Modeling Instruction in college/university (compiled by Jane Jackson)

Modeling Instruction began in calculus-based general physics at Arizona State University, in the early 1980s. That early effort is discussed at the end of this compilation. Modeling Instruction is an evolving research-based pedagogy, and the focus here is current-day Modeling Instruction in college physics. (updated in Sept. 2017)

PHYSICS IN ARIZONA:

* **Estrella Mountain Community College,** in a western suburb of Phoenix, Arizona, is the world leader in post-secondary use of Modeling Instruction. All physics faculty and chemistry faculty use Modeling Instruction, and courses are taught workshop-style (i.e., lab is integrated with lecture). Estrella Mountain CC has excelled at Modeling Instruction in all three levels of general physics since Dwain Desbien became the founding physics faculty there, in 2002.

From 1995 to 2002, Dwain taught Modeling Instruction as a graduate student in physics at **Arizona State University** (ASU). His calculus-based physics courses evolved into studio format (combined lab and lecture; typically 65 students, "scale-up"). Courses were team-taught; Dwain's co-instructors included, in different years, Eric Brewe, Michael Politano, Nicole Herbots, and Mangala Joshua. Students achieved high learning gains, as measured by the Force Concept Inventory (FCI) and Mechanics Baseline Test (MBT), among others. His Ph.D. dissertation, entitled "Modeling Discourse Management" is at http://modeling.asu.edu/modeling/ModelingDiscourseMgmt02.pdf . Later he was a subject of study in Colleen Megowan's ASU doctoral dissertation, Framing Discourse for Optimal Learning in Science and Mathematics . Excerpts are at http://modeling.asu.edu/Projects-Resources.html.

In some of these same years, Dwain was an adjunct instructor at **Chandler-Gilbert Community College**. His calculus-based physics students had extremely high FCI posttest scores, even though a sizable fraction of students were disadvantaged minorities and/or female, and few had taken high school physics. FCI scores at both institutions are documented at http://modeling.asu.edu/rup_workshop/

Dwain Desbien received the AAPT 2015 *David Halliday and Robert Resnick Award* for Excellence in Undergraduate Physics Teaching. The press release states, in part, "Building on the accomplishments of Malcolm Wells, who revolutionized high school physics teaching with his contributions to Modeling Instruction, Desbien has creatively and tirelessly worked to encourage students to take charge of their own learning. He developed new techniques to achieve that goal, such as Modeling Discourse Management, Circle Whiteboarding, and Seeding. His skill in implementing such techniques has made him a very effective physics teacher. His continued efforts to help others develop these skills have made a major contribution to physics education." http://www.aapt.org/aboutaapt/pressreleases/DwainDesbien_2015HallidayResnickAward.cfm

* At **Mesa Community College** in Arizona, Mangala Joshua wrote, "I use a modeling approach using models and model-centered discourse and sometimes the modeling cycle in the algebra-based and calculus-based courses. I teach the courses in a lecture/lab integrated style, making it possible to use the modeling approach. Typical post-test mean score for FCI has been around 70% for calculus-based courses and around 65% for algebra/trig-based courses. I haven't administered the FCI for a while now. I do continue to administer the MBT."

Her son and daughter-in-law, Ph.D. students in physics and math, respectively, took a mechanics Modeling Instruction graduate course at ASU in 2016. Mangala produced a 13-

minute video of Dwain Desbien's calculus-based physics class at Chandler-Gilbert Community College: view it at https://vimeo.com/channels/modelingphysics. She invites queries at Mangala.joshua@mesacc.edu

* At **Central Arizona College**, Clark Vangilder uses Modeling Instruction in all three levels of physics courses: calculus-based, algebra, and non-science major courses. He wrote in December 2015, "however, in many ways, what I do is a bit of a departure from the standard model according to David Hestenes. We construct models in a more fundamental way than the modeling curriculum prescribes; but nonetheless construct (then deploy) models within a model-centered discourse that relies heavily on Dwain Desbien's Modeling Discourse Management (MDM). I have written my own curriculum that leverages the best parts of CIMM [http://modeling.asu.edu/CIMM.html] with the method developed by Rob MacDuff and me, whereby one can craft physical laws from natural language descriptions of empirically familiar regularities by means of arithmetic. We blend the theoretical and the empirical. I take it a few steps further by using Visual Python and facilitating a writing-intensive course (i.e., journals, concept maps, learning outcomes essays) that demands students express their understanding of models in multiple representational systems (MRS): natural language, symbolic, diagrammatic, graphical, etc., as well as continuously describing how this impacts their views of physics and reality. Giving attention to personal epistemology with respect to the content of physics and reality appears to be a more fruitful way of delivering that content because it is more of a whole-brain approach to learning." He invites educators to email him at clark.vangilder@centralaz.edu if they have questions.

* At **Chandler-Gilbert Community College** in Arizona, Sean Flaherty wrote, "My MNS degree is what qualified me to teach @ CGC full time. Modeling Workshops were the most important for preparing me to help my students learn content, as they provided the pedagogical structure that is student-centered and effective."

* At **Arizona State University** in Tempe, Jeff Hengesbach, an adjunct faculty and Modeling Workshop leader, teaches calculus-based general physics to 70 students in a 'scale-up' type classroom. He is constrained by separate labs. He "uses practicums in class to facilitate discourse and generate cooperative engagement among the students." His FCI normalized gains are high! --typically 0.5 [much better than typical gains of 0.15 to 0.25 with lecture-based instruction]. In 2017 he accepted a full-time position at Estrella Mountain Community College.

* At **Cochise Community College** in southern Arizona, Joann Deakin wrote, "I use modeling instruction with my students, interspersed with other techniques. I use it in both the introductory college physics and university physics. I give the FCI with all my students as a measure of what I need to focus on. I am currently collecting some interesting data that I intend to use to in a written document at some point. The problem is that the classes are small and I am trying to give the FCI to students in both Algebra/Trig based and then in the Calculus based with the same students. What I am finding is that students who are taught in the Algebra/Trig based course with the modeling approach perform much better in the calculus-based course even when the instructor uses a typical "sage on the stage" approach. The students make tremendous gains on the FCI, especially when they are high school "running start" students and taught in a college setting with a modeling approach. They continue to make small gains in the follow-on

University Physics classes, and I suspect this is not so much due to the instruction but more the fact that the students have all or most of the fundamental underpinnings and now can teach themselves." She invites educators to contact her at deakinj@cochise.edu

* At **Eastern Arizona Community College**, Ms. Madhuri Bapat wrote that she has "used partial modeling method for calculus-based physics for 11 years. Students were not comfortable teaching without a book. Very little for trig-based and none for conceptual." She has "always kept records of their pre- and post- FCI test. There was a significant difference in modeling vs. traditional."

PHYSICS IN OTHER STATES:

* At **Mount St. Antonio Community College** in Walnut, California, Martin Mason wrote in December 2015, "all physics courses are taught workshop style and use a learning cycle of exploration, model, discourse and practice. The algebra-trigonometry course uses an explicit learning cycle that is derived from the modeling cycle. The discourse is based on Dwain Desbien's Ph.D. dissertation, and 3 of the lead instructors have been to one of Dwain's workshops. The course curriculum is based on the ICP/21 project, which explicitly addresses scientific models. This course has about 30 sections per year and is reasonably coherent. The first semester course is used to train adjuncts on physics education research (PER) strategies.

The calculus-based physics course is more instructor dependent. Again, since 3 (and soon 4!) of the faculty have taken Dwain Desbien's workshops, there is a strong influence of modeling discourse and modeling method in the course. There are ~15 sections per year. "

* At **Florida International University**, Modeling Instruction is used in trigonometry-based and calculus-based physics. Research on these courses shows high effectiveness. (FIU is a hispanic-serving university.) Success is documented in two publications; the lead author is Eric Brewe, who learned Modeling Instruction at ASU.
http://arxiv.org/ftp/physics/papers/0602/0602086.pdf
http://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1002&context=tl_fac

The President of **Florida International University**, Mark Rosenberg, extolled Modeling Instruction in physics at FIU, in his presentation to PCAST, the Presidents Council of Advisors in Science and Technology, on Nov. 30, 2012. The 36-minute video recording is at:
http://www.tvworldwide.com/events/pcast/121130/globe_show/default_go_archive.cfm?gsid=2142&type=flv&test=0&live=0
Start at the 15 1/2 minutes mark. His 20-minute presentation focuses on physics at FIU. At the 26-minute mark is a 2-minute video interview of a hispanic physics student, Idaykis Rodriguez, and her physics professor, Dr. Laird Kramer, the director of Modeling Instruction at FIU. In 2017, Idakis is a post-doctoral physics student at FIU. Her story exemplifies the power of Modeling Instruction.

Idakis is one of many FIU students whose lives and careers have been transformed by Modeling instruction. In 2009, Ted Hodapp, then Director of Education & Diversity at the American Physical Society, said that when he was in a meeting with physics majors at Florida International University, they were asked what made them decide to become physics majors. Many pointed to their professor, Laird Kramer, and others spoke explicitly that their introductory physics course

was taught using Modeling. They found the experience so engaging that it inspired them to become physics majors. (In May 2009, this paragraph was reviewed by Ted Hodapp, and it can be freely shared.)

* At the **University of New England**, in Biddesford, Maine, James "Jamie" Vesenka uses Modeling Instruction fully in his courses on calculus-based general physics and introductory physics for the life sciences. He has developed the latter course to focus on scientific models specifically for use by life sciences majors, including a half semester on modeling fluids. Even with that half-semester modification, his students achieve well on the FCI: their mean FCI postest score is ~60% (N>240 students). He invites queries at jvesenka@une.edu .

Jamie Vesenka had high student gains in algebra-based general physics when he used Modeling Instruction at **California State University – Fresno in 1998-99**, and the following year at the **University of New England**. Instruments included the FCI, TUG-K (Test of Understanding Graphs and Kinematics), and MBT. His publication in the *Journal of Physics Teacher Education Online* is at http://modeling.asu.edu/Evaluations/VesenkaJ_ModInst-undergrad.pdf

* **Buffalo State College**, in Buffalo NY, has a MS Ed (physics) degree that is based on Modeling Instruction. This physics content degree includes two Modeling Workshops (in mechanics and e&m) that are similar to ASU's. The adjunct physics faculty who earned this degree consistently has the HIGHEST student learning gains of the 6 faculty who teach algebra-based general physics, as measured by the FMCE and BEMA. (Private communication from Dan MacIsaac, Director of the MS Ed degree.) The website is http://physics.buffalostate.edu/ Click on Graduate: Physics Education, M.S. Ed.

* At Massachusetts Institute of Technology (**M.I.T**.), David Pritchard and colleagues adapted Modeling Instruction for students who earned a "D" grade in mechanics. A 3-week reView course using ***Modeling Applied to Problem Solving (MAPS)*** pedagogy resulted in much better achievement in the subsequent e&m course, than a control group. The course (and a similar mechanics reView online course for teachers) is described in weblinks at http://relate.mit.edu/current-projects/maps-pedagogy/ .
A reference on measured outcomes is at http://dspace.mit.edu/handle/1721.1/63094

* At **Drury University** in Springfield, Missouri, Brant Hinrichs wrote, "I definitely use models and model-centered discourse (in fact, Dwain Desbien's Modeling Discourse Management; i.e. board meetings, exclusively)." In calculus-based and algebra/trigonometry-based physics, "in all cases we start with a lab, and/or data (in case the lab is not possible for us to do in-class, such as single photons through two slits) and see how to best model it. So, for example, (following Dwain and Eric and the *ASU Remodeling University Physics Workshops* of 2001 and 2002), I use Real Time Physics Lab #1 (RTPL), and out of that comes the constant velocity model, out of RTPL #2 comes constant acceleration, etc. I do a heavy development of a variety of representations for all models. We then apply that model in familar and novel situations. As much as possible, I try to "break" the current model by introducing data that it does not work on…" "I also use this modeling approach in ALL my classes, even upper-level, including: intro calculus-based physics III (optics, waves, magnetism), modern physics, upper-level E&M, upper-level quantum mechanics." "I took a sabbatical in spring 2009 with Dwain to shadow him

for an entire semester. You can see some effect on my conceptual/beliefs data, but it had an even better effect on my end of semester evaluations. I learned a lot from Dwain." His student normalized FCI gains each year in calculus-based physics are excellent: 0.6 to 0.8. His class size is typically 15 to 20 students. His PERC Proceedings paper on board meetings is at http://modeling.asu.edu/Projects-Resources/HinrichsB-discourse-PERC13.pdf. His PERC Proceedings paper on system schemas is at http://modeling.asu.edu/modeling/SystemSchema_3rdLaw_Hinrich.pdf . He invites educators to contact him at bhinrichs@drury.edu .

* At **Judson University** in Elgin, Illinois, Dr. Pete Sandberg, Professor of Math and Physics, wrote that in his algebra-based general physics course (of mostly architecture students) "models and model-centered discourse are used extensively, but not much of the modeling cycle." "Non-science majors: models quite a bit, and model-centered discourse some but not as extensively." He invites interested educators to contact him at psandberg@judsonu.edu .

* At **Eastern Illinois University** (EIU), Cherie Lehman wrote, "The EIU physics department is still set up in the traditional way — lecture courses and lab courses. My assignment varies from semester to semester. I always approach lab courses from a modeling perspective, but we use department lab manuals that do have pretty detailed instructions. Even so, we are always looking for the mathematical model which relates the variables…. The summers spent with you folks in Arizona had a major impact on my teaching. Even though I am not able to incorporate a full-out modeling approach, I try to use my own version of it in both my lecture and lab classes.

* At **Otterbein University** in Wooster, Ohio, Paul Wendel wrote, "Wells-style modeling instruction is part of what I do at Otterbein University, along with POGIL, Physics by Inquiry, and other evidence-supported practices. However, **the process of building, evaluating, refining, and replacing models is at the forefront of my practice.** For example, in a general education course I co-created with chemistry professor Dr. Robin Grote, Integrative Studies 2404 *Fearless Investigators: How to Ask Questions About Energy*, the class builds and refines a particle model for temperature, thermal energy, and energy transfer through heating & radiating (and to a lesser extent through working). As we refine the model, we gradually apply the model to increasingly complex systems. Students design each investigation, then compare results in board meetings and critique experimental technique. We've experienced moderate success…"

"Modeling also plays a strong role in my Physics 2100 Physical Science course (a one-semester course surveying mechanics, E&M, optics, and modern physics—ridiculous breadth, I know). We build crucial models using multiple representations, but model-building is one of many tools in my tool bag, given the crazy breadth of this course."

MODELING INSTRUCTION IN CHEMISTRY: (I asked only one faculty, Lorelei Wood, of Chandler-Gilbert Community College. Her reply is long, and she invites educators to contact her at Lorelei.Wood@cgc.edu .) Modeling Instruction is used extensively at Estrella Mountain CC, led by Levi Torrison, Ph.D. in chemistry.

MODELING INSTRUCTION IN "METHODS OF TEACHING SCIENCE" COURSES:

* **Brigham Young University** in Provo, Utah has two methods courses for undergraduate physics education majors. Duane Merrell, Associate Professor of Physics, wrote, "We teach

Physics 310 and Physics 311. First semester modeling is in Physics 310, and Physics 311 is CASTLE electricity with use of the Modeling-adapted CASTLE electricity units, but we go through all CASTLE units and some have not been adapted for Modeling Instruction.

I measure FCI scores, but to be honest the physics majors taking the test are almost always above 60% and most above 80%, with quite good FCI pretest scores." He invites educators to contact him at Duane_merrell@byu.edu .

* At **California State University – East Bay**, Michele Korb wrote, "I am currently using models and some model-centered discourse in my science teaching methods courses for secondary teaching majors. This is related mainly to the use of models and discourse related to the Next Generation Science Standards. Since CA is a state that has adopted NGSS, we integrate the aspects of models in planning lessons for middle and high school students.

I have worked on a grant in the recent past, and we used the Physical Science Concepts Inventory (PSCI) for middle school students. This was part of a large NSF grant working with middle school teachers and developing their inquiry-based teaching skills. The PSCI was used pre and post instruction. If you want a basic report from that, I have some analytics related to that. Educators are welcome to contact me at michele.korb@csueastbay.edu, regarding my thoughts on modeling and connections to NGSS."

* At the **University of Illinois at Chicago**, Nathan Harada, adjunct faculty, wrote, "This is my second year of teaching a methods course at the University of Illinois at Chicago. Last year, I taught just the methods of teaching physics class and had seven students (six were student teachers and one was a graduate student in geology). This year, due to funding issues, the university has changed the minimum requirement to run a class from 5 students to 10 students. As a result, we wouldn't have been able to run either the physics methods or the chemistry methods courses. We decided to combine the two classes, so this year I had nine chemistry students and three physics students.

I run my class like a modeling workshop where we worked through a semester's worth of material. I tried to use the three components [models, modeling cycle, model-centered discourse] in class with the students playing the role of high school students to give them some experience with teaching. The students also were required to teach two sample lessons, discussing how their lesson connected to previous lessons and how they used the models that we developed. This year, with both disciplines combined into one methods course, I tried to run each discipline separately to give them experience with their material. However, about a quarter of the time, we were together to do discussions, talk about modeling and general teaching aspects, and discuss common topics to both disciplines such as energy, fields, forces, and whiteboarding techniques.

I pre- and post-tested all the students with the ABCC (for chemistry) and FCI (for physics). For the physics, my FCI post-test results are: 2014 (7 students) - 25.4 [out of 30]; 2015 (3 students) – 28." Nathan invites educators to contact him at nharada@gmail.com.

* At the **University of North Carolina**, Nick Cabot wrote, "I introduce Modeling and scientific argumentation to experienced elementary and middle grades teachers seeking a master's degree, but this is not full-fledged Modeling. This is changing next year when I will be teaching methods to pre-service MAT candidates." (In 2017 Nick teaches at Oregon State University, in the College of Education Master degree program in science.)

* At **Otterbein University** in Ohio, Paul Wendel wrote, "In my science teacher preparation courses, (elementary, middle-level, and secondary), students learn to use experimental evidence to build and refine models together with their students. However, there is insufficient time to conduct anything resembling a modeling workshop, so these one-semester courses produce, at the very most, novice modelers. I strongly encourage/nag future high-school-level teachers to attend the nearby content-focused modeling workshops offered through Ohio State University (Kathy Harper). I strongly encourage our elementary teachers to take our Fearless Investigators class, as this course employs modeling practices we hope they will apply when they become teachers."

AN AWARD FOR COLLEGE MODELING INSTRUCTION:

* The Science and Mathematics Teaching Imperative (SMTI), an initiative of the **Association of Public and Land-grant universities** (APLU), recognized **Modeling Instruction in university physics** as a ***Promising Practice***, after a review of evidence supporting the impact on quantity, quality and/or diversity of science teacher candidates.

For information and context, see
http://www.aplu.org/projects-and-initiatives/stem-education/science-and-mathematics-teaching-imperative/smti-projects/smti-past-projects-promising-practices.html

An excerpt from that webpage:

Modeling Instruction: Content & Pedagogy at Florida International University

The first university course in the preparation of physics teachers is the introductory physics course. The introductory course may be viewed as the first sanctioned exposure to physics. During this initial exposure, students learn what content is valued by the discipline as well as the expected ways that this content is conveyed. Student experience in these introductory courses is therefore critically important for the recruitment and preparation of physics teachers. Florida International University has implemented Modeling Instruction in several sections of the introductory physics sequence, which has had the effect of improving pre-service teacher recruitment and preparation while simultaneously improving overall student learning retention and attitudes. Modeling Instruction is a transformed learning environment for introductory physics and is a promising practice for the recruitment and preparation of physics teachers.

For more information, contact:
Eric Brewe, Associate Professor of Science Education and Physics
Florida International University
Eric.Brewe@fiu.edu

To learn more, visit: http://casgroup.fiu.edu/fiuperg/index.php

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APPENDICES:

I. Modeling Instruction began in calculus-based general physics courses at **Arizona State University**, in the early 1980s. David Hestenes & I. Halloun published this paper on their method: Modeling Instruction in mechanics: http://modeling.asu.edu/Halloun,Hestenes-Mdlg87.pdf .

They justified the need for better instruction than traditional in their two earlier publications:
-- The initial knowledge state of college students. http://modeling.asu.edu/R&E/InitialKnowledge.pdf
-- Common sense concepts about motion: http://modeling.asu.edu/R&E/commonsense.pdf
David Hestenes published the theoretical foundation in "Toward A Modeling Theory of Physics Instruction", available at http://modeling.asu.edu/R&E/ModelingThryPhysics.pdf

II. Background information on APLU and SMTI (compiled in 2011 by Jane Jackson):

The Association of Public and Land-grant Universities (APLU) -- the nation's public research universities -- launched an initiative, known as the Science and Mathematics Teacher Imperative (SMTI), to transform middle and high school science, technology, engineering and mathematics (STEM) education by preparing a new generation of world-class science and mathematics teachers.

As of 2011,The SMTI initiative had grown to include 129 public research universities in 44 states. Collectively, SMTI members prepare more than 8,000 science and mathematics teachers annually -- making it the largest STEM new teacher initiative in the country.

FIU, ASU, NAU, and UA belong to APLU and are committed to SMTI. ASU produces about 70 math and science teachers each year; and it intends to double the number.

Core purposes of SMTI are to increase the quantity, quality and diversity of science and mathematics teachers.

The APLU is a membership institution of presidents and provosts. It is working with the American Physical Society (APS) as a grant partner in a leadership effort, a component of SMTI. The APS is a disciplinary society with physics faculty as members, which has a nationwide initiative called the *Physics Teacher Education Coalition* (PTEC). The APLU is also working with the American Chemical Society as they create the *Chemistry Teacher Education Coalition* (CTEC). Objectives are to create and support a national leadership network of presidents, chancellors, provosts, and their designees who are active in improving mathematics and science education and especially teacher education. Another objective is to increase the number of faculty who contribute to teacher preparation, including mentoring, induction, and professional development.

III. More information and documentation of effectiveness at:
Arizona State University Modeling legacy website: http://modeling.asu.edu
American Modeling Teachers Association (AMTA): http://modelinginstruction.org