

Facilitating Change: Experiences with the Reform of STEM Education
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The context for reform today: How science, technology, engineering and mathematics are used in the creative economy.

The changing nature of knowledge production and international competition and collaboration will affect the organization, working relationships, educational strategies and societal roles and expectations that we attribute to our universities as well as how our p-12 educational system prepares its students for the workplace, for citizenship and for postsecondary education. Our educational institutions will begin to work together and interact in different ways to create research and educational environments that are easy to traverse and responsive to the changing knowledge and skill needs of a global, multidisciplinary, collaborative and open business and community landscape and to address the daily challenges of life in the regions we serve. Before moving to a new phase of seeking to improve the outcomes of STEM education at both K-12 level and in postsecondary education, we can learn a great deal from the progression of reform efforts that have occupied us in waves of about 10 year duration since the launching of Sputnik set in motion a new era of concern about the competitiveness of science and engineering in this country and a new wave of investment in STEM education at both Federal and state level. As we shall see, many of the reasons why these earlier waves of reform have had limited effects are still present today.

The creative economy: global, multidisciplinary, collaborative and open

The nature of innovation is changing as business, technology and society increasingly intersect and influence each other. These new forms of interactions and new opportunities for collaboration are changing some of the fundamental

concepts that have driven our approach to education, knowledge transfer and the management of human capital, intellectual capital and social capital.

In 2006, IBM Corporation brought together 248 thought leaders from nearly three dozen countries and regions representing 178 organizations on four continents and asked them to explore the evolving nature of innovation. The first conversation (*GIO 1.0*), conducted in 2004, concluded that innovation is increasingly *global, multidisciplinary, collaborative* and *open* (summarized in IBM Monograph *GIO 2.0* 2006).

Global: New ideas are driven by interactions made possible by networked technology and open standards that are removing geographic barriers to interaction and moving the economy from a reliance on natural resources to people resources. In this environment, people can work together across both time and space but location still matters because the quality of life in a particular region affects who will choose to live there. No longer, however, are the options open to a particular geographic area bounded by or limited by the people and ideas and natural resources found there.

Multidisciplinary: A number of years ago, Michael Gibbons et al (2004) developed the concept of *transdisciplinary* to describe the remarkable changes that are taking place in how and where knowledge is generated and how and where it is put to use. The *GIO* conception is very closely related to the concept of transdisciplinary. *GIO 2.0* is based on the observation that the challenges and opportunities we now experience are complex. If we are to respond to them in an innovative way, we need a "diverse mix of talent and expertise (p.2)."

Collaborative and Open: *GIO 2.0* argues that increasingly, "innovation results from people working together in new and integrated ways (p.2)." This is occurring both within our more traditionally organized enterprises, both public and for-profit and in modes that bring shifting networks of people and organizations together, shaped by common interests rather than by unique institutional affiliations or identities. In these environments, we need new definitions of such classic concepts as

enterprise, intellectual property, risk and benefit, trust and responsibility and brand. As we shall see, we also need fresh interpretations of the classic university functions of research, teaching and service that embrace new ways of working together, new standards of proof and warrants for action and new participants. We will explore this further when we discuss new ways in which knowledge is being generated and utilized.

It is becoming clear that changes in the very nature of business and how it develops will have significant implications for how we organize and operate our societal institutions both public and private, how the field of competition changes, what individual and collective behaviors will be rewarded, and how the workings of industry will be judged in the broader context of the social and environmental impacts of their operations. GIO 2.0 offers some tantalizing glimpses of a new reality that will be earth-shaking. The impact of these changes also will shake the foundations of our social systems---how we organize and deliver health care, how we act as stewards of the natural environment and work together to ensure that we leave sufficient resources for coming generations, how we educate, how we work together and how we learn. In this paper, we will explore primarily one of these sectors---the nature of tertiary education and the role of research universities as creative hubs for regional development.

Adopting the qualities of the Creative Economy as we undertake the reform of STEM education in a new era.

The changing nature of knowledge production and international competition and collaboration will affect the organization, working relationships, educational strategies and societal roles and expectations that we attribute to our nation's colleges and universities as well as the functions of K-12. It will reshape how our educational system prepares its students for the workplace, for citizenship and for postsecondary education. As we change what we do at the college level, our definition of what it means to be "college ready" will also have to change. It will expand from an emphasis on content knowledge to a more comprehensive

conception of what students will need to know and be able to do and how they can respond to a changing world both innovatively and creatively.

We have a long way to go to match our environments, habits and expectations to the realities of the growing number of enterprises that are working in global, multidisciplinary, collaborative and open modes. To do that, we will have to work together in ways that capture the best of a 21st century environment. We must be just as open, global, collaborative and interdisciplinary as the places that will hire our graduates.

We will only see an alignment between the realities of the creative economy and the goals and aspirations of K-12 AND higher education when these realities are reflected in the policy environments that govern and assess the quality and productivity of K-12 and postsecondary institutions and in the policies and expectations of most governing boards that oversee public and private higher education. Our schools and colleges are still considered largely as self-contained and solely responsible for whether their students learn and progress successfully to graduation and for whether and how intellectual capital is distributed and used. Within public educational systems in the United States, resources are generally distributed according to the student credit hours generated (that is, according to enrollments) and attributed to individual institutions. Assessments of productivity such as retention and graduation rates of students are still measured within the context of individual institutions even though increasingly students move through a complex pattern of participation in K-12 and postsecondary education and enroll in multiple institutions, often concurrently.

Our efforts to trace individuals through our system will change what we measure and what we know about our students as well as what we reward and will begin to open up our policy environment, change our sense of what it means to be accountable to ourselves, to each other and to society.

Intellectual capital is still regarded as intellectual property to be owned and protected and treated as a means for institutions and their employees (usually

academic staff) to generate much-needed revenues. It is rarely considered to be "open source" to be used by a social network of interactive and creative people. With some exceptions, knowledge production by such social networks takes place beyond the bounds of higher education.

Measures of learning are still being approached as a means to assess quality and mete out rewards or punishments rather than as a mechanism to gauge the overall intellectual assets of a state or a region and to guide further investment in the human, social and intellectual capital that will allow a community to thrive in a networked and global environment. According to Paul Lingenfelter (2007)ⁱ "meaningful, collective, self-disciplined accountability requires evidence--- monitoring results and working for improvement." Note especially the mention of the concept of *collective*. It is the introduction of the concept of shared responsibility that will most characterize the educational environment of the future, both within the context of individual institutions and across the educational sector. We can learn how to produce this kind of environment through working together in an effective P-16 collaboration that is built on the ideas of collaborative scholarship.

The production and use of knowledge is changing in dramatic ways that will challenge the traditional organization of the disciplines and their reflection in the typical undergraduate and graduate/professional curricula. A decade ago, Michael Gibbons et al foreshadowed these developments in *The New Production of Knowledge*. He argued that a second form of knowledge production that he called Mode 2 was emerging from within the classic research model (Mode 1) and that both how knowledge was being developed and where the work was being done were starting to change. The interactive space made up of many institutions and sites, knowledge cannot be said to move linearly from the lab bench or basic investigator to application and the marketplace of ideas and technology. Donald Stokesⁱⁱ captured the essence of this new model in *Pasteur's Quadrant*. In his conception of knowledge transfer, Stokes argues that the original linear model in which basic research leads to applied research which leads to development and then application on a large-scale offer only a limited understanding of how knowledge is generated

and put to use in contemporary ways. He developed the concept of Pasteur's Quadrant to describe a model in which theoretical research and practical research and application come together, as they did in the career of Louis Pasteur, to create a continuously turning *cycle of innovation* driven by changing environmental conditions and the competitive landscape. This is the kind of learning that can drive the development and create conditions for success of a P-16 partnership.

Research and learning as well as innovation and invention are becoming concurrent, iterative and ever-shifting in their focus and their participants. As Gibbons et al (1994) explain, a new mode of knowledge production is emerging alongside the traditional one "affecting the context in which knowledge is being produced, the very way it is organized, the reward system it uses and the mechanism of quality control (iii, p. 1)" used to validate the work. This new mode is not approached in the frame of a particular discipline. It is not vetted through the usual hierarchical, discipline-based set of warrants for validity. It is not conducted primarily within research universities or their associated laboratories and it is heavily interactive within a community of investigators and experimenters drawn from a variety of fields and representing multiple interests. These interactions are supported by the networking capabilities of cyberspace as well as by new and more innovative mindsets and institutional models that foster collaboration.

In this new mode, disciplinary warrants are no longer the basis for deciding what counts as a significant problem, who should be allowed to conduct experimentation and innovation and what constitutes "good science (iii, p. 3)" Similar in concept to the way we now talk about engaged universities and engaged scholarship and learning, Mode 2 problems are set in the context of application. Insights and methods are drawn from many disciplines. We are starting to see a gradual blending of models and methods to create a different, more integrated approach that Gibbons et al call "transdisciplinary" to distinguish the phenomenon from "interdisciplinary" where a common problem is studied from several angles but the different perspectives do not co-mingle.

What might this new mode of inquiry and application mean for the intellectual and structural organization of a university and how its intellectual resources are

applied to regional innovation? The question is critical because the emerging Mode 2 models appear to hold great promise for supporting the kind of outreach and engagement that will best utilize the resources that society has underwritten in public universities to support the formation of creative centers and competitive regions in a creative economy. An effective P-16 partnership will certainly include the capacity to generate knowledge in Gibbons' Mode 2.

What have we learned about why reform movements in K-12 succeed or fail?

As many states, including my own state of Minnesota, undertake a statewide, aka systemic approach to the improvement of science and math education, it is worth taking some time to understand the larger system in which our efforts will play out and the many influences that will shape how successful our work may be. Over a decade ago, the National Science Foundation published the first of a series of foundational monographs that captured much of what it had learned by that time about what it takes to move a reform agenda. As the authors of the Foundations monograph put itⁱⁱⁱ

...teaching and learning are part of a complex, interactive system previously misrepresented or underestimated by simplistic and disjointed reform models of the past.

The basic problem that has beset all of our decades of reform can be stated quite simply. It doesn't do any good to focus on only one part of a large system and assume that attending to that one variable will change the behavior of the whole thing. Social systems are complex and they have many mechanisms to return to their steady state when perturbed.

Each era of reform has reflected contemporary currents in policymaking and politics. In the 1960s and 1970s, we focused on equity and reallocated funds to schools in low-income communities. In the 1980s we read A National at Risk^{iv} and marching to its ringing words, we began to address a set of imperatives that would help us restore our nation to a position of world leadership. Remember the famous lines:

If an unfriendly foreign power had attempted to impose on America the mediocre educational performance that exists today, we might well have viewed it as an act of war.

The litany of concerns that followed that preamble sound remarkably like our formulation of our challenges today. So do the recommendations made by the Commission.

- Introduce a more rigorous curriculum during the four years of high school
- Adopt more rigorous and measurable standards at all educational levels
- Devote more time to learning the New Basics, including computational skills.
- Improve the preparation of teachers
- Provide the necessary stability, clarity of purpose and financial resources to sustain these efforts and bring about much-needed reform

In the 1990s educators faced even more urgent calls for action than their predecessors. Evidence had accumulated that the gap between the haves and the have-nots remained and, if anything, had grown. The beginnings of the information age and the earliest signs of what we now would call the creative age had made clear that scientific and quantitative literacy would be needed by everyone. During that period, the AAAS helped lay the groundwork for the assumption that with good instruction, all students could acquire a working knowledge of these ways of thinking. It was during that period that the National Science Foundation launched its systemic science initiatives and sought to build capacity to work on a larger scale.

The Foundations document captured the lessons learned from the 1960s to the mid 1990s and the authors offer some cautionary tales. They outline what happens when "an ill-conceived effort at curricular reform is imposed on underprepared and under supported teachers working in difficult conditions (p.2)." After recounting several examples of shallow and ineffective attempts to introduce more engaging practices in the classroom, the authors make their point very clear.

The deeper moral to [this] story lies in a more subtle sermon on the nature of change: there are too many complex, interconnected programs present

for any one, simple solution---like the introduction of a new curriculum---to alter the fundamental dynamics of teaching and learning in the overall education system or even a single classroom for that matter. (p. 2, ii)

The advice that the foundation monograph offers can serve as a starting point for our working together to change the dynamics of our own education systems today. As we shall see, to do that, we first must model these dynamics ourselves in the nature of our partnerships---but more of that later.

A renewed sense of urgency today

There have been so many recommendations for improving STEM education and so many analyses of what is wrong with our efforts that Project Kaleidoscope published a second Report on Reports in 2006 and called it "Transforming America's Scientific and technological Infrastructure. Recommendations for Urgent Action." The Report on Reports summarizes nearly twenty separate calls for reform, all issued within the past three years. Several more have appeared since the PKAL document was prepared. Of those, I shall only discuss two, namely two reports issued by the National Science Board, one in 2006 provided as a companion to Science and Engineering Indicators -2006 entitled "America's Pressing Challenge--Building a Stronger Foundation" and the other published on October 20, 2007 called a "National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering and Mathematics Education System."

It should not be surprising that all of these reports tend to focus on similar concerns and that they offer similar remedies. The set of reports summarized by PKAL delivered the following recommendations:

- Focus on students who show promise in STEM fields as they prepare to pursue their undergraduate studies and give each of them opportunities for inquiry-based experiences that immerse each in a deeper understanding of the nature of science. the language of mathematics and the tools of technology.

- Focus on the future workforce by connecting the study of STEM to the world beyond the campus through collaborations within academe as well as partnerships with business and civic groups that place STEM in the context of contemporary society.
- Introduce students to science as it now is advanced, including the richness of interdisciplinarity. Focus on new ways of working together---the conversations, connections and combinations that bring new insights to virtually every situation.
- Be innovative in exploring ways to strengthen the student experience and in piloting and taking to scale new ideas, tools and approaches to keep the work of transforming student learning at the cutting edge. Be disciplines about this and set clear and measurable goals.

It is also not surprising that a set of common themes emerges from these reports about what is wrong with our current systems and how they function (from PKAL p. 2).

- Insufficient resources invested to foster the professional development of a workforce that can adapt to rapidly changing conditions.
- Organizational barriers that create competitive rather than cooperative environments among academic departments and across organizations.
- Cultural differences between disciplines and across agencies, including Federal agencies that compete for resources.
- Lack of innovative approaches in education.
- Scientific departments that are too compartmentalized and tend to focus research on narrow disciplinary interests.
- Hostility to any change in the status quo.

To this set of observations, we can add the recommendations provided by the national Science Board in their National Action Plan (2007). They provide the following diagnosis of our national problem. According to them, we have

1. We lack a coherent curriculum and focus on a set of critical concepts. We are, in other words, a mile wide and an inch deep in our coverage of STEM disciplines in K-12 especially.
2. We have too many players acting independently, creating an inconsistent pattern of experiences across the nation. The range of collaborations, partnerships, interventions and agencies trying to influence what happens in the schools is bewildering and rarely are these efforts pursued consistently enough and over a long enough period of time to make a difference or demonstrate a convincing effect.
3. We have at least a dozen offices in the Federal government that contain STEM education programs but no consistent coordination or any coherence in how these offices, departments and agencies frame their goals or design their programs.
4. Too many of our high school graduates enter college without sufficient competence to pursue college-level work in mathematics or science.
5. We have a shortage of qualified teachers, at least in part because we do not pay them enough.

To this list, I would add several other observations based in part on my experience at the National Science Foundation and in part from my presidential experience in three different states.

- Lack of consistent support for introducing and sustaining a change effort over time due to the timeframes of sponsoring agencies (often 2-3 year awards), legislative bodies and Governors Offices (4 year cycles), frequent leadership transitions.
- Lack of experience with adapting promising programs and practices to new environments (knowledge transfer).
- Lack of experience and a sufficiently supportive environment to take pilot projects to scale and to sustain them over time.
- A significant gulf between the time frames, sense of urgency, standards of proof and warrants for action of researchers, educators, policy-makers and external sponsoring agencies either Federal or state.

How to undertake real, sustainable change^y

After three decades of support for the improvement of science and math education, the education community has learned some very valuable lessons about change. Although the Foundations monograph is about science education, K-8, it is easy to substitute a broader context of P-16 and both science and mathematics and apply this advice to our own efforts.

Any approach to large-scale change, either within a system or across an entire state, should incorporate several features.

- A transformation of people's beliefs about science education well-informed by the processes of science and by our growing understanding of children's ability to learn complex and thought-provoking material.

This is a gentle way to deal with what remains a significant controversy in both science and mathematics education about what it means to know these subjects, how the material should be taught, what students ought to know and what constitutes "real" science or mathematics. There is a growing agreement that science and mathematics should be approached as a professional scientists or mathematician would, modeled on a framework of genuine discovery and inquiry.

Science is seen in this case as "a constructed set of theories and ideas based on observations of the physical world, rather than a set of irrefutable, disconnected facts. It focuses on asking questions, considering alternative explanations, and weighing evidence. It includes high expectations for students to acquire factual knowledge, but it expects more from them than the mere storage and retrieval of information (ii, p. 7)."

Unless things have changed a lot recently, we have fewer consensus on teaching mathematics and what constitutes "authentic mathematics" and how it is similar to or different from quantitative literacy and reasoning.

- The creation in each district and school of a clear vision of effective science teaching and a set of goals that will advance that vision;

- High quality instructional materials that support a coherent presentation of important science concepts---and the resources necessary to make those materials available to every student;
- New kinds of tests that more accurately measure students' deep understanding of ideas, not just their short-term recall of facts;
- A long-term commitment to professional development of a generation of educators capable of turning this vision of teaching and learning into reality accompanied by respect for their ability to do so;
- A broadening of public understanding and support for effective science education and the development of community partnerships that spur schools, universities, museums, foundations and corporations to work toward common goals;
- Steadfast support from district administrators and state policymakers who recognize the critical importance of local school-based initiatives;
- Enlightened leadership that understands how all of these factors affect and depend upon each other and that recognizes that all of these changing will need to happen at the same time if reform is to be successful.

The contemporary environment for reform

Today, we live in a policy environment shaped by No Child Left Behind, a Federal policy framework that can be traced back in its basic logic to A Nation at Risk. The transition team that articulated the problems that a reworking of the Federal Elementary and Secondary Education Act into NCLB would address identified three core issues

- Lack of challenging materials and access to advanced learning at the high school level
- Lack of rigorous standards
- Lack of qualified teachers

In 2001, the National Science Foundation was directed by Congress to design a Math Science Partnership (MSP) program that would address these issues. Since NSF is a research agency, its approach incorporated the three form-giving concerns but wrapped them in a discovery model that would build a knowledge base that states, districts, individual schools and P-16 partnerships could use to guide their efforts to build science and math competence and proficiency among their young people. Consistent with this overarching philosophy, the three goals of the NSF approach to math and science partnerships are as follows.

- Ensuring that all students have access to, are prepared for and are encouraged to participate and succeed in challenging and advanced mathematics and science courses;
- Enhancing the quality, quantity and diversity of the K-12 mathematics and science teacher workforce; and
- Developing evidence-based outcomes that contribute to our understanding of how students effectively learn mathematics and science.

Our own regional academies have incorporated some of these ideas. The MSP Goals, as formulated by NSF have continued to evolve. They will surely sound familiar to you.

- Enhance the capacity of the schools to provide challenging curricula for all students and encourage more students to succeed in advanced courses in science and mathematics;
- Increase the number, quality and diversity of mathematics and science teachers, especially in underserved areas;
- Engage and support scientists, mathematicians and engineers at local universities and local industries to work with K-12 educators and students;
- Contribute to a greater understanding of how students effectively learn mathematics and science and how teacher preparation and development can be improved;
- Promote institutional and organizational change in education systems---from kindergarten through graduate school---to sustain the promising practices and policies being developed by partnerships.

What have we learned about P-16 partnerships as a vehicle for the enhancement of science and math education?

There are so many different kinds of partnerships that it is difficult to generalize across them all. Many factors influence what kind of relationships will form, what resources they can draw upon, how easily the group can arrive at a common purpose and agenda, how quickly a level of trust will form and whether the relationships can adapt to changing conditions and experiences that might place a strain on the working relationships within the collaboration or offer reasons to adapt the partnership to reflect new lessons learned.

Among the factors we have to think about^{vi} that can shape both the organization and operation of a partnership we should include

- The types of higher education institutions: university, college, community or technical college, public or private
- The historical relationship between the community and the higher education institutions that serve the community or to be blunt, is there a town-gown problem to be overcome or a history of difficult interactions that have not been resolved?
- The distribution of power among the participants
- The motivations that have caused the partners to consider working together—external mandates, opportunities that require a partnership, early successful experiences that are building a strong inclination to work together?
- The funding sources and any expectations and directives that go with that funding
- Whether or not there is public sector support for the relationships
- The capacity of the partners to engage with each other
- The culture of the higher education institutions and the schools that plan to collaborate
- The backgrounds, experiences and demographics of the participants and their experience with each other before, if any

It is important to be thoughtful about the cultural divide that often separates educators at the P-12 level and in postsecondary education. Sarena Seifer and Cheryl Maurana^{vii} lay out the issues that any community will have to address as

potential partners decide whether they wish to work together, articulate the mutual benefits of collaboration, work out how power will be shared and decide how to structure their relationship. The history and experience of communities and schools working with higher education is not always a positive one. To illustrate the challenges that may arise, consider the following experience recorded in the Boston area.

First, let's sketch out the context. The neighborhoods of Boston are part of a "medical Mecca" that draws people from around the world for study and for care. At the same time, these neighborhoods exhibit the worst health care status indicators in the country! As Seifert and Maurana describe the situation (x, p. 21)

Articles and research grants on the persistent health disparities of racial and ethnic minorities in Boston appear in the tenure dossiers of the majority of faculty members of the three medical schools, two schools of public health, and four schools of nursing in the city. They measure the disparity but not the despair. They identify the problem but not the solution. They conduct the research but not the action.

To address this desperate situation, the Center for Community Health Education Research and Service was established in 1991 with a major award from the W.K. Kellogg Foundation to be the mechanism for redirecting medical and nursing education in Boston. It began as a partnership that brought together Boston University School of Medicine, Northeastern University College of Nursing, the Boston Department of Health and Hospitals and four community health centers throughout the city.

Of particular interest to me is that the idea that animated this work is almost identical to the way that WSU and its partners fifteen years later approached the design of our Center of Integrated Health Science Education and Practice, now called HealthForce Minnesota.

To educate health professions students for careers in primary care in community-based settings through "academic/community health centers;" to integrate service, education and research to influence and change health professions education, improve health care delivery and promote health systems change (vi, p. 20).

A great cultural divide existed between the faculty and students of Boston's prestigious health care centers and the people who lived in the neighborhoods in the shadow of these distinguished places. Here is what things looked like as the partners began their discussions.

<u>University (IHE)</u>	<u>Community</u>
Disrespect for community members	Distrust of motives of IHE
Theoretical expertise	Practical orientation
Education mission	Service mission
Intellectual rhetoric	Concrete action
Analytical framework	Political arena
Stagnant culture and resistance to change	Dynamic environment with too much change.

To cope with these basic differences in the pattern of daily life and the accumulated damage caused by years of observation without productive action, the group set out to work through their perceptions and experiences in order to arrive at a mutually shared vision of education, research and service in the communities served by the partnering health centers. Their journey offers some guidance to us as we begin to work together in our regional centers. They developed the following principles for partnership (x, p. 21, slightly modified).

- Mutual respect for the partners and their representatives.
- Mutual benefit accrual to all participating partners (as expressed in their own terms).
- Shared vision of the mission as a basis for determining strategic goals and objectives.
- Shared decision making regarding the policies and use of resources available to the partnership and generated by its joint efforts.
- Leadership at various levels and in multiple arenas
- Work across boundaries of organizations, institutions and communities

Developing a productive partnership: Working together in new ways.

The most important lessons for us are not the principles we can gather from the recent surge of articles about productive partnerships but rather the learning that goes with putting a partnership together and working together in new ways---which offers my segue to my final message, namely that we must practice within our working relationships the things we want to make happen in our schools.

As the discussion in Boston within the brand-new Center for Community Health Education Research and Service (CCHERS) unfolded, it became clear that the challenges of collaboration were also its opportunities.

- ✓ If you trust people, you earn their trust.
- ✓ If you give power to others, you gain power.
- ✓ If you think carefully about how to organize your collaboration, it will slowly and surely change your own institutional organization because of the experience you gain.
- ✓ As the individual organizations change, the environments created by that change can lead to profound shifts in the systems to which the institutions are linked---in this case, the community health care system in the Boston neighborhoods. In our case, our entire educational system in Minnesota!

From these experiences, we can draw up a check list of things to think about as we begin working together on a regional basis, in part with trusted and familiar colleagues and, in part, with people we do not know well yet. I shall draw this checklist, with some artistic license, from the summary of a recent conference held at Wingspread in Racine, Wisconsin in April 2006 on "Achieving the Promise of Authentic Community-Higher Education Partnerships: A Community Partner Summit."

1. Make sure that the partners commit to strong relationships of trust, honesty, transparency, respect and equity. This will be a challenge since the culture of higher education is often resistant to valuing and treating community partners as peers and allies. In addition, in the earlier days of university civic engagement, higher education often treated communities as

"pockets of needs, laboratories for experimentation or passive recipients of expertise." ^{viii}It will be important to elevate the credibility and recognition for the life and work experience of partners from other sectors of society as well as to ensure that participation in P-16 collaborations is seen as genuine and rigorous scholarly work by peers in higher education as well as worthwhile by colleagues in K-12.

2. Take time for relationship building early on and explore the mutual benefits of the partnerships, using language derived from the domains and ways of thinking of each.
3. Learn how to talk about difficult issues like racial, ethnic, and economic inequalities and reform efforts that have not lived up to their promise. Allow time for people to talk about the realities of their professional lives and their own concerns about this latest reform effort. Many educators, especially in K-12 have become quite cynical about the "reform of the day" movement and the number of demands on their time and energy.
4. Be clear about the roles, expectations and responsibilities of each partner and each organization contributing to the collaboration.
5. Spend time learning as much as possible about the culture and daily realities of each partner. K-12 and higher education do share a common mission of education but we go about our work in very different ways and with different urgencies. We use time and expertise differently and, as individuals and institutions, we are judged by different standards. We also generate and use knowledge differently unless we have been working together for a long time. For example, "colleges and universities place great value on academic integrity and legitimacy, educational value, knowledge production and dissemination, individual expertise and specialization, peer review and critique and academic freedom." When we welcome community partners into our collaboration, we encounter yet more cultural assumptions and expectations and ways of acquiring knowledge and solving problems.

"Successful partnerships develop over time a deep and mutually respectful understanding of the expectations, norms, culture and traditions of each contributor (from vii, p. 17).

6. Make sure that the funding agency (in this case the Minnesota Department of Education) learns along with its grantees about what an authentic and effective partnership looks like, what it can do and what it takes to build and maintain productive collaborations.
7. Take time to learn from the experiences of working together and keep that learning and the effective sharing of the production of new knowledge and skills at the core of the collaboration.
8. Work on meaningful and tangible outcomes that are realistic and achievable. Make sure that you develop both *leading indicators* (that tell you that you are on the right track) and *lagging indicators* (that tell you that you have arrived).
9. Pay attention to your working relationships. Like any other kind of personal commitments, partnerships require nurturing and care. Be clear about what you want from the experience and reflect upon the changing nature of your partnership as you gain more insights. Remember that "good partnerships are created and sustained over time, through the cumulative efforts of even the most routine interactions and outcomes. In this instance, the devil really IS in the details."^{ix}
10. Be ready for genuine transformation at many levels and be prepared to deal with the consequences of those changes, some of which may be hard to predict.
 - a. Personal transformation for the individual participants, including self-reflection and a heightened understanding of the political and social context that shapes a change strategy.

- b. Institutional transformation, including different policies, new interpretations of roles and responsibilities, new investments and infrastructure, new forms of assessment.
- c. Community transformation, including the development of new capacities and new working relationships.
- d. Transformation of knowledge itself-how it is generated, who participates in asking questions and caring about the answers, who uses what is learned and in what ways
- e. Political transformation, including new approaches to concept of social justice

THE CHANGING NATURE OF KNOWLEDGE PRODUCTION

The changing nature of knowledge production and international competition and collaboration will affect the organization, working relationships, educational strategies and societal roles and expectations that we attribute to our nation's colleges and universities as well as the functions of K-12 and how our educational system prepares its students for the workplace, for citizenship and for postsecondary education. As we change what we do at the college level, our definition of what it means to be "college ready" will also have to change. It will expand from an emphasis on content knowledge to a more comprehensive conception of what students will need to know and be able to do and how they can respond to changing conditions and needs innovatively and creatively.

The changes captured in *GIO 2.0* are also taking place within the academy and are reflected in the portfolios of the Federal agencies that support research and education in science, technology, engineering and mathematics (STEM). The early signs are promising but we have a long way to go to match our environments, habits and expectations to the realities of the growing number of enterprises that are working in global, multidisciplinary, collaborative and open modes. We will only see

an alignment between the realities of the creative economy and the goals and aspirations of higher education when these realities are reflected in the policy environments that govern and assess the quality and productivity of postsecondary institutions and in the policies and expectations of most governing boards that oversee public and private higher education. In these environments today, enterprises are still considered as self-contained and solely responsible for whether their students learn and progress successfully to graduation and for whether and how intellectual capital is distributed and used. Within public educational systems in the United States, resources are generally distributed according to the student credit hours generated (that is, according to enrollments) and attributed to individual institutions. Assessments of productivity such as retention and graduation rates of students are still measured within the context of individual institutions even though increasingly students move through a complex pattern of participation in K-12 and postsecondary education and enroll in multiple institutions, often concurrently. Intellectual capital is still regarded as intellectual property to be owned and protected and treated as a means for institutions and their employees (usually academic staff) to generate much-needed revenues. It is rarely considered to be "open source" to be used by a social network of interactive and creative people. With some exceptions, knowledge production by such social networks takes place beyond the bounds of higher education.

Measures of learning are still being approached as a means to assess quality and mete out rewards or punishments rather than as a mechanism to gauge the overall intellectual assets of a state or a region and to guide further investment in the human, social and intellectual capital that will allow a community to thrive in a networked and global environment. According to Paul Lingenfelter (2007) "meaningful, collective, self-disciplined accountability requires evidence--- monitoring results and working for improvement." Note especially the mention of the concept of *collective*. It is the introduction of the concept of shared responsibility that will most characterize the educational environment of the future, both within the context of individual institutions and across the educational sector.

The production and use of knowledge is changing in dramatic ways that will challenge the traditional organization of the disciplines and their reflection in the typical undergraduate and graduate/professional curriculum. A decade ago, Michael Gibbons et al (1994) foreshadowed these developments in *The New Production of Knowledge*. He argued that a second form of knowledge production that he called Mode 2 was emerging from within the classic research model (Mode 1) and that both how knowledge was being developed and where the work was being done were starting to change. The interactive space made up of many institutions and sites, knowledge cannot be said to move linearly from the lab bench or basic investigator to application and the marketplace of ideas and technology. Donald Stokes captured the essence of this new model in *Pasteur's Quadrant* (Stokes, 1997). In his conception of knowledge transfer, Stokes argues that the original linear model in which basic research leads to applied research which leads to development and then application on a large-scale offer only a limited understanding of how knowledge is generated and put to use in contemporary ways. He developed the concept of Pasteur's Quadrant to describe a model in which theoretical research and practical research and application come together, as they did in the career of Louis Pasteur, to create a continuously turning *cycle of innovation* driven by changing environmental conditions and the competitive landscape.

Research and learning as well as innovation and invention are becoming concurrent, iterative and ever-shifting in their focus and their participants. As Gibbons et al (1994) explain, a new mode of knowledge production is emerging alongside the traditional one "affecting the context in which knowledge is being produced, the very way it is organized, the reward system it uses and the mechanism of quality control (p. 1)" used to validate the work. This new mode is not approached in the frame of a particular discipline. It is not vetted through the usual hierarchical, discipline-based set of warrants for validity. It is not conducted primarily within research universities or their associated laboratories and it is heavily interactive within a community of investigators and experimenters drawn from a variety of fields and representing multiple interests. These interactions are supported by the

networking capabilities of cyberspace as well as by new and more innovative mindsets and institutional models that foster collaboration.

In this new mode, disciplinary warrants are no longer the basis for deciding what counts as a significant problem, who should be allowed to conduct experimentation and innovation and what constitutes "good science (Gibbons et al, p. 3)" Similar in concept to the way we now talk about engaged universities and engaged scholarship and learning, Mode 2 problems are set in the context of application. Insights and methods are drawn from many disciplines. We are starting to see a gradual blending of models and methods to create a different, more integrated approach that Gibbons et al call "transdisciplinary" to distinguish the phenomenon from "interdisciplinary" where a common problem is studied from several angles but the different perspectives do not co-mingle.

TRANSDISCIPLINARY WORK AND ENGAGEMENT

What might this new mode of inquiry and application mean for the intellectual and structural organization of a university and how its intellectual resources are applied to regional innovation? The question is critical because the emerging Mode 2 models appear to hold great promise for supporting the kind of outreach and engagement that will best utilize the resources that society has underwritten in public universities to support the formation of creative centers and competitive regions in a creative economy.

Transdisciplinary work employs a distinct but evolving framework to guide problem-solving. Inquiry is shaped continuously by what is being learned in the investigation. The core questions of how observations will be collected, how evidence will be marshaled, how arguments will be drawn and how the results will be evaluated and interpreted, remain unsettled within transdisciplinary work. These core concepts, all of which are pre-set by consensus within a discipline (Shulman 1988), remain uncertain when knowledge is generated outside a single disciplinary framework because there is no single arbiter of validity. As a result, the knowledge generated by transdisciplinary work is not structured in a particular disciplinary mode but

rather within "its own distinct theoretical structures, research methods and modes of practice (Gibbons et al 1994, p. 5)

The results are diffused through a network of participants and their colleagues and carried forward as knowledge into a next set of projects and activities. The transmission is via social networks rather than through approved and refereed channels maintained by the authority of a single discipline. The knowledge is, as a result, cumulative, since it is integrated into the other things that the participants know. The process of validation, integration and interpretation is tacit and not codified or visible to others who were not on the scene. It becomes part of the intellectual assets of a network of people held together by "persisting and highly mobile communication networks" (Gibbons et al 1994, p. 5 or communities of practice (Brown and Duguid 1991). Finally, transdisciplinary work is dynamic and can be described as "problem-solving capacity on the move" (Gibbons et al 1994, p. 5) marked by "the ever closer interaction of knowledge production with a succession of problem contexts (Gibbons et al 1994, p. 5). In other words, the approach evolves as people gain experience and as the value of their work is tested within contexts. Knowledge is increasingly transmitted not by formal, peer-reviewed channels but through contact and relationships within a network of interacting people.

Consider how very different Mode 2 work is from the structure of universities with their departments and carefully codified disciplines. In this environment, even interdisciplinary work is often difficult. In universities, the unit of measure is the individual, not a group or team. It is necessary to distinguish the contributions of a particular person or department to either the generation of intellectual capital or the attraction of prestige and recognition. Meanwhile, in society at large, knowledge workers and their inclination to experimentation and intentional learning continue to spread throughout the professions and organizations, both for-profit and non-profit and the locus of research within the research university continues to shift. Much intellectual work and innovation occurs in situations often quite remote from universities. In fact, knowledge and capacity for innovation are increasingly being seen by economists as a valuable, if hard to measure, commodity whose movement and trading resembles a marketplace (Foray 2004.) Gibbons et al

(1994, p. 14) calls this "socially distributed knowledge production." Increasingly, new ideas and knowledge are being generated in many places, involving many types of people and organizations interacting with each other in a variety of ways. With the opening of cyberspace, these relationships appear to be expanding endlessly. What will be the role of the disciplines in providing quality assurance for ideas and "facts" or observations generated by such a distributed system of people working in increasingly different settings on complicated, multi-dimensional problems? How must we prepare our students to function as professionals and knowledge workers in a genuine learning society? What should our educational objectives be? How will we deal with the fact that we are no longer the primary or dominant arbiter of what is true and valid and what is not? What will be the role of higher education in the knowledge-based economy and society of the future? What will we do as technological solutions cease to derive from previous experience or existing science but instead represent adaptive solutions to previously unforeseen problems and opportunities? How in fact can we cope with adaptive problems in the first place?

According to Heifetz and Linsky (2002), an adaptive challenge requires

"experiments, new discoveries, and adjustments from numerous places in the organization or community. Without learning new ways---changing attitudes, values and behaviors---people cannot make the adaptive leap necessary to thrive in the new environment. The sustainability of change depends on having the people with the problem internalize the change itself. (p. 13)"

They distinguish a challenge of this kind from the much more familiar **and comfortable** technical problem. For problems like those, we already know the solutions or we can draw upon existing knowledge to solve them without having to change ourselves, our ways of thinking or our interactions with each other. Heifetz and Linsky (2002) devote an entire book to the basic issue of how to lead when the challenges facing a group of people or an organization are adaptive ones, not technical ones. The problem is captured in the title of their text *Leadership on the Line. Staying Alive Through the Dangers of Leading.* Adaptive challenges do

not have easy answers and they require Mode 2 knowledge production. People often find these situations upsetting and it is important to prepare for the likely unleashing of difficult emotions that can threaten both leadership and effective application of adaptive expertise.

IMPLICATIONS OF THE CREATIVE ECONOMY FOR HIGHER EDUCATION

The IBM exploration of global innovation offers several core observations that point the way to the competitive/collaborative environment of the future. This new landscape will be the ground upon which different, ever-changing institutional collaborations and educational models will be built.

1. Powerful new social structures are evolving that transcend physical and geographical borders more easily and that open up new forms of interaction and collaboration in which individuals can exert a different and more powerful influence over networks of people. This influence is exerted by "their ability to tap into and sometimes transform a larger network of people and ideas"(p. 9)."
2. The development of networks organized according to working relationships rather than organizational affiliation will change what we mean by an *endeavor* or an *enterprise* as well as *employer* and *employee*. The focus around which we may organize our work in the future may be a "common set of interests, goals or values" rather than our affiliation with a particular institution or community of interest. People may move freely from one focal point or endeavor to another and may never be permanently attached to any one organization or discipline or program.
3. Our current forms of quality assurance are institutionally based, both in education and in industry where we have various forms of accreditation or certifications. In the future, we may, instead, operate according to principles of *reputation capital*, "a kind of accumulated trust, a standard of accountability that enables diverse, and often virtual, networks of people to confidently strike partnerships with one another. (p. 10). We can see this now in the way that open source software is designed by large loosely

coupled networks of people that become self-organizing, held together by tangible results and trust rather than by structures and regulations.

4. Our approach to decision-making will surely change as leaders are offered a much more comprehensive *line of sight* (p. 10) through their relationships, partnerships and virtual networks into the world in which their efforts will be judged, adopted or rejected and put to use. In other words, we will be given more insight into the full consequences of our actions. This in turn may inspire us to examine a wider range of choices and to explore more dimensions of the world in which we are operating in a world made up of shifting networks of other people and places.
5. A different set of experiences and a different line of sight may lead to a process that GIO 2.0 calls "flipping the equation." In this mode, we may start looking at things in new ways. For example, we may focus not only on how to build something but also on its eventual decomposition and recycling. This would mean a different approach to assessing the qualities of composite materials and designs. Similar reversals of thinking could apply to issues in transportation (for example the dispersal of people rather than the concentration of people) or any other aspect of life today that would benefit from a fresh perspective. To do this, we must move beyond either/or thinking and embrace the ability to link economic progress, environmental protection and societal enhancement into one larger, complex and multi-dimensional enterprise. Just as our organizations are less and less self-contained, so must our thinking grow to be more expansive and inclusive.
6. Management models will have "to contend with how to orchestrate a complex and changing network of individuals within and outside the boundaries that previously defined 'the enterprise (p. 16).'" This will surely include the ability to embrace self-organizing networks, new forms of outsourcing and shared responsibility, customer-driven design and new forms of trusted interactions with people and organizations over which we have little, if any, control. We will organize ourselves into ever-changing patterns expanding, contracting and reconfiguring (p. 17) as needs change or a project advances and requires different expertise or as the marketplace changes. What will hold these shifting working models together will be a common vision, shared principles

and a common purpose rather than rules and regulations or company or institutional autonomy and culture.

7. In this environment, intellectual capital will cease to be property to be controlled and protected but instead will become an asset or capital to be invested. Continued learning will take place as an integrated component of the collaborations that now increasingly characterize innovation, rather than in separate and often heavily funded education and training programs. The linear model of knowledge production and transfer that has long defined our approach to sharing the results of our research enterprise will be replaced by a concurrent model or *cycle of innovation* in which people will learn, apply what they learn, validate that knowledge and incorporate it into a shared community of practice as a continuous and integrated process. Within higher education, early examples of this can be seen in setting where research, education and the improvement of practice are being approached as aspects of a single comprehensive cycle and where the experiences that higher education has traditionally kept relatively separate and called research, teaching and service, become facets of a single form of engaged scholarship.
8. Our approach to education will change. Today, we tend to think that education occurs in classrooms, fostered by interactions between teachers and students. Anything that happens outside the classroom is considered, at best, extracurricular and while valued, these activities (e.g. band or choir, sports, science fairs, theatre, fine arts, community service) are not thought of as part of a more comprehensive approach to growth and development. Under financial pressure, many K-12 schools are limiting these activities or relying on community support to continue them for those students who can afford them. They are not considered part of a *structured and publicly funded space*¹ that advances our educational agenda and prepares our young people for life and work in a new, global and networked age.
9. The experience of students mirrors the shifting relationships of people in the networks that are forming in the business community today. There is a

¹ This idea emerged in a discussion of innovation held at IBM-Rochester on February 1, 2007 with Walt Ling, Vice President and Senior State Executive, and members of the IBM leadership team. The conversation was wide-ranging. Much of this document is influenced by both the IBM-sponsored Global Innovation Outlook, 2.0 Report and the experiences described by Team IBM as they explained what the GIO 2.0 ideas look like in practice.

great deal of churning and mobility, produced by instabilities in family life and social challenges rather than primarily by opportunity. These mobile and largely underserved young people are the least likely either to have competent instruction or meaningful co-curricular activities or to be active in their communities. We need to examine better uses of after school and weekend time and make it possible for students, many of whom work at least part-time, to participate in programs that can stimulate their interests in STEM and in entrepreneurship and innovation through interesting and hands-on activities.

10. Like their industry counterparts, educational institutions spanning our current K-12 and postsecondary systems will begin to work together and interact in different ways. We will need to encourage institutions to be distinctive (our equivalent to a region of innovation) and to work together well to create educational environments that are easy to traverse and responsive to the changing knowledge and skill needs of a *global, multidisciplinary, collaborative* and *open* business and community landscape. Workers of the future will need to be able to navigate these competitive and collaborative spaces. In order to prepare their students for a GIO 2.0 world, educational and research institutions will need to adapt in order to operate in ways that reflect the properties of a 21st century organization and its working relationships, both internal to its own structure and external to its boundaries.

SUMMARY

the premise of this paper is that the pivotal change required to create regions of innovation is to have well-placed colleges and universities that are equipped and able to engage in meaningful, sustainable and effective collaborations across all sectors. Government policy and investment can create conditions that will allow a network of institutions to develop that can collaborate and, in conjunction with community-based partners, create the knowledge and people infrastructure---the social, intellectual and human capital---that a region of innovation will require.

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