The Interdisciplinary Development of Products. A Case Study from Industry and Health Care

Teodor Winkler

Faculty of Organization and Management
Silesian University of Technology
Zabrze, 43-600, Poland

ABSTRACT

In this paper, on basis of case studies from distant areas; mining, rescue and surgery some aspects of the interdisciplinarity will be discussed. They show, that the interdisciplinary knowledge transfer and migration of interdisciplinary teams across branches are needed. It gives the chance for better use of human and knowledge resources.

Keywords: interdisciplinarity, mining, rescue, hip surgery, interdisciplinary team, longwall shearer, surgical tools, personal protective equipment

INTRODUCTION

Development process starts the product lifecycle and is its first stage named the designing stage. This process is almost fully computer aided. Assessment of design solutions take place within *Virtual Prototyping* in the light of criteria formulated by specialists being involved in different, also subsequent lifecycle stages, (Winkler et al. 2013). They represent different professional specializations and they use specific knowledge resources belonging to the specific disciplines. Therefore we can say about the interdisciplinary approach to the development process.

There are the following factors stimulating interdisciplinary approach:
- complexity of needs of contemporary society and responsive
- complexity of contemporary products,
- required innovation level of the product.

The product complexity results from the complexity of its functional structure. This a structure of logical character. The functional structure consists of elements realizing the *individual functions* (of transformations and couplings), which contribute to the *overall function* of the product. Fulfillment of individual functions is determined by phenomena (i.e. physical, chemical and other), which can be explained in different scientific disciplines. Functional structure represents product on system-level. On physical-level functional elements are represented by parts, subassemblies and assemblies manufactured within different industrial branches. Engineering tasks creating system-level precede engineering tasks leading to the physical-level. In the Methodology of Engineering Design this two

https://openaccess.cms-conferences.org/#/publications/book/978-1-4951-2110-4

types of tasks are called respectively: *Conceptual Design and Embodiment (Detail) Design*.

Regarding innovation level, two specific types of design solutions are defined, (Beitz, Kuettner, 1994):

- *original design* with new, original functional structure, and
- *reengineered design solution* with adopted solutions from system- and physical level.

Product innovativeness is displayed on several levels of the functional structure and concerns assemblies, sub-assemblies or elements. So the innovation's extension or depth could be considered.

Interdisciplinary approach generates following organizational problems:

- management and coordination of interdisciplinary development teams,
- communication within interdisciplinary teams,
- knowledge transfer and knowledge absorption.

Interdisciplinary approach overlaps with the existing organizational forms of project management, which in turn result from organizational forms adopted by companies realizing development processes.

Coordination of interdisciplinary development teams focuses on mutual relationships between represented disciplines. Product's solutions are verified and assessed in light of criterion formulated on basis of *primary discipline* accepted by the team. This discipline is more or less defined by the area of the product application. In the further discussed cases there are: mining, rescue, surgery. The product development is subordinated to *leading discipline/disciplines*. Knowledge resources and competencies from this discipline/disciplines most of all contribute to innovativeness of the product under development.

Regarding the structure of interdisciplinary teams two basic situations are observed:

- the development tasks are realized on basis of many disciplines by the team consisting of participants without formal background in given discipline. Their knowledge and skills are acquired by self-education inspired by current requirements.
- the development tasks are realized on basis of many disciplines by teams consisting of participants with formal background in given disciplines.

The communication within interdisciplinary teams depends in large measure on the age structure of teams, since education processes and knowledge transmitted there change in subsequent generations. Therefore methods and tools assimilated by different in age participants of interdisciplinary teams could be insufficient to generate new knowledge, which is outside of existing disciplines. On the other hand, because of complexity of engineering tasks and required acquaintance of relationships between them, the existing knowledge could be enhanced by people having interactional expertise in one or more additional disciplines. As is known, this ability comes with age. In this paper case studies from industry and from health care will be presented. They show the necessity of knowledge transfer between disciplines and required migration of interdisciplinary teams between traditional established branches. It results in better utilization of existing knowledge and human resources.

CASE STUDIES

For the analyses of chosen case studies, following factors are taking into account:

- product to be develop,
- required level of the innovation: original or reengineered design solutions,
- required extension and depth of the innovation,
- primary discipline,
- leading discipline,
- organization of the interdisciplinary team.

Case study from Mining

Subject - Mining Machinery: Longwall sheaer

The longwall shearer is a basis extracting machinery in the underground coal mines using longwall technology. Assemblies constituting the shearer belong to different engineering disciplines. Therefore their development is realized by complex teams consisting of specialists from several disciplines, (INERG).

Required level, extension and depth of the innovation

Company which undertook the development tasks, had a platform of established and proven design solutions on the system-level. Increasing expectations formulated by Mining Industry regarding safety, maintainability, reliability and efficiency, determine current development of longwall shearers on the level of subsystems and responding assemblies. Part of innovative solutions were derived by reengineering of existing shearer's assemblies. The existing platform was extended by new, original solutions like subsystem for observation of working conditions. Other subsystems were reengineered accordingly to the changed technical parameters.

Primary discipline

Requirements regarding new shearer's solutions are formulated by Mining Industry using terminology from primary discipline; i.e. mining sciences. Exploitation of thin seams became the direct cause initiating development of innovative extraction machinery.

Leading discipline

Since the subject of development is extraction machinery, the leading discipline became Mechanical Engineering. The overall function of the machinery was defined by Mechanical Engineers who coordinated all activities of the interdisciplinary team. The earlier mentioned subsystem for observation of working conditions was developed by specialists from electronics including requirements formulated by Mechanical Engineers regarding assemblies, which should be observed.

Organization of the interdisciplinary team

To develop the new longwall shearer a consortium consisting of R&D institute and mining machinery manufacturer was appointed (INERG). Both partners had a many years experience on the mining machinery market and had specialists from both, primary and leading disciplines (respectively Mining and Mechanical Engineering). The development tasks are coordinated by R&D institute.

Interactions/relationships between disciplines

Relationships between disciplines were formalized and took form of specifications and documents prepared using terminology of disciplines of teams which were constituted. In engineering disciplines different forms of design documentation are used. So in Mechanical Engineering there are technical drawings of assemblies, subassemblies and parts. Documentation of subsystem for observation of working conditions had form of schematic diagrams containing symbols representing real elements excluding their geometrical dimensions and spatial placement. As common communication level assembly drawings were accepted. They showed the position of electronics elements and theirs connections with mechanical assemblies to be observed.

Case study from Rescue

Subject - Rescue Equipment: Intelligent Personal Protective Equipment -embedded system for personnel in high-risk environments

For active protection and information support for personnel operating in high risk and complex environments (in particular in fire fighting and chemical and mining rescue operations) a highly advanced and intelligent Personal Protective Equipment (PPE) system is to be developed. The new PPE system should be ergonomically designed and adapted to needs and working conditions of rescuers.

The interdisciplinary character of the development works consists in R&D activities in various fields of science and technology and requires expertise in integrating numerous elements – based on different technologies - into one functional and reliable system (i-protect).

Required level, extension and depth of the innovation

The innovative concept of PPE consists in application of advanced materials, physiological and environmental sensors, information support modules, wireless communication units and knowledge management systems, and integration of these innovative components into traditional PPE solutions.
PPE, at its current stage of development, belong to the original solutions (according to the classification from (Beitz, Kuettner, 1994). Original is the functional system of PPE as a whole, and original are their component subsystems (modules).

Primary discipline/disciplines

Rescue operations are focused on saving of life, or prevention of injury during an accident or dangerous situation. The term rescue covers several particular disciplines, like: health & safety, physiology, rescue medicine, law and other. Therefore it would be difficult to point one, primary discipline within it.

Leading discipline

Three types of high risk and complex environment are taken into account: fire fighting, chemical and mining rescue. Each of them has its own specific character. Also mentioned, particular disciplines constituting term "rescue", are addressed to mining, fire fighting and chemical rescue services.

Organization of the interdisciplinary team

Three target groups were created by:

- rescuers from: fire fighting, chemical plants and mining,
- manufacturers representing relevant competencies in the ICT area,
- R&D partners.

Interactions between disciplines

Within the mining, fire fighting and chemical rescue services, particular specifications and requirements are formulated for PPE's solutions to be developed. In the course of research and development works specialists of involved disciplines collaborate due to the defined functional structure of the PPE to be developed. First: health monitoring sensors, environmental microsensors for personal protection, 3D localization of the end-users were developed. Then, internal (between sensors modules and data collecting device) and external (between user and Rescue Coordination Centre) communication network were developed and integrated with the information support module for the end-user.

All the safety and quality parameters of new PPE solutions were first tested in laboratory conditions in order to assess a proper functioning of each individual element to be elaborated as well as protective properties of modified PPE.

Developed solutions of PPE were then tested according to scenarios elaborated by rescuers from: fire fighting, chemical plants and mining. Scenarios took into account several risk factors and formal limitations occurring in this specific working environments. In underground mines in some places occur concentrations of methane, or coal dust. Electrical or electronics equipment that are installed in such locations should be especially designed and tested to avoid arcing contacts or high surface temperature of equipment. An EU directive with acronym ATEX (from the French title of the 94/9/EC directive: ***A****ppareils destinés à être utilisés en* ***AT****mosphères* ***EX****plosibles*) decides what equipment is allowed in an environment with an explosive atmosphere. Because electronic modules under development didn't have special ATEX admittance, part of „mining oriented" scenarios were carried out in framed-up conditions in special trainings galleries.

Case study from Surgery

Subject – Surgical tools for hip surgery

The aim of the development activities in this case study was to design instruments for hip surgery under a new point of view, the ergonomics. The surgical tasks should be simplified as well as the working conditions of surgeons should be improved. Earlier researches pointed out the scale of this problem. Each year more than 500.000 orthopedic operations are performed worldwide to recover hip joint functions of individuals (ENHIP). Each year this number is increased because of the ageing of population. Apparently surgical instruments should be improved due to their importance and impact on working conditions of orthopedists.

Required level, extension and depth of the innovation

The structure of surgical tools for hip operations is very simple comparing with previously mentioned cases. There are manually operated metallic tools consisting of few parts. Better ergonomic features of surgical tools was achieved by designing of new geometrical form which improved grasping, reduced mass and vibrations, simplified assembling, facilitated cleaning. To fulfill this expectation, tools under development were considered as a whole.

Primary discipline/disciplines

The primary discipline was hip surgery. Video recording of orthopedic operations, interviews with surgeons, questionnaire inquiry provided the interdisciplinary team with requirements regarding the functionality of surgical tools in real working conditions.

Leading discipline/disciplines

The leading discipline was ergonomics. The scope of questionnaire was defined in terms of ergonomics and comprised questions regarding: level and cause of pain during use of the tool, assessment of grasping part, tool dimensions, shape as well as safety of use. Criteria for assessment of computer models of surgical tools and scenarios/ content of prototypes tests, were also formulated in terms of ergonomics.

Interactions between disciplines

Recorded working environment (operational theatre) and operations carried out, were reconstructed as *Virtual Working Environment* consisted of computer models of geometrical features of medical equipment, surgical tools and Human Body Models of surgeons and nurses, (Winkler et al. 2013). Scenarios of hip operations were created.
Tools under development were modeled using CAD systems, then analyzed and optimized by means of Finite Elements Method. Assessment in light of ergonomics criteria was carried out within the mentioned Virtual Working Environment using biomechanical programs. By means of Rapid Prototyping methods physical prototypes of tools were produced. This prototypes were assessed by surgeons using mannequins according to the mentioned scenarios.

Organization of the interdisciplinary team

The interdisciplinary and international team was composed of hip surgeons, surgical tools manufactures (Production Engineers from Small and Medium Enterprieses) and specialists from R&D institutions: specialists from biomechanics, ergonomists, Mechanical Engineers. The scope of the project was divided into workpackages led by specialists from represented disciplines. The project coordinator represented R&D institution from biomechanics and ergonomics area.

CONCLUSIONS

Discipline, which is defined as the academic discipline, comprise branch of knowledge that is taught and researched on the university level. Disciplines are also defined and recognized by the academic departments, or faculties to grant scientific titles. In engineering sciences, interdisciplinarity means rather integration of researchers around several, particular technologies (with their roots in academic disciplines) in the pursuit of a common task. Interdisciplinary activities are undertaken to acquire (or enhance) knowledge beyond the existing academic disciplines. In the development of product, interdisciplinary activities are oriented towards elaborating of new, innovative product by implementation of existing knowledge from the existing disciplines. Product development process showed, that interdisciplinary approach allows to develop innovative products, what would be not possible within only one, particular discipline. Knowledge transfer and knowledge absorption in interdisciplinary teams are subordinated to the leading discipline. Specialists representing the leading discipline usually coordinate the interdisciplinary projects and integrate tasks to be realized on the grounds of the leading discipline.

ACKNOWLEDGEMENT

This paper presents some generalizations derived from participation in projects INERG, i-protect and ENHIP carried out in Institute of Mining Technology KOMAG, Gliwice, Poland.

REFERENCES

Beitz W., Kuettner K.-H. (Editors) (1994) “Dubbel Handbook of Mechanical Engineering”. Springer Verlag London Limited.

ENHIP - Ergonomic Instruments Development for Hip Surgery an Innovative Approach on Orthopaedic Implants Design. Contract No. 017806-ENHIP. European Commision. Sixth Framework Program.

INERG - Innovative solutions of extracting machinery enhancing energy security of the country. ZPB/5/64812/IT2/10. National Centre of Research and Development. Poland.

i-Protect - Intelligent PPE system for personnel in high-risk and complex environments. Contract NMP2-SE-2010-229275. European Commision. Seventh Framework Program.

Winkler T., Tokarczyk J., Michalak D. (2013), “Virtual Working Environment”, in: Handbook of Loss Prevention Engineering, vol. 1, Haight Joel M.(Ed.). Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim. pp. 393-421.