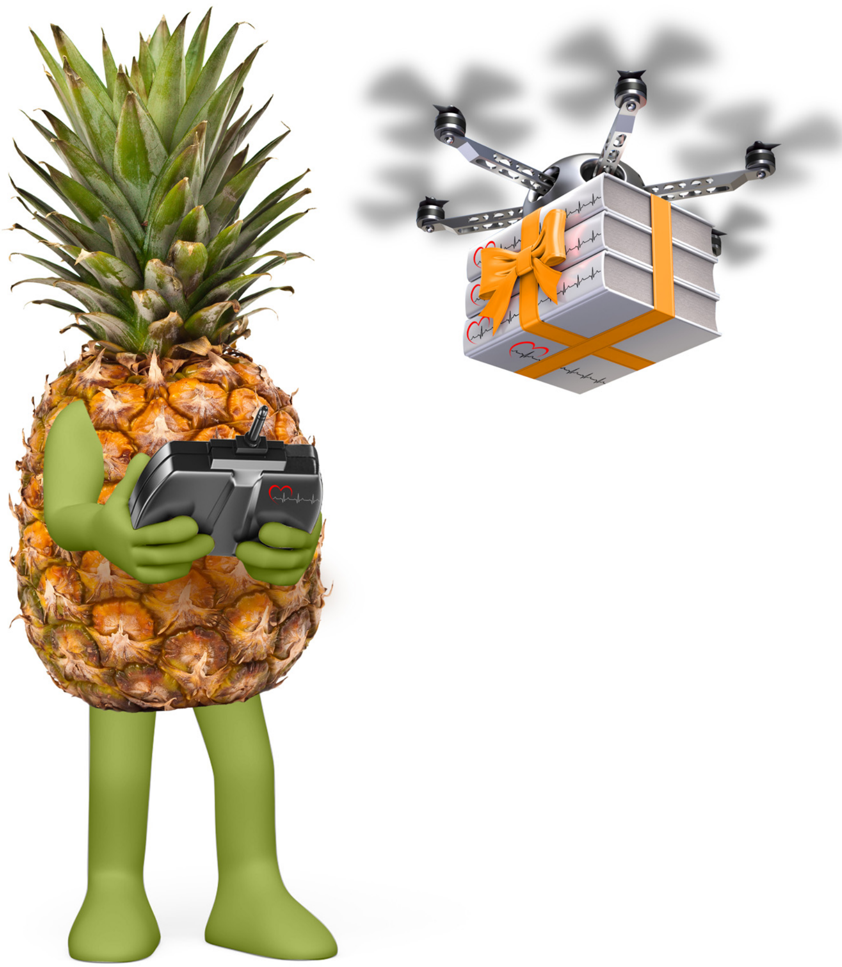

KNOWLEDGE MANAGEMENT IN R&D CENTRES, IN THE FIELD OF BIOMEDICINE, USING CONTEMPORARY INFORMATION AND COMMUNICATION TECHNOLOGY AND THE METHODOLOGY OF CONTINUOUS IMPROVEMENT

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Summary

Some sophisticated medical applications, including advanced therapeutics with monoclonal antibodies, stem cells, and gene therapies are currently available in clinical trials. More revolutionary technologies are coming soon and will be marketed by the best technically advanced companies in the world. R&D companies with a much smaller indicator of technological progress and organizational efficiency, but with a great desire to become a major player in this industry, will also compete for a share of this market.

However, in order to become a fixture in the changes initiated, both must constantly learn and be more innovative. In the current market situation, a hypercompetitive economy with the entrepreneurs' focus on the prosumer[1] , creativity is becoming extremely important in achieving final success. Creativity, which is the result of proper knowledge management, especially in science. The market value of R&D companies and their further future depends to a large extent on the prosperity of knowledge transfer.

The most important role in the process of knowledge transfer is played by information and communication technologies (ICT) and tools for continuous improvement. If companies implement these efficiently and safely, they can develop and benefit from competitive advantages for a very long period of time. Such an approach would give them the possibility of reducing the cost and time to deliver new products to market, and create a new platform to generate innovative products. This is a new perspective for R&D businesses, and a great opportunity for institutions in the biomedical arena to become part of the upcoming bio-revolution.

Keywords: knowledge management, research and development institutions, biomedicine, ICT, tools for continuous improvement

Introduction

The paper deals with the issue of effective and safe management of knowledge in R&D units embedded in the model formula in the reality of the biomedical sciences, preceded by a simplified description of the state of innovative research in Poland. This paper aims to show the power of modern information and communication technologies implemented within activities in the field of continuous improvement, as not only the perfect remedy to the problems associated with maintaining low costs in laboratory work, but also the means to take the initiative in research in high-risk markets, advanced products, and innovation.

A simplified diagnosis of Polish innovative research

The state of innovative research in Poland in bio-medical sciences does not need a deep analysis to see that not only are we not leaders, but also that there has been no significant progress to be seen in this area over a long period. Associated with this fact are the following groups of problems:

I group "systemic problems relating to Polish science"

Not introducing the principles of open innovation, the rules of co-option[2] and not taking up the challenge of building interdisciplinary research, the lack of representation of Polish studies at prestigious international conferences and effective cooperation with foreign centres and work at the international level in recognized journals. The development of Polish science is also not served by the hierarchical and closed community of scientific institutes/universities where young people and doctors continue the work (not always innovative) of scientists with long experience. There is poor mobility of researchers, which impedes the flow of ideas, and therefore an absence of innovative topics, everyone is therefore a potential competitor, and many often emigrate abroad permanently. There is a lack of motivation systems (incentives) for scientists and successful efforts at deregulation of the laws constraining innovation at universities.

Consequently, this causes Polish science to fall into the "trap of medium development", i.e. a lack of opportunities for rapid economic development through its own non-imitative growth model and the construction of its own advanced technology.

II group "problems associated with investing in Polish science and the use of funds"

The low spending on Polish science, and the ensuing poor pay and scientists having to take several jobs impede their up-skilling and conducting innovative research. Bureaucratised competitions, and as a result the decisions on grants awarded, instead of supporting the best innovative projects, not infrequently supply the budgets for restorative work. In turn, the success in the domestic market is not always reforged into a desire to obtain a European patent, which would frequently guarantee good final financial results for such an undertaking. The threat to the future of Polish science is inaccurate investment in research and development infrastructure/equipment, narrow penetration in the market for seeking financing for international teams, an underdeveloped network of cooperation with business, resulting from weaknesses in research on application and gaps in understanding each other motivators, and the absence of a mechanism for alleviation/insurance of risks taken by companies in the area of innovative research.

The lack of effective paths for funding the best ideas/technologies is particularly acute and clearly visible in the area of biomedical sciences, where the necessary amount of expenditure on innovative research and risk of failure is much greater than in other industries.

Of course the classification problems of Polish science summarized above may be organised in several other ways. Also, we should not generalize and list in this problematic area all or even the majority of R&D institutions. The most important thing, however, is that outside these two large groups which prevent its development, there is a third, no less important group, and in many cases it constitutes the root cause of all the failures of the research. This is the group with the unfavourable inclination associated with poorly designed and implemented management processes in the R&D centres. The process focused on generating the best scientific product (invention), even before its marketing processing — packaging (promotion) and hooking up the process of its commercialization, but after market research and positioning the offer of the research unit[3]. A process consisting of a proper research phase and supporting laboratory work. Using these thematic shackles, these problems can be recorded in Group III of the set of problems of Polish science relating to managing Polish R&D units.

Group III "problems associated with the management of the Polish scientific and research units".

Firstly, there is an absence of properly trained management personnel. This is often because the management teams from both the academic and business spheres do not have the managerial skills/qualifications or theoretical underpinning in terms of the offer/scientific research, and are not able to organizationally control such a technologically sophisticated product and very specific group of employees.

Secondly, there is a lack of use of tools to enhance the effectiveness of project activities and the abandonment of improved methods for motivating personnel, work planning, and operational decision-making. There is no skilful inclusion in the management process of tools which increase the tendency of scientists to creative activity (CEDAC/TRIZ)[4] and optimizing the cost and time of research (Lean Product Development and DOE[5]). There are also shortages in the proper processing of organization (results tables, improvement actions), as well as unproductive exploitation of technologies to support the work of the laboratory (LIMS, BMS/RMS)[6].

And thirdly, there is inefficient management of organizational and scientific information. One of the most important, if not the most important, links in the management of an R&D institution. The absence of an attempt to implement a knowledge management model that would allow an exit from stagnation in the development of the company is also a diversionary action in relation to the researchers/scientists in such units. Indeed it prevents them from achieving operational excellence in laboratory work and deprives them of the opportunity to introduce rapid changes/corrections in the research conducted. With proper introduction, this model can also be a response to other dilemmas and problems of units operating in the R&D market, including those of the first and second group, being a kind of original source and panacea.

The type of management based on effective and safe transfer of knowledge is thus by all means recommended to be introduced not only in companies/research institutes struggling with the blend of problems outlined above, but also in more prosperous R&D organizations which want to achieve constant success in highly competitive, dynamic and technologically advanced markets.

In the longer term for innovative economic policies of countries such an approach would shift from concentration on the economy at the macro level to entrepreneurship at the micro level, from government to governance, from synthetic to analytical thinking.

Polish biotechnology, biopharmacy, and biomedicine, despite some significant achievements at the global level, and a few promising products/technology, are constantly faced with an array of negative issues that prevent their full and rapid development. Therefore, here especially the introduction of management mechanisms, including first and foremost tools for effective knowledge management, will constitute in the near future the strength and growth potential and functioning of research units in this market.

Knowledge management in research institutions

In today's economic trading one of the most important business assets, providing a competitive advantage, especially for R&D centres operating in innovative markets, is all kinds of information-knowledge.

Research activity is characterized by specific requirements in knowledge management. In contrast to the needs of manufacturing or service activity typically focused on supporting operational activities, one of the most important tasks of research activity is to explore potential directions of development.

In academic institutions, the main motivations are associated with the individual goals of the creator of knowledge (increasing scientific reputation, gaining degrees and titles, to a lesser extent the realisation of commercial goals) and enlarging the intellectual heritage of humanity, and therefore the individual and public ownership of knowledge. In commercial institutions, the main motivations are related to the objectives of the group (income and reputation of the company), and thus the corporate privatization of knowledge. These are therefore contrary motivators for which joint development is not easy. A reflection of this situation are the difficulties faced in transferring knowledge between academia and the business sector, and more broadly in commercial ventures between business and university.

The processes that describe the formation of knowledge in organizations (including R&D) have been collected through the theory of the "creative environment"[7]. One of the elements of this theory is a model of scientific activity called the triple helix, describing a typical way of creating knowledge in research institutions. It consists of three co-existing processes known as the spiral of knowledge creation, relating to: literature research (EAIR spiral, Enlightment-Analysis-Immersion-Reflection, also known as the hermeneutics spiral), experiments (EEIS spiral, Enlightment-Experiment-Interpretation-Selection), and discussions (EDIS spiral, Enlightment-Debate-Immersion-Selection)[8].

Another popular concept that describes the process of creating new knowledge is the concept of SECI (Socialization-Externalization-Combination-Internalization) popularized by I.Nonako and H.Takeuchi (1995). According to this, the accelerators of development of new knowledge include socialization consists in sharing experience and leading to acquire new knowledge confidentially (socialization), as well as outsourcing (externalization), which is the process of articulating confidential knowledge into open. The processes comprised in this concept also include turning knowledge into formal knowledge into confidential, called internalization, and the pooling of formal knowledge — known as combination.

In practice, in order to maintain knowledge a further mechanism should still be redefined: its transfer in student-master relationships (transfer of an educational character), making better decisions and comprehensive protection of resources and sources of information.

No matter what strategy for knowledge management a company accepts, or codification (the use of knowledge already developed, explicit knowledge stored in databases/knowledge) and personalization (under which employees with knowledge/expertise on a chosen topic, during ongoing tasks and projects transmit it to less experienced colleagues), great attention should be paid to the providing a set of tools for this management area.

Therefore, instruments of efficient management of such as collaboration tools (groupware), workflow systems, and video conferencing systems — NetMeetings — are introduced. To do this, a process of improvements is started to explicate the tacit knowledge of experts, such as creating lists of specialists and competences to help you quickly find the professional desired at any given time, or mind mapping of experts. These should constantly be developed and reasonably entered into the structure of the knowledge management system.

The construction of a knowledge management system should begin by clarifying concepts like data, information and knowledge[9]. Data, i.e. facts unattached to each other, are the simplest objects and original in relation to information and knowledge[10]. Alone they do not have decision-making significance and exist in the form of documents, forms, and computer repositories. Only data placed in context have some meaning. They become information, which is the result of data alignment, interpretation/analysis or finding causal relationships. Information in terms of creating is not a primary factor, nor final. On its base, and that of the data collected, after lessons are learned in the mind of an individual, knowledge is created, which is a much wider concept and has a superior position in relation to both data and information. Knowledge is a category relating to people and you cannot talk about it as an abstract, detached from specific people, gathered in books or databases[11].

Data, and information are specifically the domain of information technology, while knowledge is the domain of human individuals, groups, and societies. Knowledge is strongly connected with such aspects of the work as organizational culture, management style, intuition, working conditions, and often not expressed by them. Today, knowledge is regarded as one of the four basic resources (along with capital, labour, and land) . Its value in the enterprise is equal to the sum of the whole intellectual potential of the company's employees performing tasks in accordance with the strict aim of both individual and team. In certain exceptional circumstances, the knowledge resource will also be an expert system that is able to simulate decisions that are normally man-made.

In the management of the company information is believed to be data processed in a meaningful form for the recipient, which has a real or implicit value in the decision-making process. It is located at the output of the management information system. Information should not be confused with the data, the term which is usually understood as sets of figures or facts that for the purpose of processing are ordered into structures and groups[13]. They are located at the entrance of the management information system[14].

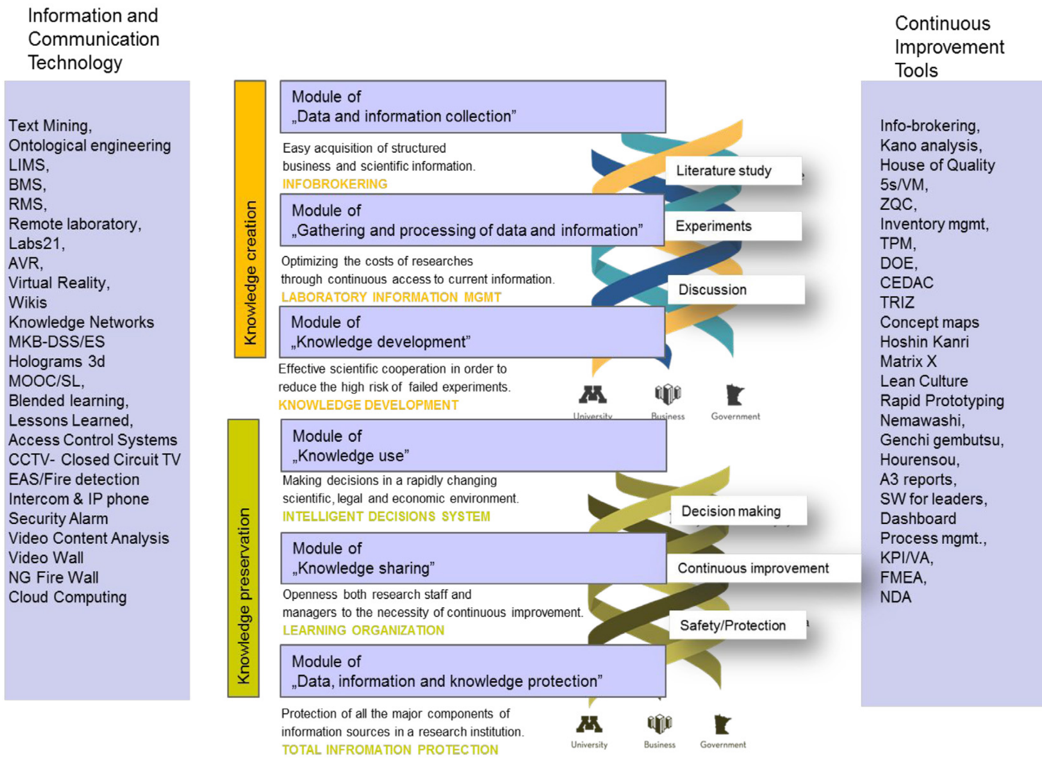
Unfortunately, to the detriment of the transparency of terminology, as I.Nonaka and H.Takeuchi say, the terms knowledge and information are often used interchangeably[15]. Such cases are fortunately isolated and it seems that nowadays there has been a constant reinterpretation of these concepts and categorization of them in the hierarchical system of data-information-knowledge here presented. This specific trio is also the basic units that power the modern information system, including the laboratory, creating its modular structure.

Taking into account its specific characteristics and interactions occurring between them a model of efficient and safe transfer of knowledge has been drawn up comprising the following six modules: collection of data and information, gathering and processing of data and information, protection of data, information and knowledge and development, and sharing and use of knowledge. See. Fig. 1.

The first module of the system described is the collection of data and information module. Each search for data and information usually starts with the gathering of data on a specific topic from secondary sources, especially sources inside the company. The nineties saw the introduction into information management of the greatest technological achievements of recent years — the Internet — which can be described as a gigantic, global information base.

In a situation with as much excess data and information, the ability to search their vast databases and sets (articles, information from conferences, biomedical company reports) cannot be overestimated. If it is not possible to obtain the expected information on the basis of secondary data, collection processes are run on primary sources on their own or with the help of units/entities specialized in this area known as infobrokers. For many companies, running primary research is a continuous process. A sign of the times are studies conducted through social media. The latest form of operationalization of conceptual information are ontologies[16].

Figure1. Efficient and safe transfer of scientific knowledge



Source: Own report.

Another domain extracted in the course of work on the analysis of issues related to the management of information and knowledge is the area of collecting and processing data and information. This module is composed primarily of tools from the border of management and computer science — laboratory information management systems (LIMS) — that collect, compile, and consolidate data from multiple laboratory sources. A number of modern companies see opportunities in attaining higher levels of management, more efficient use of scientific projects and client orders, and the reduction of operating costs only using such techniques. An incomparably large role for the data/scientific bases compared with the technical or economic databases, is played by data transformation technology, called data mining. Data mining is understood as the process of automatic and efficient discovery of generalized rules contained in databases and extracting information not directly resulting from the data themselves, but rather from mutual dependencies and the relationships between them.

In addition to the modules of acquisition, data collection, and information processing, using the theoretical foundations of knowledge management we can try to add three additional areas which fit within the overall model of a knowledge management system.

The first of these is a module to develop the knowledge which aims at the creation, full disclosure, and recording of tacit knowledge by creating a forum for the exchange and creation of new knowledge platform and social networking portals such as: Knowledge Networks (KN) and Communities of Practice (CoP). In the KNs new knowledge is created through exchange of information and drawing conclusions from the information obtained in a particular cognitive context in a virtual environment prepared for this purpose on the basis of existing possessed knowledge, experience and skills in its processing. CoPs use the indexation of key words contained in accompanying documents by network users, identified later in search engines. They are focused on solving problems and improving creativity and allow selected papers/documents and contact information for people interested in similar subjects of research to be easily found in the common space.

On the other hand the module for using knowledge is the result and at the same time an appropriate tool for creating the appropriate organizational culture by providing managers and employees with knowledge at the time when they most need it. This platform, which from the capacious information resources of the Internet selects the most relevant information and transforms the massive amounts of data generated by users, known as information overload, into the ability to collectively find a solution to the problem, better than individual solutions submitted by individual members of the working group (collective intelligence). This is where the expert systems support and Lean tools improve the final quality of decisions.

The fifth module, "sharing knowledge" breaks the interpersonal organizational barriers that prevent effective knowledge sharing. Its functionality makes all employees collaborate and focus on the continuous development of competencies. To do this, specialized training courses are run designed to complement the missing knowledge.

The last component of this system, standing at the opposite pole in relation to the rules of "open innovation" is the unit protecting data, information, and knowledge. The axis of this approach are sophisticated ICT measures that protect the physical and telecommunication path from possible theft, hacking, and other forms of violations of the confidentiality of the company's information resources.

The system described is strongly supported by communications functions linking internal and external organizational contacts into a single network of information for a given entity, where a critical element of the media is based on communication and information technologies, especially interactive and social media. Information and communication technologies allow this information to be collected, processed and used in different areas of the enterprise, thus significantly increasing the efficient use of their resources. One such area is research in biomedical laboratories, in which both the scope and intensity of use of the tools of knowledge management in the area of ICT is growing rapidly.

Knowledge management has many features in common with quality management, such as the focus on continuous improvement, inclusion in the system of all the company's employees, including its top management, covering a range of practically all the organizational measures, resulting in support of operations in a process approach to customer needs as the chief paradigm oriented to the long-term development of the company.

With the strategic objectives so set the most important determinants for operational activities are to provide an adequate level of income and steady growth in market share, low manufacturing costs, high quality products, and ever shorter lead times and introducing new products to market. To capture these indicators at the highest level and maintain them over a long period of time the previously mentioned elements of ICT and largely CI tools of continuous improvement are used. One of the most popular methods of supporting the process of continuous improvement in the company is a compilation of two methodologies, dating back with their roots in the area of quality management, called Lean/Six Sigma (LSS).

Lean management is the management concept which has its roots in the Japanese Toyota company and the methodology of Six Sigma derives from

Motorola. In a nutshell, Lean management eliminates steps do not add value to the product/service in the manufacturing, administrative, and research process assessed from the perspective of the end customer and the owner of the next stage of the process. The objective of Six Sigma improvement programs is to reduce the variability occurring in the process with broad participation of statistical tools (reducing the number of defects to 3.4 defects per million opportunities).

LSS is a method of action used by companies that have become leaders in their industries (Toyota, General Electric, Glaxo SmithKline). Successful implementation of LSS instruments have also been carried out in entities from the biomedical market, thus gaining a competitive advantage. Often without the need for substantial investment, but by continually improving the organization of production and administrative activities.

Information and communication technologies and tools for continuous improvement in the coming years will change the face of technological advanced R&D laboratories and set trends in the management of research centres. Operators who understand the nature of these changes and begin the process of implementation will be able to fight in global competition and a turbulently changing market environment.

Below, in the following paragraphs ways to improve/strengthen the functioning model of knowledge management in R&D units in its individual modules will be presented.

Improving the process of collection of data and information as part of ontological engineering and brokerage

In recent years, the importance of developing knowledge engineering[17] techniques in a new version has become important, by inventing logical formulas and relationships for selected models of information and knowledge (expert systems) contained in the large collections of data/text available online. Consistently a strong emphasis is placed on the development of areas related to the processing of text called ontological engineering, which is strongly associated with constructing taxonomies and complementing its structure with a variety of logical relationships. This ontology is a description/definition of content (specification) of a system of concepts in a defined set of information (conceptualization), which use two cognitive entities or an entity and a computer system in a certain area of expertise. Otherwise, it is also defined as a hierarchically structured set of terms to use to describe a particular domain, which is used as a skeletal structure/foundation for the construction of a knowledge base[18].

The top-down design stems from the knowledge, experience and intuition of industry experts, and bottom-up automatic based on a computer analysis of large collections of text. Ontological engineering is also present in the form of a personalized user ontology and then combines the qualities of a top-down ontology values from local bottom-up with universal characteristics. The ontologies thus built make it significantly easier to get information from large text sources, e.g. the Internet.

Life Sciences are developing an ontology database that biologists use to make sense of their experiments. Through skilful development of a set of formal terms/concepts, ontologies allow scientists representing different nationalities in laboratories with heterogeneous specializations to use the same, common vocabulary. To learn the appropriate lessons from the experiments, ontologies [...] should be adjusted continuously to the field they represent, so as to precisely express its current status[19].

Due to the size and complexity of biomedical information resources (which are in a state of permanent experiment) the challenges in formulating their dependencies are incomparably more multithreaded and harder to define than other scientific disciplines. The key to rich knowledge in the domain of healthcare and life sciences (HCLS) may be semantic web technologies[20] and the principles regarding linked open data[21,22], where the former are used to create portals for virtual societies, and the latter open up new possibilities for publishing scientific data, their integration, and reuse. Improving this area also depends on introducing new solutions for obtaining information in the form of summaries (obtaining messages that are not included in any of the various documents) and lists of publications authors on the same theme (synopsis).

These technologies achieve maximum usefulness, in cooperation with specialized human units searching network, library, and other resources in any form, having a real ability to interact with ICT. Such deep cooperation on the line of man-machine, sometimes leads or will lead even to intimate unity (AR glasses, smart clothes, micro-chip implants).

The profession/business which involves collecting information about customers, bids, markets, and then selling that information to other organizations is infobrokering. Information brokers also called data brokers and information vendors can gather information from various public and private sources of information. Usually scientific information brokers create individual profiles of information materials, prepare comprehensive information on a given technology/research area and sell this directly to research institutions.

In a world of increasing savings in the area of medical experiments and the "depletion" of research/commercial operations, each time before taking action in application research to ask the question: will someone want to pay for this innovation? The answer assesses the supplied value and determines the revenues, profits and market share. Data and information prepared by the infobroker in the correct way (e.g. using Quality Function Deployment, QFD) educate and increase the investigator's awareness of the selected product and help make the company decide whether and how a particular technology/product should develop.

Currently in science (including science disciplines/biomedicine), the problem may also be all the surrounding redundancy of information, its unlimited availability, and the naturally limited perception of the researcher. Not all the information collected, particularly from electronic sources, has the same scientific value, much of it is unbelievable, meaningless, or worthless.

Smart search is used to reduce the number of results collected by the Search program and to increase their relevance. Especially in research institutions, a frequently appearing problem is the issue of search in large collections of data/text not only for interesting information, but more — useful relationships, in other words — exploring the hidden knowledge through artificial intelligence.

Despite the enormous technological progress, the separation of the layers of information desired and valuable remains the domain of people. Especially, specially appointed individuals/research teams — infobrokers who search and have the appropriate theoretical and often practical knowledge for a preliminary assessment of the value of information and interpretation of the results. Such persons can also make use of the rules of advanced search, enter operators (boolean and proximity operators), with which they can combine search terms and determine their priorities. In addition, there are skills to search databases of specialized scientific articles (e.g. Pubmed), search using specialized scientific metasearch engines and databases and hidden network resources (deep web).

Not by chance is it these sites that are of most interest to academics because it is here, in many cases, that publications, electronic magazines, references, patents and results of experiments can be found[23].

Infobrokering is not limited merely to the digital flow of information. Many information brokers as well as economic searches extract information about interesting research work, scientists, companies and institutions directly from the market during phone calls, conferences and other more or less formal meetings.

Presentations of their research, findings and interpretations of research phenomena occurring in the world in a given discipline enjoy great popularity among researchers at Western universities. These people are considered to be part of the research team, and their knowledge is treated as tacit knowledge passed within an organization on a confidential basis and with limited availability.

The need for such accurate, current, difficult to get information searched for using sophisticated queries in specialist search engines and social engineering is at the leading edge and has not yet reached its extremes. The world of science, however, must learn to skilfully use these sources on the one hand, and on the other to protect their intellectual gains at the level of research units and adequately protect and prevent their transfer to other competing teams.

Increasing the efficiency of laboratory work by integrating the area of collecting and processing data/information in LIMS

Incorporation of lean tools in laboratory work system enables efficient management of information and other resources. Both before making the implementation as well as during research it is important that at every stage the level of costs should be optimized and the time to carry them out minimized.

To this end, the design of experiment (DOE) method is used. This is an interdisciplinary field of science lying at the border of metrology, applied mathematics, statistics, and computer science, the aim of which is to answer the question: how to plan the experiment to obtain as much useful information as possible for the least cost[24].

In the research centre, scientists as a professional and social group with exceptionally specialized sensory tools, for whom the backbone of responsibilities and tasks is the ability to conduct research, treat other organizational tasks as a secondary activity. Hence, information on laboratory resources is something that, from the point of view of the study itself, the researcher and the recipient of the research process, is a non-value added but necessary activity. However, it should be borne in mind that they are also the part of the laboratory assets that provide economization of work and allows for the coordination of funds that have been granted for carrying out research. Hence, the transfer of critical information in the field of laboratory resources, forcing concrete action, should be carried out in an effective and efficient way with the smallest possible coefficient of absorption of the time of the science team.

Indirectly, the maintenance of the estimated daily work schedule (day-by-hour boards), stocks at the desired level (to receive them on time), maintaining efficient equipment, permanent tidiness of the workplace and immediate control of work done become a critical factor in the success of the research team. And in the case of failure (lack of positive research results), based on the information generated based on the methodology of implemented lean tools allows for a very reasonable settlement from the costs and duration of the research project. In Table 1, see the examples of the lean tools used in this area.

Most of the information thus acquired is introduced into the information management system, which in a laboratory environment has a greatly expanded span of functions than information systems in the field of administration or even manufacturing. Laboratory Information Management Systems (LIMS), sometimes called a Laboratory Management Systems are laboratory software that manage the work of people and machines, the flow of test samples, and circulating information to structure its acquisition, collection, and distribution. Its key feature is built-in workflows and mechanisms for data tracking, intelligent interfaces for exchange/extrapolation/data analysis and modules for planning and the use of resources, managing research and the application of the electronic laboratory notebook (ELN). The primary objective is to provide — for a limited time and in an automated way — validated information.

Modern laboratories consume a lot more energy and water per square metre than other offices and buildings. That is why so much importance is attached to savings in terms of their consumption. This is achieved by a holistic approach to the design and maintenance of laboratories, improving ventilation efficiency, optimizing energy costs (light, work equipment, air conditioning), to the design of windows, and the use of renewable energy sources. The information system may correspond for the implementation of the selection of optimal settings. In an integrated scenario for an R&D centre, LIMS appears with software supporting accounting/finance, project management and HR, as well as the application providing/monitoring the relevant environmental conditions in the laboratory (building monitoring system — BMS, room monitoring system — RMS).

A specific junction of the ways (techniques and tools) to enable effective and efficient collection and processing of data/information in an integrated system of laboratory information management may become the technology of augmented reality which consists in imposing virtual information on real objects through a system of cameras and position sensors. This technology allows you to send information to laboratory staff often despite the lack of the ability to easily use the computer/other means of communication (obstacles might be laboratory suits/overalls and gloves are designed to protect skin of the hands), equipped with the appropriate glasses receives the message in a format augmented reality and it may to respond to changes in the laboratory environment (temperature drop, stocks below the set value, unscheduled test results). Especially in laboratories with high requirements for air/microbiological cleanliness or a high degree of biological hazards such a solution can very significantly affect the quality and efficiency of economic research.

Table 1. **Lean tools to streamline lab management**

No.	Area/name	Description of the Tool
1.	Day-by-hour Boards	The method used for the management of human resources in the HMLV environment (high — mix, low -volume), where the volatility of commercial/research tasks is very large and difficult to accurately estimate. This table of daily performance should easily allow for planning capacity, the ability to prioritize, visualize the plan vs. performance, and identify the "bottlenecks" and report any problems.
2.	Lean inventory mgmt	The aim of this tool, dedicated to inventory management of R&D centres, is setting optimal levels of laboratory inventory, taking into account such data as: average consumption, delivery time and eventual delays, and fluctuations in demand for laboratory services/changes in research tasks. The output parameters include: size of composition at the time of order and inventory security, which are then be adjusted depending on the size of packaging, transport conditions, and the validity of the store and determined according to the method of ABC/VED[25]. From this fact the direct strategy for the storage of a given material is also apparent. Taking action in this area improves inventory turnover ratio and releases the storage space, thereby freeing often frozen considerable cash resources and improving the overall financial health of the company. However, it is important to manage orders of laboratory materials needed for scientific/commercial research on an ad hoc basis, especially in the situation when a company/institute uses public money and must carry out the contract in accordance with the rigors of public procurement law[26].
3.	Total Productive Maintenance, TPM	Total productive maintenance of equipment in the laboratory (TPM) is defined as emergency-maintenance service of test equipment implemented in the form of a daily inspection, fixing of minor breakdowns by laboratory workers and planned predictive-preventive activities by the team maintaining movement. TPM works towards the goal of maximizing the effectiveness of equipment and maintenance services (zero failures, zero defects, zero accidents) by involving all departments in planning work, maintenance and repair of all equipment. The experience of laboratory personnel resulting from the operation of equipment is used in the design of the next versions. Increasingly, TPM in the laboratory is implemented for support of computers and is supported by laboratory information systems.
4.	5s (jap. *seiri*, *seiton*, *seiso*, *seiketsu*, *shitsuke*) (ang. *sort*, *set in order*, *shine*, *standardize*, *sustain*)	The introduction of the 5s method is the basis for the implementation of other LSS methodology tools also working in such an environment as a research and science laboratory. The purpose of 5S is to organize the workplace, allowing for the introduction of visual management. At the work

Cont. table 1

No.	Area/name	Description of the Tool
		station there are only the laboratory materials and equipment necessary for the implementation phase of a given process. The principle of everything has its place and is in its place is strictly adhered to by each employee of the lab. Any non-compliance with the established standards/shortcomings, after the use of visualization are visible at first sight (visual management, VM). And this is not about "spring cleaning" but permanent maintenance of order at the workplace. Companies with high-tech laboratories introduce to this method a further, sixth, element — safety, or health and safety in the laboratory (6S, 5S+1), which, taking into account the biological and chemical hazards is most warranted.
5.	Zero Quality Control, ZQC	The aim of the zero quality control system, an approach with from the scope of the quality of applied ZQC, is to ensure performance of the product or service with a zero level of defects right on the first try. ZQC theory assumes that making mistakes is human and focuses on the creation of such conditions in the laboratory to prevent these errors. ZQC prevents errors by the combined forces of four components: source inspection, 100% inspection, immediate feedback, which shortens the time to take corrective action, and poka-yoke devices.

Source: Own report.

A specific junction of the ways (techniques and tools) to enable effective and efficient collection and processing of data/information in an integrated system of laboratory information management may become the technology of augmented reality[28] which consists in imposing virtual information on real objects through a system of cameras and position sensors. This technology allows you to send information to laboratory staff often despite the lack of the ability to easily use the computer/other means of communication (obstacles might be laboratory suits/overalls and gloves are designed to protect skin of the hands), equipped with the appropriate glasses receives the message in a format augmented reality and it may to respond to changes in the laboratory environment (temperature drop, stocks below the set value, unscheduled test results). Especially in laboratories with high requirements for air/microbiological cleanliness or a high degree of biological hazards such a solution can very significantly affect the quality and efficiency of economic research.

An efficient information system is also a fundamental pillar for virtual research environments and online laboratories.

The combination of "big data" and "open data" based on full data availability for each user, due to advances in the field of cloud computing and grid computing, has found its expression in the "virtual research environment" (VRE), allowing for scientific cooperation through the network, processing and analysis of information from one place on the basis of software for mining data which is located in another remote location.

Cooperation between research e-infrastructures opens up entirely new possibilities for the use of ICT in remote laboratories. These laboratories connected with each other, also known as online laboratories, link scientists working in different locations with research instruments attached to a common IT network and allow real experiments to be conducted at a distance, as part of interactively cooperating teams and equipment in real time.

This approach improves access to sophisticated and expensive research equipment, improves work efficiency, and can involve many participants in dispersed research centres together to solve a specific problem. An additional advantage is that the above technology can be integrated with the e-learning package Moodle (modular object-oriented dynamic learning environment), accessible through a web browser, which is probably the most widely used model for distance learning (e-learning/LMS).

The development of new knowledge on a platform of virtual communication supported by lean culture processes

Just as with production and administrative processes in service and production units, the process of research and development of technologies in R&D centres consists of value-added (VA) and non value-added (NVA) activities. The primary objective of Lean in R&D is to develop an efficient process for generating and using new knowledge by introducing improvements in the procedures in force in the laboratory and increasing the labour productivity of the research team.

Thanks to these there follows a substantial reduction in the time required to introduce a new product on the market, minimizing the cost of manufacture of the product (but not to the detriment of the product itself) and creative generation of ideas and coming up with innovative products. It is used in companies with a mature lean enterprise approa[29]. Reduction of manufacturing costs is the fastest way to get more profit from sales; however, shortening the time-to-market gives much higher overall profits. Innovation is considered here as a process consisting of two parts: the original inventive idea and confirmation of its value in the applied research/translational process, i.e. moving it into the realm of practical market application.

In many cases in R&D, the focus on the improvements of lean R&D moves from MUDA (waste) to MURI, MURA (overload, irregularity), and on technical aspects in the sphere of personnel management and teamwork, which is absolutely critical in this area of work.

Creating new knowledge and maintaining it can be achieved primarily through the involvement of all employees. The creation of such a creative process, however, requires a lot of patience, and its effects can only be seen after some time. This approach to invention should become, in spite of all, priority number one not only in the scientific and research units. Here, however, the ability for cooperation/teamwork, setting goals, and quickly resolve issues, takes on particular importance. The key tools that can support such a course of action and allow an organization to learn to achieve a higher level of functioning include:

a) in determining the organization's goals — policy deployment/X matrix, Jap. *hoshin kanri*,
b) in the area of staff development — lean people development,
c) in order to standardize/improve laboratory work — standard work and refresher workshops — Jap. *Kaizen*,
d) and in terms of creative problem solving — problem solving (CEDAC/TRIZ).

The greatest importance is attached to instruments serving lean people development which are a kind of a set of tools that invest in employee-scientist development and enrich employee-superior-company relationships. In this approach, the company's staff, in particular the research team, should have considerable autonomy, and its work should consist of many challenges and areas to solve problems. People as exceptional as scientists/researchers are most motivated by very ambitious targets and the possibility of their implementation. In the field of science the height of the objectives set and the risk is usually much higher than in organizations that do not conduct research and the transfer of scientific knowledge. Removing demotivators that are in conflict with the work of a scientist, such as a bureaucratic organizational culture and initiating incentives for teamwork opens up unprecedented opportunities for continuous improvement. Its driving force is standardized organizational processes (e.g. purchases of equipment/reagents), conceived and planned experiment, and the ability to continuously improve both working methods and ways of achieving scientific results.

This cooperation in the framework of open innovation and greater investment in rewarding the performance team should support this form of action. The turning point is a well-designed process of monitoring and accounting of results, information about them, and drawing conclusions for further stages of research. A good way is to engage the researcher at the very beginning in the course of its formulation (policy deployment, DOE), and then enabling, based on current scoreboards (dashboards) to allow self-assessment. See also tab. 2.

All the actions taken in the company implementing LSS must comply with the requirements for standard work and be based on a Lean/*Kaizen* culture using the most effective problem-solving techniques, including research. Looking at the biomedical or pharmaceutical area, the impression is gained that the standard work is in situ, in the form of documentation of SOP's (standard operating procedures) developed in accordance with the guidelines of quality systems GMP (Good Manufacturing Practice) and GLP (good laboratory practice). This impression, however, is sometimes misleading because standard work in research is much more than operating procedures and protocols based on quality systems. Standard work is operations set on a timeline, illustrated graphically, with a very well-functioning apparatus, their improvement associated with technology aimed at simplifying documentation and facilitate troubleshooting (creative problem solving).

Table 1. **Lean tools enabling the production of new knowledge**

No.	Area/name	Description of the Tool
1.	Policy deployment (jap. *hoshin kanri*)	This is a planning process aimed at combining the functions and responsibilities of companies in a bundle of projects implementing the strategic objectives of the company, included in a matrix X. This is usually done within the framework of information exchange top-down and bottom-up between the different levels of management based on a consensus about how to perform tasks, the availability of resources, and the time needed to complete these projects. This dialogue is often called catchball because ideas are trafficked from different levels of the organization, serving vertical and horizontal integration of the company through a very effective manner of communication.
2.	Standard work	Standard work (SW) presents the best and most secure working method at a given time. It is also a tool for defining the interaction between the laboratory worker and the devices they sevice. SW is based on a factual analysis and is always approved in writing. However, it is useless if it is not respected and used by employees. Therefore, an important role in this process is the appropriate communication and training system. It is not determined once and for all, it serves to consolidate best practices at a given time and is modified with the advent of even better solutions. It is a base for operations within groups of improvement, *Kaizen* (Jap. 改善 — good change), aimed at continuous improvement of organizational processes and management, in Europe and the US it is frequently carried out in the form of multi-day workshops. It's the golden rule of lean. According to this philosophy, the quality of action leads to lifestyle — a never-ending process of improvement, because if you standardize something it can also be checked, and if you can check it you can also improve it.
3.	Problem solving (CEDAC/TRIZ)	Problem solving is defined as a multistage structured process of advanced thinking requiring more than routine skills. It allows transitions from the existing to the desired state by eliminating a given problem. In an era of permanent competitive struggle, a company encounters problems in adapting the offer to the changing needs and requirements of customers at every step. Further, in R&D units there are also issues related to the scientific problem, and those concerning the management of such a specific group of human resources as are research teams (herding cats). The Cause-and-Effect Diagram with the Addition of Cards (CEDAC) is the introduction to a simple analysis of cause and effect of the issue with cards with ideas to solve it. The idea discussed is later evaluated and tested. On the other hand the Theory of Solving Innovative Issues (Rus *Теория решения изобретательских задач*, TRIZ) is a universal, methodical system approach to help solve non-standard problems and create new innovative ideas, called "invention". With the introduced algorithm, TRIZ tries to formulate an optimal solution to the problem, eliminating time-consuming and costly trial and error methods.

Źródło: Opracowanie własne.

The shape of human resource management and the interior organization also exerts a distinct pressure on the newly introduced technology, which is also one way of stimulating changes in the company. The starting point is personnel fatigue with an excess of anonymous, unrelated information, subconsciously waiting for individualized interactivity. This manner of interaction is featured in media generated on the basis of technologies based on ICT (Internet), characterized by high interactivity of communication, allowing the recipient to contact the sender in return, and which are the opposite of mass media. This is a group of social media, called online communities, through which information flows in all directions and from many informal sources. These media are characterized by a very democratized message, transforming the one-sided monologue of mass media into a bilateral dialogue with the recipient. It is significant that social media using the Internet are building a whole new kind of communication that works with information and knowledge systems, forming machinery supplying modern companies with information and streamlining communication flow. Through them, companies attract attention, generate incentives to make conversation, and encourage customers to share information in their online community.

Communication is not only providing information, but also the creation of a community during and as a result of communication[30]. As a result of dialogue with research and scientific staff, the company on electronic platforms creates opportunities to speak to their employees about the current offer and scientific research projects being conducted. Bidirectional communication and personalization of communication mean that the researcher becomes more involved in shaping the new offer, and thus strongly associated with the company, and the symmetry allows him to assert his rights in terms of partnership[31].

In modern management, through the increasing use of interactive media the problem of asymmetric communication disappears, and the overall solution to this question is resolved by social media. All this means that today's information system, particularly in R&D companies, is marked by a completely new perspective on internal and external contacts.

The emerging platforms/forums for the exchange of experiments — Knowledge Networks/Wikis — enable researchers from different research centres, of course within the framework of permission received from their parent institutions (provisions in contracts for confidentiality), to exchange information and undertake discussions on various scientific topics. The scientific modus vivendi manifested during such transfer strengthens the virtual binding of these sessions and well-chosen, virtualized tools to structure the topic/issue of talks. Paradoxically, it is this oxymoron, more efficient conduct of scientific debates and developing of direct contacts in virtual reality, that allows the impact of such tools of improvement as CEDAC and TRIZ to be tested. This that seems illogical, namely the fact that scientists talking to each other indirectly, but using information and communication technology on electronic platforms, often appearing anonymously in the form of avatars, are open to greater expression and establishing more open relations, coincides, however, with the knowledge of our human nature and is visible in all electronic forums for the exchange of information. It is a casus that should be used in the process of creating new knowledge, as a weapon in the EDIS spiral (Enlightment-Debate-Immersion-Selection), in the process of socialization and externalization of expertise.

Strengthening the effectiveness of decisions taken by the proper use of expert systems and instruments for efficient management

One extremely important factor in knowledge management is leadership. Overturning a long-term scientific team effort can be accomplished very easily by incompetent, reckless or protracted decision-making by the people managing the R&D unit. A new idea/invention must quickly find its fulfilment in the launch of new research/market product. In the area of innovative pharmaceuticals, or pioneering medical treatments, success is decided by time like nowhere else. Time counts as the whole process including the duration of discussions and meetings devoted to preparing the way for a decision. At the same time we must remember that a decision based on "fast thinking" taken out of emotion, automatism and inaccurate analysis and verification, can also cause millions of dollars in losses for the company. Therefore, closely following the issue of effective decision making in companies operating in a rapidly changing environment of advanced technologies is a measure of professionalism in the departments responsible for the management of the aspect of information.

Referring to the deliberations on improving decision-making processes by Drucker, [...] We can identify some guidelines for effective decision-making, namely[32]:

a. group decision making increases the efficiency of the whole process,
b. decisions should stem from the conflict between the opinions of team members, and not the consensus,
c. to take effective decisions requires the use of non-traditional approaches, formulation of non-standard questions, and the acceptance that custom is not always logical solutions.

In science, however, group decision making and setting up creative conflict in some unconventional formula of asking research questions is extremely difficult to implement. It results from the hierarchical structure of scientific institutions, attachment to known methods and means, the need to ensure continuity and stability of the technology, and a lack of willingness to take excessive risk and a revolution in the approach used, that is, with a certain "vector of inertia"[33].

It should also be remembered that "group thinking" is also associated with certain risks. Among these we can include group thinking syndrome, which involves succumbing to the suggestions and pressure of the group, and can cause atrophy in individual thinking.

The solution not only for companies in the area of R&D activities thus lies in pushing the staff of such establishments towards creative cooperation and at the same time in activities that encourage competition and generate conflict in order to boost the sources of progress and innovation. Success in this area is also a good recognition of information technology supporting decision-making processes and the gradual introduction of decision support systems/artificial intelligence techniques to facilitate the decision-maker's perception of estimated results through a well-designed multimedia interface.

Decision Support Systems (DSS) enrich the decision-making construct with different analysis options and refresher programs, helping management to optimize decisions and efficiently manage the business. Noteworthy here are troubleshooting systems and GSSD (Group Decision Support Systems). Group decision support systems, which are a straight line extension of the functionality of decision support systems — DSS — and focused on solving the problems in the group of people from business and science, through the exchange of information and integration in solutions of diversity of opinion.

In turn, the problems of unstructured uses the most technologically sophisticated class of expert systems (ES) or another form of development called systems of artificial intelligence — SAI — benefiting from the knowledge base or neural networks techniques that create knowledge based on personal experience. It is precisely this learning capability that differentiates SAI from all other classes of information systems and automatically entered into the set of dedicated systems for knowledge management.

Yet another category of systems to support decision-making are KB-DSS (knowledge based DSS). KB-DSSs arose as a merger of DSS and ES, and in addition to the current capabilities of DSS have additional capabilities to advocate, offer judgments, assessments, and advice. R.J. Mockler and D.G. Dologite (1992) argue that: knowledge-based systems are a computer system that tries to mimic the specificity of reasoning of the human expert using available databases containing data, information, expertise, or broader knowledge of a given field[34].

The new quality in information management in the organization are also skilfully put intelligent multimedia decision support systems (IMM-DSS). IMM-DSS through its increased interactivity and sensoritivity to the management process, enables policy-makers at the highest and medium levels of the organizational hierarchy to effectively interact with a variety of IT systems, as well as between each other and selected customers.

Another interesting solution is VIM (visual interactive modelling). For some researchers it is a separate multimedia approach to information management in a systemic manner, for others a conversational computer program with a graphical interface. For still others it is an inherent part of the DSS, defined as an interactive visual modelling technique that uses computer-generated images to interactively show graphically the effects of various decisions in order to improve the efficiency of the decision making process.

The main distinguishing feature of multimedia systems is the intelligent multimedia interface (intelligent communication link) allowing information to be entered into the system by voice, issuing orders by telephone, computer network, as well as free control of the application based on the movements of the human body. The turning point for the introduction of this technology will undoubtedly be the implementation of an IT infrastructure with fully voice-activated interface, working in three-dimensional environments, displaying three-dimensional projection in the air through holograms[35] and the development of environments in which the user can create their own scenarios of events[36]. An example is the environment, integrating object-oriented programming and multimedia technology MOO (multi-user domains object oriented) or MMOO (multimedia MOO), allowing any objects and characters to be placed and watched in motion.

In the future such extensive use of multimedia information and communication technology, including the concept of the extension of the communication channel functioning in the external business environment inside an organization may bring even many valuable changes in the structure of knowledge management systems, and so many tangible benefits to companies.

This process applies both to decisions taken regarding daily operational issues of lesser importance and urgency, as well as the model developed for strategic critical and financial decision making.

Since most decisions are and probably will be taken intuitively, beyond the technological aspects (automation and analytics) of very great importance is the attitude of the manager/scientist and his research team management style. The style reflected in the manner of direct control of their staff in place in the laboratory (Jap. genchi gembutsu[37] and indirect, as expressed in the analysis of daily prepared reports operating results (e.g. in the formula of A3 reports) concerning the most important events in the company (Jap. hourensou).

The reports generated should refer to the approved scoreboard (dashboard) and show the current value of indicators. It should be noted that, just as with no data, an excess of indicators in certain situations may be a problem in the loss of time needed for their calculation and analysis. Therefore it is definitely worth considering the simplified scoreboard describing the efficiency of the lab — the laboratory dashboard — which may not fully cover the information needs of managers, but fundamentally reduces the time spent by academics over its updating.

A very important step in the decision-making process is the step before the decision (Jap. nemawashi), which is to obtain acceptance of the solution by other managers of the company before its official announcement on the management team forum. And, finally putting standard rules in the work of managers relating to the performance of the tasks of management and time management (standard work for leaders/time savers techniques).

To sum up this part, the importance of the decision making process in the overall concept of knowledge management should be emphasized. The process is particularly important in organizations working in the field of increased operating costs, high risk involved in operations, and long-term returns on investment. Understanding its interior requires a unique perception in relation to the various factors influencing this process starting with the multi-faceted, structural organization-internal links and ending with interpersonal relationships and the personnel interests of different stakeholders. Therefore, technology that automates and objectivizes this extremely complex process and also methodology to streamline the entire path leading until a decision deserves special attention from the organization's management.

Building a learning organization through virtual training combined with training in the workplace

At present almost universally we hear of the need in R&D companies to build a system of continuous training with the emphasis on self-directed learning, leading to the creation of a learning organization. It is believed that the organization of this type has the ability to learn alone, creating for employees the space and formal conditions for thinking, questioning, reflection and learning, and encouraging them to challenge the status quo and propose improvements[38].

Systemic approaches to training have been defined by the Manpower Services Commission (1981) as: a planned process designed to change attitudes, knowledge and behaviour skills of employees through transfer of experience/best practice in order to achieve high efficiency for a given task or group[39,40]. The result is achieved here by constantly positive influence on the staff of the company and increasing its involvement in the transition process, and not merely changing the operating procedures.

The systemic approach is also used in the process of interaction between training and improvement operations, providing feedback to the company management that can contribute to the improvement of subsequent editions of the training course. A very important element preceding the training itself is a diagnosis of training needs[41].

Continuous updating and expanding the state of knowledge of employees in R&D organizations is a necessity and not subject to discussion. The question that one can put is how to most effectively train a team of scientists/researchers.

In academic institutions, increasingly, so as not to distract for too long a period of time, well-paid and busy running/promotion of research staffing and make the required knowledge at an affordable co[42] applies blended learning, consisting of the elements of classroom training, and on-the-job-training (OJT) as well as distance education.

On-the-job training occurs at the workstation and concerns the tasks carried out in this position, consisting of observation of the trainees by their superiors, mentors and coaches when properly performed by them and then on their exact imitation. OJT allows the relationship with the supervisor/instructor to be strengthened and makes it possible to quickly modify the substantive scope of the training program. It happens that the changes introduced after completion of the course relate to the procedure itself, if during the training any errors/better ways of implementation are discovered.

The ideal field for the implementation of the OJT are biomedical research, laboratory work, and clinical studies, where despite the large theoretical knowledge of technicians/clinicians, correct implementation of their functions/tasks is largely the result of many practical training courses held and participation in real operations/research. Providing on-the-job training in the field of biomedicine is not possible everywhere, however. In the event of a deficit of expertise (trainers/coaches), found for example in rural areas in developing countries (low-income), or in newly established medical and research and development facilities, where the lack of well-trained biomedical staff and adequate laboratory and hospital infrastructure are particularly disadvantageous, other alternatives must be sought. In such places, even if it were possible to recruit qualified personnel, due to the relatively infrequent treatments/studies (usually due to lack of funds for their financing), trained specialists do not have the possibility of consolidating and extending their acquired knowledge into practice.

A good response to this situation is to launch a complementary suite of e-learning (distance) that properly prepared may be of similar value as complementary OJT training.

Historically, distance learning was initiated as a series of educational television programs and the development came with the appearance on the market of such supports to educational programs as: tapes, floppy disks, and CDs. All these methods did not match, however, to the modern concept of virtual schools primarily because they did not provide full interactivity, as well as feedback possible to achieve in real-time[43].

Only widespread deployment of ICT popularized the use of interactive educational techniques on line and off line[44] to the initial and supportive training and the professional development of employees. Their essence is learning without constant contact with the teacher at any place and time, based on instructional materials typically derived from the network as multimedia files. Distance learning[45] can take place in two modes — synchronous and asynchronous. The first is the combination of real-time teaching of pupils (virtual classrooms), in the second learning materials are available via the Internet/Intranet, depending on the needs of the person concerned, and chosen by them at any time[46].

Such an approach means it is possible to select the appropriate class coach or specialist who will have the appropriate knowledge of both content and sector of the economy. The problem of the person's availability at a time and location is no longer. Training also enables the standardization of curricula in different countries and conditions, which in turn allows the harmonization of the process of accreditation of acquired competences.

Modern "e-learning" technologies have a high degree of flexibility in relation to "traditional" training courses and access to solutions that can be used in teaching techniques both for the individual and complex systems. The trainee can adapt the learning process to their individual timing and pace of learning preferences, as well as receive alerts about the need for reminders for sections of material already covered, in order to repeat and permanently remember.

E-learning among workers reinforces a sense of responsibility for their own professional development and generally does not require a large budget. Using existing ICT infrastructure here, it is possible to reach a large number of employees and monitor the use of the system and check the results of the training. Furthermore, as a result of free access to the courses they do not interfere with other tasks performed in the company and do not interfere with their normal rhythm. The decision to train a select group of employees can theoretically come at any time.

Information technology is also useful to assess the creation of a database of training centres and the course itself, as well as the process of selection and planning training. This last feature is implemented by LMS software (learning management system) or even more complex in its assessment LCMS (learning content management system). These are tools to facilitate the analysis of training needs for creating, approving and issuing training content and tracking academic progress and reporting resul[47]. All this affects the rise in popularity of training conducted using electronic media.

Among the technologies enabling distance learning virtual classes deserve a mention, that is, classes usually in real time in a system where there is the capability of mutual contact by a network of participants among themselves and a skilled trainer hired for this purpose. The interactive software provides knowledge through various means of presenting information: audio, video, text, graphics, animations. Through this method many employees are trained to a unified standard in the selected area of training content both at home and abroad. An integral part of these courses may be testing and educational group games and online meetings. Equally important is to create an organizational culture of spontaneous cooperation, peer exchange of experience.

On the basis of the "virtual classes" arose the concept of massive open online courses (MOOC), which is training available via the Internet to an unlimited number of participants. The latest technological novelty, in addition to the other qualities of e-learning (video recordings of lectures, classes in interactive format), also provides tools (forums) for the construction of an academic community. MOOC contains both elements of mastery learning[48] and adaptive learning elements, involving the creation of such a computer interface via which a continuous analysis and evaluation of perceptual habits and skills of assimilation of information by the trainee take place and at the same time it is possible to adjust training material and pace of learning to their needs.

Despite the many advantages of remote training, it also has its limitations. Namely, in many cases, there is a lack of learning opportunities for manual work, and there is the need to have access to computers/laptops and the Internet and the ability to motivate oneself. One obstacle to the dissemination of this form of learning may be insufficient acceptance of automated assessment of progress in teaching.

These defects may be offset partly or wholly by a learning system based on mobile applications, and primarily a compilation of the traditional model of teaching — OJT, called the blended method study. In this way the circle closes.

The axis of the system of blended learning is good quality multimedia courses conducted in the virtual world and simultaneous access to the scientific institution offering the opportunity to discuss the learned material in the group by professor/mentor, complementing the range of teaching about with the opportunity for manual exercise/OJT and receiving a certificate recognized in the worlds of science and business. In this system, the presenter, instead of giving monologue lectures, and preparation and conduct of examinations, will be able to devote their time to discussion with the students/course participants.

The future emanation of blended teaching methods may be a three-dimensional space environment combining the virtual world (e.g. Second Life, High Fidelity, OpenSim) with OJT and an online e-learning platform and gaming elements accelerating the learning process (massively multiplayer online game, MMOG). Such a hybrid system supporting education equipped with e-learning tools for teaching and learning is fully integrated with the system moving in the virtual world.

An example of this idea is the SLOODLE project (Simulation Linked Object Oriented Dynamic Learning) connecting with one of the leading distance learning platforms Moodle (modular object-oriented dynamic learning environment), with the virtual environment of Second Life and OpenSim and normal classes conducted by any scientific institution.

In university centres doing research in the sciences, natural sciences, and engineering (science, technology, engineering and mathematics, STEM), e-learning is used in the form of various courses on stem cell/gene expression issues in biomedical engineering, quantum physics or advanced departments of mathematical analysis.

A major ally of solutions for blended learning methods are the American Next Generation Science Standards (NGSS), which create standards of education rich in content and practical lessons, setting a uniform method for their transmission and setting a universal international benchmarks.

There is, however, still no compilation of e-learning training as part of a wider program of blended learning, combined with the traditional model, carried out in collaboration with a university/department with a similar profile/specialization. The obvious challenge in this area will to create a training course range on the basis of a blended study methods with a large share of virtual classes, really supporting practical learning by an investigator-experimenter in the field of laboratory work.

Construction of a comprehensive system protecting knowledge and personal data using sophisticated physical, ICT and procedural security

In R&D units and innovative companies for many years, and not only in Poland, the process of information protection often came down to the patent protection of intellectual property prototypes, and new products and technologies, i.e. explicit protected knowledge[49].

It is worth mentioning here from W. Kotarba that the issue of knowledge protection strategy contains some other issues, thematically distinct. In the classification he proposes are distinguished[50]:

a. knowledge fully available — free.
b. explicit knowledge — protected.
c. inaccessible knowledge — latent and hidden.

Today, in research and development organizations the third range of topics is considered a priority. Unavailable knowledge should be protected to the full extent of its occurrence and in a very professional manner. The actions undertaken in this area are an important form of safety net against theft of intellectual property not yet patented and bringing security to the entire process of generating new knowledge. In relation to the activity of reinforcing open innovation and knowledge sharing it is at the opposite pole. Its implementation, however, is taken as seriously as the introduction of solutions related to the development of knowledge. They are designed to minimize access to sources of information on a "need to know" basis to employees within the unit and completely unavailable to outsiders. They are also a barrier to the leakage of personal data of employees of the company, especially for those most valuable personal data, i.e. the data on sensitive scientists[51].

The absence of regulations regarding the legal protection of inaccessible knowledge, i.e. not to include a confidentiality clause in businesses, particularly in innovative organizations may require the disclosure to public opinion of confidential information which the institution would not want to expose. In the Polish context, this happens where due to the lack of formal security of confidential information, a decision of the Administrative Court (in accordance with the Law on Access to Public/Overt Information), information that is theoretically part of the set of inaccessible knowledge, must be issued to the institution requesting access, or de facto, be made public[52].

To effectively ensure the confidentiality of information, therefore, it is necessary to properly qualify it as confidential. The present classification in Polish legislation can be based on the provisions of the "Act on Combating Unfair Competition" dated 16.04.1993, defining confidential information in Art. 11 as a "trade secret"[53].

A trade secret (pursuant to paragraph 4 of Article. 11 ACUC) is technical, technological, organizational enterprise or other information having commercial value not disclosed to the public, for which the entrepreneur has taken the necessary steps to preserve its confidentiality."

So information is a "trade secret" if three conditions are simultaneously satisfied[54]:

a. it is information of a technical, technological, organizational business nature or other information having commercial value,
b. it is confidential information, i.e. not disclosed to the public,
c. the business has taken the necessary action to maintain the confidentiality of such information.

Today in the legal literature it is generally accepted that constitute a trade secret may, inter alia, include:[55]

- patentable or non-patent inventions,
- technical plans, customer lists,
- knowledge and methods of administrative and organizational nature,
- quality control methods [...],
- content of contracts, agreements, business correspondence,
- strategy of the enterprise's operation, etc.

In R&D organizations, protected confidential documents would include, in particular, the following materials in paper and electronic form: offers submitted and received, plans for sales, development and marketing campaigns, business plans, profit and loss accounts, and the methods of applied/research protocols, and above all the results of studies, an invention before filing a patent application, positive/negative lessons learned/knowhow after conducting research experiments.

The implementation of the necessary measures to preserve the confidentiality of information known as "trade secrets", i.e. implementation of personal, physical and electronic security, is based on an information protection system and an integrated physical security and information system — information security management system, ISMS. Very often the ISMS is supported by an FMEA analysis (failure modes and effects analysis), enabling the identification of hazards — the level of the factors affecting the risk of disclosure or loss of information.

The complex composition of security is built on the foundations of two systems. The first one, the system of Physical Security Information Management (PSIM) is a category of software that allows the integration of platforms, applications and devices in one integrated system enabling the collection, processing and gathering of information in the system according to specific security procedures.

The PSIM allows the collection of data from video cameras, sensors and other devices that generate security reports from SKD[56], Intrusion[57], CCTV[58], DSO[59], EAS[60], VCA[61], SSP[62], HVAC[63], GIS[64] systems, intelligent lighting control and those that use video wall, intercoms and IP phones. This allows personnel responsible for protecting the building to engage in rapid identification and analysis of threats and take action, as a rule proactive.

The second computer system which plays an immense role in the information security management system is the data communications system. The security policy implemented on its foundations in the field of ICT systems is the most commonly a set of policies/procedures regarding information security management and risk in IT usually included in an ISMS system (information security management system). Parts of it are also included in the previously described PSIM system.

The security policy in the field of ICT systems protects against a large and diverse range of hazards such as: intellectual property theft and industrial espionage carried out by hacking into an IT system or unauthorized copying of data and information or their wrongful taking out from the company by its employees. For this type of activity we should also include acts of electronic vandalism such as the partial or total destruction of the infrastructure of information and communication system or a violation of the integrity of the data processed (modification, deletion).

The ability to monitor and eliminate these phenomena without adequate procedures and tools is very limited. This is why there is a growing demand for software solutions, next-generation firewalls, applications enabling geolocation of equipment and its users, as well as monitoring the use of the system and safeguards for the collection and processing of data in the cloud, and internal, dedicated networks with a limited number users or devices of the TEMPEST[65] class.

Certainly, the challenge here is to determine the influence of the local criticality factor (risk) on the level of security of the entire system and to provide adequate security for the information contained and processed by the user in a diverse group of devices (PCs, laptops, telephones, test equipment).

The method allowing such an assessment, and at the same time perfecting the process of information security, by eliminating or minimizing the risk of disruption in its operation and optimizing solutions maintaining its effectiveness of action it is to analyse the types and effects of possible errors — FMEA. This method is the essence of creative group collaboration and a very efficient way to introduce appropriate solutions for ISMS. FMEA allows assessment of the scale of impact of existing threats to the system of physical security information management and the ICT system and the effectiveness and sustainability of the measures, planned and used to eliminate them.

In innovative biomedical companies it is used to identify and reduce risk in the scope of the ICT system beginning with desktop and laptop computers, via tablets and phones with different operating systems, and ending with scanners, network printers, and specialized online test apparatus.

The use of FMEA to evaluate PSIM extends to the identification and exclusion of the risks associated with the specifics of work in a given laboratory and does not concern merely information security. Among the diverse range of scientific R&D laboratories (chemical, measurement, biological) are laboratories where pathogens are examined which can be transmitted through the air and even cause fatal infections. Their terms of use "Biosafety and Biosecurity", are regulated by Polish law in separate legislation[66]. . These laboratories must have, inter alia, a high degree of atmospheric sealing, and be clearly separated from the public area of the building with a complementary access control, an installed window for observing the interior of the laboratory and communications/video surveillance and alarm. These solutions obviously influence the final form of the implemented ISMS, and are some of the most sophisticated safeguards introduced in this field.

Regardless of the discipline and the kind of laboratory work, the actions of R&D units in order to prevent access by unauthorized persons, defence against attacks by hackers/crackers, and preventing dishonest practices among their own employees are a priority at the highest level and cannot be ignored.

The financial temptation to provide access to sensitive information to competitors about the research work by the staff of the company is also limited in a professional way by the clauses contained in the agreements of confidentiality and non-competition (non-disclosure agreement — NDA/Confidential Disclosure Agreement — CDA and non-competition agreement — NCA), and the principle of the transfer of confidential information only to those giving a pledge of secrecy and only to the extent necessary to carry out their work in the positions they occupy. Knowledge "stolen" is in most cases reproducible knowledge, but its appropriation and use by competing teams is usually very expensive for R&D businesses.

Conclusions

The use in R&D units of ICT technologies and continuous improvement tools is a reality. However, taking into account the current technological possibilities and needs for improvement of research processes, it can be seen that we are only at the beginning of the road. The innovative knowledge-based economy in the biomedical sciences needs the full integration of knowledge management and engineering knowledge around which the core regardless of subject is finally built. Only then will interdisciplinary teams of Polish R&D units leading small and large biomedical projects (big science) be able to succeed in such a rapidly changing and globally competitive market.

References

[1] According to P. Kotler a prosumer is a consumer who is not content with the standard product offered by the manufacturer, but actively participates in the production process shaping the commercial offer.

[2] Co-option — the process of converting competitors into allies. In turn, co-opetition is a combination of co-operation with competition. True, pure competition takes place at the level of a network of firms co-opting with each other.

[3] Once the process starts with market segmentation, aim at the most profitable segments and positioning in them their own offer (Segmenting, Targeting, Positioning, STP).

[4] CEDAC — Cause-and-effect diagram with the addition of cards. TRIZ — Theory of Solving Innovative Issues (rus. *Теория решения изобретательских задач*).

[5] DOE — Design of experiments.

[6] LIMS — Laboratory information management system. BMS/RMS — Building monitoring system, Room monitoring system.

[7] Wierzbicki, A.P., Nakamori, Y. (2007).Creative Environments: Issues of Creativity Support for the Knowledge Civililzaton Age. *Studies in Computational Intelligence*, nr 59, Spinger, Berlin.

[8] Chudzian, C., Granat, J., Klimasara, E., Sobieszek, J., Wierzbicki, A.P. (2011). Wykrywanie wiedzy w dużych zbiorach danych i przykład personalizacji inżynierii ontologicznej. *Telekomunikacja i techniki informacyjne*, nr 1–2, s. 6. (Their cyclical nature gives continuity and repeatability to the process of knowledge creation).

[9] For more see. Depta, R. Struktura systemu informacji marketingowej opartego na nowoczesnej technologii informacyjno-komunikacyjnej i komputerowych systemach zarządzania wiedzą. In: Woźniak, M.G. (ed.) (2011). Nierówności Społeczne, a wzrost gospodarczy, Społeczeństwo informacyjne, stan i perspektywy rozwoju , *Zeszyty Naukowe UR*, No. 22, p. 203–214.

[10] Na nich również buduje swoją tożsamość komunikat.

[11] Subieta, K. Informatyka służebna. *Computerworld* from 2.06.2003, p. 36.

[12] Śmigielska, G. (2006). Wiedza jako źródło trwalej przewagi konkurencyjnej przedsiębiorstw handlowych, *Zeszyty Naukowe AE Kraków*, No. 694, p. 124.

[13] Defining the concept of information and forms of occurrence is not easy, despite appearances. For some researchers, the phenomenon of information spreading everywhere and in different forms is a random element in stimulating the development of all matter on the path of evolution. The converse of this hypothesis is the option for programmability of the whole world - everything including information is already in advance contingent - called the deterministic hypothesis. (Kowalski, P. (1997). Świat informacją żyjący — świadomość. *Computerworld*, No. 2, p. 43–49.)

[14] Steward, D. (1996). *Praktyka kierowania*. Warszawa: PWE, p. 467.

[15] Nonaka, I., Takeuchi, H. (2000) Kreowanie wiedzą w organizacji. Warszawa: Poltext, p. 2. IN: J. Kisielnicki, *Zarządzanie wiedzą we współczesnych organizacjach*. Wrocław: Wydawnictwo Akademii Ekonomicznej we Wrocławiu, 2004, http://www.wz.uw.edu.pl/ksiz/download/Zarzadzanie%20Wiedza.pdf (accessed on: 12.06.2013).

[16] Operationalization of information is the choice of its representation in such a form that it can be adapted for use by computer automatically .

[17] Traditionally associated with artificial intelligence and automated methods of machine learning. With its broader meaning, its common understanding is accompanied by two additional sections: engineering extracting hidden knowledge from large data sets and engineering, and word processing, hence the extraction of knowledge, but expressed in words.

[18] Corcho, O., Fernandez-Lopez, M.,Gomez-Perez, A. (2003). Methodologies tools and languages for building ontologies Where is their meeting point? *Data and Knowledge Engineering*, 46, p. 43.

[19] The model for other ontologies in the field of Life Science is Open Biomedical ontologies. Founded in 2006 in the US at the initiative of the National Center for Biomedical Ontology, it provides a pattern of action for, inter alia, projects such as The Generic Model Organism Project and Gene Ontology Consortium, Sequence Ontology.

[20] These allow data sets called metadata to be transferred describing the relationship between them and the context. They are an ontological method of knowledge representation, relationships between objects presented in the form of a graph in which objects are nodes and relationships are the branches.

[21] In Linked Data links are used instead of text and the syntax of simple affirmative sentences is used: subject - predicate - complement (Resource Description Framework, RDF). Making a given institution's data of good quality in this format significantly increases its prestige throughout the world.

[22] The technology used in the field of advanced virtual manners of representation of knowledge are also conceptual graphs (graph-based knowledge representation, GBKR) and markup language, a format for the document/system consisting outside the text basic of information describing the text.

[23] Grala, B., Kozakiewicz, W.(2009). Infobrokering and Searching the Deep Web — the New Role of Employee of the Department of Medical Scientific Information, *Forum Bibliotek Medycznych*, Uniwersytet Medyczny w Łodzi. R. 2, nr 1, s. 404, http://cybra.lodz.pl/dlibra/docmetadata? id=4855&from=publication (accessed on:08.08.2015).

[24] Pietraszek, J. (2015). *Planowanie doświadczeń — możliwość czy konieczność*. Instytut Informatyki Stosowanej, Politechnika Krakowska, StatSoft Polska 2004, s. 180, http://www.statsoft.pl/portals/0/Downloads/doe.pdf (accessed on: 08.08.2015).

[25] Especially for R&D centres is applied here the method of ABC-VED, which is a compilation of known methods of management of stockpiles ABC (grouping according to their value and turnover) and VED (vital, essential, desirable), based on the criticality assessment actual possession of the material in stock. As a result a matrix is created structured into three categories for inventory items (I, II and III), where the first category consists of items belonging to the consolidated sets of AV, AE, AD, BV and CV. In turn sub-segments BE, CE and BD form category II, the remaining from the combination of areas C and D fill category III.

[26] The methods of inventory management in biotechnology, medical or pharmaceutical firms differ primarily in the need to create appropriate storage conditions including temperature, humidity, and air conditioning in storage areas. Characteristic features include dedicated quarantine storage facilities, dedicated space for special products such as flammable materials, narcotics, psychotropic substances, and drug precursors.

[27] Laboratories are a highly energy-intensive type of premises, often consuming four to six times more energy per square metre. Most functioning laboratories can reduce 30-50% of the cost with the use of existing technology, which gives approx. 1-2 billion yearly more on the cost of energy used in the US. Almost half of these costs are attributed to ventilation. The exact % are as follows: ventilation 44%, connected devices 23%, cooling 22%, light 11%. (Optimizing Laboratory Ventilation Rates, Laboratories for the 21st Century: Best Practice Guide, p. 1, http://i2sl.org/documents/toolkit/bp_opt_vent_508.pdf, dostęp 02.02.2012).

[28] It is often confused with virtual reality, where the whole world observed by the recipient is generated by computer.

[29] Lean Enterprise - an approach focused on creating value for the end customer with minimum waste of resources.

[30] Malinowska, M. (1999). Interakcje — podstawa komunikacji marketingowej. *Marketing i Rynek*, No. 10, p. 15.

[31] Symmetry is understood here as a state in which both the sender and recipient are of similar or even identical status. (For more see: B. Sobkowiak, Komunikowanie społeczne. IN: B. Dobek-Ostrowska (ed.) (1999). *Współczesne systemy komunikowania*. Wrocław: Wydawnictwo Uniwersytetu Wrocławskiego, p. 13).

[32] Drucker, P. (1993). Managing for Results. New York: HarperCollins, cyt. za: K. Malewska (2013). Doskonalenie procesów decyzyjnych w organizacji. Wrocław: Uniwersytet Wrocławski. *Nauki o zarządzaniu — Management Sciences*, No. 1/14, p. 39.

[33] The TRIZ methodology used by H. Altszuller - the psychological phenomenon of the search for new solutions in familiar areas of science/knowledge, while for a good solution you need to look in a different direction/field of science

[34] Bielecki, W.T. (2001). *Informatyzacja zarządzania*. Warszawa: PWE, p. 156.

[35] 3D Holograms allow you to project the image in space, which is done with a special foil, gathering and reflecting the image. The image is displayed from multiple projectors with high power and very good resolution in real mode and with some advance registration and issuance in certain situations.

[36] Olszak, C.M. (2000). Systemy informatyczne wobec nowych paradygmatów zarządzania. IN: J. Gołuchowski, H. Sroka (ed.). *Systemy Wspomagania Organizacji SWO'2000*. Katowice: AE w Katowicach, p. 62.

[37] T.Ohno (one of the creators of TPS) has always admitted more important to the facts than the data received in the report, thus increasing the importance of physical checks.

[38] McKenna, E., Beech, N. (1997). *Zarządzanie zasobami ludzkimi*. Warszawa: Gebether i Ska, p. 218.

[39] Morgan, P.J., Starling, P. (2005). *The Integrated Personnel Development System: the training & development of competent fire fighters*. University of Bolton Institutional Repository, s. 4, http://digitalcommons.bolton.ac.uk/cgi/viewcontent.cgi?article=1001&context=bbs_journals&sei-redir=1#search='System+Training+aproach+Manpower+Services+Commission+(1981), accessed on: 02.02.2012.

[40] Training is divided into training focused on acquiring knowledge, skills and attitudes and appropriate behaviours, and methods of training and staff development most commonly include: lecture, conference, group training, programmed instruction, on the job training and interactive training via the Internet or company Intranet.

[41] For more see: I. Janiak, Od posiadanego do pożądanego. *Personel — Dodatek Narzędzia. Wzory. Procedury*, z 16–31.05.2000, p. 2.

[42] Training costs related to research and laboratory work, and support for research and scientific equipment are usually very expensive.

[43] Maciejewski, J. (2001). Nauczanie na odległość staje się faktem. *Łączność* z 22.01.2001, p. 12.

[44] A distinction is made in e-learning:online - learning in contact via IT network and off-line - learning at a station separated from the network computer, TV, etc.((Tworzyński, J. (2000) Zaprząc sieć do e-nauczania. *Personel i zarządzanie*, No. 21, p. 43.)

[45] Other terms specifying a teaching system using a computer network are "distance learning" or "open learning".

[46] Klimaszewska, E. (2000). Bez nauczyciela i sali wykładowej. *Łączność* z 07.08.2000, p. 12.

[47] Rypson, P. (2001) E-learning krok po kroku. *Personel* z 16–30.06.2001, p. 21–22.

[48] An educational philosophy maintaining that a student must achieve a certain degree of perfection of the processed part of the material to be able to move on to the next batch.

[49] Intellectual property is an intellectual process that is completed with the creation of artefacts in material form. This area is legally protected under the following legislation: Law on, artistic, scientific and literary property - Act of 4 February 1994 on Copyright and Related Rights (Journal of Laws Dz.U. of 1994, No. 24, pos. 83, as amended) and the Industrial Property Law — Act of 30 June 2000.Industrial Property Law (unified text *Journal of Laws Dz.U.* of 2003. No. 119, item. 117, as amended), as well as the Law on the protection of databases of 07.27.2001 r. and the law on unfair competition from 04.16.1996 r.

[50] Kotarba, W. (2005). *Ochrona wiedzy w Polsce*. Warszawa: Instytut Organizacji i Zarządzania w Przemyśle — Orgmasz, p. 9.

[51] Personal data in Polish law are protected under the Act of 29 August 1997 on the Protection of Personal Data (*Journal of Laws Dz.U.* of 2002. 101, pos. 926 as amended 2015)

[52] All aspects relating to access to data/information explicit, fully available - are contained in the Act of 6 September 2001. Access to Public Information (*Journal of Laws Dz.U.* of 2001 No. 112, item. 1198, as amended).

[53] The rules for including a "trade secrets" clause in companies for selected groups of information/documents are regulated by the Act of 16 April 1993 on Combatting Unfair Competition (unified text: *Journal of Laws* Dz.U. of 2003 nr 153, pos. 1503). In some situations for companies operating in the area of security and military guidelines for conduct regarding the protection of classified information are contained in the provisions of the Act of August 5, 2010. Protection of Classified Information (*Journal of Laws Dz.U.* of 2010. 182, pos. 1228).

[54] Bieda, R. (2007). *Zakres pojęcia „tajemnica przedsiębiorstwa” na gruncie ustawy o zwalczaniu nieuczciwej konkurencji*, p. 2, http://itlaw2.computerworld.pl/wp-content/uploads/2007/11/0710_pojecie-tajemnicy-przedsiebiorstwa_rbi.pdf (accessed on: 08.08.2015).

[55] Sołtysiński, S. W: Komentarz do art. 11 ZNKU. W: Szwaji, J. (red.) (2006). Komentarz ZNKU, Warszawa p. 312; Wojcieszko-Głuszko, E. *Ochrona prawna know-how*, p. 63; Mozgowa, M. *Ochrona informacji stanowiących tajemnicę przedsiębiorstwa w świetle ustawy o zwalczaniu nieuczciwej konkurencji,* s. 321; Mozgowa, M. (1997). *Zwalcza-*

nie Nieuczciwej Konkurencji Środkami Prawa Karnego, p. 35; Nowińska, E., Du Vall, M. *Komentarz do ustawy*… j.w., p. 89, http://itlaw2.computerworld.pl/wp-content/uploads/2007/11/0710_pojecie-tajemnicy-przedsiebiorstwa_rbi.pdf (accessed on: 08.08. 2015).

[56] Access control systems (ACS)

[57] Alarm system for burglary and robbery.

[58] Closed circuit television.

[59] Audio warning system, used to transmit verbal information in situations requiring rapid evacuation of personnel.

[60] *Electronic article surveillance*, — an anti-theft system consisting of antennas that emit an electromagnetic field which are excited by price tags and the central data processing.

[61] Video content analytics.

[62] Early fire detection and alarm systems.

[63] *Heating, ventilation, air conditioning*.

[64] Geographic information system — a geographical information system for entering, storing, processing and visualization of data related to the location of geographic features.

[65] The TEMPEST standard (temporary emanation and spurious transmission), established in the US, is a way to protect against accidental emission of electromagnetic radiation generated by each device through which current flows.

[66] Regulation of the Minister of Environment dated 29 November 2002 On the list of pathogenic organisms and their classification, and the measures required for each grade of hermeticity. Regulation of the Minister of Health dated 22 April 2005 On harmful biological factors for health in the workplace and to protect the health of workers occupationally exposed to these factors. The Act of 22 June 2001 On genetically modified organisms.

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4. Ustawa z dnia 29 sierpnia 1997 r. o ochronie danych osobowych (tekst jednolity: Dz.U. z 2002 r. nr 101, poz. 926 z późn. zm. 2015 r.)
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