Chapter 8
Technological Transformations and Their Implications for Higher Education

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Russian and Soviet economist Kondratieff (1892–1938) in the 1920s discovered the presence of periodical changes in macroeconomics and price cycles of four world leaders in the economy: Germany, Great Britain, France and the USA (Kondratieff 1925, 1984). There are some synonyms of this term in the world literature, namely technological waves, supercycles, great surges, long waves, K-waves or the long economic cycle (Schumpeter 1942; Mensch 1979; Freeman 2001; Goldschmidt et al. 2005; Lvov 1991; Šmihula 2009; Morgan 1991). The duration of the cycle is about 40–60 years.

The economists who adhere to this theory are Austrian-American Joseph Schumpeter (1883–1950), German-American Gerhard Mensch (b.1937), Englishman Christopher Freeman (1921–2010), Russian Dmytriy Lvov (1930–2007), German Andreas J. W. Goldschmidt (b.1954), Slovak Daniel Šmihula (b.1972) and others. Technological wave is a set of technologies that are characterized by a certain level of production and development (see Table 8.1). In the frame of technological wave, the self-contained macroproduction cycle is realized. It includes the way of power generation, all stages of processing and production of a set of final products, and it meets certain requirements of public consumption as well as professional education of staff.

The 6th Technological Wave

The 6th cycle started formally in 2015 and is mainly concentrated on the following technologies: nanotechnologies, biotechnologies, information technologies and cognitive technologies (Bainbridge and Roco 2005). The historical point of view

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Table 8.1 Technological waves with character features

Technological wave	Years	Title	Key technologies and applications	Main features
1	1770–1830	The industrial revolution	Textile, textile machinery, cotton-based technology, cast-iron smelting, water engine, canal building	Water-powered mechanization of industry
2	1830–1880	The age of steam and railway	Ferrous metallurgy, machine tool and coal-mining industry, transport, steam engine, steamship and railway building	Steam powered mechanization of industry
3	1880–1930	The age of steel and heavy mechanical engineering	Steel and rolled metal production, electrical and heavy engineering industry, transmission facilities, inorganic chemistry, internal combustion engine, automobiles, the highway system, mass production, beginning of motorized agricultural mechanization, telephony, radio Big firms, cartels, syndicates, trusts have shown up. Monopolies were dominated. The concentration of bank and finance capital have been started	Electrification of industry, transport and buildings
4	1930–1975	The age of oil, electricity, cars and mass production	Non-ferrous metallurgy, motor-car and tractor construction, oil industry, consumer durable, synthetic materials, organic chemistry, fertilizers, television and electronics, diffusion of commercial aviation and air conditioning, beginning of nuclear utilities Oligopoly competition was dominating at the market. Transnational and international companies have arisen, they have made direct investment in the market of various countries	Motorization of transport, oil chemistry

(continued)

Table 8.1 (continued)

Technological wave	Years	Title	Key technologies and applications	Main features
5	1975–2015	The age of informatics and telecommunications	Electronic industry, soft- and hardware, optical fibre engineering, the gas industry, telecommunication, robotics, information services The transition from separate firms to the single network of big and small enterprises combined by the Internet and put into practice close collaboration in the field of technologies, quality testing of production, planning of innovations	Computerization of economy
6	2015–2050	The age of critical technologies	Nano-, bio-, info- and cogno-technologies, cell and gene engineering, alternative and renewable energy, knowledge-based economy	NBIC convergence

shows that the countries or companies which have chosen the promising direction of development related to modern tendencies have taken advantage of future business (see Official sites of Sigma-Aldrich and Apple Inc.; Song 2003). For example, Sigma-Aldrich Corporation is a life science and high technology company with over 9600 employees and operations in 40 countries. Its chemical and biochemical products and kits are used in scientific research of biotechnology, pharmaceutical development, the diagnosis of disease, and as the key components in high technology manufacturing (see Official site of Sigma-Aldrich). Another example is Apple Inc., which is one of American Multinational Corporation that designs, develops and sells computer electronics consumer electronics, computer software, online services and personal computers (see Official site of Apple Inc.). Apple was founded on 1 April 1976, and Fortune magazine named Apple as the most-admired company in the USA in 2008, and in the world from 2008 to 2012 (see The World's Most Admired Companies 2012). Another example concerns South Korea (Song 2003). Starting from the gross domestic product per capita of about $79 in 1960, South Korea has already achieved approximately 30 per cent of the annual gross domestic product (GDP) in 1986. Figovsky (2011) explains this phenomenon in the following way: to overcome the gap between 3rd and 5th technological waves, South Korea had the biggest number of physicists in the world per capita in Seoul in the 1990s (Figovsky 2011).

That is why it is necessary to follow current vectors in knowledge and technologies, taking into account the results of accurate analysis of science, education, business and economics (see Horizon 2020; Official site of Venture Planning Group; Bainbridge and Roco 2005). The motivation of this article is to give brief information about technological waves, to pay attention to real-world tendencies in education and science and to emphasize urgent steps to be done in the modern environment for persons, institutions and states.

Challenges of the 6th Technological Wave

The main features and challenges of the 6th technological wave coming have been described by Bainbridge and Roco (2005). In Fig. 8.2, the main technologies are shown as well as the fundamental disciplines that are bases for this wave. "NBIC" are rapidly taking place today among nanotechnology, biotechnology, information technology and cognitive science. NBIC as converging technologies have the potential impacts on economics, stimulate and steer innovations. Actually, NBIC are the emerging technologies.

Challenges of new technologies in 6th wave are the following (Bainbridge and Roco 2005):

1. Development of nano-, bio-, info- and cogno-technologies;
2. Convergence of NBIC technologies;
3. Formation of staff with new mentality;
4. Interdisciplinary education;
5. New equipment;
6. Novel approaches to metrology;
7. Biosafety and ecological impact; and
8. New principles of energy production.

One of the prognoses for the nearest future is the following: comfortable, wearable sensors and computers will enhance every person's awareness of his or her health condition, environment, chemical pollutants, potential hazards, and will provide information of interest to local businesses, natural resources, etc.

Technology in Ukrainian Society

For last decade, the question how and what we have to develop is under hard discussion (e.g. Wonglimpiyarat 2005; Wilenius and Kurki 2012). The main slogan was formulated by Wonglimpiyarat (2005) as following: the key to success would lie in how each country could find the right application to focus on to survive through international competitions. From the analysis of the K-waves, Forrest

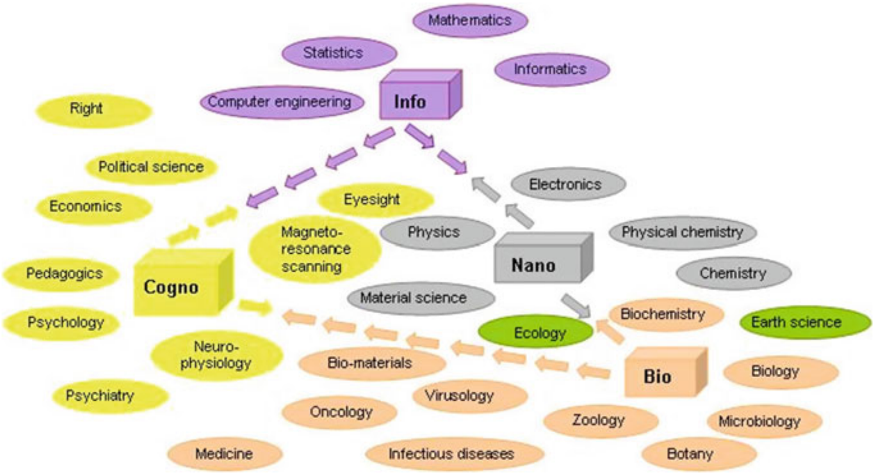

Fig. 8.1 Main technologies of the 6th technological wave and its surrounding

(1981) determined five character key factors that influence the future development of society: (1) movement of people between sectors; (2) the long time span to change the production capacity of capital areas; (3) the way capital sectors provide their input capital as a factor of production; (4) the need to develop excess capacity to catch up the difference demand; and (5) the psychological and speculative forces of expectation that can cause overexpansion in the capital sectors. At the same time, tasks for Ukrainian society could be separated into two spheres: education and R&D (Fig. 8.1).

The world trend in education is the creation of NBIC faculties for the preparation of persons with an interdisciplinary understanding of new technologies. According to the interim report of the Finnish project "The 6th wave and systemic Innovations for Finland: Success Factor for the Years 2010–2050 (6th Wave)" (Wilenius and Kurki 2012) in the long-term development of societies, the most significant factor predicting a success will be the education system that encompasses all members of society. And, the authors of the report appointed two driving forces for the next wave:

1. E-learning, which has already been a hot topic for a few decades, but now the technology, societal needs, attitudes and structures finally seem to align in this regard; and
2. International migration of young generation to get an education due to the lack of traditional outlet for it, as well as institutions, which can provide high-quality education.

At the first time, presently, technological development enables to meet the above two requirements.

In R&D, the spectrum of directions is wider and includes bilateral and multidisciplinary cooperation and collaboration for the creation of entirely new approaches and technologies. Fortunately, Ukraine is strong in material science (Smertenko et al. 2014) and has known well enough in the world achievements in bioengineering, informatics and even in the creation of training complexes which are concerning to cogno-technologies.

The 6th wave demands new tasks for material science. They have to be based on:

1. "Green" technologies;
2. "Smart" technologies;
3. "Cheap" technologies; and
4. "Energy-saving" technologies.

Nanotechnology is characterized by the manipulation of objects at the molecular level. Biotechnology will use living organisms in the production process. Such approaches will radically change our understanding of production in industry and treatment in the medical sphere. There will be a greater emphasis on various alternatives to current production processes that will be less ecologically harmful.

Partial tasks for materials science are the following:

1. Production of constructional materials with predetermined properties;
2. Nanomaterials and nano-structural coating; and
3. Materials for space and green energy.

Nanotechnologies will be applied to get more robust, flexible and durable materials. New materials have to increase the efficiency in all existing technologies including space technologies.

To follow the idea of convergence, it is necessary to form consortia from universities, research institutes, SMEs and larger firms. The centres of technology transfer have to be a very important chain of such consortia. These consortia can and have to be a part of clusters, technology platforms and big international projects. Financial support has to be provided at least partly by the government. And the government has to promote the bottom-up approach in leading technologies for the 6th wave because the human potential is the main engine of innovations.

As an example of nano- and biotechnologies convergence, the formation of silver nanoparticles from plant extracts (Pirko et al. 2012) and self-organized organic films on a patterned silicon substrate (Gorbach et al. 2011) is shown in Figs. 8.2 and 8.3, respectively.

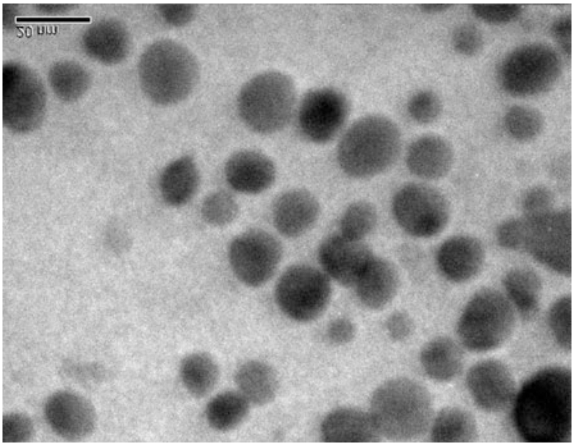

Fig. 8.2 Transmission electron microscopy image of silver nanoparticles from plant extract. *Source* Smertenko (2014)

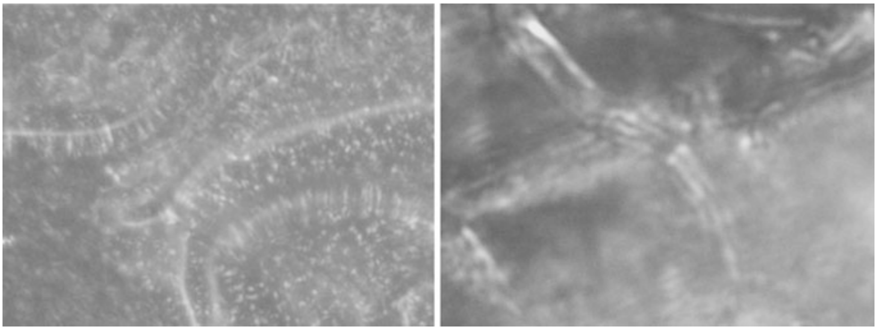

Fig. 8.3 Optical image of self-organized organic films on silicon substrate. *Source* Smertenko (2014)

Conclusion

1. Understanding of global changes in economics for a long time can help for priority formation of each country;
2. We have to change ourselves, i.e. our knowledge, our understanding, our mentality and enhance our skills;
3. One of the perspective directions of nanotechnologies in Ukraine can be development of constructional material for innovations in all industrial branches; and
4. One more direction can be related to investigation and production of multifunctional materials like self-organized, self-reproducing or biologically compatible ones.

Afterword

1. What is the next? This is a usual question for researchers and creative persons. The 7th technological wave titled “Age of socio-humanitarian technologies” will be coming after 2050 with new technologies in sociology, psychology, political sciences and economy (Šmihula 2010). As a rule, the next technological wave is formed in the depth of previous or even before the previous technological wave. For example, DNA sequencer, the device for determination of the order of the four bases: G (guanine), C (cytosine), A (adenine) and T (thymine). This device is one of the main instruments for biotechnologies. It was proposed in 1973, actually 42 years before starting of 6^{th} technological wave (Gilbert and Maxam 1973). Now we can see the rise of cogno-technologies, which will dominate in the 7th technological wave. The recent analysis of last events, such as Brexit and presidency election in the USA, shows the application of newest technologies for influence on lots of people by Big Data technology (Grassegger and Krogerus 2016).
2. Each of technological wave is accompanied by a certain source of energy, for example coal (2nd wave), electricity (3rd wave), oil and gas (4th wave) and nuclear energy (5th wave). The renewable energy is characteristic for the 6th wave. It is necessary to note that here the energy-to-energy transformation has to be the central principle to obtain the power contrary to the previous principle matter-to-energy-to-matter transformation. Here we have always the problems with waste. It is possible to mention such approaches as extra energy (energy of space) and energy from the vacuum (Cole and Puthoff 1993), or cool nuclear synthesis (generator Rossi) (Rossi 2009).

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