To reform any human affair exacts great effort from
the people who direct the affair. So it is with ocean sci-
ences education. Many of the people directing it are
striving to make "the change for the better" that we call
"reform," because it will enable students to learn bet-
ter. The nucleus consists of the K-12 teachers and col-
lege and university education instructors and ocean
scientist instructors who have made the change. The K-
12 teachers are being prepared in the pedagogy of
reform by their education instructors. In this manner,
ye learn how to teach in support of the National
Science Education Standards and the Benchmarks. But,
like all other students, they must learn the science con-
tent from ocean scientist educators who, for the most
part, do not know how to teach by the Standards. As
a result, the teachers are not being taught ocean sciences
as they are expected to teach them. Nor are other
undergraduate or graduate students learning ocean
sciences in the manner that assessment studies have
reported to be most effective. In brief, a major impedi-
ment to the reform of ocean sciences education is the
ocean scientist educator whose teaching does not sup-
port the reform. That this impediment should be the
ocean scientist educator ought to surprise us. Although
it doesn’t, here’s why it should.

The historian of science Alexander Vucinich, in his
book Science in Russian Culture: A History to 1860, notes
that: "Every scientist is an agent of cultural change. He
may not be a champion of change; he may even resist
it, as scholars of the past resisted the new truths of his-
torical geology, biological evolution, unitary chemistry,
and non-Euclidean geometry. But to the extent that he
is a true professional, the scientist is inescapably an
agent of change." Deep inside us we know this to be	ru, for change for the better—better understanding,
in the case of our research—was inculcated into our
minds as graduate students and has persisted as a
value ever since. It is remarked on by the late Nobel
immunologist Sir Peter Medawar in his classic Advice
to a Young Scientist: "...a scientist does not hold exactly
the same opinions about his research from one day to
the next, for reading, reflection, and discussions with
colleagues causes a change of emphasis here and there
and possibly even a radical reappraisal of his way of
thinking." And so, change for the better—that is,
reform—comes as second nature to ocean scientists.
Why, then, do so many resist the reform of ocean sci-
ences education? I think the answer has two parts.

The first part is found in the answer to a question
formulated imaginatively by the science-and-technolo-
gy scholar Franklin A. Long: "What are scientists for?"
He answers: "And clearly it is not adequate just to say
that they are to produce science. Most scientists have
always been something more than purely scientists.
Some scientists are also educators; others are partly
managers; and still others are partly industrial or gov-
ernmental technicians.... The number of scientists
devoted solely to the production of basic research has
always been small and will almost surely always
remain small." It is as researchers that we relish change
and reform, but beyond graduate school only a few of
us remain solely basic researchers, or purely scientists.

Most scientists assume additional responsibilities.
Those who will succeed as partly managers must pre-
pare themselves to manage. In academia, candidates
for positions as department chairs and college deans
are now attending workshops or being assigned to
mentors for training. Once appointed, they must
change their department or college in accord with the
economic, demographic, political, and other social
pressures exerted on the university. Scientists in indus-
try must prepare to fit in with the vision of the com-
pany and change as the company deals with economic
and other external forces. Government scientists must
prepare for political realities and be able to change sci-
ence programs so as to align them with ever-changing
national purposes. Even such sketchy examples as
these demonstrate that scientists are indeed adept at
preparing themselves to be successfully "something
more than purely scientists" and at making changes
within these roles—except, that is, for the role of "educator."

Most ocean scientist educators do not prepare to be educators and they resist the reform of science education. I believe this omission and resistance are not in defense of research time, for scientists accept positions as part managers, industry scientists, or government scientists and tolerate less time for basic research. Nor is it due to a lack of reward for teaching, though there's little. No, the lack of preparation for education and the resistance to educational change seem to arise logically because scientists approach the role of educator in possession of a fully developed paradigm of education, that is to say, a fully developed frame of reference that allows them to make sense out of how they educate students. They see no reason to change.

Ironically, this paradigm, which they have accepted tacitly through experience as student and faculty member, has become so internalized that they are oblivious of its existence. It has been referred to as "deeply ingrained in each of us," as being as "invisible" as "the context in which [we] live," and as seeming to be "a force of nature." It is called the Teaching-Centered Paradigm. Although discussions of the paradigm are normally confined to its lecture teaching method and its passive classroom environment, the paradigm, "invisible" though it is to the educator, determines the educator's educational assumptions, goals, and assessment of results. It also determines the educator's sense of educational responsibilities, relationship with students, and motivational and mentoring responsibilities. The following outline of the paradigm should indeed feel "deeply ingrained in each of us."

The principal educational assumption of the paradigm is that subject matter content is sufficient. The principal goal is for the educator to transfer information and for students to accumulate knowledge. Assessment usually aims to determine whether this information still resides in the students' minds. The principal responsibility of the educator is to possess science content knowledge. It follows from this that anyone who knows the science content is capable of teaching it. Learning how to teach is a waste of time over a routine activity. The educator's relationship with students can be impersonal, because it is the educator's job only to provide the information. It is the students' job to learn it. Today's students differ little from the educator as student. Students are expected to be self-motivating. Mentoring is helping the student with science content.

The paradigm of reform in science education is quite different. It is the Learning-Centered Paradigm. The principal educational assumption of this paradigm is that the process of forming knowledge—that is, of learning—is just as important as the content learned. The principal goal is for the educator to create a learning environment in which students can discover how to restructure the new information and their prior knowledge into new knowledge about the science content and practice using it. The students' learning is assessed often in the classroom in order to change the teaching immediately so as to enhance learning. Classroom teaching methods are mainly active learning methods rather than lecturing. The principal responsibility of the educator is to possess both science content knowledge and the knowledge of how to present the science content so that the particular students in the class, who are today very different from the educator as student, can learn it most effectively. Teaching is a complex skill that is learned well through training. The educator's relationship with students is a partnership of learning. The educator motivates students by helping them learn how to learn and mentors them for lifelong learning.

I believe that the fundamental difference between these paradigms is the extent to which they require educators to reflect critically on their teaching. The Learning-Centered educator's teaching cannot exist without critical reflection, because the process of student learning is as important as the science content learned. The question "How do I help my students learn better?" abides with this educator. By contrast, the Teaching-Centered educator has little need to reflect deeper on teaching than "What topics do I cover, what problem sets to use, which questions to put on the tests?". It is ironic that "reflection," an ability that, as noted in Medawar's quotation, is used by scientists to change their opinions and ways of thinking about their research, is not used here to change their ways of thinking about their teaching. They stand true to their paradigm, which doesn't require it. And the paradigm invests them "invisibly" with the self-assurance of "a [presupposed] force of nature." Why challenge such a "force"? A few ocean scientist educators know why: because it is not a force. It is an experiment. They teach with the Learning-Centered Paradigm, a better experiment. Join them in the reform.

(The two paradigms are contrasted in my paper "in press" in the Journal of Geoscience Education.)