



WHAT WORKS - A PKAL ESSAY

ON LEADERSHIP IN STEM

Leadership in disseminating ideas about reforms and about the process of reform, leadership toward maintaining creativity in a time of change for undergraduate science and mathematics education is what I would like to talk about today. These are the issues at the very heart of Project Kaleidoscope; these are issues critical to the strength of the undergraduate science and mathematics community into the 21st century.

Through my work during the past three years, reviewing over three hundred college math departments and a large number of exemplary high school math programs, I have begun to identify something called “leadership.” Leadership is present where we find people working together believing that their cooperative efforts will lead to improvements in the system for everyone and to systemic change. Where leadership is present, we find people working together because they believe their collective actions will be capitalized and leveraged by their leaders for the greater good and that the results of their collaborating can and will be sustained.

These natural communities of interest (natural science communities in PKAL rhetoric) are in contrast to the circumstances without visible leadership, where we find small, one-person spheres of action and responsibility in individual classrooms, focused on individual projects.

Our first concern here is the role of leadership in building local communities of interest in undergraduate science and mathematics, communities where people become deeply committed to working on a particular problem and bringing about change, where they begin to solve a local problem by taking a novel idea, exploiting the idiosyncratic features of their campus environment, where they become engaged in reform because of their commitment to students and institution, and indeed— for their own intellectual pleasure.

Our second concern is the role of leadership in the process of disseminating ideas about successful projects on individual campuses so those ideas and projects can be adapted in other settings, and so that broad reform of undergraduate science and mathematics in this country can be effected.

How do we link local solutions to national problems? Every hard problem has a beautiful solution somewhere; solving problems locally is not the hard part. What can we learn from those who have solved particular problems in particular environments to advance the process of reform in other localities? What is it about those projects that we disseminate?

Dissemination is the most poorly thought-out and under-conceptualized aspect of innovation. Many good individual programs die when they move into dissemination mode because innovators stopped asking the right questions and addressing the critical issues. Innovators begin “disseminating” because they need more soft money and see their project as complete, rather than as an evolving effort. Too often, the project loses creative energy once it moves into the dissemination mode.

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Macalester College, July 1993
Edited by Jeanne L. Narum



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The process of reform: Key questions

Dissemination is as hard as creation; it has to deal with ideas and process just as innovation does. If it is seen dealing with a completed project, dissemination sows the seeds of obsolescence. For PKAL—an umbrella dissemination project—these issues are critical to your work.

Understanding what it takes to create, develop, and sustain innovative reforms locally is the first step in developing a successful dissemination project such as PKAL. I would like to describe the process of reform as I have experienced it in my work in developing learning communities for minorities and mathematics and in changing institutional environments so students can succeed.

First, a clear sense of the idiosyncratic features of the environment is necessary. The process of reform begins by understanding:

- ◆ who our students are, what are their strengths
- ◆ what are the habits of mind of our students
- ◆ who are the students who major in our fields
- ◆ who are the students who do not major in our fields
- ◆ the types of problems we are dealing with in mathematics and science programs on our campus
- ◆ what impact does the larger curriculum have on the capacity of students to internalize an affection for science and mathematics

- ◆ what are the particular strengths of our faculty
- ◆ the particular strengths of our administration
- ◆ the “contextual strength” of our institution
- ◆ our vision of education for all students on this campus
- ◆ our institutional niche in the nation’s higher education infrastructure.

Knowing their own situation very well, and able to exploit the particular features of their environment, persons who are creative problem-solvers and who have a deep commitment to their students, their discipline, and their institution can begin wrestling with an innovative solution to the problems at their home campus. Ideas have to be rooted in reality.

However, as reform begins to take place, the successful project changes the ambient dimensions of the local environment, and new soundings need to be taken. Because of these changes:

- ◆ expectations about what students can learn and how students learn have to be altered radically
- ◆ as students take new knowledge and enhanced skills to other courses, programs and departments across the campus, there is an impact on all parts of the campus
- ◆ because students came with new knowledge and enhanced skills, the track through the major has to be rethought

- ◆ faculty members respond in different ways to new challenges and possibilities, and the collaborating community needs to be reshaped and reassembled
- ◆ administrative actions reflecting pre-reform policies, in danger of becoming obsolete, need to be examined
- ◆ a new set of demands are made on the budget and budget priorities need to be reconsidered.

These were some of the changes in the ambient environment at Berkeley, and something similar happens in other settings when reforms begin to take root.

The challenge to campus leadership is to understand and respond to such internal changes and to recognize that successful innovations demand continual wrestling with the issues by the community of interest, and persistent soundings of the local context.

The external environment for reform

Particularly in this constrained fiscal environment, attention needs to be given to change by substitution rather than change by accretion. As I once said to my colleagues at Berkeley, “Let me show you how it works, and then let’s add it to the system.” This statement will not work and no longer makes sense. The challenge to the leadership is to understand how to negotiate substitution, and how such substitutions affect the total campus community.



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Administrators who cut uniformly to keep the political peace effectively randomize mediocrity as they balance budgets. Equally, faculty must be aware that the local fiscal environment sets parameters for the kind of innovation that can be tried, will work, and thus can be adapted on their campus.

The external environment for reform also changes as the project evolves. Issues that are salient, even volatile now, may not be long-term issues. Certainly the decreasing public support for higher education, and the changing public expectations about the purposes of higher education affects the kind of solutions we construct and adapt on individual campuses and for the entire educational community.

For example, my work with multi-cultural learning communities came at precisely the right time when there was growing agreement that racially-isolated academic and support programs did not work, but that learning communities with shared intellectual interests and common professional goals did work.

The connection between the local needs on the Berkeley campus and within the larger environment meant that it was easy to find support for and to institutionalize the innovation.

The lesson for leaders is that while projects continue to evolve, the internal and external environments also change. Everything is volatile; leaders have to monitor and respond to such changing environments to ensure that innovative solutions are not short-lived.

It is the responsibility of leadership to be able to capitalize on and leverage reforms and to support the innovators on their campus by signaling that the results of working together can be sustained. Visionary leaders generate such a community.

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Leadership in reform: Success and failure

Other changes occur because of successful reforms. Those who have taken the lead in the reform effort learn something about the process of change and how to translate an idea into action. They have better insights about how students learn and how to help students internalize an affection for science and mathematics.

Success breeds success; those who have wrestled creatively and productively with one problem, arriving at a successful solution, are more confident in moving ahead.

But, more than from success, reformers learn from their failures; this is part of what being researchers means— we learn from the limitations of our work. And in examining our failures, we find larger impediments to access and reform that cannot be fixed with our particular solution (in my case, learning communities and pedagogical changes).

When you analyze failures further, you find courses that effectively do not work, and no one had ever known they did not work; you find internal contradictions and limitations in the curricular structure and subtle problems in the way math and science is taught.

For example, the curriculum is structured with a kind of verticality (You miss one week and you are gone; so you are now a history major.) that is not found in the discipline, that does not reflect what the discipline is like. In reality, mathematics is a bushy field. Mathematicians run around and make connections; they dig deep holes. The curriculum as presented is more vertical than the discipline is in reality, and this is one of the impediments that restricts access. We do not introduce students to the real world of science and mathematics.

But another curricular impediment we find when we examine our failures is that we lay out the material for students in an horizontal fashion, organizing it around a lot of isolated facts (more isolated facts than words in a foreign language textbook), rather than around larger ideas in which students can immerse themselves, and develop intuitions and benchmarks for understanding.

In trying to overcome these curricular impediments, innovators and leaders must continually go back to questions about the local environment: who are our students? what are our goals for our students?



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In examining successes and failures in our work as reformers, the issue is to understand how and where students learn to make sense of the discipline, and how and where they learn to form the over-arching meaning and internalize the discipline, how they internalize an affection for science and mathematics.

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When you use a skill to create something, you internalize that skill.

In college, I majored in both art and mathematics, and became sensitive to these questions. As you study art, you learn from day one the humility of the field, that you will never be good enough from a skills perspective, and that you will have to be able to learn everyday of your life, but you also learn to speak through symbols. You get to learn by creating. When you use a skill to create something, you internalize that skill.

So, one of the curricular impediments to reform is that in the study of mathematics, for example, students don't have the opportunity to create anything— unless they take an independent study or work on their Ph.D. The study of mathematics requires enormous delayed gratification. The curriculum is constructed to keep students from gaining the larger insights that come from learning by creating.

There are other impediments, structural and perceptual, that we uncover when we examine our failures. As advising and counseling have been professionalized out of the departments, students are given advice that has no empirical base (“you are suppose to work two hours for every class hour”).

We find that perceptions about students also have no empirical base, e.g. “students from families with no college experience, for example rural students, depend on advising and counseling more.”

We also find that perceptions about effective routes into and through the major, about what makes students connect to and internalize the discipline, are both persistent and wrong. Countless studies (Astin, et al.) make it clear that the particular courses that students collect are not as significant as how students connect to the institution and interact with faculty and with other students.

This is particularly evident in the experience of women who go on to graduate school in mathematics. Where women have significant one-on-one connections with faculty, but no larger sense of community and connections, few go on to grad school.

Where we find men and women working together, where the department is the locus of community life, where the social organization of the department/major represents a scientific and mathematical life to the students, we find departments that make the disciplines accessible and attractive. These are the places where we find encouraging numbers of women students who persist in the study of mathematics. Indeed, how we live in our departments makes the disciplines accessible and attractive to all students.

This is where, in our consideration of local reform efforts, we circle back to the role of leadership and the responsibility of leaders to nurture collaborative efforts at the departmental and institutional levels. The isolated agent of change is not going to be able to single-handedly overcome the curricular and structural impediments to reform.

People work on things because they care about them deeply, and the challenge to leaders is to capitalize and leverage such individual commitments for the greater good.

This brings us to the final impediment to reform: faculty culture. As reforms proceed, faculty will be asking where they should be putting their time, and what their priorities should be for their work in classroom and lab, in their research done alone and with students. Faculty will be asking where the rewards are, what the rewards are.

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Again the answers to such questions emerge out of the common understanding of the local environment— knowing the strengths of your students, faculty, and administration, having a clear sense of the contextual strength of your institution, and of your educational goals for your students. (If access to science and mathematics is the critical issue, faculty salaries need to be spent in first-year courses; if providing early opportunities for students to create their own knowledge and definitions within the discipline, this is how you spend your faculty time and energy.)

A community's responsibility for reform

It will take the collective strength of the faculty to address curricular and structural impediments to reform, which include curricular stagnation, separation of advising and counseling from the life of the department, and the isolated spheres of activity within departments. It will take the action and vision of leaders to change the faculty culture and reward structure to bring that collective action into congruence with institutional goals and with the external environment.

It is not individuals who determine curriculum or the institutional structure, it is the faculty as a whole. It is not individuals who determine community life in the department or in the institution. When reforms are one-person projects, change is not sustainable.

These are issues of leadership; getting people to collaborate is political work. Faculty and administrative leaders need to think collectively about the link between the mission and the practices of the institution. They must be doing this in a time of budgetary crisis and a time of decreasing public support for what we do.

For reforms to succeed and be sustained, leaders have to figure out how to build an environment in which faculty are rewarded for working on problems that are educationally significant and of highest concern to the institution. The success of any reform effort, and thus of any dissemination effort, is in defining the collective responsibility for systemic reform. Formulating and publicizing this definition is the role of leaders.

Leadership to accomplish this at the local level requires a deep sense and knowledge of the external environment, of current issues in higher education, and of disciplinary and faculty culture. It requires the capacity to connect and make complex linkages between different spheres of action, at many levels in an institution. It requires the ability to communicate across institutional, disciplinary, and departmental borders and to speak the language of others in the community.

These are some of the same skills that are needed in the work of dissemination, woven in and through the skill of understanding the process of successful reform as described above. But there are other challenges to those, like in PKAL, who would be leaders in dissemination and who seek to maintain creativity in the time of change.

The challenge is to help build institutional environments in which reforms can take root and flourish and to connect those local reform efforts into a broader, stronger undergraduate science and mathematics community. To meet that challenge, those who will be leaders in dissemination as well as those who provide leadership on individual campuses must:

- ◆ **Respect the diversity and stratification of higher education in this country.** You cannot take a project from one kind of institution and successfully transplant it in another (“transplant dementia”). If a project speaks to everyone, it speaks to no one.

The unique, distinctive features of the local environment—the strengths of faculty, administrators, and most importantly of students— provide a hospitable soil for adapting, but not for transplanting.

Leaders in dissemination efforts should make this their first commandment: host sites for potential dissemination efforts examine critically and have a clear understanding of the idiosyncratic features of their institution before they begin considering their local efforts toward reform.



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- ◆ **Understand the real cost of making change.** Institutions should be prepared to put up hard money for the things that matter most to them. Soft money can become a virus, and many projects fail because people had not clearly thought through the cost of change. Institutions should be prepared to make hard budget choices, to substitute rather than add.

Reforms should be begin only if there is a clear sense of what, including resources, it will take to make the change succeed over the short-term and to sustain the reform over the long-term.

- ◆ **Understand that real reform has to be departmentally-based and have institutional support.** Reforms that succeed in addressing problems over the long-term are those where departments and larger groups of faculty have figured out how to work on a problem as a part of their regular, collective faculty responsibility, and where the faculty culture makes it possible. Reforms that do not have a ripple-effect beyond a single classroom or lab will not result in systemic change.

- ◆ **Be prepared to think outside of and beyond your own limited sphere of experience, expertise, and environment as you consider the potential of reforms.** Force yourself and your colleagues to see solutions as multi-dimensional. Remember that solutions cannot be routinized and compartmentalized without being watered-down.

Understand the impact of change on the faculty, the curriculum, and the institutional structure; understand how it changes the ambient environment. Be open to new ideas; read and discuss broadly; learn to speak other languages, make connections.

- ◆ **Understand the tendency of reforms to “recrudescence.”** Reform agents must be vigilant and guard against recrudescence, a wonderful, little-used word meaning a fresh outbreak of something unpleasant. If you are not careful, just as you think you have one problem solved and leave it, another breaks out.

Once you become involved with the process of reform, you have to be in it for the long haul. You have to be on guard to preserve the essential features of the reform as the environment changes, otherwise things will “recrudescence.” For one thing, this means you must build program evaluation and renewal into the project from day one, not once recrudescence sets in.

- ◆ **Be prepared to deal with the politics of change.** As reforms begin to reverberate in the immediate environment and across the campus, turf wars will break out— on many different levels. The challenge is to anticipate and prevent such turf wars and to inoculate the process of reform against them.

This involves seeing reform as a collective action, and the problem as multi dimensional. It means building bridges from the very first day, and designing formal and informal mechanisms to bring people together to engage in collaborative activity.

Leaders must challenge everyone to see the broader picture in the local setting, and beyond the boundaries of their discipline and institution.

- ◆ **Be prepared to work hard,** understanding that just having the right idea is not enough and that reforms call for lots of energy and hard work. To be successful, reform efforts call for and forth a community that is committed to working together to translate ideas into action, to realize and reinterpret them as the environment changes.



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Leaders care deeply

The challenge to leaders is to build an environment in which ideas can flourish, where risk-taking and the possibility of failure are acceptable, where the structure has the flexibility to accommodate new ideas, and provides regular opportunities for collective action.



Ideas alone are not enough. It is the community who realizes the ideas, who reinterprets them, who make things work.



The challenge to leaders is to capitalize on the diverse strengths that different members of the community bring to the reform effort, understanding how senior and junior faculty each bring a particular perspective to the work of translating ideas into action. The challenge to leaders is to develop a culture of faculty recruitment, reward, and renewal that supports the free flow of ideas and the collective efforts of the community.

Ideas alone are not enough. It is the community who realizes the ideas, who reinterprets them, who make things work. The success of reform is two parts ideas and five parts people. This is as true for the work of dissemination as for local reform efforts.

Finally, those involved in dissemination have to care as deeply about the work as the ones with the initial innovative idea about a local solution to a local problem. Furthermore, just as reformers at the local level must have a clear sense of the context for their work and a clear vision of what is possible, so must those who are thinking about global strategies for change.

Those who will be leaders in dissemination must learn how to run around and make connections, develop intuitions and bench-marks for understanding. They must be open to new and uncomfortable ideas, to examining persisting perceptions about students, learning, teaching, and research. They must understand the over-arching meaning of their work.

We should not underestimate the power and significance of the commitment to make a difference on a single campus; it will take this same commitment and passion about the work to build a national community of interest committed to making a difference for the undergraduate science and mathematics community in this country. ■