

IMPROVING KNOWLEDGE TRANSFER IN THE LIFE CYCLE OF SURGICAL INSTRUMENTS WITH THE USE OF VIRTUAL TECHNIQUES

Joanna BARTNICKA

Abstract: The aim of the study was the recognition of the possibilities in range of supporting the knowledge transfer among stakeholders of surgical instruments life cycle in the context of improving their utility and ergonomic features. There was performed four-stages research path: (1) Medical staff needs identification in frame of utility and ergonomic features of surgical instruments; (2) Recognition of ways and determinants of knowledge transfer between surgical instruments manufacturers and medical staff; (3) Recognition of the barriers in knowledge transfer; (4) Designation of proposals in range of the activities for improving knowledge transfer between surgical instruments manufacturers and medical staff based on virtual techniques.

The studies were executed with the use of questionnaire methods, direct observations and ergonomic analysis.

An example of how to support the transfer of knowledge in the surgical instruments life cycle using e-learning platform was presented, the development of which runs in the framework of an international research project.

Key words: ergonomics, surgical instruments, knowledge transfer, product life cycle

1. Motivation

The currently accepted business models are based on continuous product / consumption / sales life cycle [1] and forced by the global competition rules. The successful functioning of the enterprises depends on the ceaseless supply of new and improved products that could meet the growing needs of future customers.

The essence of the product life cycle is a system of intentionally shaped relationships between different sectors and their representatives, also called stakeholders of the cycle. The mentioned sectors and stakeholders are following: design - designer, manufacture - manufacturer (wherein these two concepts are used interchangeably in the study), distribution - sales representative, operation - the user of the product.

These relationships take the form of mutual interactions and are caused by specific individual and often conflicting needs of stakeholders of the cycle [see 2].

For example, the needs of sales representatives are the needs of the profit, while for the user the most important aspects are the low price, safety in use, or effectiveness of the product. The essence of the interactions is therefore receiving a consensus which will give a sense of fulfillment the needs by each side of the cycle.

An example of such consensus is an appropriate effectiveness of the product in the process with a certain purchase price (important from the point of view of the user / buyer) and respectively manufacturer's low financial expenditures dedicated to design and manufacturing processes.

The above mentioned interactions can be implemented through various mechanisms of knowledge transfer. Wherein the knowledge transfer can be defined as the process by which knowledge is transmitted to and absorbed by a user [3].

It should be emphasized that it is not limited only to the areas of communication and mutual exchange of information, but first of all it includes such other processes namely knowledge identification and knowledge absorption [4]. They give the opportunity to appropriate knowledge interpretation and fulfillment its primary function which is the efficient use within a given action.

In the context of these considerations, the transfer of knowledge is therefore a key factor by which the mutual understanding and matching the requirements and expectations of the various stakeholders of the product life cycle can be done. Such an agreement is particularly important between the designer and the future user of the product for at least two reasons.

The first reason has an economic nature, considering the fact that over 70% of the total product life cycle costs is generated in the early stage of design [5], when it is recognized the design features of the product based on the real needs of the future users.

The second reason is situated in the social field, taking into account the fact that the products which are the surgical instruments are the products for a special destination. Therefore it is recommended to make recognition of both: (a) the needs in terms of desired manners of operations of surgical instrument as well as (b) the degree of adjustment of its design to the requirements referred to surgical techniques and capabilities of the operator, in order to minimize the potential negative consequences for the patients.

There was noticed a problem of adverse effects of using surgical instruments like: direct tissue damage, malfunction related damage such as critical bleeding, and retained pieces of broken instruments [6].

In addition the problem is the lack of an appropriate response of medical personnel for defective surgical instruments due to the little recognized risk of errors caused by improper tools [6]. An alarming phenomenon is also the fact that almost half of the defects in surgical instruments were caused by incorrect handling by surgeons [6].

The described problem has a technical nature. As shown in [7], most surgical errors concern precisely the technical sphere of surgery.

In addition to the consequences of using defective tools with respect to a patient, it is also needed to consider the negative impact to the operators themselves. The lack of adjustment the design and utility features to the predisposition of surgeons causes such effects as paresthesia of hands or nerve irritation [8, 9].

In this context the concept “defective” means “ergonomic deficiencies”.

Similarly, it can be analyzed an adverse effect of tools features on the work processes of scrub nurses. An example is the problem of the high degree of surgical instruments complexity which causes difficulties in the correct and rapid assembly and disassembly of the tools.

The complexity of surgical instrument design may also cause problems with sterilization. The tools after sterilization might not be sufficiently cleaned, making necessity to re-mechanical washing and re-sterilization.

Such action could have negative impact on the tools distribution within a hospital with respect to the time, where a timely delivery of surgical instruments to operating rooms is critical for success in surgical operations [10].

The delays and failures in the flow processes within an organization have a direct influence on the growth of its operating costs.

2. Objective and methodology

Taking into account the above-described problematic area, the recognition of the possibility of supporting the knowledge transfer among stakeholders of surgical instruments life cycle in the context of improving their utility and ergonomic features was formulated as the research objective. Where the utility features are defined as features that provide the ability of the product to perform the function for the realization of which the product was designed and produced. These features decide on the ability of the product to meet the needs of the user. In turn, ergonomic features determine the impact of a product for human and the adjustment to the anatomical, physiological and psychological characteristics of them. These features relate to, among others, safety in operation and service of the tools and the product side effects on humans.

There was formulated a specific research path for the study which is shown in diagram in Figure 1.

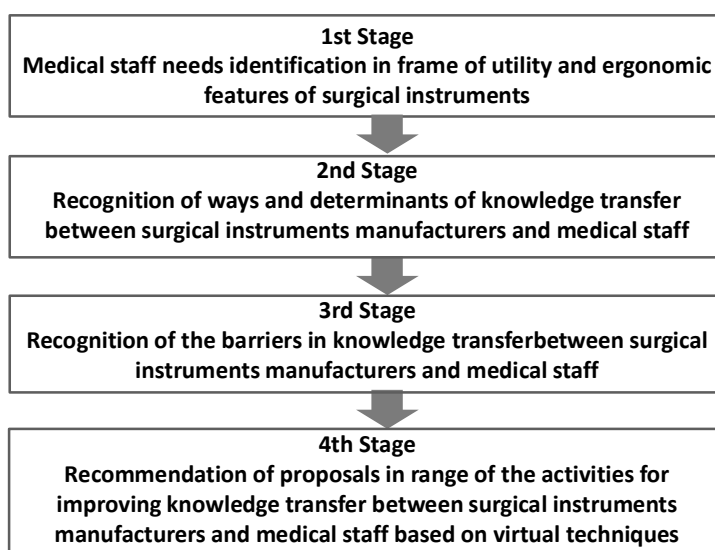


Fig. 1 Research path

In order to implement the indicated in the Figure 1 research path the following methods were used:

- 1st Stage: analysis of the literature in the field of surgical procedures assessment, alia; direct observation of work processes, including the surgical procedures: arthroplasty, laparoscopy; organoleptic and ergonomic analysis of surgical instruments including knee arthroplasty instruments and laparoscopic instruments.
- 2nd Stage: free interviews, including representatives: head of general surgery department, head of scrub nurses, surgical instruments producer, surgical

instruments and sales representative.

- 3rd Stage: deductive analysis of previous Stages outcomes.
- 4th Stage: analysis of the literature in the field of up to date technologies, building concept solutions.

The total number of observed surgical procedures was $n=8$, where $n=1$ was hip arthroplasty; $n=1$ was knee arthroplasty; $n=6$ laparoscopic procedures. In general, the research was conducted in $n=4$ hospitals.

There was studied the concepts "virtuality" and "technique in order to organize the research procedure. The concept of „virtuality” has the ambiguous meaning and refers not only to technological aspects [11]. For example, this concept is considered from the point of view of management processes indicating the ability to cooperation in business processes on the global market, inter alia cooperation between suppliers and bidders, without the physical presence of the participants in one place.

This term is also used to determine the "Network Society" and the "Information Age" highlighting the new organizational forms in the entities activities, unlimited to time and place [12].

Undoubtedly, the technology is an element supporting the mentioned activities defined as a virtual business. Some authors suggest that the virtual (intangible) activities are those that are supported by information and communication technologies ICT [see 13].

"Technique", in turn, means the field of activity of producing phenomena and items which do not occur naturally in nature. The concept technique means also the technical devices [14] and the way they work. In addition, technique refers to skills or the ways of performing certain actions allowing for mastery of craftsmanship in a particular field [15].

Considering the indicated definitions of "virtuality" and "technique" and the aim of the study the meaning of "virtual technology" is determined as a means and ability to apply ICT in fostering the cooperation between a user and a manufacturer of surgical instruments, based on the transfer of knowledge between them.

3. Research outcomes and discussion

3.1 Medical Staff needs identification in frame of utility and ergonomic features of surgical instruments

The literature draws attention to the necessity of improving the ergonomic features of surgical instruments. It should be emphasized the ergonomic shape and grip of tools handle. The tools which are maladjusted to the hand and upper limb motor abilities of surgeons can lead to fatigue and work discomfort [8].

Figure 2 shows a typical design of the laparoscopic instruments handle, such as scissors, graspers, extractors, indicating the somatic and receptor relations [16]. Where, somatic relations describe spatial relationship between surgical tool and the human body and are realized by musculoskeletal system, especially of hands and arms and receptor relations are realized by receptors of sight, hearing and touch, and respond to stimuli coming from the environment - in this case from surgical tools.

The relations define the degree of adaptation of a tool to anthropometric characteristics and movement predispositions of surgeons, and hence the degree of ergonomics the tools.

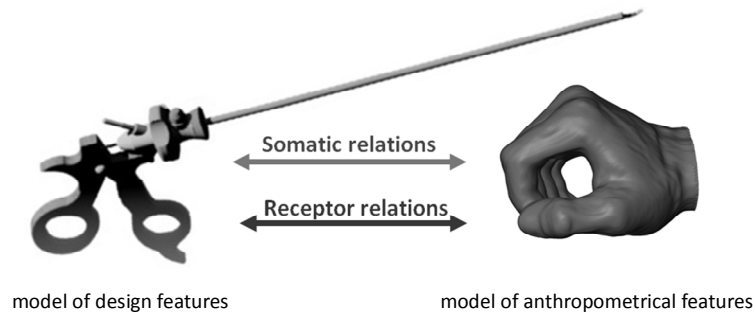


Fig. 2 Typical design of laparoscopic tool grip on the background of relations between tool and operator's hand

The shape of laparoscopic instruments and the way they are used determine the unusual positions of arms, hands and fingers. There are different types of handles in the surgical practise, e.g. in minimally invasive surgery. However, the principle of their use is similar and is based on the positioning the tools by the hand and fingers, which may lead to local pressure and hand injuries [17].

Few studies have been conducted in the frame of designing and validation of correctness of usage of ergonomic laparoscopic instruments. An example might be a prototype of the gripper tool that was designed basing on the analysis and evaluation of current tools in combination with the opinion of the surgeons. There was developed a special survey containing questions identifying problems related to using traditional instruments, and questions evaluating ergonomics of prototype tool. The illustrations of the prototype as well as the detailed results of the study are presented in [18]. Another example is an ergonomically designed grasper described in details in [19] or ergonomic system for laparoscopic instruments with special semi-spherical handle based on a spring system [20].

The research indicates that the users are not always aware of their needs regarding work tools and the way of performing operations, hence the errors associated with unergonomic tools can be replicated by designers. Such problem is largely due to the bad habits of users of these tools learned through many years of practice and customs of the people resulting from the belief that certain solutions are the best and should not be changed [see 21]. The way of raising awareness of ergonomic needs among people who design and use surgical tools may be followed by common (manufacturer – user) analysis of previous video registered surgical procedures.

Additionally, the operators of surgical instruments can articulate their needs through a questionnaire. An example is the survey which was conducted in six hospitals in the Silesia region on a group of 56 surgeons performing laparoscopic procedures. The study revealed the needs of surgeons in terms of changes in both tools shape, as well as other ergonomic factors affecting the difficulty within laparoscopic procedures. Figure 3 shows a chart depicting the main factors causing physical discomfort, indicated by the respondents. Nearly one third of these factors are associated with the surgical instruments grip design.

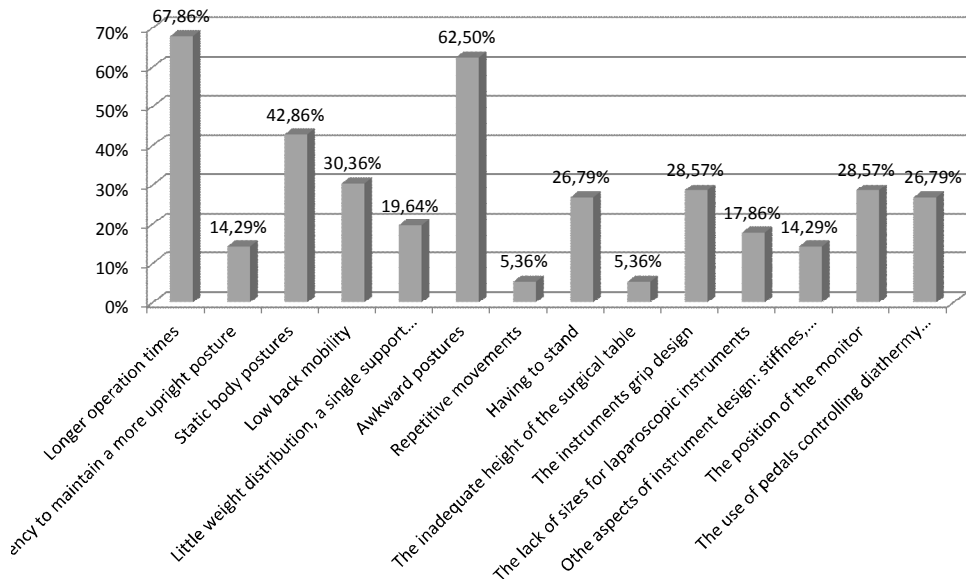


Fig. 3 The factors causing a major physical discomfort within performing laparoscopic procedures

Another way to identify the needs in terms of utility and ergonomic features of surgical instruments is the use of qualitative and quantitative ergonomic analyses. Figure 4 shows examples of such an analysis carried out on the basis of sensory method, the essence of which is to assess the comfort during using surgical instruments (supported by checklists) and computer tool Anthropos-ERGOMAX, which allows for an ergonomic variant - analysis depending on such features like specific percentile values, body position etc.

The analyses carried out with using the software Anthropos-ERGOMAX are performed in a virtual environment. The advantage of using virtual techniques is the possibility of including multi - variant data, in relation to both the operator (such as gender, percentile), tools (variant design characteristics) as well as to a way of handling the tool.

In turn, the basis for this type of analysis is previously made recordings and measurements of tools and how to operate them. Registrations can be performed during surgery (Fig. 5), as well as during the staging of the key parts of procedures with participation of surgeons.

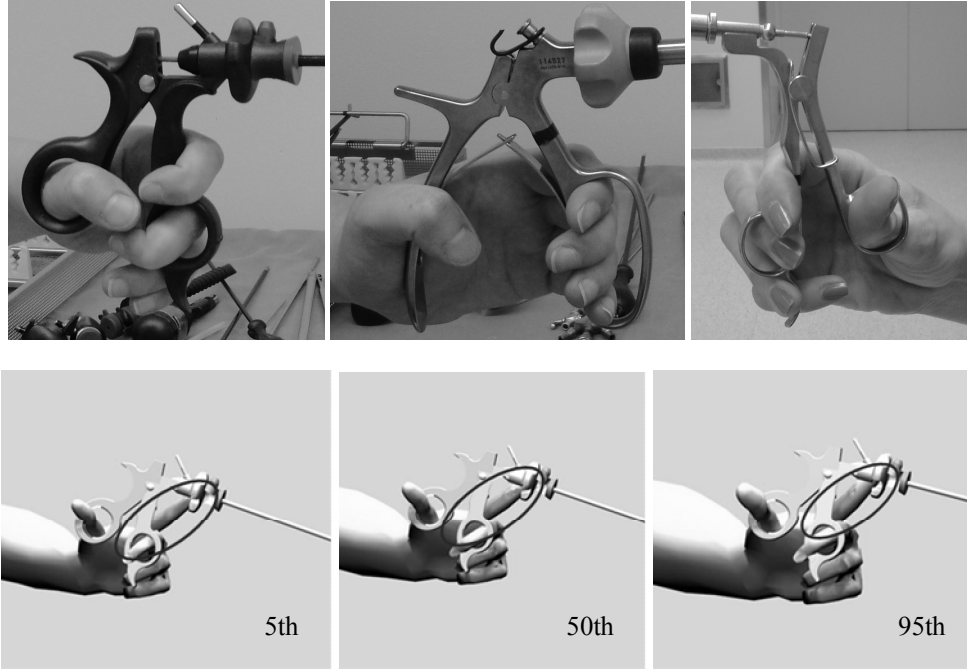


Fig. 4 The example of ergonomic analysis process using the methods: organoleptic and computer Anthropos-ERGOMAX (photo: J. Bartnicka, A. Ziętkiewicz)

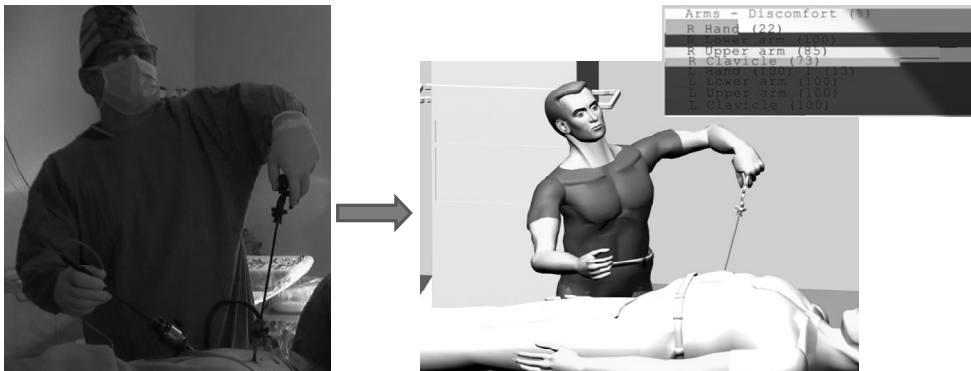


Fig. 5 An example of representation the way of manipulation laparoscopic tool in virtual environment (photo: J. Bartnicka)

Summarising the 1th Stage of the research it can be concluded that the identification of needs in range of surgical tools design, should be carried out in a differentiated manner based on both technical and medical knowledge: shared by doctors and nurses.

The ways that brought positive results in terms of identifying the needs was to learn the surgical operating techniques through direct observations of surgeries and consultation with surgeons operating during recorded procedures, moreover survey diagnosed the problems

associated with the use of surgical tools by the users, for example in the form of electronic checklists, as well as ergonomic analyses, including the use of virtual work environment.

The recognition of the needs in frame of surgical instruments features, allowed for substantial preparation for 2nd Stage, which was identification and analyze the ways and conditions of the transfer of knowledge between the manufacturer of surgical instruments and medical staff.

3.2 Recognition of ways and determinants of knowledge transfer between surgical instruments manufacturers and medical staff

The aim of the research undertaken in the 2nd Stage was to determine the conditions and methods of communication between the manufacturer and user of surgical instruments. The result of analysis has provided the answer to the question, whether diagnosed in 1st Stage problems are identified by the participants in the surgical instruments life cycle by themselves and are the subject to the transfer of knowledge between them. The scope of the interviews with the producers ($n=2$) and sales representatives of surgical instruments ($n=2$) included such issues as:

- 1) professional education,
- 2) possessing degree of medical knowledge in the field of surgical procedures,
- 3) motives meetings with surgeons,
- 4) the preferred ways to communicate with surgeons (e.g. a phone call, Internet, direct meetings, meetings within the trade fairs and conferences, etc.),
- 5) the forms used to support mutual understanding, such as drawings, computer simulations, video, etc.
- 6) the degree of mutual understanding.

Table 1 contains the synthetic outcomes from the interviews.

Tab. 1 The results of the interview with manufacturers and sales representatives

Issue	Manufacturer	Sales representatives
	Micro and Small Enterprise	Large Enterprise
1)	Technical education	Technical and/or managerial education
2)	Medical knowledge is acquired in the course of professional work thanks to the contacts with representatives of medical environments, participation in medical conferences or participation in surgical procedures as an observer.	
3)	<p>The main motive from the business side is to offer and sale the surgical instruments. On both sides there is also willingness to make improvements to existing products.</p> <p>Moreover, the manufacturers establish permanent cooperation with hospital units or individual doctors creating informal research and development departments.</p> <p>In the framework of the substantive meetings there are rarely taken into account the ergonomics aspects of surgical tools. If there are any, the initiator is generally a surgeon. This is largely because of the lack of ergonomic knowledge on both sides the business and medical representatives. The curriculums at the technical and especially management and medical studies, contain subjects including ergonomics at minimum level.</p> <p>The main subject of discussions is the issue of how to improve the existing tools in terms of functionality, e.g. how to change the shape of the tools' ends</p>	

	so that they could be more adjustment to the human internal organs.
4)	The preferred forms of communication are intentional, direct meetings or meetings on the occasion of the trade fairs or conferences. Less popular are ways of communicating via the Internet or telephone. They take place rather in the later stages of cooperation.
5)	Within the individual meetings regarding the design of the new surgical tools, the supporting forms of mutual understanding are sketching or analysis of existing catalogue drawings creating a base of potential changes of the design features of the tools. In turn, in the bids meetings, e.g. at trade fairs and conferences, in addition to catalogues there are presented films, computer animations, and selected items of the tools.
6)	During discussions with the medical staff there have been cases of misunderstanding the discussion subject, when it was related to the technical aspects.

The main finding of the study is that surgical personnel want to engage in the work of the new-improved surgical instruments. However, the hints provided by the surgeons do not touching the issue of comfortable use and ergonomics, and are limited to a method of interaction with the patients' tissues. There are also inspired by the designers in this area. In turn, sales representatives touch issues of ergonomics, but they do this mainly during the bids meetings and treat ergonomic features as one of the strengths of the product. They do not look for feedback and opinions of the surgeons and verify whether the ergonomic criteria are really fulfilled.

Table 2 shows the aspects included in the interviews conducted with hospitals representatives: head of the general surgery department, head of scrub nurses, as well as synthetic outcomes of their opinions. The respondents participating in the interviews are experienced in contacts with numerous sales representatives.

Tab. 2 The results of the interview with hospitals representatives

Issue	Description
Recognizing the needs for product improvement	In general, meetings are a business background and are not intended to identify the needs of users. Meetings are related to product offers or conditions and requirement in range of implementation of the training sessions or the trial surgeries with use of the offered tools. However, after completed training or trial procedure with use of the offered tools there are not recorded feedback in the form of questionnaires, checklists or other forms of evaluation of the utility and ergonomic tools features.
Ergonomic needs	There were no cases of discussions inspired by the sales representatives regarding ergonomic problems associated with the use of surgical instruments.

Participating in project teams	Medical staff expressed the willingness to participation in the concept and design work on improvement of the ergonomics surgical instruments.
The degree of mutual understanding	The mutual misunderstanding is the result mainly one-way sales representatives target, which is the sale of the product. Therefore, the attempts to draw attention to the incorrectness of the product are often ignored.

The meetings with sales representatives have mainly business background and are not focus on identifying the needs of medical staff, but rather on emphasizing the advantages of offered tools. However, there have been cases of surgical intervention regarding the errors in the tools operations but less ergonomic errors, which could be considered by the manufacturer in the process of product improvement.

3.3 Recognition of barriers knowledge transfer between surgical instruments manufacturers and medical staff

The process of knowledge transfer depends not only on the ability to correct interpret by recipients of knowledge, but also on the ways and forms of its expression by the sender, and thus by the manner of its codification [3].

Any interference occurring between the source and recipient of knowledge create barriers in the process of its transfer. Based on the analysis from the 1st and 2nd Stages of the research, the diagnosis of barriers in knowledge transfer between sales representatives and manufacturers of surgical instruments and their users in the process of improving the utility and ergonomic features of the product was performed. To the main barriers it should be included:

- the lack of mutual understanding and a different interpretation of terms resulting from the use of language appropriate to the persons skilled in the certain specialization: technique, medicine, marketing;
- the lack of ergonomic knowledge by stakeholder of the life cycle of surgical instruments;
- the lack of ability to transfer of knowledge, which is largely tacit knowledge [23], possessed by the individual stakeholders, causing misunderstanding;
- the lack of convergence of targets among participants in the process of knowledge transfer;
- the lack of methods for supporting the manufacturers in the process of correct interpretation of knowledge which is encoded in the form of recorded surgical procedures.

The above-mentioned barriers are related to the barriers of a technological nature. In this case, the attention is drawn to:

- the lack of tools supporting manufacturers in the process of identifying the needs of users of surgical instruments,
- the lack of tools supporting the dissemination of knowledge transfer in the life cycle of surgical instruments.

The use of technology in supporting the process of knowledge transfer means supporting the process of tacit knowledge codification, i.e. the extraction from the source of

knowledge and its transformation into a human-readable representation. The result of this action should be the ability of the recipient to the same interpretation of the knowledge as the knowledge source.

3.4 Designation of proposals for improving knowledge transfer between surgical instruments manufacturers and medical staff based on virtual techniques

Taking into account the above described barriers of knowledge transfer as well as the formulated study objective, which is an indication of supporting virtual techniques, there is shown in the 4th Stage an example of a proposal in range of the use of Internet technology for the ergonomic knowledge dissemination among stakeholders of life cycle of surgical instruments.

In particular, the way of dissemination of knowledge is a mobile training for designers and users of surgical instruments available on the e-learning platform. The training material has been developed within the international group (Poland, Germany, Spain), and corresponds to the previously identified needs of the analysed groups of stakeholders. This e-platform for designer and surgeon is the international project titled “Online Vocational Training course on laparoscopy's ergonomics for surgeons and laparoscopic instruments' designers”, performed in the framework of the Lifelong Learning Programme: Leonardo da Vinci Multilateral Projects for Development of Innovation, Agreement number: 2012-3649/001-001, financed by National Agency for Lifelong Learning Programme Organismo Autónomo Programas Educativos Europeos (OAPEE). Silesian University of Technology is the project partner and co-author of training materials. The content of the training on the Silesian University of Technology side has been developed based particularly on the ergonomic analysis and assessment of workflow processes during some laparoscopic procedures. The ergonomic and workflow assessments were made based on direct observation and video recording of the following treatments: removal of the gallbladder, gastric resection and inguinal hernia. In turn, the ergonomic methods used in the study were: REBA - Rapid Entire Body Assessment [24] computer softwares: 3D Static Strength Prediction Program, 3D SSPP [25] and Anthropos-ErgoMax.

Based on the analysis outcomes, the framework of the e-learning course about ergonomics in laparoscopic procedures was developed. The program is divided into modules and within the modules certain thematic sessions are formulated. The modules were developed separately for practitioners from the field of the surgical instruments design and separately for the medical staff.

To meet the need of breaking the barriers in terms of lack of ergonomic knowledge the training content has been prepared in such a way that should be correctly interpretable by the users without any knowledge in this range.

There were used, among others, various forms of presentation of information, such as generally understood key sentences, drawings, photographs, computer models, diagrams, etc. In addition, e-learning platform, in its premise, is to acts as an intermediary in the exchange of knowledge between stakeholders, with the substantive support of the specialists from the field of ergonomics. Such a procedure is intended to allow the recipients for an efficient and effective training mode, resulting the creation of a common space of knowledge transfer within the stakeholders of life cycle of surgical instruments. Figure 6 shows the network of connections between course participants as well as a part of the training materials available in mobile manner. The arrow drawn with a dashed line

means the relationships between surgeons and designers implemented through the e-learning platform and through the Academic Tutors.

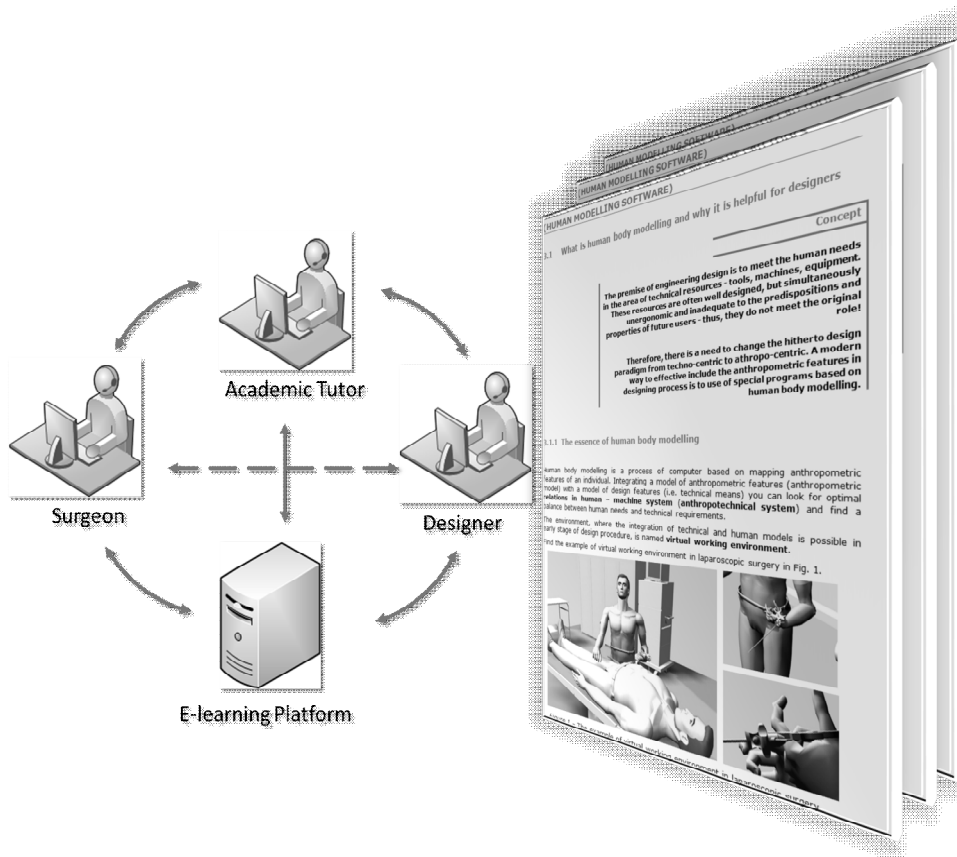


Fig. 6 An example of supporting knowledge transfer between surgeons and designers of surgical instruments through e-learning platforms

The training will be available in international space in the following languages: Polish, English, German and Spanish.

4. Conclusion

The length of the life cycle of surgical instruments, as a high-technology product, becomes shortening. First of all it is connected with the development of medicine and associated to this, new techniques of treatment requiring new surgical tools and the continuing need for their improvement. Undoubtedly the strong competition on the market of medical products creates the situation that knowledge, including knowledge of the needs of future users of the tools decides about the competitive advantage. The research has shown that this knowledge is neither sourced nor used in a satisfactory manner. The reasons

for this may be the lack of appropriate mechanisms to support the transfer of knowledge in the product life cycle.

In this study there was indicated the possible use of virtual techniques, such as electronic checklists, collaboration platform based on virtual environment or mobile courses for business and medical representatives based on e-learning platform.

The direction of further research is to test the mobile pilot course in frame of ergonomics intended for designers of surgical instruments and surgeons. The test will have an international character and should become the basis for effective supporting transfer of knowledge between designers and users in the field of improvement of the product in terms of work comfort and ergonomics.

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Joanna Bartnicka, Ph.D., Eng.
 Institute of Engineering of Production
 Silesian University of Technology
 Faculty of Organization and Management
 41-800, Zabrze, Roosevelta 26-28 Street
 phone/fax: +48 (32) 277 73 11/ +48 (32) 277 73 62
 e-mail: Joanna.Bartnicka@polsl.pl