

Economics, Innovations, Technology, and Engineering Education: The Connections

John M. Ritz and P. Scott Bevins

Abstract

Throughout history the success of economies around the world has in large part been influenced by technological growth and innovations. Along with such growth and innovations came higher living standards and an improved quality of life for citizens residing and participating in those economies. However, not all countries were able to grow and develop at the same rate, resulting in considerable differences in economic welfare across populations. As nations around the world address the 21st century, economic growth and prosperity for some nations will depend upon how well their citizens are equipped and motivated to seek new technological discoveries and innovations or participate in the supply chain for the production of such new innovations. Such decision making by individuals will be influenced by both economic and political factors existing within each respective country. After providing a description of economic development, the researchers analyze the current economic conditions in several advanced and developing countries and regions around the world, identifying factors that impact the development in those areas. In the remainder of the article, the focus is placed on the skills needed for 21st century workers and the role technology and engineering education might play in eroding the gaps in skill sets required for developing a workforce, thus moving a country forward in development and affluence.

Keywords: Economics, Innovation, Technology and Engineering Education, 21st Century Skills

Economic Growth and Development

Economic growth is important for the well-being of people and nations. According to Herrick and Kindleberger (1983) “economic growth means more output, and economic development implies not only more output but also different kinds of output than were previously produced, as well as changes in the technical and institutional arrangements by which output is produced and distributed” (p. 21). That is, economic development encompasses new innovation and technological improvements and discoveries, leading to growth in real output and higher living standards. In short, economic

growth implies the increased capacity or ability to produce either more goods or provide more services for which consumers are willing and able to buy. Factors contributing to economic growth include additional resources, innovations, and increased labor productivity.

Economic growth is measured in terms of the standard of living or per capita real gross domestic product (GDP), yielding the real monetary value of final goods and services produced for each individual in a given year. Although there is no guarantee that each individual will have the means to acquire that monetary amount, increasing living standards will provide greater opportunities for populations to succeed. Higher living standards mean more goods and services are produced for consumption, and sales revenues, employment, and personal income increase. As more goods and services are produced for consumption, economic welfare or satisfaction gained from the consumption of those goods and services is assumed to increase. Per capita real income is a better indirect measure of economic welfare or well-being than per capita real GDP, because it reflects more closely the average purchasing power of the individual. Consequently, growth rates, as exhibited by percentage changes in real income, provide a better indirect estimate of improvement in the quality of life.

Changes in living standards occur from variations in either real GDP or population. If the population grows at a faster rate than real GDP, mathematically, goods and services would be spread more thinly across all individuals. Historically, countries developing the fastest were those classified as capitalist nations having market-oriented economies, the G7 nations – Canada, France, Germany, Italy, Japan, United Kingdom, and the United States. Those economies provided greater opportunities for individual success, whether a person engaged in risk taking through entrepreneurship or elected to work for someone else. As a result of economic and political freedoms within those seven countries, technological breakthroughs and improvements flourished. The right to own and to transfer property provided incentives for

individuals to invent, to create, and to be productive. “Private property ensures that producers can appropriate the returns from efficient use of resources to satisfy consumers” (O’Driscoll, 2005, p. 33). Most of the countries that are considered to be capitalist nations would be more appropriately classified as authoritative capitalist nations, such as the Pacific Rim countries of South Korea, Taiwan, Singapore, and Japan. Even though those countries promote private ownership and enterprise as in capitalism, government heavily influences how the *basic* or *fundamental economic questions* of their economy are answered – what goods and services are produced; how they are produced; and for whom they are produced or who consumes them – as opposed to being derived from the voluntary interaction and exchange among buyers and sellers in the market system (Sievert, 1994).

Countries that have economic systems characterized by public property/enterprise and extreme government involvement in answering the *basic economic questions* would be classified as authoritarian socialist or communist nations, and these include the former Soviet Union, North Korea, and China (to some extent). However, China has made significant strides in moving its economy away from the extreme classification of communism by “allowing people to own, buy and sell private property” (Smith, 2008, para. 11). As a result, China has become the second largest economy in size and first in the rate of economic growth (Yanping, Lifei, & Leung, 2010). Relative to the United States, China’s real GDP in 2010 was equivalent to 28% of America’s real GDP (\$6,515.86 billion and \$14,657.80 billion, respectively) (International Monetary Fund [IMF], 2011).

The Global Economy

As nations address the 21st century, their economic and political systems become increasingly important in determining how well their workforces, and thus their companies, are able to compete globally. Natural geographic boundaries that had previously protected countries from global competition have been eroded by the world’s information network. The free and rapid exchange of information has reshaped both labor and product markets, making them more symmetrical in nature as opposed to asymmetrical. Producers and consumers are now able to obtain similar information about goods and services and employment opportunities. In order to succeed,

companies must be quick to adjust and adapt to market changes. Strategic planning and decision making must be iterative in nature; that is, the re-evaluation of decision outcomes must be made quickly, in days or weeks not months. According to Herman (2002), leadership must:

- Sense the territory for emerging opportunities and hazards;
- Respond rapidly with converged effort and resources;
- Innovate and keep moving; and
- Maintain [their] balance in a rhythm between emergence and convergence (focusing sufficient attention and resources to accomplish a result). (p. 9)

The ease and manner by which companies are able to follow such strategic objectives rests heavily on the freedoms extended to them through not only their respective country’s economic system, but also via systems existing elsewhere. Given the current advances in technology and innovations, companies can be lured or enticed more easily to locate or re-locate to other countries where bureaucracy, labor conditions, and production and distribution costs are more appealing. Such micro and macro policies and decisions impact the respective country’s real output as well as that of the world.

At present, economists and central banks around the world are at odds about whether inflation exists or if they can acknowledge it exists, fearing that inflation would further stifle their respective economies by reducing exports to other countries. Given the slow recovery from the financial global crisis of 2008-09, the developed countries have been hesitant to increase interest rates, fearing another economic downturn, arguing if food and energy prices are excluded, inflation is low. Since the crisis, economic growth in the developing and emerging economies has outpaced that of the developed countries, substantiating why many of those countries have elected to increase interest rates. In addition, some developing countries have chosen to expand the use of government subsidies for the populous, as a means of calming any unrest (United Nations, 2011).

Ironically, part of the upward pressure on prices is an indirect effect of developing

economies around the world, most notably from China's economic growth and policies. As countries develop globally, the cost of labor and of other inputs or factors of production increases, leading to higher relative prices for goods and services. As workers demand higher wages in developing nations, the prices of goods and services in each respective country relative to the prices in other countries increase. As wages increase, workers have more purchasing power and thus, greater ability to shop for alternatives.

In 2012, 85% of the world's real output was supplied by the regions of Europe, North America, and Asia and Oceania (see Table 1). Since 1980, countries within the region of Asia and Oceania have collectively outpaced the other regions in the growth of real GDP and per capita real income, predominately due to China's increase from \$216 billion to \$4,504 billion in real GDP and from \$220 to \$3,353 in per capita real income (see Tables 1 and 2).

As countries address the 21st century, the degree to which each succeeds globally will depend upon how much of an emphasis each one places on the development of human capital. As with private enterprise, countries must seek to

maximize their returns on their investments by developing human capital through appropriate education and workforce training; such education and training should be not only aligned with current industry needs, but they should also provide a building block from which labor can adjust and adapt workforce skills to a constantly evolving economy.

Today's labor and product markets differ greatly from those of one or two centuries ago. When individuals enter today's workforce, they realize the jobs they were trained for most likely will not last until retirement. The information highway enables buyers and sellers to quickly acquire information, process that information, and respond to it, creating a fast-paced and continuously changing global economy. "In the future, people will worry far less about how safe their current job is and far more about where their next job will be coming from" (Frey, 2011, para. 2).

Assessing and comparing the value of education and its impact on economic growth across countries is difficult given the differing economic, political, and institutional components or policies of each. Previous attempts have

Table 1. Real Gross Domestic Product and Per Capita Income for Regions of the World

	RGDP (billion \$s)			Per Capita Real Income (\$s)		
	1980	2012	% Change	1980	2012	% Change
North America	\$6,402	\$14,842	131.8%	\$25,424	\$42,575	67.5%
Latin America	\$1,540	\$3,589	133.0%	\$4,275	\$5,959	39.4%
Europe	\$8,414	\$15,381	82.8%	\$16,798	\$28,044	66.9%
Former Soviet Union	\$902	\$1,323	46.6%	\$3,489	\$4,691	34.5%
Asia & Oceania	\$3,849	\$15,073	291.6%	\$1,596	\$3,987	149.8%
Middle East	\$679	\$2,012	196.4%	\$4,852	\$6,743	39.0%
Africa	\$465	\$1,320	183.8%	\$994	\$1,254	26.2%
World	\$22,251	\$53,539	140.6%	\$5,068	\$7,745	52.8%
Developed	\$17,083	\$34,834	103.9%	\$22,360	\$37,594	68.1%
Developing	\$3,735	\$16,278	335.8%	\$1,151	\$2,916	153.5%
Former Centrally Planned	\$1,434	\$2,427	69.3%	\$3,764	\$6,000	59.4%
Emerging Markets	\$2,914	\$12,744	337.3%	\$1,191	\$3,435	188.3%

*Real GDP and real income are in 2005 U.S. dollars.

From "Real Historical Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from <http://www.ers.usda.gov/Data/Macroeconomics/> and "Real Historical Per Capita Income and Growth Rates of Real Income Per Capita for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/Historical_RealGDPValues.xls

produced mixed and often contradictory results (Fatehi, Demeuova, & Derakhshan, 2009; Lee, 2010; & Permani, 2009). However, the focus of this article is neither to measure the value of education nor to measure the impact of education on the economic growth of individual countries. The focus is to assess economic conditions of several advanced and developing countries and regions around the world, to identify factors that impact the development in those areas, to identify both technical and soft skills needed for 21st century jobs, and to project the role technology and engineering education might play in closing the gaps in skill sets required for moving a workforce, and thus a country, forward in development and affluence. The countries used in this study were selected from the top four producing regions of the world: Europe, North America, Asia and Oceania, and Latin America. Countries from the region of Asia and Oceania included China, Japan, Malaysia, South Korea, and Taiwan. Peru was chosen from Latin America and the United States from North America. Europe was analyzed as a group.

China

China's growth of approximately 2000% and 1400% in real output and per capita real income over the past three decades has positioned that country among the economic leaders of the world (see Table 2). In 2012, China's real GDP accounted for 30% of overall production from Asia and Oceania and 8% of world produc-

tion, which increased from 1% to 8.4% since 1980, respectively (United States Department of Agriculture, Economic Research Service [USDA ERS], 2012a, 2012b). Machinery and transportation equipment, miscellaneous manufactured articles (cement, chemicals, fertilizers), and manufactured goods (footwear, toys, electronics, railway cars, space vehicles, and satellites) were China's top export categories in 2010, accounting for approximately 89% of total exports (United Nations, 2010).

As China tightens its economy through contractive monetary and fiscal policies in an effort to curtail inflation, sustaining the rate of economic growth witnessed in recent years will, in the short run, depend on continued growth in consumption or household spending from heavy job creation and in the long run, on the success of educating its future workforce (The Economist Intelligence Unit [EIU], 2010). As of 1996, 70% of students eligible for secondary school were enrolled, an increase from 2% in 1949. Higher education has not experienced such success; approximately 11% of those eligible were enrolled in the late 1990s, which has the potential for problems because more than 25% of people with college degrees began retiring in 2010. Disparities among educational standards are widespread throughout China, occurring at all three levels of education: primary, secondary, and postsecondary. Not only has funding been uneven across provinces, as a

Table 2. Real Gross Domestic Product and Per Capita Income for Selected Countries

	RGDP (billion \$s)			Per Capita Real Income (\$s)		
	1980	2012	% Change	1980	2012	% Change
United States	5,834	13,584	132.8%	\$25,675	\$43,219	68.3%
Peru	47	127	167.2%	\$2,740	\$4,285	56.4%
Europe	8,414	15,381	82.8%	\$16,798	\$28,044	66.9%
China	216	4,504	1982.0%	\$220	\$3,353	1426.3%
Japan	2,412	4,690	94.5%	\$20,647	\$36,823	78.3%
South Korea	163	1,081	564.2%	\$4,270	\$22,133	418.3%
Taiwan	78	466	494.5%	\$4,394	\$20,066	356.7%
Malaysia	31	188	509.9%	\$2,290	\$6,443	181.3%

*Real GDP and real income are in 2005 U.S. dollars.

From "Real Historical Gross Domestic Product (GDP) and Growth Rates of GDP for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from <http://www.ers.usda.gov/Data/Macroeconomics/> and "Real Historical Per Capita Income and Growth Rates of Real Income Per Capita for Baseline Countries/Regions (in billions of 2005 dollars) 1969-2012," by the United States Department of Agriculture (Economic Research Service), 2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/historicalRealPerCapitaGDPValues.xls

percentage of the country's GDP, it actually declined during the 1990s (Narayan & Smyth, 2006).

Japan

Although Japan's real output and per capita real income grew by \$2,278 billion and \$16,176, respectively since 1980, the increase in real output from developing economies in the region and around the world reduced the country's percentage of contribution to the region and to the world (see Table 2). In 2012, Japan's real GDP accounted for 31% of real output in Asia and Oceania and 9% of world production, down from 63% and 11%, respectively since 1980 (USDA ERS, 2012a, 2012b). Machinery and transportation equipment (motor vehicles and ships), manufactured goods (classified mainly as electronics equipment and machine tools), and chemical and related products (textiles, processed foods) were the top export categories in 2010, accounting for nearly 83% of total exports (United Nations, 2010).

The Japanese economy suffered greatly because of both the financial crisis of 2008 and the physical destruction left by the devastating earthquake and tsunami of April 2011. In addition to these catastrophic events, the country must confront labor shortages during the next two decades, the result of an aging population, a declining birth rate, a decreasing labor force participation rate for those of age 34 or less, and falling demand for labor. In 2005, Japan's birth rate was 1.3, 0.8 less than the 2.1 rate needed for population replacement. Japan entered the 21st century with the workforce growing at a negative rate, -0.46% (Matsukura, Ogawa, & Clark, 2007; Worthley, MacNab, Brislin, Ito, & Rose, 2009).

Malaysia

Even though Malaysia's real output has increased \$157 billion since 1980, a growth rate of approximately 510%, the country's output as a percentage of regional production increased only 0.4%, from 0.8% to 1.2% (see Table 2). However, the increase of \$157 billion in real GDP improved its standing in the world by 0.3%, from 0.1% to 0.4% of the world's real GDP. The living standard, as measured by per capita real income rose by \$4,153, from \$2,290 to \$6,443 (USDA ERS, 2012a, 2012b). Machinery and transportation equipment; mineral fuels, lubricants, and related materials; and inedible crude materials (tin, timber) (excluding

fuels) and animal and vegetable oils, fats, and waxes were the top export categories in 2010, accounting for approximately 71% of total exports (United Nations, 2010).

Since achieving independence in 1957, Malaysia has worked diligently to improve its education system, realizing that economic growth requires an educated citizenry. "The overall thrusts for educational development in Malaysia [are] based upon increasing access to education, increasing equity in education, increasing quality in education and improving efficiency and effectiveness of education management" (Dolhan & Ishak, 2009, p. 16). Unlike China, whose GDP has increased dramatically in large part due to its exports, Malaysia's growth in output has resulted from both increased production in "high technology equipment" by private enterprise as well as increased household consumption or spending on final goods and services produced at home (Rady, 2010).

South Korea

South Korea's growth rate of 564% in real GDP and 418% in per capita real income positioned the country in both categories among those countries and/or regions selected for this study (see Table 2). Such growth in real output increased the country's output contribution from 4 to 7% among producers in Asia and Oceania and from 0.7 to 2% among world producers (USDA ERS, 2012a, 2012b). Machinery and transportation equipment, manufactured goods classified chiefly by material (steel), and chemical and related products (beverages, lubricants) were the top export categories in 2010, accounting for roughly 80% of total exports (United Nations, 2010).

South Korea exited the Korean War in 1953 as one of the most underdeveloped countries in the world, with per capita income of \$65. In 2010, however, South Korea's economy was the 12th largest in the world, an increase from the 29th largest in 1969. Per capita income increased over 26,000% to approximately \$17,175. Some attribute such economic growth to General Park Chung-Hee's authoritative regime and practice. Through "five-year economic plans," Chung-Hee targeted technological and chemical industrialization as the main recipients of government resources and assistance. As a result, businesses in "electronics, machinery, chemicals, and other industries" (shipbuilding, telecommunications, automobiles) were born,

leading to dramatic increases in global exports (Boateng, 2011, p. 18).

Taiwan

Although Taiwan's increase in real GDP accounted for an increase of only 0.5% among world producers, \$78 billion to \$466 billion, the population witnessed an increase in the standard of living of \$15,672, from \$4,394 to \$20,066 (see Table 2). Among regional producers in 2010, Taiwan's real GDP accounted for 3% of overall production, increasing from 2% since 1980 (USDA ERS, 2012a, 2012b). Machineries and electrical equipment (electronics and information technologies, computers, armaments), basic metals and articles (cement, textiles), and precision instruments, clocks and watches, and musical instruments were the top export categories in 2009, accounting for nearly 66% of total exports (Ministry of Economic Affairs, Department of Statistics, 2011).

Since the 1980s, four Asian economies, China, India, South Korea, and Taiwan, have discovered their comparative advantages in the high-tech, global information market, South Korea and Taiwan in hardware production, and India and China in software production. As of 2006, Taiwan controlled 86% of the market for notebook computers and had made significant gains in the production of "cable modems, servers, and telecommunications equipment" (Shie & Meer, 2010, p. 3).

During the last decade, Taiwan has sought to improve its higher education to compare more favorably to systems around the world. The global economy has forced Taiwan to think in terms of internationalization; that is, higher education and workforce development or training must address global supply and demand for goods and services as well as for labor (Chin & Ching, 2009). Increased emphasis has been placed on technological literacy education and technological and vocational education. In 2009, the "Technological and Vocational Education Reform Project" was introduced with the intended consequences of producing skilled, specialized, competitive workers (Lee, 2010). Measuring the success of these efforts is made difficult by the current global downturns in economic activity. However, as economies begin to expand, it will become clearer as to whether workers' skills are better matched with industry demands.

Peru

Over the past thirty years, Peru's economy has maintained its ranking in the production of real output among Latin American producers as well as world producers, accounting for 3.5% of total production among Latin American producers and 0.2% of world production in both 1980 and 2010. During those 30 years, Peru's real GDP and per capita real income increased from \$47 billion to \$127 billion and from \$2,740 to \$4,285, respectively (see Table 2) (USDA ERS, 2012a, 2012b). Inedible crude materials (iron ore, cement) (excluding fuels), animal and vegetable oils, fats, and waxes; commodities and transactions not classified elsewhere (coffee, cocoa, glass, natural gas); and food, live animals, beverages, and tobacco were the top export categories in 2010, accounting for nearly 69% of total exports (United Nations, 2010).

In the last two years, Peru's economy has come through the recent financial crisis in much better shape than many industrialized nations of the world. The country's economy expanded 9.2% in April 2010, 9.3% in May 2010, and 11.9% in June 2010 (Business Monitor International [BMI], 2010). In addition, Standard and Poor's upgrade of "Peru's long-term external sovereign debt rating to BBB on August 30 [2011] implie[d] the agency believe[d] the country's fiscal health will improve over the next few years" (BMI, 2011, p. 10). However, with nearly one quarter of Peru's GDP being exported (BMI, 2011), markets, such as those in Europe and Asia, could have an impact on its rate of future expansion. To promote economic growth during the last two decades, Peru, along with other Latin American countries, has targeted the younger, poor, and less educated portion of the labor force with abbreviated training programs. As a result, a greater percentage of those receiving such training gained employment, particularly "among women and younger people" (Ibarraran & Shady, 2009, p. 211).

Europe

Although European countries produced the greatest real output in 1980 and 2012 (\$8,414 billion and \$15,381 billion, respectively), the region's living standard was only 66% and 65% of the U.S. standards and 81% and 76% of Japan's, respectively (see Table 2). In 2012, Europe's real GDP accounted for 29% of world production, a decline of 9% since 1980 (USDA

ERS, 2012a, 2012b). Machinery and transportation equipment, chemicals and related products, and manufactured goods classified chiefly by material (aluminum, iron, steel) were the top export categories for the 27-member states of the European Union in 2010, accounting for approximately 71% of total exports (United Nations, 2010).

News reports in the aftermath of the recent financial crisis continue to indicate grave economic volatility among European Union (EU) nations, often suggesting a collapse of the one-currency system. However, economic problems should have been foreseen as a possibility during early plans/negotiations for moving to one currency. The number of member countries (27) and the large variations in the size of each respective economy have compounded the problems of the recent (or current as claimed by some) recession. Prior to the formation of the EU, each country (particularly smaller ones) was able to affect its exports by influencing its exchange rates through the devaluation of its currency, as is done by China. As a result, countries grew at different rates, and the larger ones grew because of exports (The Economist Intelligence Unit [EIU], 2011). “The trouble was the scale of the imbalances and related capital flows, which exploded in the run-up to the global financial crisis in 2007-08” (EIU, 2011, p. 3). Wasteful government spending has put Greece’s economy on the brink of collapse, and poor investment decisions made by private banks have contributed to Ireland and Spain’s financial woes (EIU, 2011). Given the size of the European economy and the amount of international trade among member nations and the rest of the world, fiscal or monetary decisions made by the EU have an impact on economies around the world. Since such problems arose, German Chancellor Angela Merkel has worked to convince troubled member nations to not withdraw from the EU and return to their native currency, often an argument in opposition to the preferences of members from her own political party (Boston & Lane, 2011).

The threat of monetary collapse has not only overshadowed the efforts made over the last decade to increase the EU’s global competitiveness, but it has nearly derailed their successful pursuit of producing a superior knowledge-based economy with high-tech infrastructure and a well-trained/educated workforce. Instead, the

EU has witnessed its economic growth rates slipping in comparison to North America and Asia (Bosworth, Jones, & Wilson, 2008). As a result, greater focus is being placed on vocational education and training (VET). The VET system is expected to reduce the gap between industry needs and worker skills, a result of changes in labor markets and increased democratization among member nations (Viertel, 2010).

United States

Though the economy of the United States has not yielded the greatest rates of growth in real output and per capita real income, the nation has continued to produce the greatest quantity of output of any nation in the world while maintaining the highest standard of living. U.S. production accounted for 26% of the world’s output in 1980 and 25% in 2012. A living standard of \$43,219 in 2012 was approximately four times the average standard of living for 190 countries (\$10,636). The U.S. standard of living ranked 9th among those countries, trailing only Luxembourg, Bermuda, Norway, Iceland, Macau, Switzerland, Denmark, and Sweden, respectively (USDA ERS, 2012a, 2012b). Machinery and transportation equipment, chemicals and related products (aluminum, sulfur, glass, copper, steel), and miscellaneous manufactured items (motor vehicles, appliances, machine tools, toys) were the top export categories in 2010, accounting for approximately 61% of total exports (United Nations, 2010).

As U.S. debt continues to grow at a rapid rate, many economists are hesitant about forecasting much short-term economic growth. In fact, some continue to predict another downturn, particularly if politicians choose not to address out-of-control spending, jeopardizing the nation’s credit rating. The national unemployment rate was 7.8% in December 2012, with 47% of those being males 20 years of age and older and 42% being females 20 years of age and older (United States Department of Labor, 2013). The Consumer Confidence Index (CCI) fell from 71.5 in November 2012 to 65.1 in December 2012 (The Conference Board, 2012). This index is derived from five areas:

- Appraisal of present business situation
- Expectations of business situation for the next six months

- Plans to buy an automobile, home, major appliance, or carpet within the next six months
- Vacation intended within the next six months
- Expectations of the inflation rate, interest rates, and stock prices for the next 12 months. (The Conference Board, 2011, pp. 5-6)

Fortunately for the United States, its future appears more promising than that of Europe or China, because “America is still the leader in the kind of cutting-edge technology that expands a nation’s long-term economic potential, from renewable energy and medical devices to nanotechnology and cloud computing” (Bremmer & Roubini, 2011, p. 3). In addition, the United States compares better in terms of the supply of future laborers, a result of expected continued immigration, China’s “one-child per couple” policy, and Europe’s decreasing birthrates and increasing opposition to immigration (Bremmer & Roubini, 2011). The United States must now focus attention on reducing the existing skills gap and aligning education and training with industry needs for the 21st century.

Skills for the 21st Century

Occupations have changed during the past 50 years, particularly those related to business and industry. This change includes positions in labor, supervision/management, and design/engineering. Although the term *laborer* continues to exist, in developed countries, many laborers perform their jobs differently. Fifty years ago labor meant muscle, and for some occupations it still does. Today, most labor requires much more use of the mind than muscle. Industry continues to utilize assembly-line laborers, construction workers, and service technicians, but these occupations require more use of advanced technologies (e.g., computer monitoring, data retrieval and entry, laser measurement, machine operation). Some blue- and white-collar jobs are turning into gray-collar jobs (high-tech technicians) because of the advanced technology that is employed (USLegal, 2012). Many of these skilled workers require degrees beyond high school. In addition, supervisors and managers perform most of their functions in offices without moving onto production floors or job sites. Engineering and design work continues to require problem-solving and creativity abilities, but for design and

modeling, computers have replaced most drawing boards and human-fabricated prototype models.

Societies venturing into high-technology economies, such as those emerging in the 21st century, need people with technical skills more than ever. Workers must understand processes, such as designing, forming, cutting, and finishing, but the machines and materials used in the workplace have changed; many machines are automated and a large number of products are made from engineered materials. Workers now need to understand various computer applications that apply to their careers (e.g., computer design, scheduling, inventory, materials ordering, CNC applications, testing, inspection, plus many others specific to the job).

Much of the change has occurred for two reasons – (1) the need for increased productivity and (2) machine replacement of labor due to the skills gap in the workforce, that is, there were too few trained machinists, so programmers replaced these needed skills (machines perform functions, humans push buttons to operate the machines, others program these machines). To increase productivity, industry has needed to do more with less. The less meant machines could select the best material layout options for reducing scrap, draw consecutive images on building plans, and control cutting and shaping without relying totally on human skill.

These changes began in the 1980s and 1990s when industry could not find skilled labor, for example, machinists, bricklayers, welders, and others, so engineers and computer programmers designed machines (work cells) where computers and automation could replace the shortage of skilled workers. If microcontrollers could be programmed to control work, then and today, what might happen to the future?

It is very difficult to determine the technical skills that tomorrow’s workforce will require. It will depend upon the people who design the new products and technological systems for producing them in the future. To help one think of jobs of the future, CNBC (Bukspan, 2011) posted projections of “21st Century Jobs.” Those posted do have close relationships with content for K-16 technology and engineering education. These potential jobs are listed in Table 3 and most are currently related to the emerging technologies that we read about or see in the news.

What might K-16 technology and engineering education do to shape its curriculum to include the knowledge and abilities related to the basics for these new careers? What should be taught so learners can explore and see if they have the talents that can be strengthened so they might seek careers of these types?

Technology and Engineering Education

Today, there is no shortage of workers; there is a shortage of skilled workers. American factories need 600,000 skilled workers, such as machinists, craft workers, distributors, and technicians (DePass, 2011). Knowing this, can technology and engineering education programs aid in “skilling” our future workers? Learners will need to know various knowledge and abilities related to processes and systems of conventional and bio-related agriculture, communication and information, construction, energy and power, manufacturing, medical, transportation, and other technologies (ITEEA, 2007). Some of these processes include designing (computer-aided designing), planning (using computer applications), and making (cutting, forming, fastening, finishing, packaging using computer-controlled machines). The key is to have future workers know about the processes of technology and have them develop basics, not all skills, in these abilities. Designing, processing, and developing systems are the keys to the technologies one teaches. Researchers do not project the need for specific technical skills, because machines should be “intelligent” in the future and easy to use if one understands technical processes and systems, and industry can handle this type of development in its workers (Prashad, 2011).

Technology and Engineering Education’s Connection to Future Workers

Technology and engineering education teachers must think about skills that students will need to innovate, design, and engineer our futures. Professionals in these subjects need to

teach important concepts that are required for citizens to be technologically literate and prepared to move into technical occupations. The U.S. National Academy of Engineering (NAE, 2010) has reported core ideas that need to be embedded into our education systems. The following are the concepts that future workers will need to understand:

- Design
- Systems
- Constraints
- Optimizations
- Modeling
- Analysis
- Communication
- Relationship between engineering and society

Also important for our technology and engineering education programs is the need to develop individuals who are able to think critically and apply what they know to authentic, problem-based scenarios. Teachers must encourage “young people to investigate their current world while contributing to its future. This is the type of education that can be offered through technology and engineering programs, K-20” (Carter, 2011, p. 14).

This idea is supported in *The Employee Handbook of New Work Habits of the Next Millennium* (Pritchett, 1999). Pritchett believes there are job rules for the 21st century. He believes a change in mindset is needed, so one can think and see differently. Carter (2011) connected these ideas to technology and engineering education. She reported what is required:

[Because] The marketplace simply will not accommodate old belief systems about business, careers, and future occupation development. Thinking from these new

Table 3. Jobs for the 21st Century

Custom Implant Organ Designer	Nanotechnologist
Stem Cell Researcher	Waste Management Consultant
Respiratory Therapist	Organic Food Producer
Nutritionist	Biochemical Engineer
Wind Turbine Technician	Robotics Technician

Source: Bukszpan, D. (2011). 21st Century Jobs. CNBC. Retrieved from www.cnbc.com/id/45874627/21st_Century_Jobs

angles of reality, STEM education, and technological and engineering literacy, present proactive, not reactive, concepts to the ever-evolving workplace, necessitating a knowledge-based workforce. (p. 14)

If technology and engineering education teachers truly want to contribute to the development of society and its workforce, they need to prepare students with the basic skills they will need for the years ahead. These include: digital-age literacy, inventive thinking, interactive communication, and quality, state-of-the-art results (METIRI Group, 2010). Table 4 illustrates the meaning of these skills. Each will be discussed in relationship to technology and engineering education, K-16.

Workers' Skills for the 21st Century

Digital-age literacy involves many skills and abilities. The one that technology and engineering subjects focus on is technological literacy (ability to use, manage, understand, and assess technology) (ITEEA, 2007). This is the outcome technology and engineering educators should seek in their laboratories. It also involves other basic literacies, such as learning and using reading, writing, and mathematics. Cultural awareness and understanding others and their values are part of this basic education. Computer literacy is included in visual and information literacy. These are the basic literacy requirements of the 21st century. These are what a basic general education and technology and engineering education should include. In the future work will require digital-age literacy skills of all productive workers and citizens.

Interactive Communication

Interactive communications is a skill set that is key to people trusting each other and working together for common causes – it can be called team membership. Working together and supporting each other's ideas can help an organization grow. These skills also can expose cultural divides that must be solved to circumvent complex problems that arise in business and society. Industrial communication problems that have arisen at the corporate levels (e.g., run-away automobiles, deadly chemicals in pet food and toys, nuclear and chemical accidents, energy disasters) continue because profit has become overly important to corporations and their shareholders. Every day people continue to learn the importance of interactive communications related to governments, companies, and consumers. Prosperous companies are open to the public and communicate within. If employees rethink what they know and what others report, and if they work in a collaborative environment, then they arrive at new ideas or innovations. This way personal and social responsibilities are developed (Korhonen, 2003), and companies and consumers reap the benefits.

Quality, State-of-the-Art Results

Another important skill set for 21st century citizens and workers is quality, state-of-the-art results. This implies one can prioritize, plan, and manage oneself and one's work. Workers employ real-world tools to get the job done more efficiently. The results of their work can produce high-quality results. Parenting has removed these responsibilities for youth in some nations, particularly much of the Western world (White,

Table 4. 21st Century Skills

Digital Age Literacy – Today's Balance	<ul style="list-style-type: none"> • Basic, Scientific, and Technological Literacy • Visual and Information Literacy • Cultural Literacy and Global Awareness
Inventive Thinking – Intellectual Capital	<ul style="list-style-type: none"> • Adaptability/Managing Complexity and Self Direction • Curiosity, Creativity, and Risk-taking • Higher-Order Thinking and Sound Reasoning
Interactive Communication – Social and Personal Skills	<ul style="list-style-type: none"> • Teaming and Collaboration • Personal and Social Responsibility • Interactive Communication
Quality, State-of-the-Art Results	<ul style="list-style-type: none"> • Prioritizing, Planning, and Managing • Effective Use of Real-World Tools • High Quality Results with Real-World Applications

Source: METIRI Group in partnership with The North Central Regional Laboratory. (2010). Retrieved from <http://enGauge.ncrel.org> and www.metiri.com. These skills resulted from their meta-analysis of other skill reports. The full report can be retrieved from <http://ncrel.engauge.org>.

2005). Through group work in technology and engineering courses and other subjects, teachers can redefine these skills and put them into practice, so young people will again recognize their importance as individuals, to society, and in the workplace.

Inventive Thinking

Inventive thinking is one of the key skills needed in the 21st century, according to economic and government reports (European Design Innovative Initiative, 2012; Freeman & Soete, 2012; Garcia & Calantone, 2003). Invention/innovation is important to economic development for a country, region, or global environment. It is a skill needed by economies so a country can prosper in the 21st century. Next, inventive/innovative thinking will be explored for its connections between economics and technology and engineering education. It is a major attribute these programs can build upon.

Innovative/Inventive Thinking

Innovative/inventive thinking is a trait that can be taught and coached by technology and engineering educators (Starkweather, 2005). As is described by the National Innovation Initiative (Council on Competitiveness, 2005), innovation is the “intersection of invention and insight, leading to the creation of social and economic value” (p. 38). It is a key to making an economy productive. Innovation is a change “in a product offering, service, business model, or operation which meaningfully improves the experience of a large number of people” (Carpenter, 2010, para. 5). It involves change, product (or model or service), and meaningful alteration of people’s experiences.

The Council on Competitiveness (2005) indicated that there are prerequisites for a country to be innovative. Some of these include:

- Educate the next generation of innovators
- Deepen science and engineering skills
- Explore knowledge intersections (e.g., multidisciplinary, STEM)
- Equip workers for change
- Support collaborative creativity.

These prerequisites reflect skills needed for the 21st century (METIRI, 2010).

As added by Starkweather (2005), “innovation improves the quality of lives in countless ways” (p. 28). Following are a few of these ways:

- Offers new forms of convenience
- Offers new products or services
- Improves products or services by making them more affordable
- Is a way to solve the great challenges facing society
- Enables achievement of dramatically higher levels of health
- Develops product options for the aging population
- Finds plentiful, affordable, environmentally-friendly sources of energy
- Spreads demographic approaches
- Helps win the war against terrorism
- Expands access to knowledge. (p. 28)

The smartphone is one of these innovative products that has changed our experiences and expanded business and industry. Ultrasound and MRI are innovations in medicine. Microwave popcorn is an innovation in food processing. GPS farming innovations produce higher yields. Communication systems in automobiles are also innovations. These innovations have created new jobs in ever-expanding economies.

Change is a key to innovation. People need to experience situations where their mind goes into an “energized” feel-good mode. They need to feel how the product or service changes their feelings or aspirations. For teaching innovation, educators want to develop attitudes in students. Thus, educators have students ask questions such as: How can we make a product more useful? Would life be better if we had this product or that system? Educators want students to know that product/service innovations should involve something different that will affect large numbers of people and systems. Innovation sells to those who can afford a new way of doing things. Our technological world has continuously encountered these changes and many innovations will further spur economic growth.

Ruttan (2001) purported that for innovation to occur, natural resources and cultural endowments (research institutions, think tanks, suc-

successful companies) are needed. If resources do not exist, they need to be imported. Innovations can occur in all areas of technology. For an innovation to be meaningful, it should change current experiences for people. Smartphones are a major innovation throughout the world. Fewer infrastructures are needed, such as supporting land-lines for the system and phone to operate. New medicines to control the spread of HIV are also major changes to the human experience. The key for innovation to work is that it must become a way of thinking both for producers and consumers. It is not only for designers and engineers. Workers at all levels should think innovatively. In order for innovative products to get to the market, all workers must envision possible changes to enhance the products, services, systems, and models they produce, so they might promote further improvements. Such innovative thinking will keep economic growth prospering.

Connections

Through technology and engineering education and explorations in laboratories, teachers can create and deliver programs that enable innovative thinking to develop and prosper. Classes can be set into environments that will necessitate innovative thinking and performance. For example, an instructor could create a problem where learners are divided into teams to design and build self-sustaining gardens that will produce food all year round. What can the learners grow in their garden that will have local appeal? How will the plants be watered? How will the group control for changes in weather? How will they heat and cool a structure that might house the living and growing environment? Will there be a structure that will house the ecosystem? Possibly, on land next to the school building, students might create a sustainable ecosystem with a garden. The technological systems of construction, energy and power, communication and information, agriculture, and bio-related technologies could be employed. Careers in organic food production, biochemical engineering, and nutrition, along with others, can also be explored through this type of teaching.

While conducting research for the creation of the ecosystem, students will need to use digital-age literacy. They need basic literacy to research and calculate the needs for the ecosystem. Inventive thinking will be needed to design the system and to solve problems that arise with the designs. Re-thinking will be needed to work around design solutions, so the most efficient systems can be made within engineering and

environmental constraints (e.g., structure size, power to operate pumps and heating and cooling systems, costs, life cycles of producing plants). Interactive communications will be needed to review team members' ideas and the way in which they work together efficiently. Quality, state-of-the-art results will need to be kept in focus to have a resulting, operational system.

This is a complex study of technology and engineering, but the solution is a system that can be used in the future by students, the school, and society. The same could be the case in the design of a temporary structure that could be used in a disaster situation. What can be manufactured with materials at hand, can be operational in several hours, and can protect a family of six until permanent structures can be obtained? Many countries have experienced this need in recent times, so the development of such structures should be of high interest to students and develop the skills workers in the 21st century will need.

Teachers' and curriculum designers' thoughts only limit ideas for these types of design problems. The key is to prepare learners for their future, assist them in developing skills needed for the 21st century, and make them consider careers that can aid in building economic development for themselves and their countries.

Summary

Citizens need basics for daily livelihoods, and less developed economies still rely on manual labor for their economies and survival of their people. But where are economies headed with new jobs? Education is an important ingredient for new economies. To get the innovative products that those with discretionary monies will purchase, one needs workers who come up with the new innovations. One needs teams of innovative thinkers, and technology and engineering education can contribute to the production of this intellectual capital. One must re-think and not continue to offer programs that were good for the 20th century. One must change to programs that focus on core technological and engineering literacy and the skills recognized as needed for 21st century citizens.

No longer should technology and engineering education have labs where every student follows the same templates for re-producing a teacher-designed product. Teachers and curriculum designers should create problem situations and have teams of students come up with their

own ideas to answer these problems. Technology and engineering education must teach the fundamental skills of the 21st century, digital-age literacy, inventive thinking, interactive communication, and quality, state-of-the-art results. By focusing on these 21st century skills, and integrating these skills with technological and engineering literacy, technology and engineering education should be able to prepare learners to move their economies and workers forward throughout this century.

John M. Ritz is a Professor and Graduate Program Coordinator in the Department of STEM Education and Professional Studies at Old Dominion University, Norfolk, VA. He is a member of the Alpha Upsilon Chapter of Epsilon Pi Tau.

P. Scott Bevins is Director of Institutional Research, University of Virginia's College at Wise, Wise, VA.

References

- Boateng, O. (2011, April). The rise of South Korea, a lesson for Africa. *New African*, 18-19.
- Bremmer, I., & Roubini, N. (2011, November 12). Whose economy has it worst? *The Wall Street Journal*. Retrieved from <http://online.wsj.com>
- Boston, W., & Lane, M. (2011, November 14). Merkel urges party to help save Euro. *The Wall Street Journal*. Retrieved from <http://online.wsj.com>
- Bosworth, D., Jones, P., & Wilson, R. (2008). The transition to a highly qualified workforce. *Education Economics*, 16(2), 127-147.
- Bukszan, D. (2011). 21st century jobs. *CNBC*. Retrieved from www.cnbc.com/id/45874627/21st_Century_Jobs
- Business Monitor International [BMI]. (2010). Peru: Growth has peaked, but will remain strong. *Emerging Markets Monitor*, 16(20), 10-10.
- Business Monitor International [BMI]. (2011). Peru: Not upgrading sovereign ratings. *Emerging Markets Monitor*, 17(22), 10-10.
- Carpenter, H. (2010). Definition of innovation. Retrieved from <http://www.cloudave.com/202/definition-of-innovation/>
- Carter, K. (2011). Occupations of the 21st century. In J. Ritz & P. S. Bevins (Eds.), *The connection to the 21st century workforce: Technology and engineering education* (pp. 14-21). Reston, VA: International Technology and Engineering Educators Association.
- Chin, J., & Ching, G. (2009). Trends and indicators of Taiwan's higher education internationalization. *The Asia-Pacific Education Researcher*, 18(2), 185-203.
- The Conference Board. (2011). *Consumer confidence survey technical note*. Retrieved from http://www.conference-board.org/pdf_free/press/TechnicalPDF_4321_1319533202.pdf
- The Conference Board. (2012). *The conference board consumer confidence index declines*. Retrieved from <http://www.conference-board.org/data/consumerconfidence.cfm>
- Council on Competitiveness. (2005). *Innovate America*. Washington, DC: Author.
- DePass, D. (2011, December 30). American factories cry need for 600,000 skilled workers. *Star Tribune*. Retrieved from <http://www.startribune.com/blogs/132063803.html>
- Dolhan, H., & Ishak, N. (2009). National education policy: Education development master plan – charting the future. *Revista Panamericana de Pedagogia*, 15(2009), 13-32.
- The Economist Intelligence Unit [EIU]. (2010). Country report September 2010: China. Retrieved from <http://www.eiu.com>
- The Economist Intelligence Unit [EIU]. (2011). State of the union: Can the euro zone survive its debt crisis? Retrieved from <http://www.scribd.com/doc/53647174/Economist-Intelligence-Unit-White-Paper-Can-the-euro-zone-survive-its-debt-crisis>

- European Design Innovation Initiative. (2012). *Design for growth & prosperity*. Helsinki, Finland: European Commission.
- Fatehi, K., Demeuova, G., & Derakhshan, F. (2009). Transitional economies of Central Asia and business education. *Competition Forum*, 7(1), 266-272.
- Freeman, C., & Soete, L. (2012). *The economics of industrial innovation*. London: Routledge.
- Frey, T. (2011, June 17). Building a rapid job-creation engine. [Web log comment]. Retrieved from <http://www.wfs.org/content/building-rapid-job-creation-engine>
- Garcia, R., & Calantone, R. (2003). A critical look at technological innovation typology and innovativeness terminology: A literature review. *Journal of Product Innovation Management*, 19(2), 110-132.
- Herman, S. (2002). From “predictions” to “emergence”: A new fundamental. In S. Herman (Ed.), *Rewiring organizations for the networked economy* (pp. 3-19). San Francisco, CA: Jossey-Bass/Pfeiffer.
- Herrick, B., & Kindleberger, C. (1983). *Economic development* (4th ed.). New York: McGraw-Hill.
- Hilesnath, J., Burkitt, L., & Holmes, E. (2011, June 21). Change in China hits U.S. purse. *The Wall Street Journal*. Retrieved from <http://online.wsj.com>
- Ibarraran, P., & Shady, D. (2009). Evaluating the impact of job training programmes in Latin America: Evidence from IDB funded operations. *Journal of Development Effectiveness*, 1(2), 195-216.
- International Monetary Fund [IMF]. (2011). World economic outlook database. Retrieved from <http://www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx>
- International Technology and Engineering Educators Association [ITEEA]. (2007). *Standards for technological literacy: Content for the study of technology*. Reston, VA: Author.
- Korhonen, J. (2003). On the ethics of corporate social responsibility – Considering the paradigm of industrial metabolism. *Journal of Business Ethics*, 40(4), 301-315.
- Lee, C. (2010). Education and economic growth: Further empirical evidence. *European Journal of Economics, Finance and Administrative Sciences*, 23(2010), 161-168.
- Lee, L. (2009). *Technological literacy education and technological and vocational education in Taiwan*. (ERIC Document Reproduction Service No. ED508339).
- Matsukura, R., Ogawa, N., & Clark, R. (2007). Analysis of employment patterns and the changing demographic structure of Japan. *The Japanese Economy*, 35(1), 82-153.
- Ministry of Economic Affairs (Department of Statistics). (2011). Export by commodity. Retrieved from 2k3dmz2.moea.gov.tw/gnweb/English/Indicator/wFrmEnIndicator.aspx
- METIRI Group & The North Central Regional Educational Laboratory. (2010). Twenty-first century skills. Retrieved from <http://mcrel.engage.org>
- Narayan, P., & Smyth, R. (2006). Higher education, real income and real investment in China: Evidence from Granger causality tests. *Education Economics*, 14(1), 107-125.
- National Academy of Engineering [NAE]. (2010). *Standards for K-12 engineering education?* Washington, DC: The National Academies Press.
- O’Driscoll, Jr., G. (2005). Economic freedom: The path to development. Retrieved from <http://www.fee.org/files/docLib/odriscoll.pdf>
- Permani, R. (2009). The role of education in economic growth in East Asia: A survey. *Asian-Pacific Economic Literature*, 23(1), 1-20.
- Pritchett, P. (1999). *The employee handbook of new work habits of the next millennium*. Dallas: Pritchett Publishing Corporation.
- Prashad, S. (2011). Need skilled workers? Create your own. *The Globe and Mail*. Ontario: Ontario Business Partnership.

- Rady, D. (2010). A study of the major constraints on Egyptian economic growth during the period 1998-2008: A comparison with Malaysia. *Journal of Global Business and Economics*, 1(1), 120-140.
- Ruttan, V. (2001). *Technology, growth and development: An induced innovation perspective*. Oxford: Oxford University Press.
- Shie, V., & Meer, C. (2010). Is this the Asian century? China, India, South Korea and Taiwan in the age of intellectual capitalism. *Journal of Contemporary Asia*, 40(1), 1-21.
- Sievert, D. (1994). *Economics: Dealing with scarcity* (3rd ed.). Wisconsin: Glengarry Publishing.
- Smith, V. (2008). Human betterment through globalization. Retrieved from <http://www.fee.org/nff/human-betterment-through-globalization/>
- Starkweather, K. (2005). Innovation, TIDE teachers, and the global economy. *The Technology Teacher*, 65(2), 28-30.
- United Nations. (2010). International merchandise trade statistics. Retrieved from <http://comtrade.un.org/pb/CountryPagesNew.aspx?y=2010>
- United Nations. (2011). World economic situation and prospects 2011. Retrieved from http://www.un.org/en/development/desa/policy/wesp/wesp_current/2011wespupdate.pdf
- United States Department of Agriculture, Economic Research Service [USDA ERS]. (2012a). Real historical gross domestic product (GDP) and growth rates of GDP for baseline countries/regions (in billions of 2005 dollars) 1969-2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/HistoricalRealGDPValues.xls
- United States Department of Agriculture, Economic Research Service [USDA ERS]. (2012b). Real historical per capita income and growth rates of real income per capita for baseline countries/regions (in billions of 2005 dollars) 1969-2012. Retrieved from http://www.ers.usda.gov/datafiles/International_Macroeconomic_Data/Historical_Data_Files/historicalRealPerCapitaGDPValues.xls
- United States Department of Commerce, International Trade Administration. (2011). Top U.S. trade partners. Retrieved from http://www.trade.gov/mas/ian/build/groups/public/@tg_ian/documents/webcontent/tg_ian_003361.pdf
- United States Department of Labor, Bureau of Labor Statistics. (2013, January 4). The employment situation – December 2012. (Series USDL-13-0001). Retrieved from <http://www.bls.gov/news.release/pdf/empsit.pdf>
- USLegal. (2012). Grey-collar worker. Retrieved from <http://definitions.uslegal.com/g/grey-collar-worker/>
- Viertel, E. (2010). Vocational education for sustainable development: An obligation for the European Training Foundation. *European Journal of Education*, 45(2), 217-235.
- White, W. S. (2005). Students, parents, colleges: Drawing the lines. *The Chronicle of Higher Education*, 52(17), B16.
- Worthley, R., MacNab, B., Brislin, R., Ito, K., & Rose, E. (2009). Workforce motivation in Japan: An examination of gender differences and management perceptions. *The International Journal of Human Resource Management*, 20(7), 1503-1520.
- Yanping, L., Lifei, Z., & Leung, S. (2010, October 21). China's growth cools as inflation accelerates. Bloomberg News. Retrieved from <http://www.businessweek.com>