Session 3647

Development of an Integrated Mechanics Curriculum for Engineering and Engineering Technology.

Mukasa E. Ssemakula, Roger W. Pryor, Paul J. Eagle and Jonathan M. Weaver

Division of Engineering Technology, Wayne State University/
Institute for Manufacturing Research, Wayne State University/
Department of Mechanical Engineering, University of Detroit Mercy/
Department of Mechanical Engineering, University of Detroit Mercy

Abstract

Understanding of mechanics is a fundamental requirement in many areas of study in both engineering and engineering technology. This paper describes a modularized curriculum model in Mechanics designed to serve the needs of students pursuing degrees of Bachelors of Manufacturing Engineering (BME) and Bachelor of Science Engineering Technology (BSET) in Manufacturing. The curriculum provides a unified learning experience including topics in mechanical physics, statics and dynamics rather than the traditional distinct courses in these subjects. All learning experiences are rooted first in practical applications with which the students are familiar and focus on instilling an intuitive understanding of key concepts prior to the introduction of formal analytical techniques. The complete curriculum is being implemented in computer-based multimedia form, allowing for individualized self-paced learning.

1. Introduction

The Coalition for New Manufacturing Education, also called the Greenfield Coalition; is made up of Focus:Hope's Center for Advanced Technologies (CAT) - a leading edge manufacturing and education facility; academic partners University of Detroit Mercy, Lawrence Technological University, Lehigh University, University of Michigan, and Wayne State University; as well as industrial partners Chrysler, Ford, General Motors, Detroit Diesel and Cincinnati Milacron; and the Society of Manufacturing Engineers. The goal of the Coalition is to develop a new approach to the education of technicians, technologists and engineers working in the manufacturing field. The CAT, where the students (referred to as 'candidates') are full-time employees, is the primary delivery site for the curriculum. The educational experience at the CAT provides candidates with a diverse technological education integrating the manufacturing resources available on the shop floor into an applications-based engineering education.

The Coalition's overall educational model entails hands-on training in the programming, operation, maintenance, and repair of manufacturing equipment; interdisciplinary study of pertinent mathematics, science, engineering, business, and general education courses; as well as structuring and delivery of knowledge within a production environment to provide context. Another goal of the Coalition is to expand the learning experience to include team work, case studies, and hands-on activities. The idea is not that the instructor will disappear from the picture, but that his role will change from a lecturer to a coach. The curriculum is being developed in a modular fashion, making it possible to use a mix of sub-discipline experts to design and deliver modules within a given knowledge area.

2. The Engineering Mechanics Curriculum

This paper discusses the curriculum developed to satisfy the knowledge needed by the candidates in the engineering mechanics knowledge area (also referred to as "*Mechanophysics*"). The curriculum provides a unified learning experience in mechanical physics as well as statics and dynamics to both engineering and engineering technology program candidates. This curriculum organization is illustrated in Figure 1. The majority of the curriculum is a core that is common to candidates in both programs. An additional engineering specific cognate provides candidates pursuing Bachelor of Engineering degrees with the necessary analytical underpinnings of mechanics. This cognate, to be taken only after successful completion of the core, covers topics such as three dimensional vector mechanics, derivative-based linkage analysis and integration-based inertia calculations. A technology specific cognate focuses on applications of concepts such as properties of sections, mass and inertia, work and energy to manufacturing processes and equipment. For example, candidates learn how to instrument a machine for measuring various aspects of its motion, how to estimate the power requirements of a given manufacturing process, how mass and inertia influence spin-down time of a machine, and how different cross-sectional shapes affect the rigidity of structural members in a machine. Ultimately, all these are related back to manufacturing issues such as quality of parts made and feasible production rates. This is important to the candidates because it provides a familiar context for the material covered and helps provide motivation for learning.

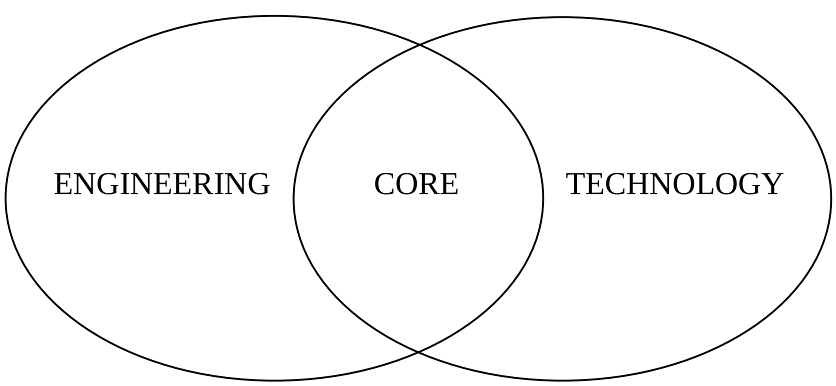

Figure 1. Curriculum Organization

The curriculum development capitalizes on the principle that students grasp principles most effectively if the principles are presented first in the context of familiar phenomena and then generalized. The curriculum is based on the premise that a clear understanding and appreciation of mechanics can be developed using descriptive applications-intensive methods. Once a candidate has an intuitive grasp of mechanics, the analytical techniques are much more easily learned. This is often demonstrated when people in the skilled trades pursue relevant academic degrees later in their careers. These people often exhibit an exceptionally clear understanding of mechanical phenomena.

The complete knowledge area was subdivided into a total of 17 different modules. The full modular content is given in Table 1.

Table 1. Detailed Modular Content

Module	Target Competencies	Degree(s)
EM-1B Units and Measurements	Units, SI/USCS, Accuracy, Repeatability, Mass, Significant Figures, Newton's 3rd Law	BME BSET
EM-2B Intuition and Kinematics	Rectilinear Motion, Vectors, Average and Instantaneous Quantities	BME BSET
EM-3B Intuition and Forces	Forces, Moments, Hooke's Law, Internal and External Forces, Resultant, Couples	BME BSET
EM-4B Mechanical Equilibrium	Equilibrium, Free Body Diagrams, Reactions at Supports and Connections, Newton's 1st Law	BME BSET
EM-5B Load Supporting Structures	Internal Forces, Beams, Trusses, Frames, Shear and Bending Moment	BME BSET
EM-6B Describing Losses and Resistance	Dry Friction, Losses and Friction Bearings	BME BSET
EM-7B Kinematics	Position, Velocity and Acceleration; Coordinate Systems, Tangential and Normal Acceleration	BME BSET
EM-8E Calculus Concepts and Motion	Relationship between displacement, velocity, acceleration and jerk. Numerical Integration	BME
EM-9E Forces in Three Dimensions	Vector Based Analysis	BME
EM-10E Distribution of Area and Mass	Centroids, Section Properties, Volume Properties	BME
EM-11E Kinetics of Translating Machinery	Newtonian Techniques, Energy Methods, Momentum Methods	BME
EM-12E Kinetics of Rotating Machinery	Newtonian Techniques, Energy Methods, Momentum Methods	BME
EM-13E Calculus and Force Systems	Force and Displacement Infinitesimal Motion	BME
EM-14T Area Properties and Stiffness	Centroids, Composite Bodies, Area Moment of Inertia, Parallel axes	BSET
EM-15T Mass Properties and Motion	Mass and Acceleration, Inertia and Acceleration, Parallel Axis Effects	BSET
EM-16T Sizing Equipment: Power/Energy	Work and Energy, Power, Power Requirements	BSET
EM-17T Instrumentation and Motion	Measuring Velocity and Acceleration Vibration Monitoring	BSET

The first seven modules constitute the core of the curriculum and will be taken by all candidates regardless of degree path pursued. The next six modules constitute the Bachelor of Manufacturing Engineering (BME) cognate while the remaining four modules constitute the Bachelor of Science in Engineering Technology (BSET) cognate. This curriculum differs significantly from the traditional classroom sequence of physics, statics and dynamics. The traditional classroom experience is largely based on analysis. This curriculum on the other hand is based on first instilling an intuitive notion and understanding of key concepts. This understanding is then supported and reinforced by introducing the appropriate analytical tools. Much of the learning will be experientially-based. The involvement of candidates with the on-going manufacturing operations of the CAT provides numerous opportunities for an applications-based introduction to mechanics. Moving and leveling a machine for example presents an opportunity to see the consequences of the equations of static equilibrium on a non-trivial scale. Lifting a non-homogeneous object, such as a lathe, with a crane provides opportunities to determine centroidal locations. Measuring surface speeds during a turning operation shows the physical significance of tangential velocities. Balancing a machine illustrates the effects of centripetal acceleration. Digitized video of such phenomena, as well as animations and simulations where appropriate, are incorporated into the computer-based multimedia instruction modules.

3. Design Considerations

This curriculum was developed in parallel with the Coalition's Thermophysics [1,2] and Electrophysics [3, 4] curricula in engineering science, designed to form three knowledge stems that are threaded together with the supporting knowledge in Mathematics [5] to form a tightly integrated educational experience.

Most students are used to a lecture which introduces important principles along with examples of applications, with the textbook serving to provide the details and reference material. An instructor can answer questions on the spot and change course if he senses the students are not grasping a particular point. For the student to learn effectively from a computer, it should provide an experience comparable to a live performance by an instructor and nearly as interactive. In any case, the student must remain actively engaged. Well designed courseware will hold the students' attention and encourage active learning [6]. Our experience in developing computer-based instruction modules suggests that such modules should be not just an electronic textbook, but rather a multimedia presentation including a mix of the following characteristics:

- Color pictures, animations, and video clips
- Audio, either stand-alone or in reinforcement of text and graphics
- Frequent quizzing of the user as he progresses through the module
- Hypertext links ("hot words")
- Access to reference material from anywhere in the module
- User-directed simulations that allow parametric investigations
- Feedback based on user response

The first seven modules were designed to concentrate on the fundamental principles that underpin the mechanics of rigid bodies. The concepts covered span the range from those topics usually covered in a first Physics course to the college level course in dynamics. Consequently the need for separate courses in Physics, Statics and Dynamics is eliminated. The novel idea is to have the modules focus on the basic scientific concepts while integrating their engineering applications in a context familiar to the candidates. For those pursuing the Engineering degree, these concepts are then treated in greater depth in the subsequent advanced modules focusing on the analytical techniques. For those pursuing the Engineering Technology degree, more extensive manufacturing applications are presented.

4. Implementation

Our development experiences so far suggests the following elements are crucial to the effective application of computer-based instruction modules:

1. Provide abundant feedback. If a user is asked to type in a numerical answer and inputs the wrong value, give hints based on the user's response if possible.
2. Use audio to support text. This should be done selectively, to emphasize important points, or perhaps when posing questions.
3. Provide abundant visual stimuli in the form of pictures, video, animations and simulations.
4. Provide clear navigation instructions.
5. Allow the user access to any part of the module at any time. The enhanced control over the learning reduces the need for remediation at problem solving sessions.

This curriculum was based on the premise that engineering principles are best understood by demonstrating their practical applications. This has been achieved through a combination of state-of-the-art computer mediated tutorials, animations, simulations and experiments incorporating the principles mentioned above. In addition to the above, our modules were specifically designed to provide the following:

- Case studies and "real-world" examples
- Manufacturing relevance

A typical module starts with a digitized video or animation demonstrating a manufacturing application of the content to be covered in that module. Figure 2 below leads into a discussion of deformations resulting from application of cutting forces.

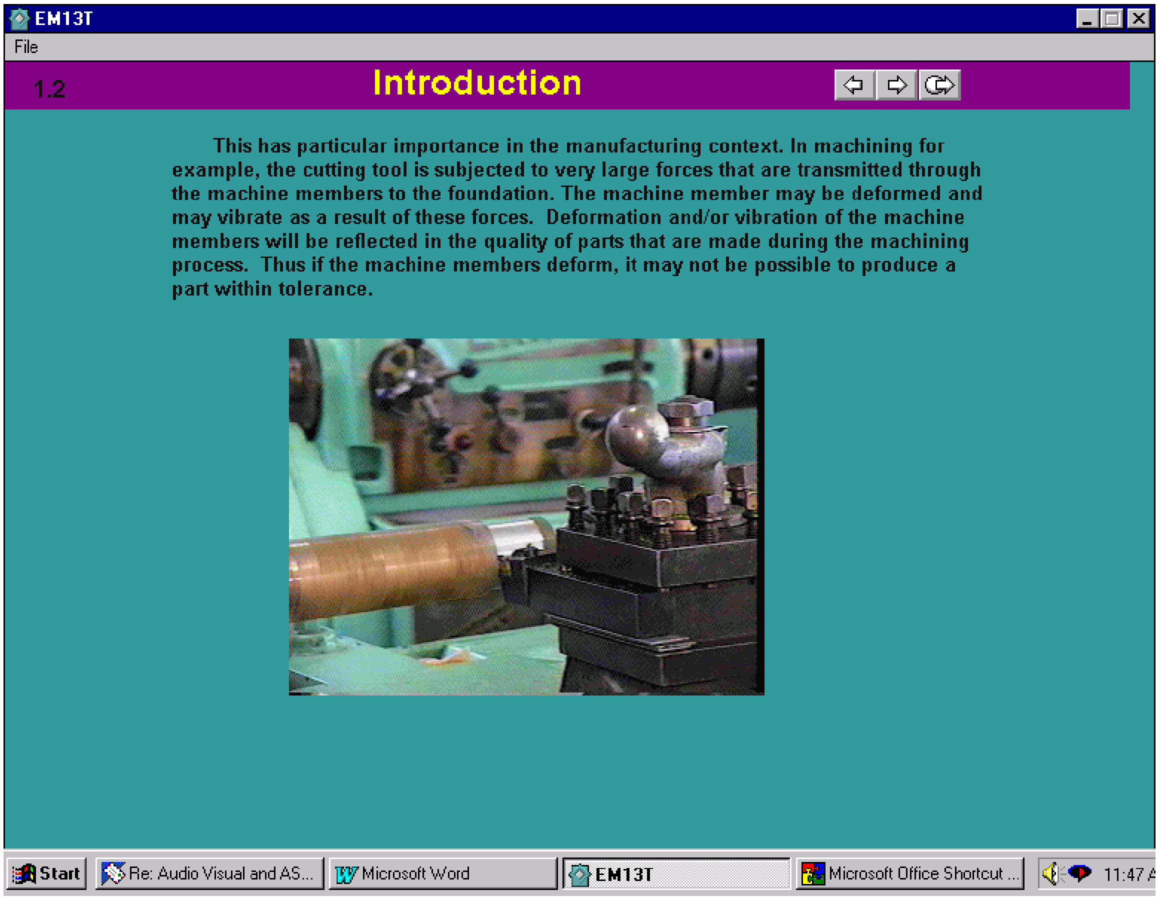

Figure 2. A Digitized Video of a Manufacturing Scene

A set of learning objectives, as well as topical pre-requisites for the module, are then presented. The interactive capability of the computer is utilized to carry out an on-line assessment of how well the candidates understand the pre-requisite material before they proceed with the new content. As originally designed, failing the module "pre-test" would lock the candidate out of the module but experience has taught us that this is not a good practice. The candidate should instead be allowed to proceed with the material if they so chose that way they can appreciate the need for the pre-requisite material as they get to sections that they cannot follow on their own. This allows the diligent student to keep abreast of the rest of the class by doing extra work as needed.

A formal presentation contextualizing the module then follows with care taken to focus on manufacturing applications. The new content is then presented using a mix of text, diagrams, digitized video, animations and simulations. The module is concluded with a case study typically taken from the shop floor. Figure 3 shows a sample animation of an objecting falling to earth due to its own weight.

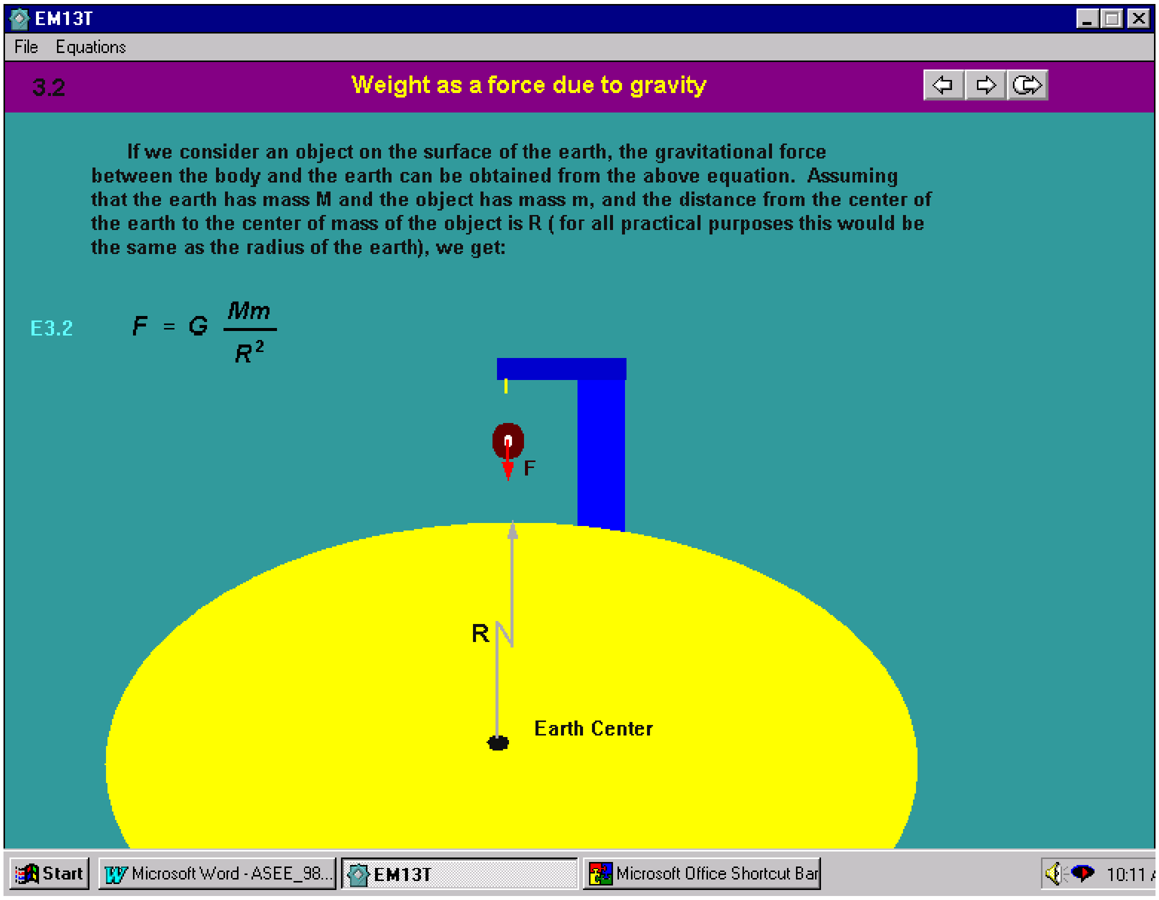

Figure 3. Animation of a Falling Object

5. Conclusion

Computer-Based Instruction is an important new technology that will continue to revolutionalise how knowledge at all levels of education is delivered to students. An experimental curriculum in Engineering Mechanics has been developed as a result of the work reported here which enables targeted content to be delivered to Engineering and Engineering Technology students, based on a common development platform. Although initially developed for a specific cohort of working students (and consequently contextualized to their work setting), the philosophy employed is easily adaptable for students in other settings. The power of the computer and use of multimedia makes this an engaging learning experience for the students.

Acknowledgment:

This work was funded by the National Science Foundation through a subcontract under the Greenfield Coalition, cooperative agreement number EEC-9221542. We would also like to acknowledge our graduate student, Ricardo Suarez, who has done the Authorware® programming for the project described here.

References

1. Schumack, M.; Vaksman, M.; Das, S; Belfield, K.; Ssemakula, M.; Pryor, R.; Sheyman, V. and Schultz, W. W.: ‘Thermophysics for Manufacturing Engineers: A Nontraditional Approach.’ *Proceedings, 1997 Annual Conference of ASEE,* June 15-19, 1997; Milwaukee, WI.

2. Ssemakula, M.E.; Pryor, R.W. and Schumack, M.: ‘An Applications Oriented Approach to Teaching Thermal Science.’ Proceedings, *1997 Frontiers in Education Conference,* Nov. 5-8, 1997, Pittsburgh, PA.

3. Al-Holou, Nizar and Bow, Nancy; "Development of A Computer-Based Instruction in Electromagnetism." *Proceedings, 1997 Spring Conference of the North Central Section of ASEE,* April 10 - 12, 1997; Dayton, OH, p.p. 282 - 286.

4. Al-Holou, Nizar "Development of Electroscience Curriculum for Greenfield Coalition" Proceedings, *1997 Frontiers in Education Conference*, Nov. 5-8, 1997, Pittsburgh, PA.

5. Ssemakula, M.E.; Sheyman, V.; Houh, C.S.; Singh, N.; Zhong, X.K. and Bankowski, E; ‘New Approach to Developing A Mathematics Curriculum for Engineers.' *Proceedings, 1997 Spring Conference of the North Central Section of ASEE,* April 10 - 12, 1997; Dayton, OH, p.p. 518 - 525.

6. Helps, C. et al "Revitalizing Technical Education with Structured Use of Multimedia." SME, ER, 1996.

MUKASA E. SSEMAKULA graduated from the University of Manchester Institute of Science and Technology, UK, with a Ph.D. in Mechanical Engineering in 1984. He joined Wayne State University in 1993 where he teaches courses in Manufacturing/Industrial Engineering Technology. His has research interests and has published widely in the areas of Manufacturing Systems and Computer Aided Instruction.

ROGER W. PRYOR graduated from the Pennsylvania State University, with a Ph.D. in Physics in 1972. He joined Wayne State University's Institute for Manufacturing Research in 1988. His current research topics are in Vacuum Microelectronics and Materials Synthesis. His has research interests and has published widely in the areas of Electronic Materials and Microelectronic Devices.

PAUL J. EAGLE received his Doctor of Engineering degree from University of Detroit Mercy in 1990. He has served on the faculty of the University of Detroit Mercy since then and is currently an Associate Professor in the department of Mechanical Engineering. His research interests are in the area of Manufacturing Systems.

JONATHAN M. WEAVER received his BSME from Virginia Tech in 1986, and his MS and Ph.D. in Mechanical Engineering from RPI in 1990 and 1993, respectively. Since 1993, he has been an Assistant Professor in Mechanical Engineering at the University of Detroit Mercy. He has research interests in the area of Robotic Systems.