

AC 2007-929: MOM IN ACTION

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MOM in Action

1. Introduction

The application of mechanics of materials continues to grow beyond aerospace, civil and mechanical engineering where it originated from the need for analysis and design of structures. Metallurgical engineers have long used mechanics of materials concepts as metal has been, and still is, the dominant material of choice in engineering design. Chemical engineers need the concepts as polymer composites and plastics usage continues to grow in engineering design. Geological engineers need the concepts for explanation of earthquakes and other geological phenomena. Foresters need the concepts as wood, like other biological tissues, becomes stronger during growth under stress. Biomedical engineers need the concepts for stress analysis of human tissues and implants.

One approach to address the growing list of applications of mechanics of materials is to fragment the body of knowledge and teach the fragment needed in individual disciplines. The increased duplication of the resulting dedicated courses will further stress the over burdened engineering curriculum, stretch faculty resources to cover more courses, and defeat the need for interdisciplinary education and research.

A better alternative to the above approach is to teach a common mechanics of materials course that covers the basic concepts and demonstrate the variety of applications of concepts through numerical examples and problems. Such an approach raises several educational challenges. One such challenge is student motivation for studying mechanics of materials concepts and then remembering them for future use. This challenge of motivation and memory can be partially addressed through development of modules called 'Mechanics of materials in action' or briefly 'MOM in Action'. This paper describes two 'MOM in Action' modules and how these modules address the issues of motivation and incorporates insights on human learning.

2. Student motivation

The mechanics of materials course serves as a pre-requisite for many courses in machine design and structures. The course content of mechanics of materials is well established and any significant changes in the content would require redesign of curriculum in many engineering disciplines. However, if the course is to meet the needs of structural analysis as well as the needs of other disciplines, then the presentation and development of principles and concepts will have to have greater generality. Mathematical generalization is an effective, compact way of organizing large amount of information. But intrinsic to any generalization is the increase in abstraction. Engineering students have a predisposition towards applied work and an increased emphasis on abstraction might have detrimental effect on motivation to learn the concepts.

Educators have long known and neuroscientists confirm the idea that repeatedly experiencing new ideas leads to deeper encoding of those ideas and improves the likelihood of successfully retrieving and using the learned material across domains¹. By repetitive use of the general principles to specific cases the students can be repetitively shown the underlying structure and patterns and thus enhance student learning and the accuracy of conceptual retrieval. By using heuristic arguments and problems designed specifically to be solved by inspection and using experimental

observations in form of photographs, one can establish a complimentary connection between intuition, observations, and mathematical generalization⁵. By using photographs with schematics drawn either on the photographs or along side it one can show the practical problems that can be solved by mechanics of materials as well as teach how to create mathematical models of reality. By connecting concepts to their historical evolution and their usage in advanced topics one builds a story of a concept which is important for motivation as well as for retention of the concepts as described in Section 3. Ideas discussed in this paragraph have been elaborated by Vable for the introductory mechanics of materials course^{5,6} and for intermediate mechanics of materials course^{7,8}.

‘MOM in Action’ modules are another teaching aid that show the practical application of mechanics of materials concepts and incorporate historical insights on human learning discussed in the next section.

3. Insights on human learning

Observers of human learning have long believed that profound and long-lasting human learning involves emotional engagement, issues involving the credibility of the information source, as well as the more superficially obvious cognitive dimensions. Aristotle, in his Rhetoric⁹, argued that effective communicators and, therefore, teachers must be able to: (i) engage students emotionally, (ii) demonstrating their profound mastery of the subject at hand, and (iii) present new ideas with clarity and cogency. Aristotle’s advice to contemporary college instructors might be that they should present real world cases that demonstrate the utility and efficacy of the material being presented as well as exposing students to theory and problem-solving protocols.

More contemporary learning theorists, like David Kolb¹⁰, argue that humans learn best when they engage in learning that complements the way that the human nervous system processes experience. He suggests that deep and more durable learning occurs when students are given an opportunity to encounter concrete experiences directly, employ reflective observations regarding those experiences, engage in a periods of abstract conceptualization, and then participate in learning activities that involve active experimentation such as projects and classroom discussions. Once, again, the inclusion of rich case studies from other domains such as MOM in Action would seem consonant with Kolb’s ideas.

Another influential contemporary educator long concerned with human learning, John Biggs, argues¹¹ that a student’s choice of learning strategy and his/her motive for learning largely predetermine the depth and durability of their learning. Biggs argues that students engage in superficial learning when their study strategies primarily involve doing the least that they possibly can during the term and then cramming at the last minute to pass exams. If a student’s primary motive is earning an acceptable grade rather than truly coming to understand and master a discipline as an emerging practitioner, their learning is likely to be superficial and quite transient. Biggs would concur that learning activities such as those proposed in this paper might encourage more direct engagement with the material and, therefore, encourage deeper and longer lasting learning.

The findings of contemporary neuroscientists also suggest that the inclusion of real world examples following exposure to the theories and problem solving methodologies that underlie our disciplines should encourage more lasting learning. Larry Squire and Eric Kandel², preeminent researchers in the molecular biology of cognition suggest that “when encoding is elaborative and deep, memory is much better than when encoding is limited and superficial.” These neuroscientists suggest that the more fully a student processes new subject matter, the better the odds of accurate retrieval later on. In effect, more practice makes for more perfect retrieval for longer periods of time. The use of real world cases from other domains to encourage student learning is also supported by the body of findings of such neuroscientists. Squire and Kandel² unequivocally argue that “memory is better the more we have a reason to study, the more we like what we are studying, and the more we can bring the full breadth of our personality to the moment of learning”.

Squire and Kandel’s review of neuroscientific research also leads them to suggest that circling back on learned concepts tends to encourage deep and durable encoding. If “we can arrange for multiple learning episodes instead of just one, we can rehearse the material to ourselves, and we can build into the learning context retrieval cues that will likely be present when memory is later to be used”³. Presenting students with real world cases from outside the primary domain should, therefore, provide students with one or more additional opportunities to link the new concepts with other knowledge sets and, therefore, improve the odds of long term retrieval.

Real world cases, especially those dealing with failure and failure mode analysis, also have the potential of stimulating students emotionally as well as cognitively. Squire and Kandel⁴ observe in this regard, “It is well known that people remember emotionally arousing events especially well. In formal experiments, declarative memory for emotionally arousing material is almost always better than memory for neutral material.”

Finally, brain imaging studies show that when we recall stories (episodic memories) rather than simply reviewing facts or theoretical constructs (semantic memories) we use the right front cortex area of our brain. While we use the left front cortex for many other activities including encoding stories and for recalling the facts embedded in stories, we add right front cortex when we retrieve the stories from our memory. James Zull, a biologist and director of the teaching center at Case Western, hypothesizes¹² that it is information processed and then stored in the right front cortex that then works with information stored in the left front cortex to produce retrievals of the stories that are not only factually correct but that are laden with the sort of contextual meaning that gives relevance and purpose to our learning. To put it bluntly, the combined data retrieval involving both the right and left frontal cortices not only assures that we can retell the story, but that we will retain the point of it all, as well. This, then, is another reason that embedded ‘MOM in Action’ might encourage deep and durable encoding and retrieval where the overarching goal or point remains intact.

4. ‘MOM in Action’ modules

The proposed ‘MOM in Action’ modules would consist of a short description of natural phenomena or an engineering triumph or an engineering disaster, the impact or consequences of the event

described, a photograph showing the event aftermath and / or a schematic for purpose of explanation, and a phenomenological explanation using mechanics of materials concept under study.

Section 3 highlights that a multitude of strategies can be and should be used in teaching. Section 3 also emphasizes that a concept will be better learned and remembered when it:

- educates beyond what is needed for passing exams;
- is a part of a story that stimulates students emotionally as well as cognitively;
- is elaborative rather than a simple review of facts and theory;
- causes reflective observations about concrete experience.

Tragedies, engineering or natural, have emotional impact particularly if these occurred in student's cognitive lifetime. The description of such an event is part of creating a story. Phenomenological explanation of the causes is elaborative and takes the student beyond the factual and theoretical description of the concept. In other words, the elements that will be used in the development of 'MOM in Action' modules are those that educational research and neuroscience considers important in the learning and the retention of concepts.

The two modules discussed below are attached at the end of this paper.

4. 1 Module 1: Stress and Sumatra tsunamis

In the introductory mechanics of materials course, the concept of normal and shear stress are introduced. Having seen some numerical examples in class and their textbooks, the student would have a rudimentary concept of stress. At this stage, module 1, which describes the tsunami that had a devastating effect on South Asia could be introduced.

The first paragraph of module 1 describes the event, nature's awesome power that is unleashed in an earthquake and the human toll it exacts. Paragraph two and three are simple explanations of earthquake mechanisms which an educated person with a BS degree in our technological society should be expected to know. The last paragraph is a summary statement that earthquakes are nature's mechanism of releasing locked up stresses.

4. 2 Module 2: Strain and Challenger Explosion

Deformation and strain is another major concept introduced in the introductory mechanics of materials course. Once more having seen some numerical examples in class and textbook the student would have a rudimentary concept of deformation and strain. At this stage module 2 that is shown describing the Challenger explosion could be introduced.

The first paragraph of module 2 describes the event, the engineering disaster, the loss of life, and the impact on citizen whose goodwill is necessary for large public engineering projects. The second paragraph describes the physical cause that led to the Challenger explosion. The third paragraph describes how engineering decisions can get superseded and the engineer's professional responsibility goes beyond the technical knowledge and decision making. The final paragraph is a summary statement about deformation and human decision making in a risky enterprise.

5. Conclusions

The educational challenge of teaching mechanics of materials that includes contemporary applications in an ongoing process. ‘MOM in Action’ is one teaching aid in the educational tool kit that incorporates insights on human learning to improve the impact of instruction. Can the impact of using ‘MOM in Action’ be measured? To answer this we must ask what it means to have a BS in the fast changing technological society. Does engineering education transcend the simple sum of all the course content? Would time spend in incorporating ‘MOM in Action’ in textbooks and lectures be better spent in solving another numerical example or covering an extra topic? The authors believe that education and neuroscience research suggests that ‘MOM in Action’ course enrichment might have a positive impact on student learning and retention of concepts.

The authors also recognize that establishing a causal link between ‘MOM in Action’ utilization and measurable increases in student performance involves the well-acknowledged problem of using old measure to quantify new effects. The present plan is to build between 20 to 30 such ‘MOM in Action’ modules that elaborate concepts generally taught in the introductory course of mechanics of materials and then to develop measures to determine if exposure to these modules has any effect on student’s capacity for rich, transferable conceptual retrieval.

6. References

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Module 1: MOM in Action

On December 26th, 2004 an undersea earthquake occurred with an epicenter off the west coast of Sumatra, Indonesia. A series of devastating tsunamis were triggered by the earthquake that spread throughout the Indian Ocean. It is estimated that nearly 200,000 people died and nearly 40,000 are missing. The magnitude of the earthquake was estimated between 9.1 to 9.3 on the Richter scale and lasted for a duration of 500 to 600 seconds. It was so large that it caused the entire planet to vibrate with an amplitude reaching over half an inch. The quake released an amount of energy equal to a 100 gigaton bomb. It was the second largest earthquake ever recorded by seismographs.

Earthquakes are caused when built up stresses along the fault lines are suddenly released. Fault lines are boundaries of tectonic plates. Tectonic plates are large segments of earth crust that float on top of the earth magma and lock up along the fault lines. Fig.1 shows the three basic types of earthquake movements. A combination of these basic movements is used in explanation of earthquakes.

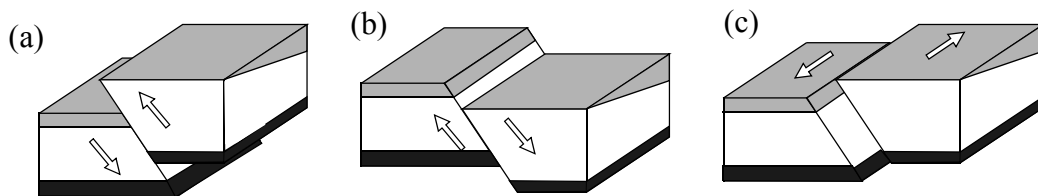


Fig. 1. Main types of geological faults. (a) Thrust (b) Normal (c) Transform

Collision of two plates cause one plate to be thrust over the other as shown Fig.1(a). Himalaya mountain range is formed this way. Two tectonic plates pulling away from each other result in a normal fault shown in Fig.1(b). Volcanic activity is common forming new earth to fill the crevasses in regions of normal faults. Transform faults are formed when two plates slide past each other. San Andreas fault in California is an example of transform faults. The Indonesia earthquake was a combination of thrust and transform faults.

Prevention of movement of one tectonic plate by another causes stresses to lock up. Note that normal stresses will lock up in thrust and normal faults and shear stresses will get locked in all three cases. These stresses will build up with time until released by an earthquake.

Module 2: MOM in Action

On January 28th, 1986, seventy three seconds into the flight, space shuttle Challenger (Fig.2a) exploded killing seven astronauts: Commander Francis Scobee, Pilot Michael Smith, Mission Specialist Ellison Onizuka, Mission Specialist Judith Resnik, Mission Specialist Ronald McNair, Payload Specialist Gregory Jarvis and Christa McAuliffe. The flight was the first time a civilian, school teacher Christa McAuliffe, was going into space. Classrooms across the USA were ready for the first science class taught from space. The explosion shocked millions watching the takeoff. A presidential commission to investigate the cause was set up and shuttle flights were suspended for nearly two years.

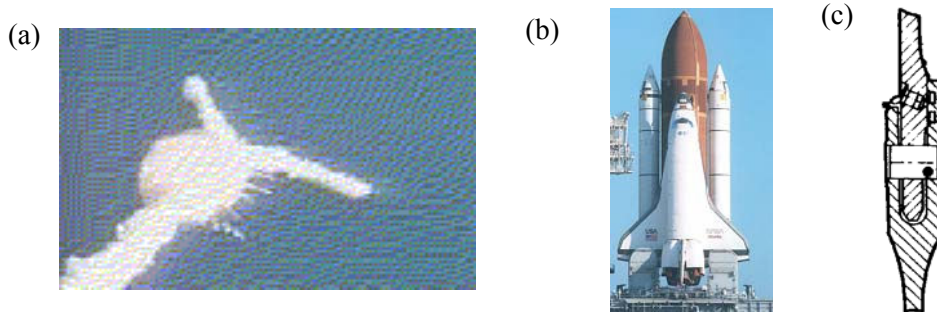


Fig. 2. (a) Challenger explosion during flight (b) Shuttle Atlantis (c) O-ring joint

The Presidential commission established that the cause of the explosion was the ignition of combustible gases that leaked through the joint between the two lower segments of the right solid rocket boosters. The solid rocket boosters shown on the shuttle Atlantis (Fig.2b), like the Challenger, are assembled using the O-ring joints illustrated in Fig.2c. When the gap between the two segments is 0.004 in. or less the rubber O-rings will be in contact with the joining surfaces and there would be no leak of gasses. At the time of launch the gap was estimated to be in excess of 0.017 in. The increase in gap was attributed to the following causes: (i) The launch forces cause the segments to move apart. (ii) Prior launches had permanently enlarged the diameters of the segments and also caused out of roundness. (iii) A compressed rubber O-ring at 78° F is five times more responsive in returning to its uncompressed shape than an O-ring at 30° F. The temperature around the joint varied from approximately 28° F on the cold shady side to 50° F in the sun.

Two engineers at Morton Thiokol, a contractor of NASA, had seen gas escape at a previous launch and had recommended against launching the shuttle when the outside air temperature is below 50° F. Thiokol management initially backed their engineers recommendation but capitulated to desire to please their main customer NASA. The NASA managers felt they were under political pressure to establish space shuttle as a regular and reliable means of conducting scientific and commercial missions in space. Roger Boisjoly, one of the Thiokol engineers was awarded the Prize for Scientific Freedom and Responsibility by American Association for the Advancement of Science for his professional integrity and his belief in engineer's rights and responsibilities.

The physical cause of the accident was the deformation at launch was in excess of the design allowable deformation. The primary cause was an administrative misjudgment of risk assessment and the potential benefits of the Challenger launch contrary to recommendation by the engineers.