# Toward a Nationwide Dynamics Concept Inventory Assessment Test

**Gary L. Gray, Don Evans, Phillip Cornwell,**
**Francesco Costanzo, Brian Self**
**The Pennsylvania State University / Arizona State University /**
**Rose-Hulman Institute of Technology / The Pennsylvania State**
**University / USAF Academy**

## Abstract

This paper will describe our efforts to develop a national concept inventory test in undergraduate dynamics, that is, a *Dynamics Concept Inventory* (DCI). This paper will present the current state of development and will discuss future efforts and directions of this project.

## Introduction

The body of research knowledge on student learning of Newtonian mechanics, including both kinematics and kinetics, has become quite rich in the last 15 years, but, because of its newness, this knowledge generally remains unfamiliar to most instructors whether their academic home is in a physics department or an engineering department. While it is not unusual for authors of papers on the *teaching* of mechanics in engineering education to refer to the history of how the *teaching* of the subject developed over the centuries since Newton published his general laws of motion (for a recent example, see Kraige[15]), this rich research literature on student *learning* of the subject has yet to have significantly influenced either the presentation of the subject in textbooks or the emphasis and pedagogy used in the classroom. For the most part, teaching of dynamics continues to be patterned after how instructors were taught when they were students of the subject, rather than being informed by research on learning. We believe that we are on the verge of seeing vast improvements in how much and how well students learn in this subject—we present this paper hoping that we can assist and even hasten this improvement.

Much of the literature on student *learning* of mechanics addresses what has come to be known as “intuitive physics”, i.e., intuition-based rules or models that students have consciously or unconsciously developed to explain their physics-related experiences in the world. This intuitive physics includes what are commonly called student “misconceptions”, which are sometimes referred to as “preconceptions” or “alternative conceptions”.[2,3,5–12,17–24] Although there is some disagreement in the literature (see, for example, diSessa[11]) over the ability of intuitive physics to represent a “coherent, even theoretical, view of the world”, the discussion involves basically how instructors should address student misconceptions, that is, primarily whether the misconceptions should be "confronted, overcome, and replaced" or they should be "developed and refined". In spite of this disagreement, there remains much that can be learned from this literature about how widespread these misconceptions are and how persistent they are, even under what is generally considered "good" instruction. Although these studies list many student misconceptions, none offer good, reliable, valid assessment instruments that can be used by instructors in a "production" mode to judge the adequacy of their instruction.

One of the significant hindrances to reform in science, technology, engineering and mathematics (STEM) education has been the absence of good assessment instruments that can measure the value added to student learning as a result of new ways of teaching the core material in a subject. As pointed out by several studies, including the three video case studies, *Lessons from Thin Air*, *Private Universe*, and, particularly, *Can We Believe Our Eyes?*,[1] students subjected to traditional instruction and assessment often do not adequately resolve the misconceptions that they either bring to a subject or gain while studying a subject. These misconceptions, sometimes referred to as "alternative views" or "student views" of basic concepts (because they make sense to the student), block the establishment of connections between the basic concepts, connections which are necessary for understanding the "macroconcepts" developed in further work.

Therefore, this paper describes our efforts to date to create an easy-to-use and easy-to-interpret instrument that assesses students' grasp of the fundamental concepts in dynamics. It is hoped that this instrument will allow instructors to discover student misconceptions and so that they may be addressed. Since the process is in its infancy, this paper will focus on the process we are using to create the assessment instrument. Future papers will provide the opportunity to publish the instrument as well as to report findings as a result of its use by us and others.

## The Force Concept Inventory

The mechanics part of the physics education community is probably farther along the reform path than other disciplines due to the existence of an assessment instrument that tests basic concepts. The well-known *Force Concept Inventory* (FCI) assessment instrument of Hestenes, et al.[14] has been in use for over 15 years and is now credited with stimulating reform of physics education. Such assessment inventories can play an important part in relating teaching techniques to student learning. The design of these instruments relies on the designer(s) knowing the misconceptions commonly held by students in a discipline. The instruments use these misconceptions as distractors to see if a student can pick out a correct concept from among the common misconceptions.

## Some Background

The impetus to create a *Dynamics Concept Inventory* (DCI) began at a Mini-conference on Undergraduate Education in Dynamics, Vibrations and Strength of Materials in San Antonio, Texas in September 2002. The purpose of the meeting was to discuss instructional innovations in these subjects, assessment instruments over and above the FCI that would be beneficial to these subjects, and the extent to which these subjects might be brought closer together in delivery. Among other things, it was generally agreed that if we are to discuss the efficacy of innovations in mechanics education, we need a tool with which we can quantitatively assess each innovation. Based on the success of the FCI in the physics curriculum at generating innovation in physics instruction, it was agreed that a DCI would (hopefully) provide the same sort of impetus for change and innovation in dynamics instruction. It was decided that a DCI team would be formed and that we would meet again at the Concept Inventory Workshop at the 2002 *Frontiers in Education* meeting in Boston (November 2002) since that meeting was to have several concept inventory teams in a variety of engineering disciplines.

At the Concept Inventory meeting in Boston, each established team gave a report on their progress and experiences in creating a concept inventory. This proved to be invaluable as many of the people on the dynamics team had little or no experience with creating a concept inventory. Several consensus items emerged at that meeting:

1. There was agreement that CIs should cover both prerequisite concepts and concepts covered in a subject/course. No firm agreement was reached on the fraction of a CI to be devoted to each. Ideas varied from 10–40% of questions devoted to prerequisite. It may be subject dependent.

2. The wording of the CI questions is very important. They need to be unambiguous and leave no room for interpretation. In addition, they need to be unbiased with regard to gender and culture.

3. The data that are emerging for the use of the new CIs with traditionally delivered instruction are consistent with Hake's FCI results[13] (max of about 30% gain)—these are very disappointing and rudely awakening, but they are the reason why we are developing CIs.

4. Validity and reliability are important. It was thought that none of the CIs have addressed these aspects sufficiently, and until this is done, use of the CIs for other than research purposes is premature. There is a potential for misuse and the concept of a CI could easily be discredited if the results don't jibe with a person's experience. For example, with regard to the thermodynamics CI, they need to resolve the dichotomy between the student experiences on how hard thermodynamics is and the high student scores on the thermodynamics CI. It was generally thought that further discussion on the issues of validity, reliability, and the use of CIs as formative or summative tools is needed.

5. A statement of the intent of the CI is needed. A quote from the article by Marchese in "New Conversations about Learning"[16] states that "Assessment is a process in which rich, usable, credible feedback from an act of teaching or curriculum comes to be reflected upon by an academic community, and then is acted upon by that community a department or college within its commitment to get smarter or better at what it does." Many participants thought that this was a good place to start.

In addition, one of the authors, Don Evans, has created a web site at Arizona State University for CI teams in Thermodynamics, Dynamics, Materials, Signals and Systems, and Strength of Materials. It includes a reference list, a list of events, a place for shared documents, a place for general discussion, a contacts page, a list of links, and a list of team members. This page is currently only accessible to CI teams and their members.

Finally, each concept inventory team met individually and the following process was established at the meeting.

## Our DCI Creation Process

The DCI team agreed that the first period (3–4 months) would be spent identifying the key concepts and misconceptions in dynamics. As part of this:

- Each person on the DCI Team was to come up with his or her own list of important concepts as well as misconceptions from dynamics.
- At the same time, the Delphi process[4] was to be used to solicit similar lists from other faculty around the country.

### Our Delphi Process

The Delphi process was developed in the 1950s by the Rand Corporation as a means to obtain a reliable consensus among a group of experts. This is done through a series of questionnaires given to the experts, along with periodic feedback.

We began our process by recruiting about 25 seasoned dynamics faculty to participate in the process. These covered a diversity of institutional types from community colleges to research universities, and included minority and women faculty. Once we had a group of faculty who had agreed to participate, an instructional email message was sent to each participant describing what they needed to do (this message can be found in Appendix A). We first asked each of the participants to sign a consent form. Then we asked them to describe those concepts in rigid body dynamics that their students have difficulty understanding. We focused on rigid body dynamics since we felt that Hestenes had done an excellent job covering particle dynamics in his FCI. We told the Delphi participants to focus on areas in which students often display insufficient *conceptual* understanding rather than focusing on student difficulties with analysis skills, problem-solving abilities, or math skills. This was a major point for us since we felt that even though a student's analysis skills may be an impediment to them doing well in dynamics, the DCI should only focus on *concepts*. We all thought that an assessment of skills is important, but this assessment should be administered via a separate test.

Once this raw data was collected from the Delphi participants, it was categorized, summarized, and distributed to everyone on the DCI team. We determined which concepts appeared more than once in the responses from the Delphi participants and then created a concept statement for each. This rather substantial list of concept statements was distributed to the DCI team for comments as to the clarity and accuracy of each statement. The team then discussed and iterated these concepts via email in order to generate final statements for each of the important concepts (and misconceptions). The 24 concepts derived from Round 1 of the Delphi survey can be found in Appendix B.

We then created a web interface for Round 2 of the Delphi process. We created a page for each of the 24 concepts and asked each of the participants to:

1. "estimate the proportion of your students that you believe understand the issue or concept at an acceptable level at the end of an undergraduate (engineering) dynamics course", and
2. tell us "how important you believe it is for students to understand the issue or concept."

The formal rating of each issue was done on a scale of 0 (0% of the students understand the issue/the issue is not important at all) to 10 (100% of the students understand issue/the issue is very important) via clicking on the appropriate radio button on each rating scale found on the web pages. When the participant was done with one of the 24 concepts, then they could simply move on to the next issue or concept by clicking on the "Next" button at the bottom of the page. We also included a field for each concept in which the Delphi participant could include any comments they would like to make on any item. We also told the participants that those topics not covered at their institution (for example, some institutions do not cover instantaneous centers of zero velocity), were to be classified as not very important. Finally, we told them to try to discriminate among the issues, that is, to take advantage of the gradations offered by the ratings scale.

## The Results to Date of the Delphi Process

Round 2 of the Delphi process allowed us to generate a consensus on those concepts that clearly *must* be covered on the DCI. After the data from Round 2 was assembled, the results for each concept question were averaged, and then the difference between

**Table 1.** Average response data from Round 2 of the Delphi process.

| Concept No. | Students Who Understand the Concept | Importance of the Concept | Difference (col 3 − col 2) |
|---|---|---|---|
| 1 | 6.29 | 9.43 | 3.14 |
| 2 | 5.86 | 9.36 | 3.50 |
| 3 | 7.21 | 7.21 | 0.00 |
| 4 | 6.50 | 8.36 | 1.86 |
| 5 | 6.21 | 7.71 | 1.50 |
| 6 | 6.50 | 7.50 | 1.00 |
| 7 | 6.50 | 8.64 | 2.14 |
| 8 | 5.31 | 5.07 | −0.24 |
| 9 | 5.07 | 7.57 | 2.50 |
| 10 | 7.43 | 9.14 | 1.71 |
| 11 | 7.14 | 9.43 | 2.29 |
| 12 | 6.36 | 7.21 | 0.86 |
| 13 | 5.50 | 8.36 | 2.86 |
| 14 | 6.14 | 8.07 | 1.93 |
| 15 | 6.29 | 7.86 | 1.57 |
| 16 | 6.57 | 8.43 | 1.86 |
| 17 | 7.36 | 7.64 | 0.29 |
| 18 | 7.14 | 7.57 | 0.43 |
| 19 | 6.14 | 8.93 | 2.79 |
| 20 | 6.21 | 8.38 | 2.17 |
| 21 | 6.36 | 8.79 | 2.43 |
| 22 | 6.64 | 8.29 | 1.64 |
| 23 | 5.17 | 7.07 | 1.90 |
| 24 | 5.00 | 7.00 | 2.00 |

the importance of the concept and the average student understanding was determined for each concept. This data can be found in Table 1. The DCI team met on March 16, 2003 at the *Share the Future IV Conference* in Tempe, Arizona, to go over the Round 2 results and decide which of the 24 concepts should be addressed on the first draft of the DCI. To decide which concepts to include, we first looked at those concepts whose importance rated 8 or above by the Delphi participants. That gave us 13 concepts from which to choose. Since our goal was to include 10 rigid body dynamics concepts, we needed to decide which of these 13 were to be excluded from the first draft of the DCI. Those concepts whose average importance is above 8 are arranged in order of importance in Table 2 for convenience. We then culled the list from 13 concepts to 11 by simply eliminating Concepts 14 and 22 since they rated the lowest in importance and both had a difference of less than two. We removed the final concept, to obtain a list of 10, by noting

**Table 2.** Average response data, with an importance above 8, from Round 2 of the Delphi process, arranged in order of decreasing importance.

| Concept No. | Students Who Understand the Concept | Importance of the Concept | Difference (col 3 − col 2) |
|---|---|---|---|
| 1 | 6.29 | 9.43 | 3.14 |
| 11 | 7.14 | 9.43 | 2.29 |
| 2 | 5.86 | 9.36 | 3.50 |
| 10 | 7.43 | 9.14 | 1.71 |
| 19 | 6.14 | 8.93 | 2.79 |
| 21 | 6.36 | 8.79 | 2.43 |
| 7 | 6.50 | 8.64 | 2.14 |
| 16 | 6.57 | 8.43 | 1.86 |
| 20 | 6.21 | 8.38 | 2.17 |
| 4 | 6.50 | 8.36 | 1.86 |
| 13 | 5.50 | 8.36 | 2.86 |
| 22 | 6.64 | 8.29 | 1.64 |
| 14 | 6.14 | 8.07 | 1.93 |

that Concepts 16, 19, and 20 all involve the work-energy principle and that Concept 16 had the lowest difference of the three and thus it was eliminated.

Finally, after much discussion, the DCI team determined that the interaction of friction with rigid bodies was an extremely important (and little understood) concept to include in the DCI. In addition, Concept 12 is related to this idea, because it involves the impending motion of a rigid body on a rough surface. Since the Delphi process will involve additional round in which we will receive feedback on the included concepts, the DCI team decided to include this idea in spite of its relatively low current ranking.

## The Future of the DCI

The DCI team will next meet at the ASEE Conference in Nashville, Tennessee to discuss the problems that are currently being developed for the 11 included rigid body dynamics concepts. Those questions will be refined and distributed to the Delphi participants for feedback. The goal is to have a working version of the DCI available for testing by the end of 2003.

## Acknowledgments

Partially supported by the Foundation Engineering Education Coalition through NSF grant 9802942, which is hereby greatfully acknowledged. Gary L. Gray and Francesco Costanzo would like to acknowledge the support provided by the National Science Foundation through the CCLI-EMD grant DUE-0127511. In addition, Francesco Costanzo wishes to acknowledge the support provided by the National Science Foundation CAREER program throught grant No. CMS-9733653.

## References

[1] "Annenberg/CPB math and science collection,", 1989. P.O. Box 2345, South Aburlington, VT 05407-2345.

[2] D. Brown and J. Clement, "Misconceptions concerning newton's law of action and reaction: The underestimated importance of the third law," in *Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mechanics*, J. D. Novak, ed., **3**, Ithaca, NY, 1987, Cornell University, pp. 39–53.

[3] ——, "Overcoming misconceptions via analogical reasoning: Abstract transfer versus explanatory model construction," *Instructional Science*, **18**, 1989, pp. 237–261.

[4] M. Clayton, "Delphi: A technique to harness expert opinion for critical decision-making tasks in education," *Educational Psychology*, **17**, 1997, pp. 373–386.

[5] J. Clement, "Students' preconceptions in introductory mechanics," *American Journal of Physics*, **50**, 1982, pp. 66–70.

[6] ——, "A conceptual model discussed by galileo and used intuitively by physics students," in *Mental Models*, D. Gentner and A. Stevens, eds., Lawrence Erlbaum Associates, Inc., Hillsdale, NJ, 1983, pp. 325–340.

[7] ——, "Overcoming students' misconceptions in physics: The role of anchoring intuitions and analogical validity," in *Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mechanics*, J. D. Novak, ed., **3**, Ithaca, NY, 1987, Cornell University, pp. 84–97.

[8] J. Confrey, "A review of the research on student conceptions in mathematics, science and programming," in *Review of Research in Education*, C. Cazden, ed., **16**, American Educational Research Association, Washington, DC, 1990, pp. 3–56.

[9] A. diSessa, "Unlearning aristotelian physics: A study of knowledge-based learning," *Cognitive Science*, **6**, 1982, pp. 37–75.

[10] ——, "Phenomenology and the evolution of intuition," in *Mental Models*, D. Gentner and A. Stevens, eds., Lawrence Erlbaum Associates, Inc., Hillsdale, NJ, 1983, pp. 15–33.

[11] ——, "Toward an epistemology of physics," in *Cognition and Instruction*, L. Resnick, ed., Lawrence Erlbaum Associates, Inc., Hillsdale, NJ, 1993, pp. 105–208.

[12] B. EYLON AND M. LINN, "Learning and instruction: An examination of four research perspectives in science education," *Review of Educational Research*, **58**, 1988, pp. 251–301.

[13] R. HAKE, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *American Journal of Physics*, **66**, 1998, pp. 64–74.

[14] D. HESTENES, M. WELLS, AND G. SWACKHAMER, "Force concept inventory," *The Physics Teacher*, **30**, 1992, pp. 141–158.

[15] G. KRAIGE, "The role of the kinetic diagram in the teaching of introductory rigid-body dynamics—past, present, and future," in *2002 American Society for Engineering Education Annual Conference & Exposition*, **Session 2268**, Montréal, Canada, 2002, American Society for Engineering Education.

[16] T. J. MARCHESE, "The new conversations about learning: Insights from neuroscience and anthropology, cognitive science and work-place studies," in *Assessing Impact: Evidence and Action*, American Association for Higher Education, Washington, DC, 1997, pp. 79–95.

[17] M. MCCLOSKEY, "Intuitive physics," *Scientific American*, **248**(4), 1983, pp. 122–130.

[18] ——, "Naïve theories of motion," in *Mental Models*, D. Gentner and A. Stevens, eds., Lawrence Erlbaum Associates, Inc., Hillsdale, NJ, 1983, pp. 299–324.

[19] ——, "Cartoon physics," *Psychology Today*, , 1984, pp. 52–58.

[20] M. MCCLOSKEY, A. CARAMAZZA, AND B. GREEN, "Curvilinear motion in the absence of external forces: Naïve beliefs about the motion of objects," *Science*, **210**, 1980, pp. 1139–1141.

[21] J. A. MINSTRELL, "Explaining the 'at rest' condition of an object," *The Physics Teacher*, **30**, 1982, pp. 10–14.

[22] S. RONCATO AND R. RUMIATI, "Naïve statics: Current misconceptions of equilibrium," *Journal of Experimental Psychology: Learning, Memory and Cognition*, **12**, 1986, pp. 361–377.

[23] L. VIENOTT, *LaRaisonnement Spontané en Dynamique Elementaire*, Hermann, Paris, 1986.

[24] S. VOSNIADOU, "On the nature of children's naïve knowledge in astronomy," in *The Psychology of Learning Science*, S. M. Glynn, R. H. Yeany, and B. K. Britton, eds., Lawrence Erlbaum Associates, Inc., Hillsdale, NJ, 1989, pp. 149–177.

## Appendix A: Letter Sent to Delphi Participants

This is the exact text of the original letter sent to the Delphi participants.

Thank you for agreeing to participate in our Delphi study to identify and rank difficult concepts and common undergraduate student misconceptions in 2D rigid body dynamics. A concepts assessment instrument for particle dynamics already exists so our goal here is to supplement this existing instrument with questions from rigid body mechanics which includes kinematics, kinetics, momentum principles and energy principles of rigid bodies in 2D motion. If we have gotten your name in error and you don't teach rigid body mechanics or courses in which students need to know the principles/concepts of rigid body mechanics, please don't respond to this email except to ask me to remove you from the mailing list.

To begin the process, we are asking you to complete the 2 Tasks listed below by December 9th.

Task 1 - Read the attached consent form and fax a signed copy to me at 123-456-7890.

Task 2 - Based on your years of teaching experience, describe the concepts in 2D rigid body dynamics that your students find difficult to understand. Note that we want you to focus on areas in which students often display insufficient CONCEPTUAL understanding rather than focusing on student difficulties with analysis skills, problem-solving abilities or math skills.

For each concept you list (you may list as few or as many as you'd like), please provide a brief description of common misunderstandings your students have about the concept.

To aid your thinking, here's an example from physics (an area related to, but NOT included in, this study, but where a lot of work has been done). Physics and engineering professors find that students misunderstand the newtonian concept of force (so the misunderstood concept here is "force").

A common misunderstanding some students hold is that when someone throws a ball into the air, the force of the hand continues to act on the ball throughout its flight (this is an example of a misunderstanding that we'd like you to provide for each concept you list).

You may send your lists in Task 2 via return email (xxxx@asu.edu) or via fax (123-456-7890)

If you have any questions about these 2 tasks, please let me know. Remember that we will close this portion of the Delphi study on December 16th. The concept list generated in this round will form the basis for the Delphi ranking tasks which will commence in January and which will be conducted via the web.

## Appendix B: Important Concepts from Delphi Round 1

The 24 concepts that appeared more than once in the survey of the Delphi participants are listed below.

1. Different points on a rigid body in general 2D or 3D motion, have different velocities and different accelerations and those velocities and accelerations vary continuously across the body.

2. The *angular* velocity and *angular* acceleration of a rigid body are properties of the body and do not vary from point to point although they can vary with time.
3. The direction of the velocity of center of mass of an object can be substantially different after impact than it was before an impact.
4. It is possible for an object to have (*a*) an acceleration and no velocity or (*b*) no acceleration and a velocity.
5. The *absolute* velocity and acceleration of different points on circular disks relate to how the disk is moving: e.g., motion about a pinned center or motion of a disk that is rolling on its periphery without slipping.
6. The *relative* velocity vector for one point on a rigid body relative to another point on that same body is perpendicular to a straight line between the two points.
7. The point on a wheel that touches the stationary surface along which the wheel is rolling without slipping has zero velocity, but non-zero acceleration.
8. Instantaneous centers are useful for finding the absolute velocities of points on rigid bodies.
9. It is necessary to include Coriolis acceleration when converting acceleration relative to a rotating reference frame to acceleration relative to a inertial reference frame.
10. Dynamics is not statics, i.e., the governing equations in dynamics are 2nd order differential equations, the solutions to which are time-dependent.
11. If the net external force $\mathbf{F}$ on a rigid body is not zero, then there is an acceleration of the center of mass of that body that satisfies $\mathbf{F} = m\mathbf{a}_{CM}$. This is true, no matter where that force is applied.
12. In problems of *impending* rotation of bodies in translation (e.g., a crate on the back of an accelerating truck), the object is not in rotational motion. That is, there is no angular acceleration.
13. Tension in a string/rope/chain with an object supported underneath it *generally DOES NOT* equal the weight of the object in magnitude, except in special cases.
14. The $g$ used in calculating the weight of an object (i.e., $mg$) is not a part of any acceleration of the object, although the acceleration might, in special cases, have the same numerical value as this $g$.
15. A hoop and a solid cylinder having the same mass and same outer diameter will begin to roll differently, i.e., the distribution of the mass in a body will affect its acquisition of velocity and angular velocity.
16. The relationship between work and energy is a scalar relationship. $x$ and $y$ component analyses are not applicable.
17. Kinetic energies and momentums are not the same and never appear in the same equation.
18. The energy in a spring is related to its extension from its relaxed state, not just its total length.

19. The expression for the kinetic energy of a rigid body involves both the kinetic energy of translation and the kinetic energy of rotation, requiring the use of a specific velocity ($v_{CM}$) and the angular velocity of the body.
20. The total of kinetic and potential energies (sometimes referred to as the mechanical energy) does not remain constant in problems involving impacts.
21. Calculating angular momentum requires using some point as a reference.
22. Angular impulses acting on an object cause changes in its angular momentum.
23. Impulses can be considered to be transfers of momentum across the boundary of a system or free body to or from the surroundings. The momentum-impulse equations can then be thought of as statements of conservation of momentum.
24. Unless the point of reference is somewhere along the path of its center of mass, a rigid body translating along a straight line has non-zero angular momentum.

## Biographies

GARY L. GRAY came to Penn State in 1994 and is an Associate Professor of Engineering Science and Mechanics. He earned a Ph.D. degree in Engineering Mechanics from the University of Wisconsin–Madison in 1993. His research interests include the mechanics of nanostructures, dynamics of mechanical systems, the application of dynamical systems theory, and engineering education.

D. L. EVANS is a Professor of Engineering in Mechanical Engineering and the Director of the Center for Research in Education on Science, Mathematics, Engineering and Technology (CRESMET) at Arizona State University. He holds a Ph.D. degree in Mechanical Engineering from Northwestern University, earned in 1967. His current interests include research in teaching and learning in science, mathematics, engineering and technology in from kindergarten through graduate school.

PHILLIP CORNWELL is a Professor of Mechanical Engineering at Rose-Hulman Institute of Technology. He received his B.S. from Texas Tech University in 1985 and his M.A. and Ph.D. from Princeton University in 1987 and 1989 respectively. His present interests include structural dynamics, structural health monitoring, and undergraduate engineering education.

FRANCESCO COSTANZO came to Penn State in 1995 and is an Associate Professor of Engineering Science and Mechanics. He earned a Ph.D. degree in Aerospace Engineering from the Texas A&M University in 1993. His research interests include the mechanics of nanostructures, the dynamic crack propagation in thermoelastic materials, and engineering education.

BRIAN P. SELF is an Associate Professor in the Engineering Mechanics Department at the United States Air Force Academy. He obtained a PhD in Bioengineering at the University of Utah and an MS in Engineering Mechanics at Virginia Tech. Research interests include biomechanics, aerospace physiology, and improvements in engineering education.