

# The Information Technology Career Pathway

Prepared for the  
Winthrop Rockefeller Foundation

By the staff of the  
Arkansas Science and Technology Authority

John W. Ahlen, Ph.D.  
Editor

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## PREFACE

This work began as a conversation between personnel of the Winthrop Rockefeller Foundation and the Arkansas Science and Technology Authority. The conversation ranged over several topics related to information technology, rural communities, and the opportunities related to distance learning and telecommuting.

The Authority, which had gained some understanding of each of these topics, proposed a joint effort to prepare a policy-briefing paper addressing two issues: information technology career pathways and distance learning. The first section, titled “Policy Perspectives about the IT Pathway,” is the final report for that project.

In the process of compiling information for analysis, it became apparent that the material had a second application. The second section, titled “Six Steps along the IT Pathway,” contains much of the compiled information, but organized as learning modules for students and their parents.

The Appendix lists the live Internet links that are used in the electronic version of *The Information Technology Career Pathway* and provides a cross reference to the Web addresses of these Internet resources for readers of printed copies.

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## NOTE TO READERS

**The** Appendix provides a resource for readers of the printed version of *The Information Technology Career Pathway*. A table lists the live Internet links that are used in the electronic version of the monograph and shows the actual Web addresses of these Internet resources.

The Arkansas Science and Technology Authority asks all readers to report problems, corrections, and updates by contacting:

Arkansas Science and Technology Authority  
423 Main Street, Suite 200  
Little Rock, Arkansas 72201  
501-683-4400

## **POLICY PERSPECTIVES ABOUT THE IT PATHWAY**

**Policy Perspectives** about IT Pathways describes policy implications related to information technology career pathways and the application of distance learning to information technology education. The Policy Perspectives section is for persons interested in the policy infrastructure related to information technology careers.

## **Policy Perspective in Brief**

**Policy Perspectives** about IT Pathways include the following.

There are numerous IT occupations.

Some IT careers require a college education; some do not.

Job performance requires educational and behavioral competencies that allow the employee to manage change.

There is not a single representative pathway to follow from high school to an information technology occupation.

There are numerous career pathways to follow.

There are numerous distance learning technologies and applications.

There are competing distance learning technologies, but they seem to be converging toward the Internet. The limiting factor is bandwidth.

Mathematics competencies for education and work can be gained through distance learning applications.

Education or training is the prerequisite for all IT careers. In the knowledge-driven economy, education at the baccalaureate level is essential.

High school students can benefit from (1) guidance on information technology opportunities and academic pathways and (2) by being calculus ready.

Knowledge has value in influencing events.

The New Growth Theory suggests that we are what we know.

A Chinese proverb warns, "If we do not change direction, we are likely to end up exactly where we are headed."

When you encounter inexplicable resistance to change, look for the competing commitment.

*A winner knows how much he still has to learn,  
even when he is considered an expert by others.  
A loser wants to be considered an expert before  
he has learned enough to know how little he  
knows.*

Sydney Harris

## **Policy Interests**

**Policy Perspectives about IT Pathways** describes the two-part policy research activities undertaken by the Arkansas Science and Technology Authority in partnership with the Winthrop Rockefeller Foundation.

The policy areas are (1) the better definition of the career pathways for information technology workers, with special attention to providing career opportunity information to middle school and high school students and (2) the status of distance learning opportunities in rural Arkansas, especially as they pertain to information technology.

### **Information Technology Careers**

The first issue is related to the need for information technology workers and explores the lack of information for students that would help them and their parents make early choices about classes and career pathways that would be beneficial to students wanting to pursue information technology careers.

### **Distance Learning Technology**

The second issue has to do with the deployment and use of distance learning technology and the distribution of educational

content. This has been of some concern to policy makers primarily because of the requests from agencies, colleges, and universities for personnel, technical, and financial resources for distance learning. A more focused observation is that there appears to be a convergence of distance learning *applications* on the World Wide Web.

## **Overlap**

There is overlap between the two issues; therefore, the approach here will be to address both issues in the context of three goals that shaped this investigation. The first goal is to understand the career pathways that lead to occupations in information technology. The second goal is to understand the information technology courses available through distance learning technologies. The third goal is to understand the information technology education programs available in rural Arkansas.

## **Understanding Career Pathways**

In order to understand career pathways, one should be familiar with information technology occupations, the endpoints for such pathways. The [Occupational Outlook Handbook](#), compiled by the U.S. Department of Labor, outlines at least 26 occupations that could be described as being related to information technology. There are undoubtedly more; an increasing number of workers in the new economy are producing or using information and, with what has been called the “digital soaking” of the economy, there is more information technology being deployed in the workplace. The increasing

sophistication of the hardware and software requires higher-level skills in the workforce.

## **IT Occupations**

To begin developing an understanding of IT occupations, consider these five occupational areas: (1) management, (2) computers and mathematics, (3) architecture and engineering, (4) office and administrative support, and (5) maintenance and repair.

Management occupations include managers responsible for general operations, computer and information systems and science and engineering.

Computer and mathematical occupations include computer specialists, such as computer and information scientists who do research, computer programmers, software engineers who design applications and systems software engineers, computer support specialists, and systems analysts. Computer and mathematical occupations also include database administrators, network and computer systems administrators, network systems and data communications analysts, and other computer specialists.

Architecture and engineering occupations include electrical, electronics, and computer hardware engineers. These occupations also include electro-mechanical, surveying and mapping, and electrical and electronic engineering technicians.

Office and administrative support occupations include computer operators, data entry keyers, word processors and typists, desktop publishers, and other communications equipment operators.

Maintenance and repair occupations include electrical and electronics repairers of commercial and industrial equipment.

***There are numerous IT occupations.***

## **Educational Requirements**

Another point to understand is that some IT occupations require a college education. As an example, [CyberCareers](#) lists eight clusters of IT jobs. Four of these, including Web developers, network administrators, digital media developers, and tech support personnel, do not necessarily require four-year degrees. On the other hand, program and software engineering, database administrators, enterprise system analysts, and technical writers all require four-year degrees.

***Some IT careers require a college education, some do not.***

## **Behavioral Competencies**

Still another important point is that some competencies sought by employers of IT workers are not available through formal educational programs. These competencies typically include skills that one learns through experience, often in educational or work environments. Charles Morgan, company leader of [Acxiom](#) Corporation, explained at a 1999 Technology Summit in Fayetteville, that the Arkansas-based IT company needed employees who could work in teams to solve client problems at Internet speed.

Since then, Acxiom employees Jeff Standridge and Ramona Autrey have prepared a monograph on skill obsolescence in an IT Company, like Acxiom, which employs many information technology workers. Their work defines the Acxiom Eight, which are key, future-oriented behaviors typical in high-performing employees. The Acxiom Eight are not technical competencies; they are behaviors that the company looks for in prospective employees. The eight behaviors complement technical competencies, which degrade over time, and equip an employee with skills needed to stay abreast of changes in their technical areas. The eight behaviors, habits, and skills are:

1. Stakeholder Orientation,

2. Continuous Self-Directed Learning,
3. Initiative,
4. Results and Achievement Oriented,
5. Planning and Organizing,
6. Teaming and Relationship Management,
7. Communication, and
8. Quality and Continuous Improvement.

***Job performance requires educational and behavioral competencies that allow the employee to manage change.***

### **Case Studies**

As part of this investigation, interviews were conducted with information technology professionals about the educational and occupational pathways that led them to an IT occupation.

The nine case studies, covering 15 individuals, are a small sample, but they describe specific pathways that are representative of the diversity of decisions made by persons along the IT career pathway. The case studies suggest the value of competencies gained in high school, certification programs, and higher education. They illustrate the different occupational choices available. In general, the case studies clearly illustrate that there is not a single representative pathway to follow from high school to an occupation; rather there are many entry, exit, and re-entry points along the way to an IT job.

The pathways in this sample can be generalized, as follows:

- Sometimes students benefit from information technology experiences in high school (e.g., participating in EAST or working in a university lab).
- Students can go directly from high school to an IT job.
- Some students go from high school to work, where they pick up some IT certifications that lead to an IT position.
- Some students go from high school to the university.

- Sometimes university students drop out of the university to take an IT position.
- Some university students do undergraduate research.
- Some IT workers are university graduates who earned degrees in engineering and computer science.
- Some university graduates go directly to an IT position.
- Sometimes university graduates go to work in non-IT jobs, get IT certifications or attend community college IT classes and move into IT positions.
- Some university graduates go on to graduate school.
- Some students earn graduate degrees and move into IT positions.
- Some people in IT firms are entrepreneurial and have started the business in which they work. Their educational backgrounds include IT certifications (with work experience), dropping out of college, graduating from college and getting IT certifications, and earning a Ph.D.

***There is not a single representative pathway to follow from high school to an information technology occupation.***

### **Entry, Exit, and Re-entry Points**

Examination of the characteristics of information technology career pathways in the sample shows that there are many ways to get an IT position. The one common feature is that each pathway in the sample begins with high school graduation. A couple of the pathways followed what might be called the traditional educational sequence from high school, to the university, to work in an IT position.

From high school, students went to work or to a university. Those who initially went from high school to a non-IT position, went on to an IT occupation after receiving IT certifications or other IT training. Those who went from high school directly to an IT occupation had some kind of exposure

to IT hardware and software applications in high school, for instance in the Environmental and Spatial Technology (EAST) Initiative.

Students who went to a university followed several pathways. Those who followed the more traditional path went into IT occupations after receiving degrees in engineering or computer science. One such student conducted undergraduate IT research. Some dropped out of college and took IT positions after receiving IT training. In a particularly interesting non-traditional step, some university graduates went to work and then either returned to classes at a two-year college to get IT skills or received IT certifications before moving into IT positions. Some university graduates went on to graduate school programs.

Students who pursued education at the graduate level followed two paths. They either went to work in IT occupations or started their own business. Interestingly, persons with graduate degrees were not the only ones to start their own businesses; they included a college drop out, a college graduate, and one who was a high school graduate with lots of experience and IT certifications.

There are a couple of other pathways that did not show up in the sample examined here. Whereas, two-year colleges played a definite role in preparing college graduates for IT positions, two-year colleges also are an important educational resource for (1) high school graduates who are on a pathway to work or to a four-year degree program and (2) workers seeking to improved their skills while in the workforce.

The important point is that there are multiple points at which one can exit the educational pathway and go to work. For earlier generations of workers, it was likely that one would stay in the workforce after leaving school, regardless of the level of academic achievement. In this sample of information

technology career pathways, employment opportunities exist at virtually all of the educational exits, including high school, certificate programs, and two- and four-year colleges. In some cases, completing a degree program is not essential and employment opportunities can be found before graduating.

As demands for, and interest in, improved and higher-level skills at work manifest themselves, and as career goals change, workers find re-entry points back into education. Some of these re-entry points may be assessed as a step “backward” by some because, as an example, the worker already has a B.S. degree from a university, but re-enters the educational enterprise at a certificate or two-year college level to pick up a needed competency. The worker, however, re-emerges to take a higher-skill occupation. Information technology career pathways frequently involve students going to work and then re-entering educational or certification programs on their way to information technology positions.

As students think about career pathways, they should understand that there are numerous career pathways to follow, as illustrated in the case studies.

When the demand for IT workers is high, the reach by businesses extends further up educational pipelines in search of persons with needed competencies. There also appear to be ample opportunities for persons with information technology skills to start their own businesses.

This investigation suggests that, at least for some IT positions, competencies are more important in information technology career pathways than traditional educational “seat time” and course content.

Beginning with high school graduation, there are multiple points at which one can exit the educational pathway and go to work. Once in the workplace, there are multiple points at which

to re-enter the educational enterprise to get new and updated skills.

*There are numerous career pathways to follow.*

## Understanding Distance Learning

The United States [Distance Learning Association](#) defines distance learning as

the acquisition of knowledge and skills through mediated information and instruction. Distance learning encompasses all technologies and supports the pursuit of life long learning for all. Distance learning is used in all areas of education including Pre-K through grade 12, higher education, home school education, continuing education, corporate training, military and government training, and telemedicine.

In 1999 the Governor's Work Group on Technology issued its *Compilation of Distance Learning Initiatives*.<sup>1</sup> The compilation summarized 39 distance-learning projects of 23 separate organizations. Five kinds of distance learning technologies were covered in the compilation, illustrating the diversity of technological approaches to what at one time was nothing more than correspondence courses.

The Compilation's most prominent technology by far was interactive video. All but one of the interactive video projects used compressed video technology; the one exception was broadband, full motion video, which was being used for high

school distance learning applications in an educational cooperative. The compressed video applications included more variety and were being used for teacher professional development; high school classroom teaching; college classroom teaching, especially programming from four-year to two-year campuses; an MBA program; health profession education and training; and military training classes. For the most part, it appears that the interactive video applications are for higher-level students taking college level courses.

The Compilation's next two most prominent distance-learning technologies were related to satellites and a ground-based broadband capability. In both cases, the application seemed primarily focused on delivering content. The satellite technology seemed aimed at one-way delivery of content to schools and libraries through satellite downlinks located throughout the state. The ground-based effort focused on a statewide broadband backbone infrastructure to support two-way interactive video and Internet applications. The overarching issues were accessibility, coordination, and scheduling of interactive video courses over the backbone.

The Compilation also addressed Audiographics, the hybrid Internet/telephone distance learning technology used to deliver mathematics and language instruction to students at high schools around the state. Audiographics appears to be a cost attractive way to deliver images and audio content to high school students at multiple remote locations.

Another effort discussed in the Compilation was the upgrade of the state's broadcast educational television network to digital technology. The application is primarily the delivery of programming, but offers a secondary, focused delivery of educational content to schools where teachers can record it for later use. The new digital technology will provide expanded capabilities for educational applications.

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<sup>1</sup> *Compilation of Distance Learning Initiatives* prepared by the Governor's Work Group on Technology for Governor Mike Huckabee and the Education/Public School Budget Subcommittee of the Arkansas Legislative Council/Joint Budget Committee, January 28, 1999.

*There are numerous distance learning technologies and applications.*

### **Technology Issues and Trends**

The *Compilation of Distance Learning Initiatives* identified five distance-learning technologies: interactive video, satellite downlinks, the World Wide Web (a global, interactive, distributed information system operating as an application on the Internet), broadcast educational television, and a hybrid Internet/telephone technology. Each technology has its own history and uses. Satellite downlinks and educational television generally provide video programming in one direction to multiple receivers, though in some cases an interactive return channel (say via telephone or fax) is used to get viewer feedback. Audiographics, the hybrid Internet/telephone distance learning technology, uses Web-based images in conjunction with interactive voice over telephones to deliver instruction to distant high schools. Interactive video relies on cameras and TV monitors in specially outfitted classrooms to bring an instructor's live lectures to students at one or more distant locations and permit live, two-way video and audio interaction between instructor and students. Lastly, the World Wide Web offers a distance learning medium where students enroll in on-line classes and use interconnected computers to study on-line content (and sometimes traditional material such as textbooks or coursepaks) at times that are convenient for their schedule (i.e., asynchronously); interact with other students and the on-line facilitator via e-mail, chat, and bulletin boards; and take tests on line. Some on-line learning is completely self-directed and self-paced; it does not involve an on-line facilitator or a cohort of students and tends to present short, tutorial type material.

The *Compilation* did not address questions concerning the best distance learning technology or the best technology for students in remote areas. It is obvious that there were (and still are) issues of competing technologies, coordination and availability, and affordability. Of particular interest, with respect to this investigation, are any trends that may have emerged in the few years since the *Compilation* was completed.

It appears that there are three current distance-learning technologies of choice. Bear in mind the consensus that the best approach to high school teaching is to have a qualified teacher in the classroom. If such a *qualified* teacher is not available, for whatever reason, then distance-learning technology offers an acceptable alternative. The issues of the availability of the specific content that is needed, the competing technologies for delivery of content, and overall affordability, remain. If the content is available, then the technology that best approximates having the teacher in the classroom is provided by compressed video. Compressed video technology for the classroom, however, is more costly, so Audiographics may become the preferred technology because its classroom technology is more affordable. On-line Web courses require the same computers (perhaps in greater numbers) and connectivity as Audiographics, but without Audiographics' concurrent telephone interactivity. In some instances, such Web-based courses may become the distance learning application of choice, especially for motivated students.

As the Web continues to evolve, as the underlying connectivity improves (i.e., becomes faster as broadband technology is deployed), and as the Web becomes even more ubiquitous, convergence to the Web seems to be a "market preference" or the channel of choice for much distance

learning. Web-based distance learning not only eliminates the distance barrier (as do compressed video and Audiographics technologies), but also allows self-paced and asynchronous study. This channel of choice allows, with increased bandwidth, expanding use of on-line audio and video clips to explain and demonstrate content in Web-based course applications. There appears to be some convergence to software for Web-based course creation and management (e.g., WebCT and Blackboard), which is engendering more high quality, cross platform content. New “smart” technologies are under development that will tailor online content for students based on their knowledge base. In other words, rather than static Web content that is the same for every student, assessments of students’ grasp of the material will affect the content that students receive. Enhancements in bandwidth, computer processing speed, and improved software suggest that the convergence to the Web is unavoidable. Adherence by some practitioners to other distance-learning technologies, such as stand-alone compressed video, is natural and may have an advantage in some applications.

As is always the case, one must be aware that new technologies are under development and have the potential to alter the distance learning landscape. The technology of choice today may not be the choice tomorrow.

*There are competing distance learning technologies, but they seem to be converging toward the Internet. The limiting factor is bandwidth.*

### **Distance Learning Opportunities for Math**

This investigation superficially examined the availability of mathematics courses through distance learning offerings. The focus on mathematics was motivated in part by the observation that students entering college in pursuit of an IT degree need to

be “calculus ready,” in part because mathematics is essential to science and engineering, and in part because mathematics skills are largely sequential. Because of this overall importance of mathematics, the author was interested in determining whether students could find math courses and acquire math competencies in locations or situations where traditional math classes were not in abundance. The following information is drawn from interviews and Web searches (with appropriate links to relevant sites).

The Arkansas Department of Education offers distance-learning opportunities in algebra II, calculus, and pre-calculus through its [Distance Learning Center](#). These courses are available to high schools via compressed video and Audiographics.

The University of Arkansas at Little Rock offers an on line pre-calculus course through its [Cyber College](#).

In an even more comprehensive approach, the [Arkansas Virtual High School](#) offers a dozen on-line classes, including math, biology, English, Spanish, history, and others. The School

is a pilot project funded through a grant provided by the [Arkansas Department of Education](#). The purpose of the Arkansas Virtual High School is to provide an online alternative learning environment for the students of Arkansas' public schools who need assistance in completing coursework that is difficult to receive due to factors such as schedule conflicts, homebound due to extenuating circumstances, and other factors that might impede a student's progress through grades 9 - 12.

Math courses offered by the virtual high school include Algebra II, Calculus, and Geometry.

There are many other on-line distance-learning courses for mathematics. Some are offered through public schools, some

are proprietary. The following courses are representative of those found in this investigation and cover a full range of topics:

- Algebra I
- Algebra II
- Geometry
- Pre-Calculus
- Trigonometry/Advanced Algebra
- Statistics
- Calculus

The competency in mathematics (as well as other courses) that one needs for both educational and occupational choices can be gained through distance learning technology, regardless of the availability of such classes locally. Mathematics courses at the high school level are available through Audiographics and compressed interactive video, and are also available on line from a variety of providers.

*Mathematics competencies for education and work can be gained through distance learning applications.*

## Understanding Education Programs

There is a logical progression of students from lower grades to higher grades. Curriculum standards and benchmarks define this progression of students. This simple and obvious progression, however, obscures some important educational landmarks and suggests a continuity of progression that may be misleading. In higher grades (i.e., 9 – 12), for example, this progression overlooks the importance of (1) prerequisite classes in course sequences, (2) complexities where bifurcations in the educational pathway require students to

make decisions, and (3) understanding applications from other disciplines that underscore relevance.

The traditional educational pathway may also have gaps, both within the K-12 educational enterprise and between high school and college. This is especially important for mathematics, where there is a demonstrable “math gap.”

## Making Decisions about an IT Education

Students in high school and even in earlier grades are making decisions every day that will set their future career pathway. The courses they select, the amount of homework they do, and the everyday choices they make about extracurricular activities and work all influence their future. Students need to understand how these decisions will shape their ability to pursue various information technology careers.

Students need to understand the following principles, which will help them make better decisions.

- Knowing how to make decisions is important.
- Decisions are important.
- Decisions matter.
- Each decision one makes either takes one toward one’s goal or away from one’s goal.
- Knowing one’s personal interests will help one to make better decisions.
- Set career goals high. Plan one’s work, and then work the plan. There is power in the plan.

## The Student’s Personal Interests Are Important

Crossing the bridge between high school and further education or training can be made easier by knowing what careers might best fit the student’s interests. A useful tool for students to use is the [World of Work Map](#) developed by ACT, Inc. The Map is a graphical representation of 26 career areas plotted in eight

major areas defined on the basis of one wanting to work with people, data, things, or ideas. By combining adjacent areas, eight possibilities arise: working with (1) people, (2) people and data, (3) data, (4) data and things, (5) things, (6) ideas and things, (7) ideas, and (8) people and ideas.

From here, there are many options for IT education and occupations that build on the student's interests.

### **The Educational Pathway**

Education or training is the prerequisite for all IT careers. A high school diploma is a virtual necessity, and from high school there are many pathways to IT certificates and college degree programs that lead to IT occupations. A glimpse of where these pathways lead is provided by the high school and higher education IT programs. When looking at the knowledge-driven economy, education at the baccalaureate level is essential.

### **High School Technology Resources**

Students in high school are near the beginning of the educational pathway that will lead them, based on their decisions, to the world of work and possible information technology occupations. A variety of high school technology programs provides a good introduction to IT activities and in some cases provides sufficient training for an entry level IT job.

The EAST (Environmental and Spatial Technology) initiative exists in a sophisticated computer environment where student problem solving is the focus. The EAST experience is structured around specific projects that can help schools and their communities. Students, working in teams and individually, tackle real-world problems using the capabilities

of a sophisticated, technology-rich computer laboratory as a resource. Learning is performance based.

Cisco Academies teach students to design, build, and maintain computer networks.

Project Lead The Way (PLTW) is a pre-engineering initiative to increase the number of engineers and engineering technologists. Derived from public-private partnerships, PLTW uses its four-year sequence of courses to introduce students to the "scope, rigor and discipline" of engineering before entering college.

ExplorNet is an information-technology learning tool with special utility in rural and traditionally under-served areas. ExplorNet provides the tools to integrate technology into classrooms and helps school districts with the basics of wiring schools for Internet connectivity, recycling computers to provide low-cost, high-speed computers in schools, and show communities how to use the growing technology capability to help promote economic development.

### **IT Certifications**

Information technology certification programs build on high school technology resources to equip workers with certified IT skills. Vendors such as Microsoft, Oracle, and Cisco offer certifications in software and systems, database management, and network management proficiencies. The Computing Technology Industry Association (CompTIA), for example, offers A+ Certification for computer service technicians. Such certifications demonstrate the proficiencies of the certificate holder and can be valuable to those seeking to enter an IT occupation or enhance existing skills. The certificates usually do not address the certificate holders' behavioral competencies, such as problem solving or the ability to work with others.

## **Two-Year College Programs**

Another way to acquire information technology certification and education is to attend one of Arkansas' 23 two-year colleges. At the end of the 1998-1999 academic year, two-year colleges had awarded 84 certificates of proficiency (from one school), 75 technical certificates (from 11 schools), and 158 associate degrees (from 18 schools, including three four-year campuses) in information technology fields.

## **Four Year College Programs**

Many information technology careers require university degrees, as offered at Arkansas' four-year campuses. At the end of the 1998-1999 academic year, 13 universities had awarded 377 baccalaureate degrees in six information technology fields.

## **Graduate Programs**

As one looks at the challenging work of researching and developing new information technology tools, one must consider obtaining the research credentials often required for such positions. In the 1998-1999 academic year, three campuses awarded 29 advanced degrees across three information technology fields.

*Education or training is the prerequisite for all IT careers. In the knowledge-driven economy, education at the baccalaureate level is essential.*

## **Issues and Gaps**

A number of education issues arose during this investigation. One major finding involves the lack of a "roadmap" for students (and their parents) showing ways from school to work in information technology occupations. Guidance counselors in high school apparently have the skills and tools to provide

direction to students, but seem to be overwhelmed with other responsibilities and therefore able to point out only the most important career and educational "landmarks."

Another finding is that there are a bewildering number of information technology opportunities available, beginning in the high school grades and even middle school. EAST, for example, is an outstanding educational experience for students whose high schools (and some middle schools) are equipped with an EAST lab. These are wonderful courses, but they are not available at all schools and they could be better connected to other IT educational programs, to IT occupations, and to the workplace. Mathematics is a case in point.

Mathematics is generally important and is essential for specific information technology occupations. The math courses that students select or don't select in high school can become limiting factors in later occupational choices. If a high school graduate wants to study computer or systems engineering in college, being ready for calculus as a college freshman is a big academic advantage because calculus is part of the freshman curriculum in engineering. In fact, calculus or pre-calculus is the first college math class for most of the four-year college degree programs in computer science. Math pathways, however, are not clearly marked and the utility of mathematics – the applications that link math proficiency to real-world problems – is not always apparent to IT students. A missed math prerequisite, the equivalent of taking the wrong road, can lead to academic delays, remediation, and even to careers different from desired. It is an academic advantage for high school graduates to be calculus ready because most college degree programs in computer science and engineering require calculus.

*High school students can benefit from (1) guidance on information technology opportunities and academic pathways and (2) by being calculus ready.*

## Understanding Knowledge

The Policy Perspectives illustrates that there are numerous information technology occupations. The key things to understand about these occupations are that the occupations themselves are relatively new; the education and training pathways that lead to IT careers are diverse and may be different from what has been traditionally expected; and each pathway is as unique as the individual who took that particular pathway.

This section underscores the general importance of understanding knowledge. In the context of information technology education and careers, the importance is in understanding *new* knowledge, understanding *change* as a result of the changing knowledge base, and understanding the *value* of creating new knowledge.

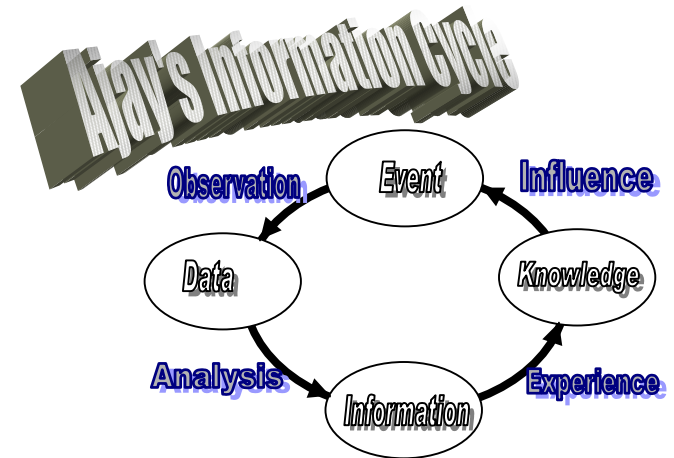
### Ajay's Information Cycle

Ajay Malshe, a professor of mechanical engineering at the University of Arkansas, Fayetteville, describes the generation of knowledge as a repeating four-point cycle with each point in the cycle connected by an activity.

The four points are an event, data, information, and knowledge. The four activities are observing, analyzing, applying, and influencing.

Ajay's Information Cycle begins with an event, which is observed and recorded as data. The data from the event is

subjected to analysis and summarized as information. The information is used and the experience of using the information leads to knowledge – knowledge about the event, its data, the important information about the event, and how the information can be used. Now the knowledge can influence the next event in the cycle.



*Knowledge has value in influencing events.*

### New Growth Theory

Another aspect of knowledge is its importance to the economy. *New Growth Theory, Technology and Learning: A Practitioners Guide* by Joseph Cortright<sup>2</sup> is summarized by two concepts, first that technological progress is a by-product of economic activity and second that knowledge and technology have increasing (not diminishing) returns that drive the growth

<sup>2</sup> Impresa, Inc., 2001, Reviews of Economic Development Literature and Practice: No. 4, U.S. Economic Development Administration. [See <http://www.impresaconsulting.com/ngt.htm>]

process. This suggests enlightening implications for IT careers. Cortright's major points follow.

- **Knowledge Drives Economic Growth**

The cornerstone to New Growth Theory is that new ideas and new knowledge are an integral part of economic growth, not an external variable to be used in mathematical models that explain growth as a consequence of bringing together capital and labor. The real world example of software companies illustrates how important knowledge is, how it is an intrinsic part of economic well being along with capital and labor, and how it and its returns grow with subsequent versions of a software product. Knowledge has three special characteristics: knowledge (1) is intangible, (2) can be shared and reused at nearly zero cost, and (3) allows the possessor, in Cortright's words, "to extract greater use out of finite resources."

- **History, Institutions, and Place Matter**

An interesting aspect of New Growth Theory is that the increasing returns associated with knowledge produce "*path dependence*," that is, chance events happening at the right time can have a long-term influence on the economy as subsequent technological developments (or extensions of knowledge) lock on to the path established by chance. The QWERTY typewriter key pattern is an example of such path dependence. The conclusion is that history matters. The implication is that one acquires new knowledge by following familiar methods shaped by previous experiences, improving on them, and surviving in the marketplace, but always at risk of being succeeded by superior know-how arrived at by an abrupt, leapfrogging improvement. Thus, the new business with a new product that redefines the market becomes the driving force of the economy. The resulting economic changes occur because the new businesses displace old ones, a process called "*creative destruction*" by economist Joseph Schumpeter.

Cortright quotes economist Paul Romer as saying, "The most important job for economic policy is to create an institutional environment that supports technological change." He goes on to explain the importance of institutions is their being where formal and informal rules are determined, and it is the rules that shape and limit transactions, values, reputations, social constructs, and the kinds of knowledge that are created. Institutions matter. The power of institutions is explained in two important regards and are summarized here as follows:

1. *Institutions shape incentives* for the creation of new knowledge (where "the cumulative learning of societies guide people's interpretations of economic and political problems and opportunities") and
  2. Dynamic adjustment to changing circumstances is required for continuing progress (that is, "institutions have to change over time to produce the incentives and rules required by new markets and technology" and that "*adaptive efficiency* ... is the critical factor shaping economic development").
- "New Growth Theory," according to Cortright, "emphasizes the central role that new ideas play in driving economic progress."

Cortright once again quotes economist Paul Romer to introduce the importance of geography in New Growth theory. According to Romer, "As the world becomes more and more closely integrated, the feature that will increasingly differentiate one geographic area (city or country) from another will be the quality of public institutions. The most successful areas will be the ones with the most competent and effective mechanisms for supporting collective interests, especially in the production of new ideas." Place matters. *Knowledge spillovers*, where some of the benefits of new ideas are shared with persons other than the creators, are important

differentiators of place because of four characteristics of knowledge.

1. Knowledge is partly codifiable, and partly tacit (that is, some knowledge can be written down and some knowledge is learned from experience and is more difficult to share with others, especially at a distance).
2. *Tacit knowledge is less mobile.*
3. Diversity and specialization shape knowledge spillovers (that is, innovation leads to the addition of new kinds of services, products, and work).
4. *Local institutions and cultures shape knowledge flows* (that is, they can encourage the kind of social capital that results from trust and reciprocity or they can encourage a more restrictive kind of social capital).

- **Five Lessons**

There are five lessons that derive from New Growth Theory that are applicable to education in general and to IT education in particular.

1. Investments in research and education are critical.
2. Creating knowledge is central to economic growth.
3. The challenge is to find the strategic opportunities to influence economic growth and then to nurture them and help them to develop.
4. Every community has different opportunities. Communities have an important role.
5. Everyone can create knowledge. Especially young, technologically savvy individuals.

*We are what we know.*

## **Macroshift**

Sometimes the ability of knowledge to influence events causes unanticipated major consequences, or as the scientist Louis Pasteur said, "Chance favors only the prepared mind."

*Macroshift: Navigating the Transformation to a Sustainable World* by Ervin Laszlo<sup>3</sup> is a book with a deep insight into the things that influence major change. For Laszlo, a macroshift is defined as a "transformation ... in which technology is the driver and the values and consciousness of a critical mass of people the decider." In the book's foreword, Arthur C. Clark explains Laszlo's vital point; "the future is not to be forecast, but created."

One theme of Macroshift is that it is difficult to predict the future. To some extent, the future is an extension, or an extrapolation, of the recent past and the present. The tomorrow one expects will be similar to today; the environment is basically the same, but some things change from day to day. The accumulation of small changes is a trend. It is possible to track various changes as trends and to project them into the future. Trends illustrate the changes that cause some persons to be better off and some to be less well off. Trends, however, are not infinite; there are limits. Sometimes the world changes, the trend line becomes irrelevant, and the trend no longer projects accurately. When trends encounter such limits, the system that the trends describe approaches a period of instability. In some situations, the system becomes supersensitive and "even immeasurably small fluctuations produce measurable, macroscopic effects." People and living systems use information to maintain – to influence, as Ajay's Information Cycle might suggest – the system. A key point of Laszlo is that,

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<sup>3</sup> The Official Report of the Club of Budapest; Berrett-Koehler Publishers, Inc., San Francisco; 2001.

In periods of relative stability the consciousness of individuals does not play a decisive role in society's evolution, but in periods of chaos it does. When a human society reaches the limits of its stability, it becomes supersensitive and is highly responsive to the smallest fluctuation.

A macroshift has four phases. The first phase is the Trigger Phase. This is marked by the introduction of innovations, new technologies, and systems. The innovations cause efficiencies that in turn effect changes. The Transformation Phase is second. During this phase the trigger brings about irreversible changes that cause complexity in the environment and in social relationships. The Critical Phase follows, when altered relationships put pressure on established culture, values, and ethics. The situation is marked by a subtle order that is especially sensitive to fluctuations. Sustainability is not possible so the path followed will be different from pre-existing trend lines. The fourth and last phase is the macroshift.

The macroshift, in the simplest terms is a bifurcation or branching that leads one way or another: either to breakdown or to breakthrough. The breakdown is marked by an inability for things to change or change that is too slow. Breakthrough is marked by a need to change, to improve. A successful macroshift is possible only if a critical mass of people evolves stabilizing mindsets, values, and ethics. Success depends on the creativity and flexibility of the dominant institutions.

*A Chinese proverb warns, "If we do not change direction, we are likely to end up exactly where we are headed."*

## **Why Good People Don't Change**

Even when new knowledge indicates the benefits of doing things differently, people often resist change. As Richard Hooker, a 16<sup>th</sup> century theologian, pointed out, "Change is not made without inconvenience, even from worse to better." Sometimes, however, the reluctance is not just because of inconvenience, or fear, or stress, or needing new skills; sometimes, good people don't change and reason is not at all clear.

Robert Kegan and Lisa Laskow Lahey<sup>4</sup> address this situation in their article, "The Real Reason People Won't Change." The reason they present is a "hidden *competing commitment*" that stalls one's ability to change. Often the person is unaware of the competing commitment, the associated behaviors that support it, and the assumptions that sustain it.

***When you encounter inexplicable resistance to change, look for the competing commitment.***

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<sup>4</sup> Harvard Business Review, November 2001 (pp. 85-92).