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A Digital Repository of Science Assets as a Tool for Knowledge Transfer to Manufacturing Enterprises

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Abstract
Knowledge management is a process aimed at enriching and effectively using knowledge assets in various areas of business operations. It also applies to manufacturing enterprises that offer tangible products combining it with the art of processing information and intellectual assets into added value for the customer. A characteristic feature of manufacturing enterprises is assigning their employees a double role: a knowledge user and, at the same time, an internal source of specialist knowledge. In the situation of dynamically changing market conditions, there is an additional need to acquire new knowledge (in practice: often to buy knowledge) from the company's environment. A solution in the above-mentioned scope in Poland may be digital repositories of science assets as tools for knowledge transfer to SMEs. Research institutes are an important element in the process of knowledge transfer from scientific units to the economy (e.g. they offer their services in open access). The paper presents the concept of such a repository preceded by a diagnosis of the existing state, an analysis of the recipients of the deposited content and the examination and analysis of the requirements of potential users of the repository.

Keywords
knowledge transfer, digital repository of science assets, manufacturing enterprises.

Introduction

Existing technological development and digital transformation are significantly influencing manufacturing processes in manufacturing enterprises. These companies have to meet the ever-increasing demands of their customers, the actions of competitors, the level of innovation of the offered products and the pressure of time. The amount of specialist knowledge, both internal – of employees and derived from the company's own achievements, as well as acquired from outside – is very important here.

From the perspective of a manufacturing enterprise, scientific and research achievements offered by research institutes are a valuable asset. These institutions, conducting research and development activities (in contrast to academic units), were established to support the industry – providing it with technological solutions ready for implementation and commercialization. Research institutes in Poland operating for several dozen years (most often from the 1950s) have accumulated vast experience and achievements for the development of industrial production of strategic sectors of the economy (machinery, construction, chemical, etc.). Such scientific and research cooperation, apart from the most typical forms (common implementation of R&D projects, licenses, know-how, patents), may also involve the transfer of knowledge to enterprises through a digital repository of science assets created and published by a research institute. In a knowledge-based economy, this asset is key in the current operations of enterprises and the degree of availability of knowledge may determine its development strategy.

Literature review

Knowledge management is a set of processes enabling the creation, dissemination and use of knowledge to achieve the goals of the organization (Daven-

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port and Prusak, 1998; Probst et al., 1999; Nonaka and Takeuchi, 1995). One of the distinguished processes of knowledge management in an organization is knowledge transfer (Davenport and Prusak, 1998).

As noted by Fabiano et al. (2020), knowledge transfer in practice consists in the flow of knowledge using two categories of means: knowledge flow channels and knowledge flow processes: "channels are media through which encoded knowledge is transferred" while "processes are social configurations in which coded and encoded knowledge is shared".

Seeking knowledge from outside the organization has become one of the core activities of most companies that are committed to acquiring and applying new knowledge for the efficient and economic development of new products and services (Siachou and Ioannidis, 2009).

The research results presented by Durst and Edvardsson (2012) emphasize the critical importance of knowledge transfer for SMEs in the context of running their business and building the company's competitiveness. The conclusions underlined an important gap in knowledge transfer: more research is needed on both sides of the knowledge transfer process: the sender and the recipient.

In the article by Harlow (2017), the lack of effective solutions in the field of knowledge transfer from university centers to industry in the United States was indicated. A similar problem is raised by Azman et al., (2019), listing in his publication a number of factors limiting cooperation between university centers and industry in Malaysia. These factors include, among others, legal regulations (including copyright). Institutional and organizational factors – as barriers to this cooperation – were also indicated by Merchán-Hernández et al. (2015). In turn, the factors facilitating mutual cooperation include not only technological but also social opportunities, such as the attitude of both sides to cooperation or good previous experiences (Santoro and Bierly, 2006).

In the article reviewing the literature on knowledge management in SMEs (Cerchione et al., 2016), the solutions used so far were classified into the so-called KM Practices and KM Tools. Among the presented solutions, the practice of using an external knowledge repository was not indicated. In turn, the possibility of using knowledge repositories as knowledge transfer tools in the shipbuilding industry was indicated by Fei et al. (2009).

The benefits of collaboration between scientists and industry are listed in (Garcia et al., 2019). Garcia et al. note that close science-industry collaboration is often a source of new ideas and joint design ventures. Experience shows that the emerging research networks are also an additional benefit resulting from cooperation between science and industry (Bhullar et al., 2019).

Such knowledge transfer tools as digital repositories have already worked at universities, public libraries and arts and culture institutions.

The issue of digital repositories of science resources is often described by authors from all over the world. Srinivasan et al. (2007) described the process of creating, growth and evolution of the institutional repository of the Raman Research Institute. The system deposits a content intended for students and scientists. It does not contain materials necessary for SMEs (e.g. construction documentation, reports on R&D works, industry standards) and does not provide for functionalities facilitating the work of R&D departments (appropriate search engines). Llorens et al. (2010) present how to combine two separate projects to create a platform for disseminating knowledge at the university. One of the projects is an institutional repository for storing teaching materials, and the other – a system that facilitates learning. It proves that repositories can be expanded depending on the needs of institutions and recipients. Both Srinivasan et al. (2007) and Llorens et al. (2010) describe their experiences with the Dspace software – the software was also selected in the case of the model proposed in this paper due to the possibility of adapting it to the administrator's needs and good opinions of existing users.

When starting and developing work on creating a repository, it is necessary to examine the expectations of future users. In the literature on the subject many examples of the use of a survey for the purpose can be found. Van Biljon et al. (2017) present the four-cycle research overview with the survey as part of the first cycle. Also, empirical data were obtained through questionnaire forms to examine motivations affecting R&D employees' acceptance of electronic knowledge repository (Hung et al., 2011; Gray and Durcikova, 2005).

Digital repositories in the literature are classified as an important knowledge transfer tool and the proposed model fills the gap in the creation of a database dedicated to manufacturing enterprises as well as research and development departments.

It should be emphasized that the solution proposed in the article is innovative due to its targeting of specific audiences. It, in turn, is due to the specificity of the activities of research institutes, which direct the results of their research primarily for SMEs.

State of the art

Research and development activities (R&D) are creative work undertaken in order to increase knowl-

edge resources and use these resources to create new applications. Both manufacturing enterprises (enterprise sector) and research institutes in Poland (higher education sector) are classified as entities of R&D activity. The remaining R&D sectors are the government sector and the private non-profit institutions sector. The activity, in the areas of operation of research institutes in Poland, is carried out in the form of research issues aimed at developing innovative technological solutions, ready for implementation on the market. The result of the work are patents, utility models, licenses, know-how, test certificates, thematic expertise, trainings, scientific conferences, etc. A record of this activity created in various forms (scientific and research reports, construction documentation, scientific articles, monographs, conference proceedings, raw data, patent descriptions, multimedia files: photos, videos, instructions) and collected by research institutes for decades is undoubtedly a very valuable asset of science. It is worth transferring as broadly understood specialist knowledge to its main partners and customers – manufacturing enterprises. A thorough analysis based on many years of experience of the institutes in the field of cooperation enabled to identify several groups of recipients of results of institutes' R&D (Starzyńska and Klembalska, 2017):

1) business entities (including: manufacturing enterprises, service enterprises, trading enterprises);
2) science and research units (universities, other research institutes, institutes of the Łukasiewicz Research Network, institutes of the Polish Academy of Sciences);
3) secondary schools (mainly profiled fields of education related to the activity of a research institute);
4) government administration institutions;
5) local government administration institutions;
6) business environment institutions;
7) foreign scientific, research and industrial units;
8) individual interested parties.

Research institutes operating in a specific legal and economic environment conduct R&D activities and transfer their knowledge to their clients – the direction of the transfer is shown in Fig. 1.

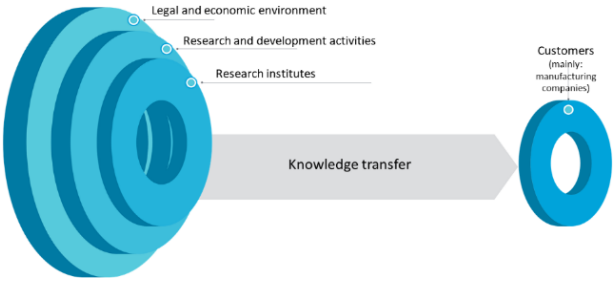

Fig. 1. Direction of knowledge transfer from research institutes to customers (source: own study)

The legal and economic environment where research institutes currently operate is based on two basic pillars: the knowledge-based economy and open access to science assets. One of the most important features of the knowledge-based economy (network economy, electronic economy, virtual economy) is the advantage of information and knowledge over material assets. The environment affects the organization (company, research institute), but also the organization actively tries to adapt to the environment. The literature on the subject defines four adaptation areas – organizational structure, strategy, human capital, ICT systems (Armstrong and Baron, 2007; Davenport and Prusak, 1998; Probst et al., 1999, Azizi et al., 2016). The last area includes tools such as the digital repository of science assets for the transfer of knowledge from science to business (S2B).

For several years, the pursuit of open science has been noticeable. Such practice is forced, inter alia, by the conditions of the activities of modern business entities and scientific institutions that base their R&D activities on interdisciplinarity. Legal guidelines for the policy of openness appear in the form of a recommendation or obligation to make the results of research conducted under Horizon 2020 widely available. Operating in such a legal and economic environment, research institutes (perceived as providers of scientific assets) must develop appropriate channels for the transfer of knowledge to their clients. Following the trends in digital technology and the practice in the field of sharing research results developed by universities, the most appropriate tool is a digital repository of science assets of research institutes, ensuring the integration of the achievements in one place and open access to content for all interested users (taking into account the protection of intellectual property resulting from the law).

The method of sharing this heritage used so far does not guarantee effective searching for the necessary content. The vast majority of research institutes (out of over 100 such units currently existing in Poland) do not have a tool that would enable the seeker to find the required resource of knowledge in an easy and quick way. The record of achievements is in dispersed locations – on websites, in institutional reporting systems (e.g. for superior institutions such as the Ministry of Science and Higher Education), in external knowledge bases (repositories and digital libraries of other institutions), in internal knowledge bases (e.g. lists of scientific papers), in thematic statements (prepared for a specific topic, project), on internet portals (branch, social media). Recognition of these resources in so many sources is burdened with two basic drawbacks – not all of these sources contain

the entire output, some sources are characterized by lack of access or limited access for external users.

The scientific potential of research institutes is very wide. Classifying the results of R&D activities in four groups, based on the data from four years reported by these units in the Integrated Information System on Science and Higher Education (POL-on), a numerical list of individual forms of results developed by scientists from research institutes was prepared: scientific journals, scientific publications, research projects, inventions and utility models (Fig. 2).

Fig. 2. Number of results of R&D works in research institutes in Poland in 2013–2016 in individual forms (source: own study based on polon.nauka.gov.pl)

The report prepared for Siemens Polska on the areas of the digitization of production in Poland (understood as a company management process including data collection and analysis, which leads to increased productivity, minimization of losses, unplanned downtime and automation of production-related processes) shows that the highest degree of digitization (the so-called digi-index on a scale of 1–4 points) was achieved in the manufacturing industry in the area of data management (Siemens Polska, 2020). Figure 3 presents a list of six areas of digitization in companies from the manufacturing industry in Poland, with an indication of the digi-index level achieved in 2020.

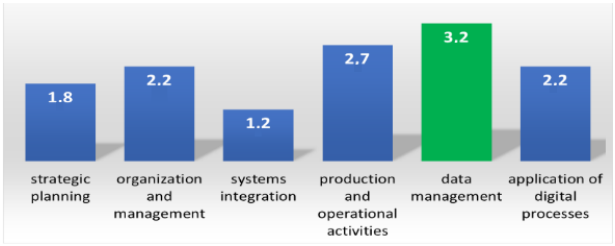

Fig. 3. List of digitization areas in companies from the manufacturing industry in Poland with an indication of the digi-index level achieved in 2020 (source: Siemens Polska, 2020)

The above list shows the high commitment and awareness of these companies in terms of acquiring and managing knowledge (data management), which is the basis for the transfer of knowledge from the scientific and economic environment (including research institutes).

Research problem

Bearing in mind the legal and economic conditions of modern R&D activity (knowledge-based economy, open access, digital transformation, interdisciplinarity of research, knowledge transfer as a mission of research institutes) and the potential of research institutes in terms of accumulated and ever-growing scientific achievements, the concept of creating an innovative, intelligent IT tool is fully justified. The tool in a form of a digital open repository of science resources will not only provide access to valuable content, but also support knowledge management both in institutes and among interested clients – especially manufacturing enterprises, including SMEs.

Methodology

In order to analyze the state of knowledge on the functioning and use of tools ensuring virtual access to scientific assets (repositories and digital libraries) and to identify the needs of users of the designed repository, their opinion was surveyed. The structure and content of the questionnaire were developed in accordance with the principles of conducting research in social sciences (Frankfort-Nachmias and Nachmias, 2008) and based on the classic stages of knowledge management (Probst et al., 1999). The study was conducted in 2018 using a questionnaire form addressed to fifteen manufacturing companies in the machinery industry cooperating with the Łukasiewicz Research Network – Industrial Institute of Agricultural Engineering. The respondents constituted a research sample of 15% of the population of about 100 companies cooperating with the institute. Most of them were representatives of SMEs (80%), the remaining 20% were large enterprises. Each of the surveyed enterprises conducts R&D activity (as part of cooperation with a research institute or having its own R&D department).

Results

The questionnaire forms were given to 15 respondents. 100% of responses were received. On their basis, data was compiled in the following question blocks (Tables 1–3).

As a result of the study, important information needed to model a digital repository was obtained – types of resources that main users most often

Table 1
The state of knowledge and the situation in the use of repositories of science assets

Question	Answer	Number	Percent
1. Did you hear about the terms (in relation to assets collected in scientific institutions): "digital repository", "digital library", "knowledge base"?	yes	10	67
	no	5	33
2. Did you use digital assets of collections of scientific institutions in your work?	yes	4	27
	no	11	73
3. If "yes" was marked in question 2 – what kind of research institution was the author of this digital collection?	university	4	27
	research institute	0	0
	institute of the Polish Academy of Sciences	0	0
	other	0	0
4. If "yes" was marked in question 2 – what type of resources do you most likely use?	science articles	4	27
	monographs	4	27
	conference proceedings	0	0
	industry standards	0	0
	raw data	0	0
	multimedia files	0	0
	research reports	0	0
	technical documentation	0	0
	patent descriptions	0	0
5. If "yes" was marked in question 2 – how do you find interesting materials?	according to title	4	27
	according to key words	4	27
	according to author	0	0
	according to date	0	0
	according to other criteria	0	0

need (technical documentation, industry standards, research reports and multimedia files) (Fig. 4) and indications of the importance of including typical search criteria (stages of the product life cycle – 80% and the area of production engineering – 73%) (Fig. 5 and 6).

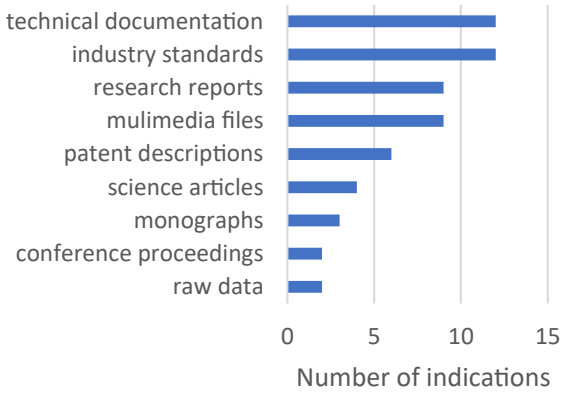

Fig. 4. Science assets expected by users in the designing repository (source: own study)

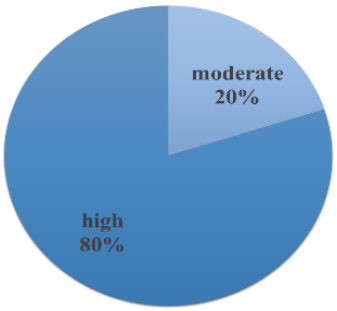

Fig. 5. Need to implement searching by stages of the product life cycle (source: own study)

The aim of the pilot studies was to obtain preliminary information on the need to create a proposed solution. The results confirmed that potential users are familiar with similar systems operating on the network (Table 1) and declare their willingness to use a similar repository offered by research institutes and express interest in additional functionalities (Table 2).

Table 2
Suggestions for increasing the efficiency of using digital repositories of science assets

Question	Answer	Number	Percent
6. How do you assess the utility (usefulness) of finding interesting material according to the basic search criteria (title, keywords, author, date of publication)?	low	9	60
	sufficient	6	40
	high	0	0
7. Is it appropriate to enter the following search criteria into the repository?			
• according to product life cycle	no need	0	0
	moderate	3	2
	high	12	80
• according to areas of production engineering	no need	0	0
	moderate	4	27
	high	11	73
8. What kind of assets would you like to use in the future?	technical documentation	12	80
	industry standards	12	80
	research reports	9	60
	multimedia files	9	60
	patent descriptions	6	40
	science articles	4	27
	monographs	3	20
	conference proceedings	2	13
	raw data	2	13
	other	0	0
9. Would a digital repository of science assets of research institutes effectively function as a tool supporting knowledge management in an enterprise?	yes	15	100
	no	0	0

Table 3
Information about the respondents

Question	Answer	Number	Percent
10. Enterprise size:	micro-enterprise	3	20
	small-enterprise	4	27
	medium-enterprise	5	33
	large-enterprise	3	20
11. Business profile:	manufacturing enterprise	0	0
	production and trading enterprise	10	67
	production, trading and service enterprise	5	33
	service enterprise	0	0
12. Industry:	machinery	15	100
	other	0	0
13. Capital:	Polish	12	80
	foreign	0	0
	mixed	3	20
14. Does the company have an R&D department (construction, design)?	yes	15	100
	no	0	0
15. Has the company ever collaborated with a research institute?	yes	15	100
	no	0	0

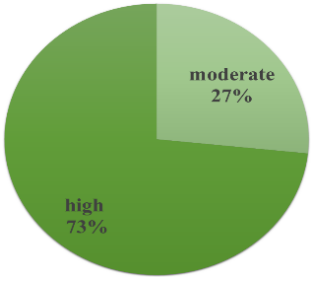

Fig. 6. Need to implement searching by areas of production engineering (source: own study)

The information obtained in the study was used to model a new knowledge management tool, corresponding to the needs and expectations of future users of a digital repository of science assets.

Discussion

In response to the needs of clients of research institutes resulting from the survey and based on the effective knowledge management process (Probst et al., 1999), a universal concept of a digital repository of science assets model was developed. The main difference, noticeable already at the stage of its creation at a research institute, is the fact that data are entered once by one editor (unlike in the existing distributed system in research institutes in Poland, where the work was duplicated in each database). Properly deposited and described data can then be downloaded by users for their own purposes (Fig. 7).

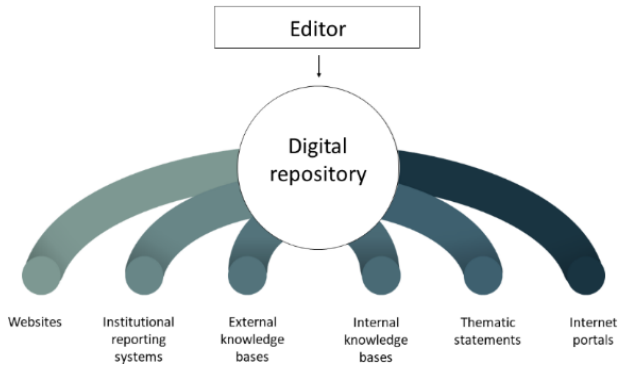

Fig. 7. Scheme of data transfer to and from a digital repository (source: own study)

Based on the conducted research and many years of cooperation with the recipients of research institutes' work, it was determined which groups of resources should be deposited in the repository. Therefore, in order for the tool to support the user's work, it is necessary to ensure that all assets (of various types – text, photos, raw data) are properly saved (downloadable, in a specific format, with the ability to recognize the text, described with metadata):

1) scientific papers, monographs, industry standards, scientific and research works, conference proceedings, technical documentation – XML/RDF metalanguage and DOI addressing, ONIX for ISBN standard with the VIAF template entry file associated with the ISNI identifier;
2) raw data – XLS, CSV, RDF and LOD formats and the CSDGM (FGDC) standard for digital geospatial data;
3) photos – Exif 2.2 (for JPG and TIFF formats).

All assets will be available in the Dublin Core (DC) standard. The metadata of scientific papers and monographs will be available in the Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) standard. Due to that, it is possible to search the repository with search engines such as Google Scholar, Web Citation Index, OAIster, Scirus. The basic metadata standards on which the repository will be based are Dublin Core and OAI-PMH and MARC 21 (Klembalska, 2020).

In the proposed model of a digital repository of science assets of a research institute, taking into account both economic and technical aspects, as well as functional and non-functional requirements of the system (scalability, security, interoperability, availability), it was decided to use a cloud-integrated system. In case of insufficient computing power, the size of the matrix surface can be increased to the required values at any time. Data in the cloud will be additionally replicated (backup) to ensure protection against loss of collected data. The architecture of the IT system creating the repository model, based on the DSpace system, provides for the adaptation of the following elements:

- layers of databases and indexing mechanisms;
- portal logic layer using the database layer, search engine and components supporting the effective processing of collected data;
- the view layers responsible for interpreting the user's query;
- API layer responsible for data exchange with other systems;
- routing layer responsible for connecting URLs with data views prepared by the system, selected according to the user's query.

A module extending functionality and operability will be implemented in the system – a mobile access module, executing queries from the mobile application for viewing the repository resources (responsiveness). The universal layout may refer visually to the lay-

out and colors of the website of the institute creating the repository, making it easier for the user to identify the author. The interface includes search engines with available typical search criteria: keyword, title, author, date, product life cycle, production engineering area (Klembalska, 2020).

The proposed approach to the system of collecting and disseminating the achievements of research institutes may solve many problems and have a positive impact on the knowledge management process both in a research institute and among recipients of scientific resources (mainly manufacturing enterprises, including SMEs). This includes:

- the integration of achievements in one place reduces the time-consuming process of depositing and acquiring resources – attractive appearance, comprehensive and ongoing content supply and intuitive search contribute to the increase in the promotion of the institute and S2B communication,
- digitizing and preserving analog materials increases their protection and ensures long-term archiving.

Conclusion

Knowledge management – regardless of its basic definition as a process which consists of several stages (Probst et al., 1999) – is based on the desire to develop methods and techniques to effectively create, collect and use knowledge (including increasing access to information and knowledge transfer). The proposed digital repository of science assets of research institutes is a response to the needs of major clients (manufacturing enterprises, including SMEs) identified in the study. By taking into account individual groups of resources and the implementation of specific search criteria, it is an innovative, intelligent and original concept of a management support tool and knowledge transfer to manufacturing enterprises – the uniqueness of the solution in Polish conditions is based on the concept of a repository for research institutes. Considerations based on the results of the presented pilot survey are limited to the importance of a creation of the repository. Further research procedure will include the preparation of a feasibility study (in terms of technical, financial, organizational aspects), development of a complete outline of the architecture and verification of a detailed concept through an in-depth survey conducted among representatives of research institutes (management boards, editors, IT specialists, financiers) and major customer groups (manufacturing companies – including SMEs, research and science units, business environment institutions).

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