for local and global consumers. In keeping with this concept, the authors believe that the fundamental discipline of classical mechanics with respect to the current scientific interest in nanotechnologies, offers an opportunity for such assessment and revision. The focus of this paper, one of two proposed for the 2007 ASEE Annual Conference, will describe some beginning plans and actions for the inclusion of nanotechnology into a typical freshman year Statics course.

Curricular Context

Since classical mechanics is such a fundamental component of modern engineering education, see figure 1, most practitioners see little need for alterations of teaching methods that were "good enough for my generation". However a new wind is blowing and recent articles call for the

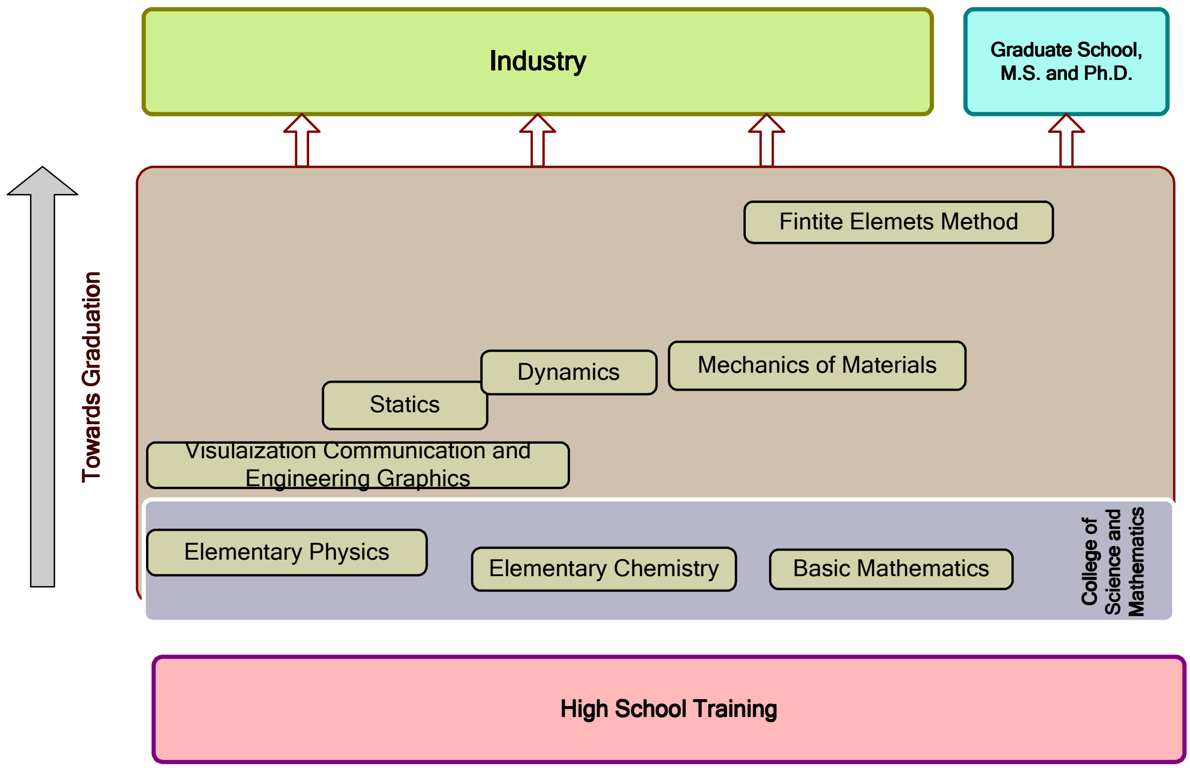


Fig. 1. Courses of Mechanics in Engineering Curriculum

review of the basic engineering curriculum from both academic and industrial perspectives [3, 4]. This is combined with a new technical realization that understanding the way materials go together at the most fundamental level, impacts the final application and properties of structures; reflecting the old material science saw that atomic structure influences properties, which influence material utilization, which influences final design. It appears to the authors that there is a nexus of communication technology, scientific development and engineering pedagogy that would make it auspicious for the incorporation of new approaches to traditional topics in some of the most fundamental engineering courses.

In this particular instance, the details of the revision involve the inclusion of multiscale mechanics at the very induction of some new practitioners to engineering. It is the authors' observation that if subject matter is presented in an attention-capturing fashion, constructing upon prior perceptions and knowledge of the surrounding world, students can then develop relatively sophisticated interpretations of their surroundings. Specifically, the authors propose that students, as a result of these innovations, will develop enhanced skills in visualizing a more complex world around them. And as an outcome of such a sophisticated understanding, these students will have a much more innate understanding and working ability with size scales that exist, and the ramifications for our environment. It is proposed that this process can be accomplished, with minimal instructional cost, through the use a series of focused modules to accomplish the following thrusts in a revitalized multiscale mechanics curriculum:

- Introduce new modules presenting multiscale mechanics as conceptual representations of existing affairs in nature.
- Apply computer-aided engineering and finite elements analysis methods to the construction of virtual space simulations, upon which students can build self-meaningful internal representations.
- Improve students' awareness and attitudes towards all the emerging implications and opportunities of multiscale-mechanics, eventually trickling down to the general academic community.

As discussed below, these modules will be simplified without being "dumb down", but will try to enhance the recognition of the universality of certain solution methods. This would appear to be a direct extension of Einstein's famous quest for a unified theory describing the behavior of all components of the universe. While the authors do not lay claim to such a grandiose quest, they do recognize that the journey must begin with a single step placed somewhere, for while the journey of a planet is on a different scale from the path of a subatomic particle, the two objects are controlled by similar laws of nature, which could lead one to speculate: "This really is ALL rocket science!"

PREPARATION OF THE AUDIENCE

As any moderately successful speaker can attest to, understanding the background and values of the audience is a good first step toward successful oration. Along such lines, an initial survey was given in an engineering statics course. Listed below are the questions contained in the survey.

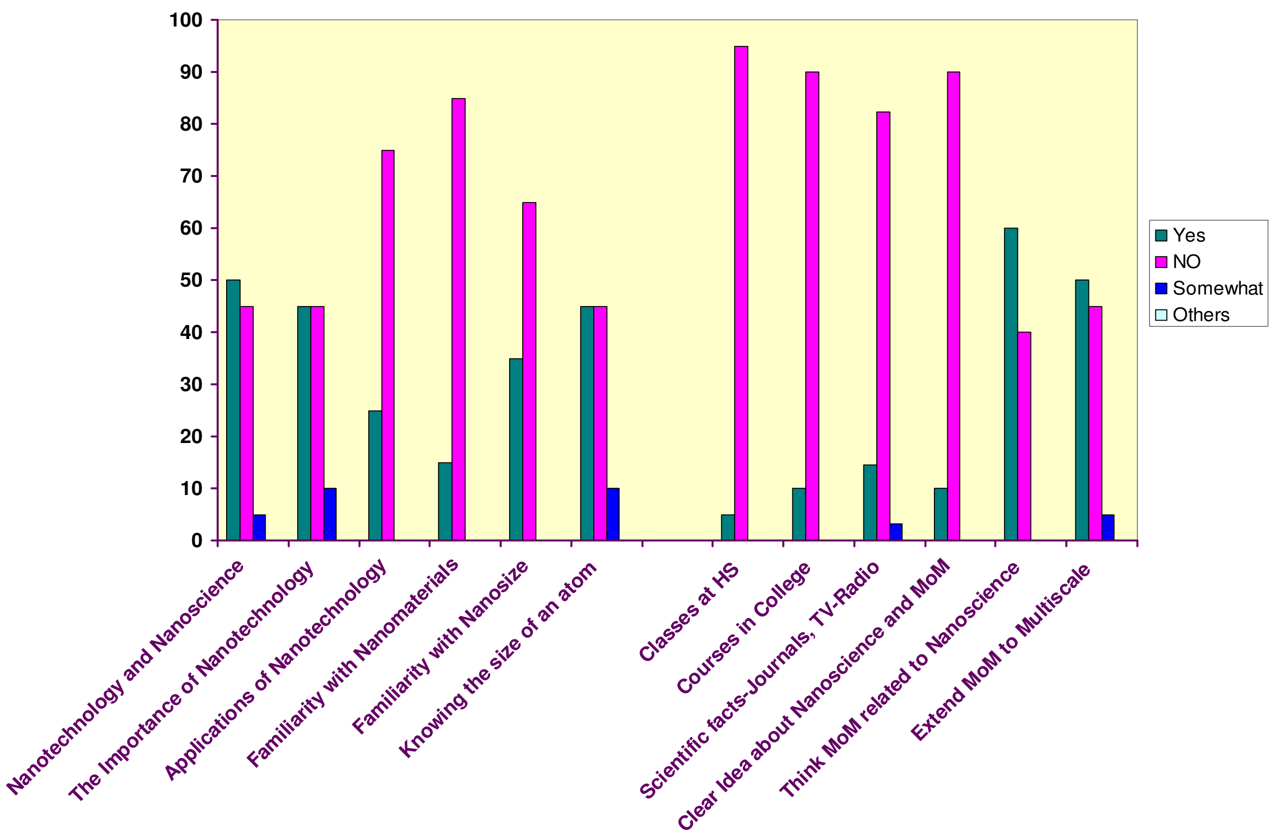
1. Do you know what nano-technology and nanoscience is?
2. Do you know why nanotechnology is becoming so important in engineering?
3. Do you know some applications of nanotechnology?
4. Do you know why material properties such as Young's modulus and heat conductivity coefficients of nanosized materials are superior to common materials?
5. Are you familiar with any nanosized material?
6. Do you know how nanosize is?
7. Do you know the size of an atom?
8. Do you think that the forces that hold you to the earth any different from the forces that hold a grain of sand to the earth?
9. What do you think the ratio between goal ports of a football field and the distance between the earth and our sun?
10. Did you have any classes in HS which was related to nanoscience and were you instructed?
11. Have you taken any courses related to nanoscience in College?

12. Have you read any scientific facts about nanoscience? Elaborate on the program, such as News, self reading, TV programs
13. Do you a clear idea how nanoscience is related to courses of mechanics you will take at college?
14. Do you think Statics has any relation with nanotechnology? And if yes in what aspects?
15. Do you think will it more beneficial if we extends the Statics to nanosized and multiscale analysis?

(Note: Word selection and phraseology were chosen to allow a single assessment tool to be used in both statics and mechanics of materials classes. As this will be an ongoing study, continual refinements of surveys and questionnaires will occur.)

A summary of responses to the survey are shown in figure 2, below. The responses displayed on

Figure 2: Preparation, Expectaion-Static Students



the left side of the chart are intended to reflect the individual's perceptions or expectations with respect to nanotechnology, while the responses on the right side of the figure are intended to reflect the level of prior exposure the students have had to nanotechnology. As one can see by the general prominence of the "no" bars across the entire chart, the secondary schools preparation of students for advanced science and engineering courses needs work. The two categories in which yes and no responses came closest, were those dealing with really broad generalities i.e.

having heard of nanotechnology and knowing that it is important and the category dealing with a specific number i.e. the size an atom, a "fact". Some of the detail questions tried to concentrate on the students' understanding of comparable ratios i.e. the day-to-day world to the nano-world or familiar distances to space distances (for example the ratio of the distance between goalposts on the ends of a football field to the distance that the earth is from the sun, a ratio of approximately 10^9).

By bringing to light such day-to-day scaling factors, the science/engineering professor is able to expand the newly developing thought process. This is comparable to recent articles in the popular literature discussing findings that a multilingual household can expand the verbal abilities of a toddler in that environment more than just a summative model would suggest. At a more aggressive level of education, application of advanced tools such as FEA or CADD, applied in introductory courses, could facilitate quicker and stronger student constructions of the nano-world from existing experiences. For example, as a new student compares the loading of a typical frame due to gravitational attraction and wind forces to the loading of a carbon nano-tube (CNT), due to gravitational and electrical attractions and Van der Waal's forces, the student should be able to focus on two key points. One, in both cases the loading is comparable in that it can be broken into components, which can be combined with other sources of load, and that for equilibrium to be maintained some resisting force has to be supplied. The second commonality for new engineering practitioners is that engineering problem solving can often be reduced to an evaluation of trade-offs resulting in the selection of attributes which most significantly contributes toward obtaining desired outcomes, i.e. ignoring "trivial" contributions to a force diagram.

MODULES

As stated above, one key objective to this suggested course revitalization is to accomplish the goals through optimal application of educational overhead, i.e. professors' time. Since a vast majority of the material covered in a statics course, or any other fundamental courses, is quite necessary, the content needs to be maintained. It would seem that the "magic trick" of covering more stuff in the same amount of time needs to focus on student engagement. Neither dry lecturers nor non-relevant examples will stimulate the student quest for knowledge needed to pull off this trick! However, short, intense and focus activities, or modules, could light the fires of learning, while not displacing much existing content. An additional benefit for the "Sage on the Stage" is that these modules should be relatively small, one hour or less, and self-contained, a handout with questions or a worksheet or an interactive Web session or podcast. Some existing or concepts for modules are described below.

Modules intended for use in existing statics courses would focus on three primary areas. The first would be examples of scale from the surrounding day-to-day world or from easily accessible research. As currently constructed this module, besides including the goalposts example given above, includes the typical diagram seen scaling a person to an molecule or smaller component. The module takes advantage of comparing available large structures, buildings, radio towers, aircraft, etc., to familiar small items such as scanning electron microscope (SEM) pictures of insects or representations of DNA strands. Another familiar aspect of this module would be the famous NASA series of pictures tending from satellite imagery of the earth to SEM scans of plant and small animal life. The concept would simply be to increase the students' familiarity and innate abilities with scales. This module this module has been handed out in a statics class but the evaluation has occurred in the follow on mechanics of materials course and presented in another paper in these proceedings.

A second module could focus on the application of basic equations, tools and processes in statics i.e. 'F = ma" and vector analysis as applied to problems at different scales with very different ratios of forces. This would allow the student to realize that, on a regular basis, problems are solved including only those factors that play a significant role in the final solution, i.e. rocket propulsion versus solar wind power. This could lead to questions such as how much acceleration can be allowed while still effectively assuming at rest conditions. Tackling these types of questions quickly leads the student to some of the higher levels of Bloom's taxonomy. This module could lend itself easily to a workbook format.

The third module could focus on applications from the nano-world still being subject to the same laws of mechanics. This would encompass such items and as a molecular motor still requiring action and reaction to be able to drive some process. Another example, as indicated above, would be that a CNT has the exact same force and moment relationship to its loads and support that a whip antenna would have. Another topic for module could be the CNT used on the probe of an atomic force microscope compared to an old phonograph needle compared to a finger feeling the texture of a piece of clothing. These comparisons should lead to a richer understanding of structure and an illustration of the application of analogies to understand phenomena. This type of module seems to lend itself to a narrated podcast/webcast type of presentation with a follow on requirement for a five-minute response paper.

Conclusion

As engineering mechanics is the starting point for some branches of collegiate engineering education, efforts should be spent to upgrade the classical mechanics courses of statics, dynamics and mechanics of materials to include multiscale concepts. As this paper illustrates, beginning underclassmen in an engineering program know little about nanotechnology as a new emerging technology, as documented in a questionnaire about students' preparation and expectations. Additionally, this paper further attempts to discuss and illustrate relatively simple concepts, exercises and examples can be used in short non-obtrusive methods to introduce and expand the students' thought processes, while still meeting the needs of fundamental course content. The suggested modules provide an avenue that could expand new practitioners experience with a multiscale universe providing them with a richer set of opportunities for problem solving in that environment.

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