ASME 2006 Environmental Scan of Learning and Innovation

Institute for Alternative Futures
Findings & Recommendations

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An Environmental Scan Report from the
Strategic Issues, Opportunities and Knowledge Committee
Strategic Management Sector

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Table of Contents

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Scan Research, Findings and Recommendations by Institute for Alternative Futures, submitted by IAF Futurists Marsha Rhea and Craig Bettles

ASME 2006 Environmental Scan of Learning and Innovation

Findings and Recommendations

ASME is exploring the leading edge of learning and innovation for mechanical engineers to understand the changing needs of its members. This 2006 research is a more in-depth study of two strategic issues identified in the 2005 environmental scan:

- **Collaborative learning communities** are individuals joining together to accelerate new knowledge through the dynamic use of social networking and collaboration technologies. Collaborative learning communities appear to be emerging as a preferred alternative to traditional forms of education and professional development.

- **Technology Innovation Networks** are interrelated systems of organizations that share technical knowledge and skills across geographic, disciplinary and corporate boundaries to create new products and processes. Technology innovation networks are replacing the firm as the dominant innovator in a knowledge intensive and interconnected world.

ASME contracted with the Institute for Alternative Futures (IAF) to research the drivers that make these strategic issues significant for mechanical engineers. IAF also identified early examples of collaborative learning communities and technology innovation networks. IAF looked at the best practices in 2006 and what they might be migrating to by 2016. This futures research is now published on the ASME Strategic Management website. This website material is incorporated into the appendix of this report for convenience.
(http://www.asme.org/Governance/StrategicManagement/Environmental_Scanning.cfm)

This report is an internal advisory of findings and recommendations to assist ASME in setting its future direction in learning and innovation. This report includes the findings from a brief survey of member interest and preferences; additional insights about the drivers that IAF found relevant for ASME; and an analysis of how these strategic issues interact with ASME's current strategic initiatives and balanced scorecard objectives. To help ASME begin thinking about its next steps, IAF offers six ideas that illustrate possible strategies or programs. The report concludes with a list of important strategic questions that will help the Board of Governors decide how ASME can best serve its members.

What ASME Members Said About Their Interests and Preferences

IAF prepared 20 survey questions designed to ascertain member interests and preferences related to collaborative learning communities and technology innovation networks. Since these terms may not be familiar to members, IAF asked very general questions about learning and innovation. The survey appeared on the Strategic Management website and was distributed to more than 20,000 members as a Zoomerang survey. As of June 15, 95 people have responded. Thirty-seven percent were from large multi-national companies; the next largest group at 24% is employees of small/medium sized companies. Nine in ten reported being involved in engineering over 20 years, so these are mature, probably long-term members.

A clear majority of the respondents say they learn best when they are working with others to solve problems. They are collaborating with professionals outside their company to get knowledge. Nine in ten respondents report seeking knowledge from other disciplines to do their jobs. Seventy-six percent said they need to learn from people with different life experiences to succeed in their jobs.

A striking 63% of the respondents disagreed or had no opinion about the statement that they get specific knowledge from ASME to do their jobs. Slightly more than a third reported sharing specific knowledge about problems they are experiencing on the job in ASME technical meetings and conferences and communities of practice. Only about one third agreed with the statement that they look to ASME for lifelong learning. The majority reported that they are not getting recognized by their peers or their employers for contributing to the profession’s knowledge.

From these statements of interest and preference, it would appear that ASME members may be interested in the attributes of collaborative learning communities, but they do not associate these attributes with ASME.

Innovation is clearly a priority for the respondents. The majority of the respondents say their companies or organizations are using innovation to differentiate themselves, and they are including both suppliers and customers in innovation processes. They view their companies as globally competitive. They are partnering to keep up with complexity. About 60% say they are building a network of relationships across companies and countries. About half said they are participating in a network for research and development expertise or have close links with government and academic research institutions. Only one third of the respondents see either nanotechnology or biotechnology having a significant effect on their future success.

From these 10 questions, it would appear ASME members work in organizations that value innovation and they are creating networks both inside and outside their companies to facilitate the innovative process. It would take more extensive research to understand how those relationships are facilitated now and whether ASME might play a role.

Insights about the Collaborative Learning Community Drivers

Collective Intelligence Is Essential to High Performance. Organizations see high performing teams as far more effective than the brightest individuals. They are using new learning processes and technologies to cultivate collective intelligence. As companies focus on learning faster and deeper, the nature of knowledge management is migrating from systems to capture and retrieve knowledge to systems to help people learn collaboratively.

Systems thinking is a critical competency for engineers. Engineers need diverse learning partners to anticipate the dynamics of complex technical and social systems. If the future truly does hold something equivalent to a global mind in mechanical engineering, who or what will enable it. Could ASME act as its synapses?

The research identifies three types of collective intelligence:

- The phenomenon that James Surowiecki calls the wisdom of crowds. When engineers search for best practices, they are seeking this kind of knowledge.
- Organizational learning processes that high-performing project teams use. This is the subjective side of the project management skills ASME promotes to its members.
- Collective consciousness which attempts to access intuition and values. When members join together to pursue a higher purpose, they are trying to connect to this experience of meaning in their lives.

Knowledge Technologies Bring a New Context to Learning. Knowledge technologies organize information and provide the context needed to create knowledge and support learning. These tools and platforms promote participation because they have easy access, linking and retrieval capabilities.

ASME will need to continue to evolve its website toward a multi-user virtual environment (MUVE) that enables people to collaborate around the world. It’s not yet clear which platforms mechanical engineers will prefer. Will they want to communicate via blogs or co-create knowledge using wikis? Will it be important to have the capacity to do simulations or exchange files peer-to-peer?

The strong trend toward open access to knowledge continues. All professional and technical societies need to consider the implications of open access journals. More specialized learning communities like ASME might be able to use “social search” technologies to enable their members to collaboratively filter knowledge from the vast quantities of available information. Today this collaborative filtering might simply take the form of having members rate the usefulness of existing information on the ASME website.

Digital Natives Make Themselves at Home in a Wired World. Young people are fluent in the digital language of computers, video games, and the Internet. Organizations must prepare to welcome them into their ranks and provide the tools they like to use.

Digital natives are creating community through social networking platforms like MySpace and Facebook. These web networks enable intense personalization and self expression. By comparison, ASME's online directory has a limited number of members and contains very little professional or personal information on members." (Engineers are not opting in.)

Productivity Requires Getting to the People Who Know. Organizations that want to boost the productivity of knowledge workers are finding that the best way to cut through information overload is to help people get to the people who know faster. ASME may want to consider mechanisms for helping members quickly identify experts in the field. This might first require using social network analysis techniques to discover who the real experts are within the membership now.

The Global Race for Talent in a Collaborative World. Companies facing a shortfall of qualified workers in developed nations are turning to emerging economies like China and India. The global economy places a premium on knowing how to learn through collaboration. Should ASME help its members develop these collaboration competencies on a global scale? Can ASME play a role in helping match engineers to highly skilled jobs wherever they may be?

Insights about the Technology Innovation Networks Drivers

Innovation Spanning Boundaries. The forces of globalization and collaborative technologies are shifting the focus of innovation from regional clusters to networks that span geographic, organizational and disciplinary boundaries. These networks span complex webs of relationships between firms, universities, government agencies, and other organizations. Research networks are increasingly international. They involve multiple organizations. They often include suppliers and customers. Is there a role ASME can play either as a convener or a member of innovation networks? Can ASME become more innovative in the products and services it offers members by spanning boundaries between organizations, disciplines, industries? How can ASME help their members and their member’s organizations span boundaries effectively?

Global Diffusion of Economic Power. Technology innovation is becoming a global endeavor. During the 1970s and 1980s Europe regained its edge in innovation and Japan became a center for innovation. In the 1990s South Korea, Taiwan and other Asian Tigers became centers for innovation. Over the next decade, China and India will develop as global powerhouses and centers of innovation. The population of the US, the EU and Japan combined are less than half that of either India or China. Will engineers look to China or India for the latest innovations in engineering rather than the US or Europe? If this shift in the locus of innovation occurs, will ASME, with its preponderance of U.S. members, be globally competitive with other mechanical engineering organizations?

Rise of Global Competition. Companies increasingly compete in the global market and outsource to gain competitive advantage. A majority of research joint ventures and strategic alliances are among multi-national companies. Even smaller companies are turning to global markets and outsourcing globally. How will engineering change as more engineering companies compete on a global scale?

4. Increasing Complexity of Technology. Complex technologies, such as airplanes and telecommunications equipment, have grown to over 85% of the most valuable world exports. The cost of these technologies is extremely high and innovation requires an equally complex network of organizations. Interoperability standards are increasingly important to these complex technologies. How will ASME's standard setting activities adjust to the increasing complexity of technology and the equally complex network of innovators?

The Coming Bio/Nanotech Wave. Disruptive innovation usually occurs in waves. As one wave crests the next is building. The current wave based around microelectronics and information technology is maturing. The next wave, based around biotechnology and nanotechnology is building. This wave will be based on networks of researchers across multiple disciplines. To what extent is ASME preparing its members for this next wave of innovation?

Best Practices for Learning and Innovation

To determine best practices, IAF looked at early examples of collaborative learning communities and technology innovation networks. Current examples of collaborative learning are communities of practice, list servers and chat, action learning, wikis and interactive blogs, and efforts to blend online and face-to-face learning. The standards and technical committees are a thriving example of collaboration. The current examples of technology innovation networks are international research projects, research joint ventures, strategic research alliances, standard setting organizations, co-development arrangements, and supplier and consumer networks.

IAF provided both a 2006 snapshot and a preview of 2016 best practices. (See the scan research in the appendix.) ASME may need to catch up to the 2006 best practices even as it looks ahead to the possibilities for 2016. For example, the current ASME communities of practice do not have facilitators and people are not pre-qualified to participate. They are run with a very basic collaboration technology. The best practices for technology innovation networks confirm that innovation is a vital competitive advantage for firms, regions and nations. This advantage is built on solid national and regional bases of scientists and engineers as well as strong support from policy makers for scientific research. They are finding that geographical proximity is becoming less important to innovation, and they must be linked together in global networks. ASME's commitment to innovation is not as clear as its commitment to standard setting, and it does not have a proactive strategy for participating in global networks of innovators.

As ASME looks ahead to 2016, the leading edge of the technologies supporting either collaborative learning communities or technology innovation networks will be even more sophisticated. What are the priorities for adopting new technologies to support member collaboration? To what extent will new technologies create opportunities for new products and services ASME can offer its membership? To what extent will new technologies make today's products and services obsolete?

How These Issues Connect to ASME Strategic Initiatives and Balanced Scorecard Objectives

In its balanced scorecard objectives, the Board of Governors endorsed a culture that is "adaptive, continually evolving (risk taking), entrepreneurial and agile." This environment fosters and encourages volunteers and staff to quickly identify opportunities and threats to the Society and be agile enough to respond effectively with new products and business development. ASME has committed to providing the human and financial resources and promises to reward this risk taking.

ASME has made three strategic initiatives a priority. Collaborative learning communities and technology innovation networks offer significant opportunities for achieving success in these initiatives.

> **Industry Initiative.** Because ASME is interested in creating more value for the companies that employ its members, it launched ASME Solutions, an integrated product marketing strategy for the major industries related to mechanical engineering. It assembles relevant ASME products and services for six industry clusters: Pressure Technology, Power, Bio/Pharma, Water Management, Homeland Security and Computer Hardware and Software.
>
> ASME could use the technologies and approaches described in this research to address common learning or innovation needs. Major companies are using similar approaches internally and may welcome the chance to collaborate across companies. For example, ASME could supplement the ASME Solutions with a wiki capability where people could easily co-create a resource of technical solutions. Companies are finding that interdisciplinary learning is needed for complex projects, and collaborative learning communities could be organized around these interdisciplinary challenges.

Globalization Initiative. To make ASME a truly global organization, the Board of Governors in 2005 approved efforts to build the association's profile in China, India and the European Union. ASME is best known in these markets for its codes and standards. The awareness of other products and programs is low, and membership is limited.

Both collaborative learning communities and technology innovation networks make good use of global communication technologies. Social networking technologies bring the world closer together. ASME could become a global convener of innovators and take an upstream and early leadership role in the direction of global codes and standards.

Early Career Initiative. ASME is working affirmatively to recruit early career engineers into active membership. The association has done extensive research and volunteer committee investigations to determine the needs and interests of early career engineers. ASME will expand its products and services by building "first-in-class" career development resources; expanding opportunities for early career engineers to generate and receive technical content; working with employers/industry to reach early career engineers; focusing on digital content and delivery; and implementing mass customized marketing strategies.

As this research indicates, digital natives expect to have interactive, customized, and instantaneous communication. They are likely to be quite comfortable in collaborative learning communities and help make them robust environments for their peers and their elders. They like social networking technologies and would find it quite normal to collaborate with their peers around the globe. Adopting the approaches and technologies envisioned in this research would give ASME the innovative, contemporary profile it will need with this membership demographic.

These ASME balanced scorecard objectives are relevant to evaluating the potential of collaborative learning communities. IAF's commentary is italicized.

- Enable self-forming communities of interest to develop—or have them seeded by volunteers and/or staff. *The best practice in 2006 is to have facilitators for these communities as suggested in this objective.*
- Increase/expand market relevant content. *Members could create new content as a byproduct of their own collaborative learning around job-related problems.*
- Digitize and repackage content. *Any materials emerging from an online community are likely to be digital already and only require a skilled editor to assemble and polish them for member use.*
- Accelerate time to market. *In this form of learning, time to market is not an issue because people are organizing around the problems they are facing in the moment.*
- Grow revenue through new products and global growth. *Collaborative learning communities can be global in scope. This approach could be used to revitalize existing products such as the annual meeting and technical conferences.*

- Develop a diverse corps of volunteer leaders. Leadership development materials will be delivered to the extent possible via the web, with generic modules on leadership topics for general use, and focused training modules for special business and service units. *People who become facilitators in collaborative learning communities are likely to move into additional leadership roles in time. Collaborative learning communities could become an inexpensive and accessible way to identify and train new leaders.*

These ASME balanced scorecard objectives are relevant in evaluating technology innovation networks:

- Enhance relevance to industry. Bring industry customers into the center of our product and service identification, development and delivery. *Innovation is a priority for companies. ASME can explore the extent to which it can play a role in helping its members form technology innovation networks as well as the role ASME can play as part of a technology innovation network.*
- Be a resource for governments. *Innovation is a priority for all governments. A strong base of engineers is vital to innovation. ASME can explore new ways to aid policy makers in developing and implementing policies that support a growing and innovative engineering workforce and industry.*
- Identify and address future markets and applications. *Technology innovation networks could be formed around emerging technologies or engineering practices. ASME can explore services and products that can help engineering businesses develop innovation networks. This could be a vital service for small and medium sized engineering businesses that do not have the level of resources available to large multinationals in forming innovation networks.*
- Provide effective representation and advocacy for the engineering profession. *Technology innovation networks will need assistance in creating supportive policy environments for new technologies. ASME can serve both the interests of its members and the greater good by identifying and advocating for policies that support both the engineering profession and the creation of innovation networks.*

IAF Recommendations for Possible ASME Strategies

The Strategic Issues, Opportunities and Knowledge Committee charged IAF with analyzing what these strategic issues could mean to ASME. IAF offers these recommendations to spark additional thinking about possible strategies.

Collaborative Learning Communities

1. ASME could adopt a community building strategy and use social networking technologies to support it.

2. IAF could lead in the collaborative creation of technical solutions by creating a Mechanical Engineering Technical Solutions Wiki.

3. ASME could cultivate interdisciplinary collaborative learning within ASME and beyond.

4. ASME could systematically identify and promote collaborative learning communities across its sectors and technical divisions.

Technology Innovation Networks

1. ASME could partner with other organizations around domestic and global innovation policy.

2. ASME could become a coordinator or convener of technology innovation networks around a few key priorities.

3. ASME could play a role in recruiting global and multi-disciplinary talent that will be needed in technology innovation networks.

4. ASME could develop products and services for small and medium sized businesses to help them in developing innovation networks.

Strategic Questions for the Board of Governors

In 2005 ASME identified collaborative learning communities and technology innovation networks as two of six strategic issues important to the future of mechanical engineering. In 20006 ASME elected to study these two issues in more depth to better understand the implications and opportunities for ASME. You will work with others to answer these questions at the ASME Board of Governors retreat:

1. How can collaborative learning communities and technology innovation networks serve ASME's current strategic initiatives and balanced scorecard objectives?

2. What role will members expect ASME to play in learning and innovation over the next 5 to 10 years? Is ASME evolving to meet these expectations? If not, what changes may be needed?

3. Technology innovation networks and collaborative learning communities are essentially next generation capabilities. If ASME developed these capabilities, how could it better enable mechanical engineers to contribute to the well-being of humankind as stated in our mission?

Appendix

2006 ASME Survey of Learning and Innovation Preferences

This Zoomerang survey was distributed in spring 2006 to the ASME membership in conjunction with this scan research. As these are new concepts and the survey format requires a quick response, this survey is only an initial probe of member interest and preferences. More market research tied to specific strategies would be appropriate to better understand how the membership would react to specific initiatives and products.

1. I get specific knowledge to solve problems I am experiencing on the job from ASME.

	Number of Responses	Response Ratio
Strongly Disagree	16	17%
Disagree	21	22%
No Opinion	23	24%
Agree	34	36%
Strongly Agree	1	1%
Total	95	100%

2. I share specific knowledge about problems I am experiencing on the job in ASME communities of practice, technical meetings and conferences.

	Number of Responses	Response Ratio
Strongly Disagree	17	18%
Disagree	27	28%
No Opinion	17	18%
Agree	29	31%
Strongly Agree	5	5%
Total	95	100%

3. I collaborate with other professionals outside my company or organization to get knowledge I need for my job.

	Number of Responses	Response Ratio
Strongly Disagree	3	3%
Disagree	16	17%
No Opinion	3	3%
Agree	61	65%
Strongly Agree	11	12%
Total	94	100%

4. I get recognized by my employer for contributing to the profession's knowledge through ASME.

	Number of Responses	Response Ratio
Strongly Disagree	23	24%
Disagree	23	24%
No Opinion	27	29%
Agree	15	16%
Strongly Agree	6	6%
Total	94	100%

5. I get recognized by my peers for my contributions to the profession's knowledge through ASME.

	Number of Responses	Response Ratio
Strongly Disagree	14	15%
Disagree	23	25%
No Opinion	23	25%
Agree	26	28%
Strongly Agree	7	8%
Total	93	100%

6. I am regularly engaged in learning activities to update my knowledge and skills.	Number of Responses	Response Ratio
Strongly Disagree	0	0%
Disagree	3	3%
No Opinion	5	5%
Agree	53	56%
Strongly Agree	33	35%
Total	94	100%

7. I learn best when I can work with others to solve problems.	Number of Responses	Response Ratio
Strongly Disagree	0	0%
Disagree	5	5%
No Opinion	11	12%
Agree	57	61%
Strongly Agree	21	22%
Total	94	100%

8. I seek knowledge from other disciplines to solve on-the-job problems.	Number of Responses	Response Ratio
Strongly Disagree	0	0%
Disagree	5	5%
No Opinion	3	3%
Agree	58	62%
Strongly Agree	27	29%
Total	93	100%

9. I need the perspectives of people with different life experiences to succeed in my job.

	Number of Responses	Response Ratio
Strongly Disagree	1	1%
Disagree	10	11%
No Opinion	12	13%
Agree	51	54%
Strong Agree	21	22%
Total	95	100%

10. I look to ASME for my lifelong learning needs.

	Number of Responses	Response Ratio
Strongly Disagree	7	7%
Disagree	28	29%
No Opinion	28	29%
Agree	29	31%
Strongly Agree	3	3%
Total	95	100%

11. Please recommend issues or problems you would like to see ASME explore in a collaborative learning community.

36 Responses

12. My company/organization is differentiating itself through innovation.

	Number of Responses	Response Ratio
Strongly Disagree	4	4%
Disagree	8	8%
No Opinion	17	18%
Agree	44	46%
Strongly Agree	22	23%
Total	95	100%

13. My company/organization is globally competitive.

	Number of Responses	Response Ratio
Strongly Disagree	6	6%
Disagree	12	13%
No Opinion	15	16%
Agree	41	43%
Strongly Agree	21	22%
Total	95	100%

14. My company often involves its suppliers in the innovative process.

	Number of Responses	Response Ratio
Strongly Disagree	4	4%
Disagree	9	9%
No Opinion	23	24%
Agree	46	48%
Strongly Agree	13	14%
Total	95	100%

15. My company often involves its customers in the innovative process.	Number of Responses	Response Ratio
Strongly Disagree	1	1%
Disagree	6	6%
No Opinion	17	18%
Agree	56	59%
Strongly Agree	15	16%
Total	95	100%

16. My company/organization expects biotechnology will have a significant impact on its future.	Number of Responses	Response Ratio
Strongly Disagree	15	16%
Disagree	21	22%
No Opinion	29	31%
Agree	19	20%
Strongly Agree	10	11%
Total	94	100%

17. My company/organization expects nanotechnology will have a significant impact on its future.	Number of Responses	Response Ratio
Strongly Disagree	10	11%
Disagree	20	21%
No Opinion	33	35%
Agree	19	20%
Strongly Agree	12	13%
Total	94	100%

18. My company/organization partners with other companies and organizations in order to keep pace with the increasing complexity of engineering systems.	Number of Responses	Response Ratio
Strongly Disagree	3	3%
Disagree	12	13%
No Opinion	17	18%
Agree	50	53%
Strongly Agree	12	13%
Total	94	100%

19. My company/organization is participating in a network of other companies/organizations for research and development expertise.	Number of Responses	Response Ratio
Strongly Disagree	4	4%
Disagree	25	26%
No Opinion	14	15%
Agree	41	43%
Strongly Agree	11	12%
Total	95	100%

20. My company/organization devotes time and resources to building its network of relationships across organizations and countries.	Number of Responses	Response Ratio
Strongly Disagree	3	3%
Disagree	16	17%
No Opinion	17	18%
Agree	50	53%
Strongly Agree	8	9%
Total	94	100%

21. My company/organization has close links to government or academic research institutions.	Number of Responses	Response Ratio
Strongly Disagree	4	4%
Disagree	21	22%
No Opinion	21	22%
Agree	30	32%
Strongly Agree	18	19%
Total	94	100%

22. Please recommend any issues in technology innovation networks you would like to see ASME explore further.

23 Responses

23. I have been involved in engineering:

	Number of Responses	Response Ratio
As an engineering student or recent graduate	1	1%
Between 1 and 5 years	0	0%
Between 5 and 10 years	0	0%
Between 10 and 15 years	2	2%
Between 15 and 20 years	8	8%
Over 20 years	84	88%
Total	95	100%

24. The type of organization I work for:

	Number of Responses	Response Ratio
Independently or as a student	6	6%
Academic or non-profit organization	10	11%
Government organization	8	8%
Small/medium sized company (under 250 employees)	23	24%
Large national company (over 250 employees)	11	12%
Large multi-national company (over 250 employees)	37	39%
Total	95	100%

Collaborative Learning Communities Accelerate New Knowledge

(Note: This research is assembled here for convenient reference for the Board of Governors Retreat July 20. This research also appears on the Strategic Management Sector website in a hyperlinked format at: http://www.asme.org/Governance/StrategicManagement/Collaborative_Learning.cfm)

Collaborative learning communities are individuals joining together to accelerate new knowledge through the dynamic use of social networking and collaboration technologies.

Here are some present examples:

- Communities of practice
- List servers and chats
- Standards and technical committees
- Action learning
- Wikipedia and interactive blogs
- Blended learning (virtual combined with face-to-face experiences)

ASME Steps Toward Collaborative Learning Communities

ASME has a strong commitment to fostering collaboration and has invested in new technologies like communities of practices and online learning. These steps are setting the stage for the next generation of possibilities.

Why Collaborative Learning Communities Are Important to Your Future

The Institute for Alternative Futures (IAF) identified collaborative learning communities as one of six strategic issues important to the future of mechanical engineering in the ASME 2005 environmental scan. In 2006 IAF identified these five drivers that are making this strategic issue a priority for ASME members.

1. *Collective Intelligence Is Essential to High Performance.* Organizations see high performing teams as far more effective than the brightest individuals. They are using new learning processes and technologies to cultivate collective intelligence.
2. *Knowledge Technologies Bring a New Context to Learning.* Knowledge technologies organize information and provide the context needed to create knowledge and support learning. These tools and platforms promote participation because they have easy access, linking and retrieval capabilities.
3. *Digital Natives Make Themselves at Home in a Wired World*. Young people are fluent in the digital language of computers, video games, and the Internet. Organizations must prepare to welcome them into their ranks.

4. *Productivity Requires Getting to the People who Know.* Organizations that want to boost the productivity of knowledge workers are finding that the best way to cut through information overload is to help people get to the people who know faster.
5. *The Global Race for Talent in a Collaborative World*. Companies facing a shortfall of qualified workers in developed nations are turning to emerging economies like China and India. Qualifications for the new global economy will include knowing how to learn through collaboration.

Best Practices for Effective Collaborative Learning Communities

If you are interested in fostering collaborative learning communities, these best practices will get you off to a great start. The people and processes are as essential as the tools. We also forecast how these best practices may evolve by 2016 to help you plan ahead for new capabilities.

Complete This Survey to Help ASME Meet Your Future Needs

You are invited to complete this survey to help ASME evaluate the relevance of collaborative learning communities and technology innovation networks for you and your company or organization. This survey will take you about ten minutes and may help you reflect on your own response to these opportunities.

Recommended Resources

We recommend these resources if you want to do further study on collaborative learning communities. There are also references listed at the end of each driver analysis.

ASME Steps toward Collaborative Learning Communities

When ASME announced its Continuity and Change reorganization in 2004, the leaders promised a structure that enables greater collaboration and flexible access to resources. The vision for this initiative is to create an "an evolving, flexible environment aimed at providing members with the control to establish communities to meet their specific needs, be they regional, professional or technical."

The ASME leaders selected collaborative learning communities as a strategic issue for the association's future. Collaborative learning communities are as old as trade and professional guilds, but new technological capabilities are creating the conditions for associations to help create a 21st century renaissance.

ASME has taken these steps toward creating the next generation of collaborative learning:

1. Codes and standards technical committees are moving their work onto a web-based platform that enables collaborative authoring and accelerates review and approval processes. This capability allows participants from more countries to work toward global harmonization of standards. The codes and standards committees have a clear purpose and group processes for achieving their task. They attract and keep talented people who have a stake in the outcome and gain prestige for their contributions.

2. Communities of practice have attracted more than 4,000 participants in more than 300 communities as of April 1, 2006. Some are limited to ASME members and serve different committees and councils. Many are open to non-members. Some have a technical focus like biomedical engineering, aerospace or product design. Some are software users groups. The Lean-Six Sigma practitioners have a community as do entrepreneurs. One group exchanges information on technical books. The Young Engineers Correspondents is a large and active group open to ASME members only. A few groups serve very specialized interests like the working mothers group or the three people signed up to discuss Fermat's Last Theorem Proof. The intensity and relevance of the discussions vary with only one half the groups active in the first three months of 2006. The communities of practice have proven most effective as a medium to exchange information, but there are limited examples of people working together to solve problems and create new knowledge.

3. ASME volunteers are using a web-based Conference Toolbox to organize tracks, topics and sessions for conferences and seminars. They are able to review abstracts and papers and share comments. Authors, reviewers and editors use a similar online toolbox to peer review journal articles. These collaboration tools not only expedite the workflow, they are helping create an extensive archive of

knowledge that is searchable by date, title and author. This archive can be accessed at http://www.asme.org/Publications/

4. ASME offers 100 online courses. They feature threaded discussions and students post and exchange resources. People can participate any time from anywhere. Online courses help busy professionals update their knowledge and skills and enhance their competitiveness in a global talent market. For more information and to view the catalog of course offerings, go to http://www.asme.org/Education/Courses/Online/

5. The International Petroleum Technology Institute sponsored a deepwater workshop where contractors and operators rolled up their sleeves on a number of risk management challenges. They produced a summary document about areas of agreement, but the real value came from the knowledge exchange and networking. The knowledge exchange was somewhat constrained by the inability of participants to disclose proprietary information. The leaders also have tried putting together a lessons learned forum, but found people reluctant to candidly share what is not working. This experience is not unique to this institute or ASME. It is easier to invoke this level of candor in collaborative learning inside a company than across companies in an association setting.

6. The International Gas Turbine Institute's big event each year has been the Turbine Expo where about 800 papers are presented. The papers were typically more theoretical than focused on applications. Now the institute board wants to go from a once-a-year event to 24-7 access to learning. They want to create a forum for hot topics and real-time issues. They plan to use webinairs, online communities and other technology applications to create a clearinghouse of timely information. The board even took a look at MySpace, the social networking site popular with young people, and is interested in creating this kind of place for member networking.

To sum up the state of the art for collaborative learning communities, ASME is committed to fostering collaboration. The association is investing in web-based platforms and tools to support collaborative learning. There are efforts to orient more conferences and forums around solutions-based knowledge. What may be needed to get to the next generation of collaborative learning is a compelling reason for individuals to join together to accelerate new knowledge.

"Without a grand challenge, why is a community willing to get together? What is the reason to collaborate unless you have a problem to solve or a common interest to share?" said Winfred Phillips, Ph.D., chair of the ASME Strategic Issues, Opportunities and Knowledge Committee.

For collaborative learning communities to thrive within ASME, "why" may be more important than "how".

Collective Intelligence Essential to High Performance in an Interconnected World

For more than a decade organizations have invested heavily in knowledge management to capture what individuals know to make it accessible to others. Now organizations see high performing teams as far more effective than the brightest individuals. They are using new learning processes and technologies to cultivate collective intelligence.

Humans have always focused many minds on a problem to make progress. What has now changed is the scale at which diverse individuals can connect into a global mind to learn faster and deeper to meet the demands of a complex and fast-changing world. Collective intelligence unites the strengths of what educator Howard Gardner has defined as multiple intelligences: linguistic, logical-mathematical, musical, spatial, bodily-kinesthetic, naturalist (making consequential discriminations in the natural world, interpersonal, intrapersonal, and existential (posing and pondering the big questions). (1)

Collective intelligence has been used to describe this wide continuum of possibilities:

- The intelligence evidenced in such places as stock markets, traffic, prediction markets and Google search engines that James Surowiecke describes in *The Wisdom of Crowds.* Crowds are wise if they have diverse opinions, sufficient independence to avoid groupthink, access to local knowledge, and a mechanism for aggregating their opinions into a collective decision. (2)
- Extraordinary group processes where people listen deeply to one another and open to new knowledge and transformation. Peter Senge and his organizational learning colleagues outline these processes in *Presence: An Exploration of Profound Change in People, Organizations or Society.* (3) People can make better decisions in the face of uncertainty and complexity when they challenge each other's assumptions about reality.
- Collective consciousness taps into intuitive, even spiritual connections, among people. While this reaches deep into what Western minds are challenged to explain, increasingly more people are open to other ways of knowing. This openness to collective consciousness may be emerging in a secular society that is searching for meaningful contributions and relationships. (4)

Collective intelligence merges the objective and subjective thinking needed by today's engineers. The National Academy of Engineering found that engineering is now expected to achieve synergy between technical and social systems. (5) These social systems can be quite complex for engineering solutions that span the globe. Engineers need to be proficient at bridging cultures, taking into account different environmental and economic conditions, and anticipating unintended consequences. Very few people can begin to anticipate everything that could happen in complex technical and social systems. Collaborative learning communities give people access to the diverse learning partners who can help them evolve this capacity for systems thinking.

Collective intelligence arises out of respecting and incorporating different knowledge and experience. It is sometimes called the global mind to signal this quality of inclusivity: uniting differences to create a higher order of capacity. Collective intelligence is drawn from different disciplines, cultures and generations. Scientists and engineers are breaking out of their silos into interdisciplinary communities to create new knowledge. Bioengineering is blending the knowledge of systems biology with mechanical engineering. Computer sciences are enabling every domain of science and engineering. The social sciences are offering new insights into everything from health to product design. As people from different disciplines focus on problems together, they are learning how to learn together. Collaborative learning communities offer the practices and environment they need to accelerate learning.

Likewise, high performance teams are learning that to thrive in an increasingly diverse society they need the collective intelligence that comes from working with people of different ethnic and cultural background. Not only are many engineers working for global companies, those not traveling the world have found the world has come to them. Many organizations and companies have an increasingly diverse workforce. The U.S. is becoming a “majority minority” population, as are many other countries where immigration is welcomed or refugees given sanctuary. Cultural awareness has evolved from political and moral correctness to economic necessity.

As the baby boomer generation moves into its retirement years, many organizations are confronting an unprecedented brain drain. Companies and government agencies that depend on specialized knowledge are racing to archive key documents and debrief retiring experts. Yet these knowledge management approaches rarely capture the tacit knowledge of experience and creative insight. When the goal is to foster collective intelligence, these individuals remain inside the community as mentors and resources to the next generation. They are connected through intranets and communities of practice, and invited to meetings and conferences where their time-tested knowledge seeds learning for new conditions and requirements. Last year Northrop Grumman engineers working on a vehicle to replace the space shuttle met with retirees who had worked on the Apollo program. (6)

We have always sought knowledge. In the past we could only easily reach as far as our colleagues, books and journals, schools and association conferences. Today the Web is creating access to people and knowledge around the globe. The visionaries who first posited the global mind largely imagined the connections would be spiritual. They could not have known that globalization and technologies would bring us closer together in a world so complex and interdependent we would need collective intelligence.

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Knowledge Technologies Bring a New Context to Learning

Knowledge technologies organize information and provide the context needed to create knowledge and support learning. These tools and platforms promote participation because they offer easy access, linking and retrieval capabilities. With the advent of digital multimedia, these platforms are robust enough to accommodate different learning preferences.

Today's virtual classroom, or multi-user virtual environment (MUVE), can support synchronous and asynchronous learning. The synchronous tools are audioconferencing, web conferencing, videoconferencing, chat, instant messaging, and whiteboards. Asynchronous tools include message boards, links, group announcements, email and listservers, surveys and polls. The content can feature courseware, streaming media, narrated slideshows, online databases, simulations and gaming. (1)

User interfaces for computers will become progressively more user-friendly and intuitive. Advances in individualization, speech recognition, and haptics will provide an immersive interactive environment for collaborative learning. Retrieving and interpreting captured knowledge (including multimedia) will be intuitive, and it will be easy to connect with similarly equipped colleagues from around the world. Engineers will be able to collaboratively explore, assimilate, model, simulate, predict, and gain understanding of the changing knowledge landscape. Combined with advances in knowledge management and acquisition, engineers will be able to collaborate on increasingly complex and sophisticated problems. (2)

Access is a hallmark of these knowledge technologies. Today access is best exemplified by blogs and wikis that enable people to easily contribute and publish their knowledge and opinions. Technorati, a search engine that indexes blogs, was tracking 33 million blogs in March 2006. Clearly not all this self-publishing merits attention, but the top blogs are commanding as much attention as mainstream media which are now offering their own blogs. Wikipedia, the free online encyclopedia created through collaborative authoring, has now grown to more than a million articles in English. It has become a ready and powerful reference that makes great use of hyperlinking to take the learner deep into any subject. The quality across blogs and Wikipedia articles varies sufficiently to reassure traditionalists that participatory media may not supersede professional journalism and research materials.

However, this open access movement is sweeping across science and technical journals as well. The Directory of Open Access Journals (3) offered 2,158 journals in March 2006. While the open access journals were still predominantly published by non-U.S. professional societies and universities, there were 6 in mechanical engineering, 10 in electrical and nuclear engineering, and 21 in general and civil engineering. The U.S. government is under public pressure to require that government-funded research be freely accessible. A voluntary program already applies to National Institutes of Health research, but the level of participation has been so low that U.S. senators are lining up behind mandatory requirements covering a number of agencies. (4)

Today people rely on Google and other popular search engines to quickly serve up a rich array of information resources. Data mining is becoming more important as the amount of data available on the web increases. The surface web, the web pages we are most familiar with, are primarily collected by search engines "crawling" across hyperlinks. A large amount of research data is only accessible by direct query and posted as dynamic web pages. It is estimated that the information resources in this deep web are over 500 times larger than those in the surface web. In the decade ahead, database architectures and information retrieval systems will focus on opening this information up to us. (5)

Artificial intelligence (AI), in the form of expert systems, have not lived up to their promise because they cover only narrow domains of knowledge and lack key aspects of 'common sense.' Computer science is now working to establish ontologies that better organize information for both intelligent agents and humans. Ontologies classify concepts into classes, objects or categories and convey their characteristics and relationships. As knowledge is increasingly reported in these structured formats, AI combined with ontologies will become a powerful tool for identifying patterns of significance within large bodies of data.

But the next generation search engines may well rely less on classification schemes and more on relationships. Yahoo is now experimenting with social search. Social search examines the bookmarks of everyday Internet users or gives them the tools to rate the sources they find valuable. Yahoo plans to tap into the collective knowledge of its online communities to improve the quality of searches for its users. (6) Those skeptical of social search question whether Yahoo or others will be able to scale up this community knowledge in a way that is more powerful than algorithm-based searches. The answer may not lie in Yahoo, but in the capability of very specialized learning communities that decide they will put this knowledge technology to use for their purposes.

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Digital Natives Make Themselves at Home in a Wired World

Futurist and educational software designer Marc Prensky coined the term “digital native” in 2001 to describe young people who are fluent in the digital language of computers, video games, and the Internet. The older generations he called digital immigrants. (1) In many organizations, the digital immigrants are still in control of organizations that now must welcome the digital natives into their ranks.

Prensky’s advice for educators about 21st century students is just as apt for their future employers. “Today’s students have mastered a large variety of tools that we will never master with the same level of skill. From computers to calculators to MP3 players to camera phones, these tools are like extensions of their brains.” He advises educators to encourage decision making among students, involving them in designing instruction, and getting input from students about how they would teach. (2)

Teachers are partnering with their students to bring these technologies into the classroom. Students are using multi-user virtual environments (MUVEs) to collaborate with students around the globe. They are learning science by participating in remote monitoring and conversations with scientists. They are taking virtual tours and trying out interactive websites offered by museums, scientific research organizations, nature centers and historic places. They are using games and simulations to experience the consequences of their decisions. They go into the field with video cameras and cellphones to interact with their environment and record their experiences. They are just as likely to produce a video as a written report for a group project. They know how to learn in teams because they have already done countless group projects. Some are using wikis. Others have blogs.

In short, the digital natives are living in collaborative learning communities already. They will expect associations and corporate training departments to accommodate their native preferences for learning.

As digital natives, they have blurred their social networks into this digital environment. They stay constantly connected to friends through instant messaging, chat and text messaging. Now millions are hanging out with their friends at social networking sites like Facebook and MySpace. The top social networking site in March 2006, MySpace had 2.5 times the traffic of Google and claims 54 million registered users. It has grown exponentially as friends encourage other friends to create personal pages or profiles where they can send private messages or post public comments, post their personal photo albums, post MP3s to share with their friends, and even keep a public diary via a blog. MySpace is working on making video sharing possible. These digital natives have few of the hang-ups about public disclosure that drive the privacy debate for their elders. MySpace is offering the tools for personalization that enable people to convey their identity in a virtual community. As more friends make Facebook or MySpace their medium for linking up with friends, the more valuable the service will grow. (3)

Social networking is the hot Web strategy in 2006. Other companies are trying slightly different technologies, but over time these applications are likely to converge into the baseline expectations for Web communication. For example, iMEEM is combining the peer-to-peer system behind the original Napster with an instant messenger. Once a user sees her friends online, she can send instant messages, join group chats, keep a blog, and share photos, videos and playlists. (4)

What will be interesting to watch over the next 10 years is how these digital natives use networking to advance their careers, stay connected with their friends and colleagues, entertain themselves, and stay current in their profession. These social networking companies are betting they will turn first to their friends who are just a click away.

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Productivity Requires Getting to the People who Know

Organizations that want to boost the productivity of knowledge workers are finding that the best way to cut through information overload is to help people get to the people who know faster.

The University of California Berkeley estimated that new information captured in print, film, magnetic and optical storage media equaled 5 exabytes—equivalent to 37,000 new libraries the size of the Library of Congress book collections. About 800 MB of recorded information is produced per person each year. Email generates about 400,000 terabytes of new information each year worldwide. (1)

People are awash in this information despite multi-billion dollar investments in information management systems. Major companies and governments have built central data repositories to archive and share documents through their intranets. Data-intensive enterprises are tracking every aspect of their businesses creating a steady stream of snapshots about the business. People have become addicted to their Blackberries to cope with hundreds of daily emails carrying reports, news bulletins, and corporate communications.

But when people need to make sense of all the information or just need an answer quick, they turn first to a trusted colleague. People with rich networks tend to solve problems faster and with better results, according to a Deloitte research study, which recommended helping people "increase the quality of their interactions and knowledge flows." (2)

Networking applications like LinkedIn and Plaxos that were created to help busy professionals expedite the exchange of basic contact information have become more sophisticated. Now network members can use these services for practical purposes like job hunting, recruiting employees, finding professional services, and coordinating group activities. (3)

To help people better define and strengthen their networks, organizations are trying to map how knowledge moves through organizations using social network analysis tools. The more complex and global organizations become the less their organizational charts reflect how work truly gets done. Social network analysis maps these informal relationships and identifies the trusted experts so that others can also reach them faster. (4)

These experts actually become more productive by helping others. Scientists who spend more time working with other researchers, especially those in other countries, are typically more productive. (5) This may be a case of a virtuous feedback loop, because the better known these scientists become, the more people want to collaborate with them.

Successful communities of practice depend on the same phenomenon. People willingly share their knowledge to gain reputation and social capital within a community of their peers. This social capital grows as they share their knowledge within the community. The more generous they are, the more likely the community is to respond to their needs quickly. As long as this exchange is equitable and makes it members more productive, the community thrives. Effective communities of practice drive strategic value by “speeding innovation, enhancing productivity, and reducing rework.” (6)

Now people are building these human attributes into technology applications. Online services like EBay, E-pinions, and Amazon.com use reputation systems to help people decide whom to trust and to encourage trustworthy behavior. They also have been used to evaluate professional advice from book reviews to stock market analysts. (7) Collaborative filtering uses algorithms to determine individual interests from patterns detected from similar users. The most familiar example of collaborative filtering are the recommendations Amazon.com and NetFlicks extract from ordering patterns. Now online communities are finding they can outperform these recommendation systems by applying the community’s context and willingness to share their preferences through bookmarks and ratings.

In our new economy, productivity as efficiency has become a commodity. What is now valued is creativity—innovations, elegant solutions, and personalization. This is why we are finding the best and fastest way to learn is with people who can spark creative thought and guide us to new knowledge the world will reward.

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The Global Race for Talent in a Collaborative World

Companies are willing to search far and wide in the global talent market to acquire the talent they need. Companies headquartered in developed nations are scrambling to overcome talent shortfalls in their domestic workforce and finding well qualified options in the emerging economies they want to enter.

The U.S. Department of Education estimates that 60 percent of all new jobs in the 21st century will require skills that only 20 percent of the current workforce possesses. In the U.S., 70 percent of students graduate high school and only 32 percent leave high school qualified to attend four-year colleges. For African-Americans and Latinos, the graduation rate is 50 percent, and less than 20 percent have the qualifications necessary to continue their education at the college level. (1) This lack of highly qualified graduates is also occurring in Europe. In Germany, "once celebrated for its streams of innovation and Nobel Prize winners, the number of engineering graduates has declined by almost a third since 1995…" which is "one-tenth the number produced by Chinese universities. The waning interest among German students was one of the motives behind Siemens' recent decision to turn to Beijing to develop its new cell phones." (1)

This shortage is exacerbated by the retirement of baby boomers starting in 2008. Within the next five years up to 40 percent of U.S. managers will be eligible to retire. NASA projects that U.S. colleges will graduate 198,000 students to fill the shoes of 2 million baby boomers retiring between 1998 and 2008. By 2050, 40 percent of Europe's total population and 60 percent of its working age population will be people over 60. (1)

In a recent study, more than 200 multinationals representing 15 industries with home bases in the United States and Western Europe rated the availability of intellectual capital and university collaboration as the decisive factors in determining where to locate research and development activities. They value access to top scientists and engineers and collaborative research relationships with leading universities. As these companies seek new market opportunities, "…countries such as China and India will continue to be major beneficiaries of their R&D expansion…" (2) They have competent educational systems, innovation centers, and an accessible pool of talent.

Even if U.S. and European schools increase the number of graduates, the majority of jobs may go unfulfilled because individuals do not have the new set of skills for an era of increasing complexity. At The World Economic Forum 2006, David Arkless from Manpower, an international leader in providing employment services, said, "The problem is we don't have the right people, in the right place at the right time. Take Germany for example. It has the highest unemployment since World War II, yet last year there were more than one million jobs vacancies in the country, because the population has not been re-skilled in the right areas."(3) The real driver behind this global talent market may be a planetary upshift in what the new economy requires of workers. More than technical knowledge, people need to know how to learn new ways of thinking and acting. They need to be able to connect to the right people with the right information at the right time.

"Integrative technologies require collaboration among scientific disciplines, between science and engineering, and across the natural and social sciences. They also require collaboration across organizations as innovation emanates from small to large firms and from vendors to original equipment manufacturers. And obviously they require collaboration across cultures as global collaboration becomes the norm." (4)

Companies "need a mix of highly analytical people with technological savvy, creativity, global know-how, adaptability, and great communication skills to collaboratively solve complex and rapidly changing issues." (1) Companies are finding they could lose their competitive advantage unless they join this global race to try to capture individuals who are breaking out of the parochial structures of existence and exhibiting the needed talent.

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Best Practices for Collaborative Learning Communities

Collaborative learning communities are individuals joining together to accelerate new knowledge through the dynamic use of social networking and collaboration technologies.

These best practices are essential to collaborative learning in 2006. The 2016 forecasts for best practice principles illustrate how the practice may evolve as new capabilities and priorities emerge.

2006	2016
People	
1. Facilitators organize the learning and create a framework for participants to contribute. They have a passion for the topic, leadership ability, networking and facilitation skills, and knowledge of the organization.	1. Individuals have developed collaboration competencies that allow group leadership to be more dynamic and invisible.
2. Talented and knowledgeable people are pre-qualified to participate. Their reputations attract others to the community.	2. Many communities span the globe, are interdisciplinary and intergenerational (children to elders).
Processes	
3. Collaborative learning communities are organized around a common problem to solve or a shared interest.	3. Communities are organized around learning to effect change.
4. They have clear group norms and ways to hold members accountable for productive behaviors, such as guidelines for online and offline etiquette and expectations for levels of participation.	4. The technologies support emotional intelligence and convey nonverbal context that helps build trust.
5. Relationships are established in face-to-face meetings then sustained through virtual collaboration.	5. Virtual technologies will be much more real and support deep relationships.
6. Trust building depends on personal reputation and the expectation of future interactions.	6. Reputation systems establish trust and make it transparent to a global and multicultural community of participants.

7. Contributors earn social capital with peers and employers.	7. Free agents create job security through the quality of their contributions.
Tools	
8. The platforms enable global participation	8. Online communities can support cross-lingual competencies and create the intimacy of a world café.
9. Easy to use participatory media are available like wikis and other groupware for easy review, revising and retrieval of written, audio and visual content.	9. Intelligent agents can interact on behalf of the participants. This is a media rich environment where gaming and simulations enrich learning.
10. Participants can create personal profiles to introduce themselves to the community.	10. A dynamic directory proposes and recruits people who have needed knowledge.

Collaborative Learning Communities Recommended Resources

To learn more about collaborative learning communities and the drivers of change affecting learning, the Institute for Alternative Futures recommends these books, articles and reports as resources. Additional resources are listed at the end of each driver of change for learning analysis (collective intelligence, digital natives, knowledge technologies, global talent market, and productivity).

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Technology Innovation Networks Scan Research

(Note: This research is assembled here for convenient references for the Board of Governors Retreat July 20. This research also appears on the Strategic Management Sector website in a hyperlinked format at: http://www.asme.org/Governance/StrategicManagement/Technology_Innovation.cfm)

Innovation Networks Transform Technology Development

Technology Innovation Networks are interrelated systems of organizations that share technical knowledge and skills across geographic, disciplinary and corporate boundaries to create new products and processes.

Here are some current examples:
- International Research Projects
- Research Joint Ventures
- Strategic Research Alliances
- Standard Setting Organizations
- Co-development Arrangements
- Supplier & Consumer Networks

Current Technology Innovation Networks

Technology Innovation Networks take a variety of forms, but are vital to the process of innovation, especially in complex, high technology fields. We highlight the Human Genome Project, the Joint Strike Fighter and Linux as examples of technology innovation networks.

Why Technology Innovation Networks Are Important to Your Future

The Institute for Alternative Futures (IAF) identified technology innovation networks as one of six strategic issues important to the future of mechanical engineering in the ASME 2005 environmental scan. Technology innovation networks are replacing the firm as the dominant innovator in a knowledge intensive and interconnected world. In 2006, IAF identified these five drivers that will transform how innovation occurs globally and in the organizations of ASME members.

6. *Innovation Spanning Boundaries:* The forces of globalization and collaborative technologies are shifting the focus of innovation from regional clusters to networks that span geographic, organizational and disciplinary boundaries. These networks span complex webs of relationships between firms, universities, government agencies, and other organizations
7. *Global Diffusion of Economic Power*: Innovation in science and technology is no longer the provenance of developed western countries. Emerging countries, especially in Asia, are increasingly looking to science and technology for the next stages of their economic development.

8. *Rise of Global Competition:* Due to global economic diffusion and the effect of new technology, the world is experiencing an unparrelled increase in global competition. Innovation is the differentiator that allows companies to thrive in a global environment.
9. *Increasing Complexity of Technology*: Technology innovation networks are becoming an essential organizational framework for dealing with the complexity of high technology.
10. *The Coming Bio/Nanotech Wave:* The next wave of innovation is building around bio and nano technology, and more than any other wave, it relies on networks for innovation.

Best Practices for Technology Innovation Networks

If you are interested in fostering or becoming involved in technology innovation networks, these best practices will help you and your organization. We also forecast how these best practices may evolve by 2016 to help you and your organization plan ahead.

Complete This Survey to Help ASME Meet Your Future Needs

You are invited to complete this survey to help ASME evaluate the relevance of collaborative learning communities and technology innovation networks for you and your company or organization. This survey will take you about ten minutes and may help you reflect on your own response to these opportunities.

Recommended Resources

We recommend these resources if you want to do further study on technology innovation networks. There are also references listed at the end of each driver analysis.

Current Technology Innovation Networks

Innovation is already occurring in networks. The following three projects, the Human Genome Project, the Joint Strike Force Fighter and the Linux operating system highlight the importance of networks to technology innovation.

Human Genome Project

Unraveling the secrets of the human genome was a project of unrivalled scale and complexity that could not be achieved by one research laboratory alone. The Human Genome Project was established in 1990 to sequence all 20,000 to 25,000 human genes. The project was designed from the start counter to the way basic research in biology was conducted. It was a massive, goal driven effort of a network of research institutions funded and coordinated by the Department of Energy and the National Institutes of Health. The project relied on an international network of research institutions in numerous countries including the United Kingdom, France, Germany, Japan and China.

In 1995, the project changed when J. Craig Venter published the first full sequence of a free living organism using a new technology called whole genome shotgunning. The technology relied heavily on previous developments in methods and tools from the human genome project. In order to create the technology, however, Venter had to rely on an interdisciplinary team of biologists, computer scientists, and engineers. The technology relied heavily on related advances in information technology.

The competition heated up in 1998 as a private consortia lead by Venter competed with the public project in a race to sequence the whole genome. Competition was the spur needed for the project to increase the pace of their discoveries. On June 26, 2000, draft sequences of the human genome were published early by Venter's Celera Corporation and the public human genome project in Nature and Science respectively.

Keys to the technology innovation network in the Human Genome Project:

7. The scale and complexity of the human genome project was beyond the capacity of any single research lab and required the efforts of an international network of researchers.

8. A key innovation, the whole genome shotgun, required a multi-disciplinary approach to the problem of sequencing and relied heavily on advances in a different field, computer science.

9. Competition drove innovation in the sequence of the Genome and helped drive the early completion of the Human Genome Project.

The Joint Strike Fighter

The Joint Strike Fighter (JSF) is the largest military contract in history and an interesting case study of innovation inside large networks. The JSF project has its origins in the incredible cost and complexity of modern weapon systems. Since the end of World War II, the cost per weapon of airplanes, tanks, and ships has risen faster than the defense budget. In response, the number of weapons in each category has fallen. In other words, the force structure of the Navy, Air Force and Marine Corps has fallen dramatically. The JSF is designed to stop this decline in force structure by building a modern fighter jet usable by the Navy, Air Force and Marine Corps as well as allied forces in the United Kingdom, Italy, Canada, Australia, the Netherlands, Turkey, Denmark and Norway.

The project is designed to share the cost and risk of innovation across the U.S. military as well as multiple Allied militaries. Three variations of the JSF will be developed for each of the branches. The Air Force will get a relatively inexpensive fighter jet with stealth capability to rebuild their force structure. The Navy will get a more robust version to handle the stress of aircraft landings. The Marine Corps had the most invested in the project and required a "jump jet" able to take off and land vertically. The Marine Corps desire for a vertical take off and landing vehicle lead to the most significant innovation in the JSF. The winning company, Lockheed Martin, bet the company on an innovative "lift fan" propulsion system that had never been put into practice before.

One of the primary goals of the JSF was to have 80% interoperability between the systems and parts of the three different versions of the plane. This will dramatically reduce the production costs of software, instruments and engines. It will also allow the three branches and allied forces to work together effectively in future joint efforts. The challenge of creating a fighter able to fill three different roles while maintaining interoperability among different versions required innovations in structure and design.

Another key difference of the JSF project and previous military projects is the degree of competition and innovation among the network of suppliers involved in the project. Most international projects have guaranteed work share agreements. However, in the JSF project all suppliers compete head to head.

Keys to the technology innovation network in the Joint Strike Fighter:

1. The incredible cost and complexity of innovation of modern military systems is driving cost sharing among different branches of the military and allied forces.

2. Suppliers are an important source of innovation and competition among them is a key component of the success of the JSF to date.

3. Interoperability is a key focus for the JSF due to its anticipated role as a global fighter able to fill the needs of different military branches.

Linux

The development of Linux is a testament to the power of technology innovation networks. However, the key innovation in Linux is not the operating system itself, but the network of programmers dedicated to development.

Linus Torvalds began Linux when he adapted the principles of the Unix operating system with other freely available software to run on his home computer. Linux has continued to evolve from its humble roots and is now supported by some of the leading names in technology such as IBM, Dell and Hewitt-Packard. They support the community both technically and financially, while selling a range of hardware, software and services based around the Linux operating system.

Behind this successful operating system is a community of several thousand programmers, almost all of whom are volunteers. The Linux community has been described as a bazaar where everyone can join and contribute. Linus runs the project as a “benevolent dictator” who organizes the project and delegates authority. One of the keys to the success of Linux is the well developed culture that rewards competence and skill. A number of developers use the experience, skill and prestige they gain in the project in their day jobs.

While there are significant differences between Linux and other innovation networks, there are some structural similarities between the Linux community and other successful innovation networks:

- There is a general culture in which authority comes from competence
- Leadership and the delegation of authority is transparent
- Linux has a modular project structure to reduce complexity
- Clear rules and norms for communication exist
- There are simple and reliable tools for sharing work and collaboration
- Credit for successful contributions are clearly highlighted

Keys to the technology innovation network based around Linux:

1. Networks can be powerful forces for innovation even in the absence of financial or institutional backing.

2. Successful networks share many of the same structural similarities, whether they are created inside a corporation or formed largely by volunteers.

3. A culture based around acknowledging and rewarding its participants for their contributions is important for developing technology innovation networks.

Innovation Spanning Boundaries

Innovation no longer occurs only in the firm or research institution. It occurs in the network of interactions between the firm and its competitors, suppliers, and customers. It occurs in the interaction between research organizations and their colleagues around the world and in multiple disciplines. Technology innovation networks span the boundaries of organizations, scientific disciplines and even geographic boundaries. As research and development becomes a more global phenomenon and technology becomes more complex, the ability of technology innovation networks to span boundaries will become central to the future of innovation.

Firms innovating in new technologies tend to cluster in areas close to research institutions and where they have access to institutional support, indigenous talent, protections for intellectual property and an open culture of sharing ideas. The growth of innovative companies around prominent research facilities have been a prominent part of the economic miracles of such regional clusters as Silicon Valley (electronics) and Route 128 (biotechnology). Most studies of innovation focus on the regional and industry specific nature of innovation (1).

However, since 1990, networks of organizations that extend across geographic boundaries have become more important for innovation. On average, there are two international cooperative agreements for every domestic one. (2) This is in part due to the increased complexity of technology and the global diffusion of economic power. In order to manage the complexity of innovation in new technology, many firms, research organizations and even countries are entering international partnerships to share the risk and cost of innovation. The Joint Strike Force Fighter and the Human Genome Project are examples of where multiple firms, research organizations and countries have come together to share the risk and cost of innovations in complex technologies. They are also examples of the global diffusion of economic power and scientific and engineering expertise that successful technology innovation networks are able to tap.

Technology innovation networks are also spanning the boundaries between organizations and their competitors, suppliers and customers. These networks can be both vertical and horizontal. Vertical networks integrate upstream suppliers and downstream consumers in the innovative process of firms. The importance of vertical networks in innovation is growing as companies outsource vital components of their business to third party suppliers, and high technology companies increasingly rely on early adopters of technology in the development of products. Horizontal networks involve the collaboration of competing firms in innovation. Horizontal networks are becoming more common as the increasing complexity and cost of high technology is forcing many companies to share development costs and pool expertise.

Innovation is inherently multidisciplinary in nature and arises at the interfaces of scientific disciplines and industrial sectors. The process of innovation develops new fields of study and new structures and frameworks for knowledge. (3) Likewise, technology innovation networks span the boundaries between those disciplines and sectors. As discussed in more detail in the Bio/Nanotech Wave in this website, the radical innovations of the future will span multiple scientific disciplines and industries.

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Global Diffusion of Economic Power

Innovation in science and technology is no longer the provenance of developed western countries. Emerging countries, especially in Asia, are increasingly looking to science and technology for the next stages of their economic development. They are investing significant portions of their resources in research and development (R&D) and linking with research institutions in the developed world through international research projects like the Human Genome Project. Multinational companies are also increasingly moving their R&D operations overseas to take advantage of these emerging R&D clusters. In the process, a network of innovation is developing where advances in R&D are diffused around much faster than ever before.

China is forecasted to become the third largest country, just after Japan, by economic size by 2015. India is forecast to become the fourth largest country by economic size by 2025. (1) Students of economic development and technology diffusion will likely see parallels to the rise of Japan, Inc. in the 1980s. However, there are three differences that will likely make this shift more profound in size and scope:

- China and India are much larger than Japan was in the 1980s. In 1980, the population of Japan was roughly half that of the United States. The current populations of both China and India alone are larger than the United States, the European Union and Japan combined. (2)

- Globalization has dramatically freed world trade. World trade has grown from about $580 billion in 1980 to a projected 6.3 trillion in 2004 and is forecast to increase another 80% by 2020 from 2000 levels. (3)

- Advances in information and communication technology (ICT) are allowing the outsourcing of white collar jobs as well as blue collar jobs. White collar jobs in information technology and business processes have already left for other countries such as India. Many believe that research and development jobs are next in line as multinationals tap into burgeoning numbers of less expensive science and engineering graduates abroad. (4)

A growing percentage of research and development (R&D) is leaving the United States. Multinational companies are moving research and development offshore to be closer to faster growing markets, to provide worldwide service to multinational clients, access science and engineering talent abroad, and to benefit from increased incentives, and spending on R&D abroad. (5) In the process, they are forming networks of innovation inside the company that are moving innovations faster from the developed world to the developing world and vice versa. This has shortened the time it takes technology to move from research to market applications.

The shortening of technology cycle times and product life cycles as well as larger innovation waves are providing opportunities for developing countries and their companies to leapfrog their more established peers. For example, South Korea has leapfrogged other countries to the top of the tables in broadband penetration. In a little under a decade, Bangalore has moved from a little know Indian city to a growing hub for software development and business processing services. This is creating a much more competitive global marketplace for both countries and companies.

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Rise of Global Competition

Due to global economic diffusion and the effect of new technology, the world is experiencing an unprecedented increase in global competition. States compete with each other to attract new companies to the area and create clusters of innovation where innovative start-ups thrive. Companies themselves are becoming more competitive as global economic diffusion opens up markets and technology makes it easier to outsource non-core functions. In many markets, innovation, both product and process, is the differentiator that allows companies to thrive in a global environment. This ongoing process of creative destruction through competition is the catalyst that propels economic growth through technological innovation.

The U.S. remains the global leader in science and engineering along with other developed countries including Western Europe, Japan, Canada, Australia and Israel. The Asian Tigers (Hong Kong, Singapore, South Korea, and Taiwan) have recently emerged as leaders in science and technology as well. However, there are technology clusters inside the emerging economies such as China, India, Brazil and Russia that are quickly becoming competitors in technology and engineering. (1)

The recent economic development of nations has shown a general pattern. Japan, both before and after the war, began its economic ascent by relying on its low costs to adopt foreign technology for manufacturing. As a country like Japan develops economically, the adoption of technology is no longer enough for economic growth and it must innovate to compete. Japan rose to the challenge with innovations in electronics, heavy machinery, automobiles and other products. It also innovated on the process side with innovations like lean manufacturing. The Asian Tigers have stolen a page from the Japanese play book and are recently coming into their own in a range of industries through increased innovation.

The next wave of developing countries, China, India, Brazil and Russia, dwarf the previous wave in both size and scope. China and India, in particular, are devoting more attention to innovation through monetary support for R&D and creating infrastructure and regulatory environments that attract innovative companies. The net effect of the development of one or more of these countries into centers of innovation will have a large impact on the global economic system and create more competition between countries to innovate.

Competition links innovation with the ongoing transformation of the global economic system. It is the basis of the creative destruction process outlined by economist Joseph Schumpeter that drives waves of radical innovation. It is the competition among individual firms that is vital to the innovative process as companies compete with each other to innovative and gain market share (2).

Companies innovate more often in highly competitive markets where they share a market leadership position with one or more rivals. They will innovate in an attempt to "escape competition" and gain a market leadership position. Companies that are well behind or well ahead in market leadership have less incentive to innovate (3).

In a global world where companies are forced to compete not only in their home markets, but in markets abroad, the number of industries with highly competitive markets where a number of multinational and national firms share market leadership position is likely to grow. This in turn is likely to increase the level of innovation among firms as they compete amongst each other to "escape competition" through innovation. This trend will be further reinforced by countries in competition with each other to spur innovation inside their own borders and attract multinational companies.

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Increasing Complexity of Technology

Technology innovation networks are becoming an essential organizational framework for dealing with the complexity of high technology. In 1970, complex technologies, such as aircraft, accounted for 43% of the most valuable world exports. In 1996, the percentage was 84% and is likely higher in the 21st century. The rising complexity and the associated cost of complex technologies are forcing more firms to innovate together in order to share resources and pool talent. In parallel to the complexity of these products, there has been growth in complex organizational networks dedicated to innovation such as research joint ventures, strategic research alliances, standard setting organizations and linkages with both suppliers and customers for research and product development. (1)

Central to the functioning of complex systems are standards for interoperability and many firms are coming together to innovate through standard setting organizations. Standard setting organizations are where networks of competing companies come together to develop the standards for interoperability among different products. These can be official organizations such as professional associations (e.g. the American Society of Mechanical Engineers) or government agencies (e.g. National Institute of Standards and Technology). Unofficial standard setting bodies, which are often loose alliances of competing companies, are also becoming more common. Increasingly, these standard setting organizations are vital to innovation, especially in fast moving industries such as software, computer hardware, consumer electronics, and telecommunications. (2)

Technology innovation networks have emerged due to the importance of organizational learning and cooperation in knowledge intensive industries. Technology innovation networks tend to occur inside complex technological sectors. There is also evidence to suggest that networks and technologies co-evolve. Many technologies today are so complex that innovation can only occur in equally complex organizational networks, which frequently cut across firms, organizations and nations. (3)

Many observers now believe that the network is replacing the firm as the dominant innovator in a knowledge intensive and global world. These are self-organizing systems that evolve in sometimes unpredictable ways. (4) The ability to think at a systems level will become increasingly important for the process of innovation. Engineering has an important role to play in this process and many engineers will need to become familiar with the properties of complex systems. The importance of systems thinking is already showing itself through the expanded role of systems engineers in complex engineering projects. The worldwide growth of advance degrees in systems engineering also points to the importance of systems level thinking to both innovation and engineering. (5)

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The Coming Bio/Nanotech Wave

The next wave of disruptive innovation is building around biotechnology and nanotechnology, and more than any other wave, it relies on networks for innovation. Both biotechnology and nanotechnology span common boundaries in research and rely on scientists and engineers in multiple disciplines working together. They are both global technologies with clusters of innovation emerging in multiple countries around the world, including in developing countries such as China and Singapore. As research in bio and nano technology progress, the importance of networks of researchers that span across the boundaries of disciplines and geography will become more evident.

Innovation occurs in waves that have a disruptive effect in the societies. The current wave of innovation is based around information and communications technology and its disruptive effects are still being felt across communities and industries. These waves of innovation were first elucidated by the economist Joseph Schumpeter who correlated these waves of innovation to productivity growth in economies. Analysts of technology innovation have identified five large waves of innovation since the industrial revolution, which include the current wave of innovation started in the 1990s with the development of microelectronics and computer networks (1).

Applications of biotechnology, similar to information technologies, have the potential to impact most sectors of the global economy and many aspects of our daily lives. Early innovations are already impacting industries such as healthcare, agriculture and chemicals (2). These innovations are likely to be the tip of the spear of a much larger and broader use of biotechnology.

To provide a better idea of the breadth of innovation in biotechnology, a classification based on different colors is used. There is considerable overlap with the different colors. In fact, as more potential uses for biotechnology are discovered, the list of biotechnology colors used by analysts grows longer. The most common and agreed on types of biotechnology include:

- **Red Biotechnology:** Usually describes innovations in the health and medical fields. Red biotechnologies make up the lion's share of current biotechnology companies and innovations.
    - Development of Therapeutics (e.g. new drugs, stem cells, gene therapies, vaccines, etc.)
    - Diagnostics (e.g. biomonitoring, biomarker identification/testing, imaging probes, genetic testing, etc.)
    - Materials (e.g. tissue regeneration, metallic biomaterials, drug delivery systems, bioelectronics, etc.)

- **Green Biotechnology:** Green biotechnology describes the modification of plants, animals and micro-organisms to produce new agricultural products, remediate environmental damage and produce active ingredients in nutraceuticals, functional foods and other products.

- **White Biotechnology:** This broad area of biotechnology encompasses the use of biotechnology for industrial purposes including the creation of new enzymes, food ingredients (e.g. vitamins), biological polymers, chemicals as well as waste recycling, water treatment and other purposes. (3)

The advances in these areas of biotechnology are possible due the convergence of biology and engineering. Examples of the explosive growth and diversity of new areas of biotechnology expertise in engineering include:

Bioagricultural Engineering	Bio-catalysis
Biochemical Engineering	Bio-energy, Bio-fuels
Bioinformatics	Biomaterials
Bionanotechnology	Biopharmaceuticals
Bioreacting Engineering	Bioremediation Engineering
Bioprocessing Engineering	Bio-sensors Engineering
Biological Systems Engineering	Genetic Engineering
Metabolic Engineering	Molecular Engineering
Protein Engineering	Tissue Engineering

Engineers are also playing an important role in creating the basic tools of biotechnology such as the molecular imaging devices, high throughput analyzers and the computer tools and databases for making sense of huge amounts of data. As the field progresses, engineers will play an even larger role in translating advances in bioscience into new processes and products through applied research, design and manufacturing. These include things like biomonitoring devices, bioremediation solutions, bioplastic materials, and new manufacturing facilities for producing biological drugs, biomaterials and biofuels. (4)

Nanotechnology, materials science on a nanoscale, is an enabling technology with a wide range of applications across industries. Many of the current and near term innovations in nanotechnology, often called bionanotechnology or nanomedicine, are enabling advances in biotechnology. Some of the promising innovations in bionanotechnology include:

- **Antimicrobial Properties:** Efforts are focused on investigating nanomaterials with strong antimicrobial properties.

- **Biopharmaceutics:** Efforts are focused on drug delivery applications using nanomaterial coatings to encapsulate drugs and to serve as functional carriers.

- **Implantable Materials:** Efforts are centered on using nanomaterials to repair and replace damaged or diseased tissues.

- **Implantable Devices:** Efforts are concentrated on implanting small devices to serve as sensors, fluid injection systems, drug dispensers, pumps and reservoirs, and aids to restore vision and hearing functions.

- **Diagnostic Tools:** Efforts are directed at utilizing lab-on-a-chip devices to perform DNA analysis and drug discovery research by reducing the required sample sizes and accelerating the chemical reaction process.

- **Understanding Basic Life Processes:** Efforts are focused on using nanoscale devices and materials to learn more about how biological systems self-assemble, self-regulate, and self-destroy at the molecular level. (4)

Outside of bionanotechnology, nanotechnology will have an immediate impact on a wide range of industrial sectors. The ability to engineer materials at a nano-level for improved properties will offer a wide range of innovative opportunities, especially in the design and manufacture of consumer and industrial products. Nanomaterials will offer superior performance properties that include increased strength, reduced weight, increased electric conductivity, supermagnetic properties, tunable optical emission, better thermal insulating, and the creation of materials that are less corrosive and more porous. There are four big areas where nanotechnology will have an immediate impact.

- **Materials & Manufacturing:** Many of the superior properties of nanomaterials will enable innovators in industrial materials and manufacturing to improve a range of industrial and commercial products.

- **Electronics:** Nanotechnology is already being used to develop faster processors and high density data storage. Nanophotonics research could create new electronic display, and dramatically increase the capacity and bandwidth of telecommunication devices.

- **Energy:** The development of nanotube based “quantum wire” could create cables able to conduct electricity more efficiently and will less heat. The additions of nanorods to photovoltaic solar cells have the potential to create a cheap and flexible material able to generate solar energy with the same efficiency as silicon solar cells. Nanomembranes and nanotubes are likely to improve both hydrogen fuel cells and hydrogen storage for use in fuel cells.

- **Environment:** Nanotechnologies have a range of potential innovations including better membranes for pollution control and water purification, cleaner synthesis of chemicals, nanotechnology based sensors for contaminants and the containment of hazardous materials such as nuclear waste. However, the environmental impact of nanoparticles is poorly understood and few toxicology studies of nanoparticles exist. (5)

Mechanical engineers are already involved in the early stages of nanoscience and engineering such as developing instruments, nanoscale imaging, and metrology. Nanotechnology is an inherently multidisciplinary endeavor and mechanical engineering expertise will be vital in solving future problems in nanotechnology including systems integration, packaging and manufacturing. (7)

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Best Practices for Technology Innovation Networks

Technology Innovation Networks are interrelated systems of organizations that share technical knowledge and skills across geographic, disciplinary and corporate boundaries to create new products and processes.

These best practices are essential to formation of technology innovation networks in 2006. The 2016 forecasts for best practice principles illustrate how these principles may evolve as new capabilities and priorities emerge.

2006	2016
At the Firm Level	
2. Innovation networks are an important competitive advantage for large multinational companies in high technology industries.	3. A firm's network of innovators is a competitive advantage for both large and small companies in almost all industries.
4. Close physical proximity to leading research and development institutions is vital to innovation. This leads many companies to locate research organizations in technology clusters.	2. Collaborative technologies make close physical proximity less important than positive working relationships with leading research and development institutions.
5. Research and development occurs inside the firm	3. Many research and development functions will be outsourced
6. Complementary skill sets among different organizations in the network is vital to innovation.	4. Complementary skill sets among different organizations in the network is vital to innovation.
7. Close links to both suppliers and consumers are both important drivers of innovation	5. Close links to both suppliers and consumers are important drivers of innovation.
8. Previous collaborative relationships and stability of personel are an important part of successful technology innovation networks.	6. Previous collaborative relationships and stability of personel are an important part of successful technology innovation networks.
At the Policy Level	
7. Innovation occurs in regional clusters where there is a beneficial combination of institutional support, risk capital, indigenious talent and strong intellectual property (IP) protection.	7. Innovation will occur in global networks that link different sources of indigenious talent together, although institutional support, IP protection and risk capital will remain important.
8. Technology innovation occurs in regional clusters around major research institutions in North America, Europe and Japan.	8. Research institutions of developing countries such as South Korea, China and India are a vital part of technology innovation networks.

9. Regional and national governments need to ensure funding for research and development, good infrastructure and a strong skills base to encourage innovation.	9. Supporting the development of standard setting organizations, research joint ventures and other technology innovation networks will also be vital for economic success.
10. The development of strong professional, social and informal networks are vital to the development of innovation clusters.	10. The development of global networks for professional social and informal networks will be facilitated by collaborative technologies.

Technology Innovation Networks Recommended Resources

To learn more about technology innovation networks and the drivers of change affecting innovation, the Institute for Alternative Futures recommends these books, articles and reports as resources. Additional resources are listed at the end of each driver of change for learning analysis (innovation spanning boundaries, global diffusion of economic power, rise of global competition, increasing complexity of technology, and the coming bio/nanotech wave).

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