

Guide for educators regarding the utilization of research results in technology education



Co-funded by the
Erasmus+ Programme
of the European Union

This guide has been developed by the EDURES project partners within the project:

EDURES: Technology education in the digital era supported by the significant use of research results

Intellectual Output 1: *Guide for educators regarding the utilization of research results in technology education.*

Intellectual Output 1 lead:

POLITECHNIKA RZESZOWSKA IM. IGNACEGO ŁUKASIEWICZA

Project partners:

- POLITECHNIKA RZESZOWSKA IM. IGNACEGO ŁUKASIEWICZA
- CENTOFORM SRL
- NATIONAL TECHNICAL UNIVERSITY OF ATHENS - NTUA
- HOCHSCHULE FURTWANGEN

Programme: Erasmus+

Key Action: Cooperation for innovation and the exchange of good practices

Action Type: Strategic Partnerships for higher education

Number of the project: 2020-1-PL01-KA203-082219

Webpage of the project: <http://edures.prz.edu.pl>

Project card: <https://ec.europa.eu/programmes/erasmus-plus/projects/eplu-project-details/#project/2020-1-PL01-KA203-082219>

Updated in December 2021.

The content will be updated within Intellectual Output no. 5.



Erasmus+

Any support the European Commission for the production of this guide does not constitute an endorsement of the contents which reflects the views only of the authors, and the Commission and the National Agency cannot be held responsible for any use which may be made of the information contained therein.

TABLE OF CONTENTS

Introduction	6
1. Organization of the education process at universities participating in the project	7
1.1. Rzeszow University of Technology	7
1.1.1. General information	7
1.1.2. Faculty of Mechanical Engineering and Aeronautics	10
1.1.3. Faculty of Civil and Environmental Engineering and Architecture	19
1.2. National Technical University of Athens	31
1.2.1. General information	31
1.2.2. The School of Mechanical Engineering	40
1.3. Hochschule Furtwangen University	55
1.3.1. General information	55
1.3.2. Institute of Precision Machining	56
1.4. Centoform s.r.l.	58
2. Ways of linking the education process with scientific research – current state	62
2.1. Rzeszow University of Technology	62
2.2. National Technical University of Athens	64
2.3. Hochschule Furtwangen University	66
2.4. Universities in Italy	67
2.5. General conclusions	70
3. The results of the surveys	72
3.1. Surveys for students	72
3.1.1. Surveys content	72
3.1.2. Results of the survey for students	75
3.1.3. Analysis of the results of the survey for students	80
3.2. Surveys for academics	82
3.2.1. Surveys content	82
3.2.2. Results of the survey for academics	85
3.2.3. Analysis of the results of the survey for academics	89
3.3. Surveys for graduates	91
3.3.1. Surveys content	91
3.3.2. Results of the survey for graduates	93
3.3.3. Analysis of the results of the survey for graduates	98
3.4. Surveys for employers	99

3.4.1.	Surveys content	99
3.4.2.	Results of the survey for employers	101
3.4.3.	Analysis of the results of the survey for employers	105
4.	Methodology of using the research results in the education processes	106
4.1.	Scientific research results presentation Toolbox	106
4.1.1.	Development of the best practices summary for using case studies in engineering education & hints on how to introduce this form into classes teaching stuff	106
4.1.2.	Development of best practices summary for using graphical visualization in engineering education & hints on how to introduce this form into classes teaching stuff.	122
4.1.3.	Guidelines on how to organize project oriented classes and shape such skills as teamwork, problem solving, creativity, critical thinking etc.	151
4.1.4.	Guidelines on the tools which can be used within preparation of classes	156
4.2.	Guide on How to find research results	159
4.2.1.	Preparing the list of on-line sources for research results	159
4.2.2.	Development of guide on results searching	165
	How to rank papers with regard to criteria set, what criteria to take into consideration when ranking papers?	170
4.3.	Scientific Writing Cookbook	173
4.3.1.	Pocket Guide on "How to write scientifically?"	173
4.3.2.	Intellectual property rights	195
4.3.2.1.	Some aspects in the universities	195
4.3.2.2.	Scientific databases available on-line at the Rzeszow University of Technology	198
4.3.2.3.	CC licenses and access to educational and scientific content	199
4.4.	Scientific Reading Cookbook	212
4.4.1.	Introduction to the Scientific Reading Cookbook	212
4.4.2.	Step1: Searching Platforms	212
4.4.3.	Step2: Selection	213
4.4.4.	Step3: Reading	214
4.5.	Research Methodology	216
4.5.1.	Research process methodology	216
4.5.1.1.	Introduction	216
4.5.1.2.	Identification of the research problem	217
4.5.1.3.	Survey of literature	217
4.5.1.4.	Preparation of research design	217
4.5.1.5.	Collecting the data of investigations	218
4.5.1.6.	Results of research	218

4.5.1.7.	Report / Discussion of results and conclusions	219
4.5.1.8.	Example	219
4.5.2.	Research based teaching activities	221
4.5.2.1.	Improving quality of teaching activity	221
4.5.2.2.	Road traffic engineering	223
4.5.2.3.	Unconventional materials in bridge engineering	224
5.	Conclusion and further tasks	231

Introduction

The guide is an extended study in which project partners present their internal practices and analyses, and on the basis of above mentioned, they work out the common guidelines useful in all educational institutions focused on technology education. The guidelines concern methods regarding utilization of the results of research in teaching processes.

Research results can be widely defined as published and unpublished articles, books, data, also as databases (e.g. web portals) presenting research. Moreover, the research results are existing test stands, research procedures and patent data which could be transferred to teaching processes.

Utilization of the recent research results is crucial for higher education institutions and stakeholders. Rapid transfer of knowledge supports developments and innovation of technological companies. The EDURES partners take into account the teaching processes which are performed at the Master's level as well as doctoral level because at these levels research and innovation interests of students can be easily formulated. However, they also analyse the current state and possibilities in the case of bachelor courses.

In this context, guidelines regarding the utilization of research results into education are formulated by the project team. Guidelines are useful for different levels of higher education and indicate links between them. Educators, teaching programme managers, teaching and learning boards are the main target groups of the report/guide.

In order to analyse the mentioned area and work out the guidelines, particular emphasis is focused on three issues:

- the state of the art in the use of scientific research results in the teaching process (implementation issues, improvement of teaching content, evaluation of teaching efficiency, existing best practices, internationalization issues and sustainability of education process),
- protection of intellectual property rights in teaching materials and contents (copyrights, licences, etc.) including national and international law and recommendations,
- the use of experience, good practices and benefits resulting from cooperation between science and business in the didactic process.

1. Organization of the education process at universities participating in the project

1.1. Rzeszow University of Technology

1.1.1. General information

Introduction

Rzeszow University of Technology's history dates from 1951, when the Engineering School was opened following the initiative of the employees of Rzeszow PZL factory, organised into the Association of Polish Engineers and Technicians. Mechanical engineers were educated in evening classes to support operations at PZL, a communications equipment maker.

In 1960, full-time studies were commenced, with local staff assuming responsibility from its overseer for instruction, administration and operations throughout the decade. During this time, the school blossomed into the Higher Engineering School of Technology and Mechanical Engineering and expanded its range of subjects with the addition of Faculties of Chemical Technology, Civil and Environmental, and Electrical Engineering.

In 1972 a significant event in the development of the University took place, as the Department of Aeronautics was founded and the instruction of personnel for the aviation industry began in earnest. As a result, in 1976 Aviation Training Centre was established with the aim of providing future pilots with the practical training.

Presently, the University is the largest technical university in the region and continues to grow. Over its history it has educated more than 55000 graduates, including almost 600 pilots. A great number of alumni hold important positions both in the region and country. As a matter of course, the University's development has been accompanied by a continual increase in the number of academic staff and independent scientists.

Systems supporting the teaching process

A. USOS: Organization of classes, management of the course of studies

The USOS System (in Polish: Uniwersytecki System Obsługi Studiów) is the result of cooperation between the largest Polish universities. The system was developed as a result of the demand for a comprehensive IT tool for managing studies at a university. The main applications of USOS include:

- support for the course of studies (classes, grades, test reports, resumption of studies, etc.) of all types and levels (1st and 2nd degree studies, postgraduate studies, Ph.D. schools),
- Electronic ID cards of a student, Ph.D. student, teaching staff (printing, renewal, etc.),
- preparation of the didactic offer (subjects, classes, groups, dates, teacher),

- management of the course of study (study programs of all levels and types, registration for classes, reports with grades, credits, etc.),
- student applications,
- applications for social assistance,
- diploma theses and exams,
- scholarships,
- dormitories,
- payments for educational services,
- support for the Bologna Process,
- student internships,
- academic teacher evaluation surveys,
- reporting,
- employee-related matters (full-time and part-time employment, settlement of working hours, etc.),
- data export to the POLON system (integrated IT platform of the Ministry of Science and Higher Education),
- inter-university (including international) student exchange,
- Career's Office,
- university archive.

Thanks to the wide range of applications, USOS plays the role of a central point for gathering information from the entire university, which significantly improves the management of studies, enables the unification of university procedures and allows for the effective implementation of university-wide initiatives, such as a common offer of non-compulsory subjects, language courses, physical education classes for students of all faculties, certification exams, as well as central authorization of students, doctoral students and employees on university websites, generating unique index numbers and diplomas. Storing data in digital form significantly reduces the number of generated traditional documents, allowing, among others, the elimination of paper reports with grades, examination cards, student applications and even students' IDs.

USOS is not only a centralized database operated by university administration employees. The system is associated with a number of websites for candidates for studies, students and academic teachers. They remotely support many aspects of the university's operations, which is associated with a significant relief for administrative staff. These websites allow, among others:

- recruiting candidates for studies,
- browsing the didactic offer (study plans and programs),
- creating and viewing lesson plans,
- registration for classes,
- issuing and viewing ratings,
- communication of students and teachers within class groups,
- booking classrooms,
- collecting electronic versions of diploma theses,

- sharing CV and viewing job offers,
- tracking the careers of graduates.

B. KRK: Public access to study plans and programs (presentation of research topics)

Employees, students and Ph.D. students of Rzeszow University of Technology can access study plans and programs through the KRK system - Educational Outcomes Panel. In this system, academic teachers edit data on the subjects they teach. The subject's module card is compulsorily prepared in Polish (the teacher may additionally prepare the card in English), which contains the following data:

- Module name,
- Field of study, degree and form of studies and the semester in which the module is implemented,
- Name of the faculty providing the field of study and the name of the department running the course,
- Course coordinator and other teachers conducting the classes,
- Hourly dimension of the module components: lectures, exercises, laboratories and projects,
- Number of ECTS credits,
- URL address of the teaching materials page,
- The module belongs to the group of technical subjects,
- Purpose of education,
- Bibliography used during classes and supplementary literature,
- Formal requirements and in the category of knowledge, skills and social competences to study the subject,
- Modular learning outcomes and their connection with the outcomes of the field of study and the outcomes of the field of science specified by the Ministry, which is responsible for science and higher education,
- Learning content along with assigning to specific types of classes (lecture, exercises ...),
- Information on the planned workload of the student, broken down into hours of classes, own work, consultations, preparation for the test,
- Description of the method of giving partial grades and the final grade,
- Examples of tasks required during the exam and carried out during the course,
- Information on the link between the lesson module and research conducted by the teacher and the list of the teacher's publications.

C. Library: Access to teaching and research resources for staff and students

The library of Rzeszow University of Technology was established in 1951. It is the largest technical library in south-eastern Poland. It collects books, magazines, standards, technical catalogues, manuals, etc. in the fields of education and research conducted by the Rzeszow University of Technology (including architecture, construction, chemistry, electronics, electrical engineering, physics, IT, environmental engineering, logistics, aviation,

mathematics, mechanical engineering, mechatronics, environmental protection, management).

The library's book collection consists of more than 161,000 book volumes, 37,000 volumes of periodicals, and 155,000 units of special collections. Each computer connected to the University Computer Network provides access to electronic journals and databases. In the library, readers can use the Internet both on dedicated computer workstations and wirelessly on their own devices. EDUROAM wireless network is also available in different places of the university.

Anyone interested can use the book collections in the library's building. This way, books, periodicals and special collections (standards, technical approvals, statistical yearbooks, doctoral dissertations, etc.) are made available. Students, Ph.D. students, employees of the Rzeszow University of Technology and the University of Rzeszow as well as postgraduate students of the Rzeszow University of Technology can also borrow books.

The library of Rzeszow University of Technology uses the online catalogue of books, journals, scientific journals and special collections - ALEPH. ALEPH is the leading integrated library system in the global library automation market. The functionality of the ALEPH system includes: cataloguing resources (electronic resources and traditional printed collections), creating bibliographic descriptions containing technical metadata (e.g. access rights), searching, booking, ordering, and borrowing and returning resources.

Employees, students and Ph.D. students of Rzeszow University of Technology can use electronic resources collected in over 50 external databases, including: ASME, EBSCO, Emerald, Elsevier, IEEE, MPDI, Nature, Science, ScienceDirect, Scopus, Springer, Web of Science, Wiley.

In addition, library users can use the e-book rental of the Polish Scientific Publishers (Ibuk Libra), containing over 400 scientific books in the fields covered by research and education at the Rzeszow University of Technology, and the rental of e-books, audiobooks and video courses run by the Helion publishing house.

1.1.2. Faculty of Mechanical Engineering and Aeronautics

Division on the types and fields of study

Faculty Of Mechanical Engineering And Aeronautics which until 1988 was named Faculty of Mechanics, is the organizational unit of the University, from which operations, the superior technical studies in Rzeszow commenced. Since the beginning of self-reliant functioning of the University, the Faculty conducted daily studies as well as evening studies and external studies later on. Currently, the classes at the Faculty of Mechanical Engineering and Aeronautics are being conducted at the first, second and third degree (cycle) studies, as well as at the postgraduate studies. Education at first and second cycle programme is being realized at the following fields of studies:

- A. Mechanics and Mechanical Engineering (full-time and part-time).
- B. Management and Production Engineering (full-time and part-time).
- C. Aeronautics and Space Technology (full-time).
- D. Transport (full-time and part-time).
- E. Mechatronics (full-time and part-time).
- F. Mechanical engineering for the aviation industry (full-time).
- G. Materials Engineering (full-time).

A. Mechanics and Mechanical Engineering

Graduates of Mechanics and Mechanical Engineering course are knowledgeable of machine construction, manufacturing processes and maintenance. They know the principles of mechanics and are able to design machines and their components using advanced methods and tools. They are able to select proper materials for production, make a design, develop appropriate manufacturing technology and supervise the maintenance process. They are good team-players and coordinators of work, able to use IT systems successfully. Students of Mechanics and Mechanical Engineering can choose from the following specialities:

- first cycle programme:
 - ✓ alternative energy sources and energy processing,
 - ✓ casting engineering,
 - ✓ welding engineering,
 - ✓ computer-aided manufacturing,
 - ✓ power drives,
 - ✓ automotive vehicles,
 - ✓ programming and automation of machining processes,
 - ✓ research and development in the industry,
 - ✓ medical engineering,
- second cycle programme:
 - ✓ alternative energy sources and energy processing,
 - ✓ computer-aided manufacturing,
 - ✓ power drives,
 - ✓ automotive vehicles,
 - ✓ production organization,
 - ✓ programming and automation of machining processes.

B. Management and Production Engineering

Graduates of Management and Production Engineering have knowledge and skills in the field of production engineering in the machine industry as well as in economics and management. Students of this course of study are prepared to manage production in order to achieve the best possible economic efficiency. They can also work in IT production support and production line design. Students of Management and Production Engineering can choose, inter alia, from the following specialities:

- first cycle programme:
 - ✓ IT for enterprise management,
 - ✓ manufacturing quality management systems,
 - ✓ management of production systems,
- second cycle programme:
 - ✓ production ecology,
 - ✓ modern methods of production management,
 - ✓ modern information and communication technologies in the enterprise,
 - ✓ integrated manufacturing systems.

C. Aeronautics and Space Technology

Graduates of Aeronautics and Space Technology course are prepared to be successful in the aviation industry and other aviation-related careers. The curriculum complies with educational standards required by International Civil Aviation Organization (ICAO), European Aviation Safety Agency (EASA) as well as European Federation of National Engineering Associations (FEANI). The Aviation Training Centre (OKL) conducts its training at Rzeszow airport. Outstanding graduates are given the chance to do Multi-Crew Cooperation training and also get a flight instructor rating. To date, more than 500 students have completed this course and most are employed with the national carrier, or work in health-service aviation and other carriers. Training base of the OKL consists of the following aircrafts:

- TB-9 „Tampico” – 7 items,
- PA-28R-201 „Arrow” – 3 items,
- Piper PA-34 "Seneca V" – 3 items,
- Zlin Z-242L – 1 item.

The high-class flight simulators of the French company Alsim (2 items) are also perfect for training pilots at various levels. Students of Aeronautics and Space Technology gain knowledge and skills in four areas of specializations:

- avionics,
- pilot studies,
- aircrafts,
- aircraft engines,
- air traffic management.

Each specialization differs in terms of knowledge and skills which are trained. The four specializations fall into two groups. The first group includes aircrafts, aircraft engines and avionics specializations which are aimed at training design engineers in particular. The other one includes specialization in pilot studies and it is designed for students whose goal is both to become engineers and to fly for commercial airlines or corporations.

Moreover, the second Aviation Training Centre located in Bezmiechowa (approx. 70 km from Rzeszow) offers perfecting flights for the glider pilot licence (after basic training) and advanced training flights using thermal, slope and wave currents. All training in the air is provided using launching techniques not found in other centres – a gravity launch, a bungee launch and an uphill winch launch. The centre also offers training for mechanics serving various aircrafts (gliders, motor gliders, ultralight planes, autogyros, ultralight trikes, balloons) as well as training for unmanned aerial vehicles operators. The centre includes a mountain airstrip, a hangar with social and workshop facilities, a laboratory building, a pilot's house and a main building with didactic and social facilities.

D. Transport (Engineering of means of transport)

Transport graduates have knowledge of the functioning of modern transport. This knowledge includes, in particular, transport engineering, traffic engineering and the analysis of transport systems. They are prepared for employment in transport companies, solving organizational problems, planning, designing control systems and traffic management. Their knowledge and skills are focused on organizing, supervising and managing transport processes. The graduate is ready to work in road, rail and air transport companies, maintenance and repair centres for mechanical means of transport, rail and air traffic services as well as industrial plants and forwarding companies. Students of Transport can choose from the following specialities:

- first cycle programme:
 - ✓ diagnostics and operation of motor vehicles,
 - ✓ logistics and transport engineering,
 - ✓ computer design of means of transport,
- second cycle programme:
 - ✓ diagnostics and automotive expertise,
 - ✓ eco-engineering of means of automotive transport,
 - ✓ technical means in logistics and forwarding.

E. Mechatronics

Mechatronics graduates have a thorough knowledge, skills and competences in the field of analysis, design and construction of automation systems, software for industrial and service mechatronics systems, system control and design of decision support systems. With this knowledge, they have skills that predisposes them to work in design offices under the guidance of experienced managers, as well as in the management and supervision of production. Students of Mechatronics can choose from the following specialities:

- first and second cycle programme:
 - ✓ computer science and robotics,
 - ✓ computer-aided design.

F. Mechanical engineering for the aviation industry – trial programme

Graduates of Mechanical engineering for the aviation industry course have a vast knowledge, skills and high level of competence in terms of analysis, designing and construction of aircraft equipment, aircrafts engines as well as machines and their components. Students can choose from the following specialities:

- second cycle programme:
 - ✓ mechanics and mechanical engineering,
 - ✓ mechatronics,
 - ✓ aircraft engines.

G. Materials Engineering

Graduates of Materials Engineering have a thorough knowledge and relevant technical skills related to the following fields of study: physics and chemistry, metal, ceramic, polymer and composite material research, proper selection of engineering materials to various applications, manufacturing technologies, material recycling and material properties. They are also capable of formulating rational conclusions in terms of application of engineering materials in various products and methods of materials research. Students of Materials Engineering can choose from the following specialities:

- first cycle programme:
 - ✓ advanced material technologies,
 - ✓ technology and processing of superalloys,
- second cycle programme:
 - ✓ superalloys,
 - ✓ material processing technologies.

After completing the first-cycle studies, the graduate obtains the title of engineer. After completing the second-cycle studies, the graduate obtains the title of Master of Science in Engineering.

The main goal of the Faculty is to provide students with an opportunity to strengthen their technical backgrounds so that they may pursue successful professional careers in engineering research, development and production. The Faculty have significant industrial experience in their areas of expertise. Thus, students have the opportunity to learn from experienced professionals. The development of personal and interpersonal skills is an important factor in the education of the graduates. The preparation of a M. Sc. thesis provides the student with an opportunity to work on open-ended problems which require synthesis of creativity and knowledge. The faculty graduates are well prepared for typical job positions:

- Manufacturing Engineer,
- Design Engineer,
- Process Engineer,
- Product Engineer,
- Quality Control Engineer,

- Project Engineer,
- Applications Engineer,
- Sales Engineer,
- Production Supervisor,
- Test Engineer,
- Field Engineer,
- Assembly Engineer,
- Pilot in commercial aviation,
- Air-traffic controller,
- Airlines manager,
- Airport director.

In the academic year 2000/2001, doctoral studies in the field of Machine Design and Maintenance were launched at the Faculty of Mechanical Engineering and Aeronautics. Since 2006, doctoral studies are also conducted in the field of Mechanics (including Aviation). This new form of studies (third-cycle studies) resulted from the rapid scientific development of the employees of the Faculty of Mechanical Engineering and Aeronautics which enabled the Faculty to obtain the right to confer the DSc degree. In 2019, the Doctoral School of Engineering and Technical Sciences started its activity, replacing doctoral studies. In the 2020/2021 semester, recruitment for the following scientific disciplines was announced:

- Materials engineering,
- Mechanical engineering.

A significant number of postgraduate studies were or are carried out at the Faculty of Mechanical Engineering and Aeronautics. Examples of them are as follows:

- integrated quality, environmental and safety management,
- quality assurance in aviation production,
- integrated education of personnel for aviation industry,
- logistics management,
- lean Manufacturing,
- aircraft engines,
- aircraft flow engines,
- construction of injection moulds.

Students' scientific groups on the Faculty of Mechanical Engineering and Aeronautics

Any young scientist who is interested and wants to pursue his passions and explore the secrets of knowledge can join a group of like-minded people. There are 10 students' scientific groups at Faculty of Mechanical Engineering and Aeronautics:

- Students' Scientific Group – Management Engineering,
- Scientific Group – EUROAVIA,
- Scientific Group of Mechanics – Automotive Section,

- Scientific Group – Transport,
- Students' Scientific Group of Aviators,,
- Scientific Group of Gliders "Bezmiechowa",
- Robotics Science Group,
- Cosmonautics Science Group,
- Formula Student,
- Students' Scientific Group of Modern Computer Systems in Production Engineering,
- Scientific Students' Group Programming and Automation of Machining.

Departments, services, laboratories etc. from the Faculty of Mechanical Engineering and Aeronautics

Faculty of Mechanical Engineering and Aeronautics has **12 departments**:

- Department of Avionics and Control Systems,
- Department of Mechanical Engineering,
- Department of Materials Science,
- Department of Applied Mechanics and Robotics,
- Department of Casting and Welding,
- Department of Materials Forming and Processing,
- Department of Aerospace Engineering,
- Department of Manufacturing Techniques and Automation,
- Department of Manufacturing Processes and Production Engineering,
- Department of Computer Science,
- Department of Thermodynamics,
- Department of Combustion Engines and Transport.

Each department offers services to industry, business representatives and other interested parties as well as and allows faculty students to familiarize themselves with them. Examples of such areas are as follows:

- Aerodynamic shaping and optimal design,
- Design, construction and investigation of control and navigation systems,
- Theory and diagnosis of turbine aircraft engines,
- Experimental, modelling and aerodynamic examination in wind tunnels,
- Kinematics and dynamics of mobile robots and their control;
- Application of approximate-set theory in diagnosing neural networks in controlling and multi-value logic in computer management systems,
- Optimisation of working parameters in automotive drive systems including fuel injection systems in high-pressure engines,
- Optimisation of temperature distribution of high thermally-loaded elements,
- Heat and mass exchange and investigation of diphase transitions,
- Investigation of high-ratio gears (wave, trochoid) and joint action of spur-gears with point-of-contact area,

- Optimisation of chip, abrasive and erosion machining of materials including near-unworkable (ceramics and composites),
- Cast material properties and quality, and surface layer formation with casting and welding technology,
- Quality improvement of assembly processes,
- Theoretical and experimental analysis of metal and plastic-working processes, shaping methods and property evaluation of composites,
- Numerical methods in modelling the structural effects in titanium alloys undergoing plastic strain,
- Modification of surface-layer properties in the process of burnishing; including impulse-impact, electron-beam and laser beam machining,
- Application of Rapid Prototyping method in a product development process,
- Thin-walled carrying structures over critical conditions,
- Physical and mathematical modelling of construction-loading conditions,
- Energetisitic conditions of alloy structures in liquid and solid-state and phase transitions in iron, nickel and titanium alloys; dynamic recrystallization in titanium alloys and the formation of Sn-Zn-Ag and Sn-Zn-Cu solutions,
- Determination of the influence of surface topography and surface condition on tribological properties,
- Determination of the influence of the surface layer of machine elements on tribological properties,
- Determination of tribological characteristics of various frictional pairs,
- Determination of the influence of a lubricant and frictionally co-acting materials on tribological properties,
- Determination of durability and fatigue strength of machine elements and their connections,
- Determination of the influence of the layer condition on the fatigue strength of machine and device elements,
- Improvement and optimization of material removal machining processes in the selection of parameters, tools and equipment,
- Development of static and dynamic burnishing technology,
- Development of the glue joint technology of machine elements,
- Determination of the impact of manufacturing process parameters on the condition of the surface layer and performances,
- Application and improvement of Lean Manufacturing tools,
- Improvement of assembly processes of machine elements,
- Improvement of production logistics,
- Design and improvement of systems for monitoring and control of machining processes,
- Development of gears and transmission systems.

On the 1st of October 2005, by the decision of Rzeszow University of Technology Rector, the Research and Development Laboratory for Aerospace Materials has been created. The Laboratory carries out RND in the field of high-tech materials for the aerospace industry. Research and Development Laboratory for Aerospace Materials is divided into specialised **sub-laboratories**:

1. Mechanical Properties Research Laboratory involves mechanical properties testing of structural materials, mainly metal alloys, ceramics and composites, with particular emphasis on materials used in the aerospace industry.
2. Chemical Composition Analysis Laboratory takes the qualitative and quantitative determination of the chemical composition of metals and alloys.
3. Metallographic Laboratory involves work on: metallographic sample preparation, hardness measurement by indentation method, microscopic observation using light microscopy (LN) and scanning electron microscopy (SEM), chemical composition in microscale identification (SEM/EDS).
4. Phase Transition Laboratory is specialized in quantitative and qualitative analysis of phase composition in solid materials - primarily nickel and cobalt alloys, steels - and powders, including ceramics.
5. SC and DS solidification laboratory is engaged in manufacturing of directional, equi-axed and single crystal structured he structures by Stockbarger-Bridgman method.
6. Thin films and coatings laboratory is the fastest growing division of the Research and Development Laboratory for Aerospace Materials.
7. Computer simulations laboratory due to the area of application of phenomena and processes simulations methods is divided into four sections:
 - Section 1. Casting processes modelling,
 - Section 2. Modelling of deformation and fracture of metal alloys,
 - Section 3. Highly nonlinear, transient dynamic finite element analysis,
 - Section 4. Didactic Laboratory of Computer Simulation.
8. The Laboratory of thermo-chemical treatment involves heat treatment processes of nickel superalloys, titanium alloys, tool and bearing steels in temperatures up to 1350°C and carburizing and nitriding processes of steels using acetylene and ammonia.
9. Laser Laboratory is equipped with a laser stand which includes TruLaserCell 3008 machine with 6-axis operations enabled (range of motion in X: 800mm, Y: 500mm, Z: 400mm) and two laser sources.
10. Physical and Chemical properties Laboratory conducts research in the following areas:
 - Analysis of the solids density in the gas pycnometer,
 - Analysis of bulk density (apparent) in the quasi-liquid pycnometer,

- Measurements of grain-size distribution of particles in the air.

11. High speed machining laboratory.

12. Corrosion and electrochemical processes laboratory.

Currently, the number of students at the Faculty of Mechanical Engineering and Aeronautics is approximately 3000 at full-time studies and 1000 at part-time studies. During the entire functioning period of the Faculty, over 15000 students have received the graduation diplomas. The condition of human resources employees of the Faculty decides on the possibilities of education, as well as on the level of scientific and implementation works. What is more, the number of hired academic teachers and auxiliary workers is constantly increasing along with the general development of the University.

1.1.3. Faculty of Civil and Environmental Engineering and Architecture

Courses offered by the Faculty of Civil and Environmental Engineering and Architecture

A. Architecture (AR) – full-time undergraduate studies of BSc degree and full-time graduate studies of MSc degree.

For the AR studies, the entrance examination in architectural predispositions and artistic talents connected with a competition for secondary school-leaving certificates (BSc engineering studies) is required. Students of MSc course can choose from the following specialities: (1) Architecture, (2) Conservation of Architectural Monuments, (3) Town planning and architecture.

The AR graduates are prepared to competently participate in the process of shaping the space that forms the framework for the life of individuals and social groups. Apart from being predisposed to technical sciences, candidates for this field are required to have spatial imagination and artistic skills. Graduates' skills and knowledge can be presented as follows:

- preparation for work related to architectural and urban design,
- renovation and restoration of monuments and their adaptation to new functions;
- interdisciplinary education,
- designing architectural objects with various functions (residential buildings, public utility buildings, production, entertainment and leisure),
- qualifications for the preparation of spatial development plans and urban layouts.

B. Construction (CO) – full-time undergraduate studies by BSc degree, graduate studies of MSc degree and doctoral studies. Moreover, the CO studies are performed for the part-time studies, as follows: undergraduate studies by BSc degree and graduate studies of MSc degree.

Students of MSc course can choose from the following specialities: (1) Building and Engineering Structures, (2) Building and Engineering Structures - Sustainable Construction, (3) Roads and Bridges - Road Construction and Maintenance, (4) Roads and Bridges - Bridge Construction and Maintenance.

Construction graduates, thanks to the acquired theoretical knowledge and practical skills, have the basics to work in the design and construction of housing, industrial, livestock, public utility buildings as well as roads and bridges, using modern computer techniques. After completing the relevant professional practice, they can apply for building and design licences. Graduates' skills and knowledge:

- carrying out repairs and modernization of building and engineering structures,
- supervising construction processes and managing them with the use of modern techniques and technologies,
- qualifications for the production of certain building materials,
- organization of production processes, i.e. the rational location of technical activities and means of production in time and space,
- organization of optimal control (management) of the construction process, taking into account legal, economic and environmental requirements.

C. Power engineering (PE) – full-time undergraduate studies of BSc degree and full-time graduate studies of MSc degree.

Graduates of the 1st degree studies obtain the title of engineer in the field of energy. They have general and specialist knowledge, skills and social competences in the field of proper technical design of energy, electrical, heating, ventilation systems, installations using alternative energy sources. They can create and read technical drawings. They know theoretical basics in the field of technical thermodynamics, fluid mechanics, biology and environmental chemistry. They can formulate and solve practical engineering tasks specific to the power industry. They know the current trends in the implementation of construction works in the field of energy. They can work in a team. They know the regulations related to the implementation of investments related to the broadly understood energy sector, are responsible for their own and co-workers' work safety, are aware of the need to improve professional and personal competences, and act in accordance with the principles of professional ethics.

Students of MSc course can choose from the following specialities: (1) Power Engineering in Civil, (2) Power Engineering in Environmental Engineering.

The field of power engineering prepares specialists whose task is to ensure conditions for sustainable development, while maintaining the possibility of using various types of energy sources. The acquired knowledge, skills and social competences give graduates of the 1st degree in the field of power engineering full professional preparation for work in industries related to the construction of installations producing and transmitting energy in various forms.

Graduates of the power engineering faculty may be employed in design offices, construction companies, state administration units, and enterprises providing energy transmission services. A graduate completing his studies will have the necessary knowledge enabling further education in the second degree studies in the field of energy.

D. Geodesy and spatial planning (GSP) – full-time and part-time undergraduate studies by BSc degree, full-time and part-time graduate studies of MSc degree.

The practical field of study belongs to the area of technical sciences and is related to such fields of study as Geoinformatics, Engineering Geodesy, Real Estate Management, Town Planning, Landscape Architecture, Environmental Engineering. The leading field of science is the discipline of civil engineering and transport. Moreover, the complementary discipline is Architecture and Urban Planning.

A graduate of Geodesy and Spatial Planning will have theoretical knowledge and practical skills that will give a good preparation for engineering activities in the field of geodesy, cartography, information systems about the area and specialist tasks. As a result of the implementation of basic and major subjects, the graduate will be proficient in the use of methods and tools in the field of geodesy and spatial planning, as well as modern techniques of geodetic, satellite and photogrammetric measurements. They will acquire knowledge and skills related to obtaining, processing and using the results of these measurements. Will be able to operate in unpredictable and changing circumstances, requiring solving complex engineering problems.

Subjects related to economics, organization and management as well as law will allow students to develop organizational skills and acquire competencies in managing a team and resources in the workplace and study. The graduate will have knowledge in the field of the humanities and social sciences, which will allow him/her to make accurate interpretations of social situations and problems that students may encounter in the course of practicing his/her profession. He/she will also have the ability to communicate in a professional environment in foreign languages.

Choosing one of the education specializations, the graduate will implement the curriculum enabling him to acquire additional knowledge and practical skills in a narrow, specialized range of issues. Completion of the specialization Geoinformatics and engineering geodesy will prepare you to perform independent production tasks related to the operation of computer systems for creating numerical maps and related databases, as well as to perform specialized geodetic measurements. A graduate completing the specialization Real estate management and spatial planning will be prepared to carry out tasks resulting from adjusting real estate management and spatial development to European standards, including the preparation of obligatory and optional planning documents at all levels of design, real estate valuation, real estate management and trade in market economy or modernization of rural areas. After completing the field of Geodesy and spatial planning, the graduate will be prepared to work in larger enterprises and small surveying companies as well as in government and local government administration. Students will have the knowledge and skills enabling him/her to develop further and develop continuously. Due to the profile of studies, the participation of

employers in shaping the concept of education is included in the process of conducting internships and in forums of practical classes.

**Graduate of the first degree studies in the field of Geodesy and Spatial Planning,
specialization: Geoinformatics and engineering geodesy**

In addition to general geodesic knowledge, the graduate will also gain specialist knowledge in the field of engineering surveying, special measurements, programming techniques, and spatial data processing and analysis. As a person whose significant part of his professional work will be related to the investment process, student will also have knowledge of the design and technique of building infrastructure networks. The combination of specialized geodetic and IT knowledge with a wide spectrum of knowledge from other fields will allow for active participation in the work and better understanding of the specifics of interdisciplinary teams whose goal is to provide and analyse spatial data and to develop IT products based on these data. The graduate is prepared for the work of a surveyor while handling engineering works and a person dealing with the broadly understood analysis and processing of spatial data. A graduate of the field of study may, after meeting additional requirements specified in legal regulations, apply for professional qualifications enabling independent activity in the field of Geodesy and Cartography. The knowledge and skills acquired during the studies may also constitute the basis for further self-education and development both in the profession of a surveyor and geoinformatics, or other related professions.

**Graduate of the first degree studies in the field of Geodesy and Spatial Planning,
specialization: Real estate management and spatial planning**

After graduation, the graduate has an education enabling to perform independent tasks in the field of geodesy, spatial planning and urban planning. Has interdisciplinary knowledge of the principles and techniques of spatial planning and urban design, general economic, natural and social knowledge, as well as specialist knowledge in the field of conditions and principles and techniques of spatial shaping, environmental protection, planning the development of technical, construction and transport infrastructure. They will acquire the ability to determine and record the ownership status of real estate, geodetic arranging agricultural and forest areas and real estate management, as well as determining their value, obtaining data for spatial information systems, land management, supplying bases and implementing basic, record, economic, topographic and thematic maps and geodetic implementation and service of investments.

The theoretical knowledge and practical skills acquired by the graduate predisposes him/her to conduct engineering activities in the field of geodesy and cartography, taking care of the quality of space in the context of social and economic development. Student has the competence to cooperate with employees of other industries in the process of space development and shaping, as well as to develop planning documents at all levels of design. Student has the knowledge and skills of shaping the spatial order as well as knowledge of the legal aspects of engineering activities, preparation of planning documents, including

documents prepared at the municipal level, such as the Study of the Conditions and Directions of Spatial Development, Local Spatial Development Plans and administrative decisions on building conditions and land development.

A graduate of the faculty may, after meeting additional requirements specified in legal regulations, apply for professional qualifications enabling independent activity in the field of Geodesy and Cartography or Spatial Planning. The knowledge and skills acquired during the studies may also constitute the basis for further self-education and development, both in the profession of a surveyor and urban planner, or other related professions. The knowledge and skills acquired during the studies may also constitute the basis for further self-education, second-cycle studies, post-graduate studies.

E. Environmental Engineering (EE) – full-time undergraduate studies by BSc degree, graduate studies of MSc degree and doctoral studies. Moreover, the EE studies are performed for the part-time studies, as follows: undergraduate studies by BSc degree and graduate studies of MSc degree

Students of MSc course can choose from the following specialities: (1) Alternative Energy Sources, (2) Heating and Air Conditioning, (3) Infrastructure and Water Management, (4) Environmental Protection and Management, (5) Water Supply and Sewage Disposal, (6) Integrated Technologies in Water Protection.

Environmental engineering graduates have knowledge in the field of ensuring the conditions for sustainable development, while maintaining the possibility of removing and liquidating environmental hazards resulting from human activity. After completing the relevant professional practice, they can apply for building and design licences. Graduates' skills and knowledge:

- design, construction and operation of sanitary installations,
- water treatment and supply as well as sewage treatment and discharge,
- heat and gas supply, ventilation and air conditioning systems,
- waste disposal,
- water retention, protection and monitoring,
- protection of air and soil,
- use of renewable energy sources.

F. Transport (TT) – full-time undergraduate studies by BSc.

Transport graduates are prepared to work in companies dealing with road or rail transport. After the second semester, the student has the option to choose the "road transport" or "rail transport" specialization. Transport is an interdisciplinary direction. Graduates have general and specialist knowledge in the field of road and rail transport, traffic control, transport network planning, environmental protection in transport, reliability of transport systems and transport infrastructure: railways or motorways and engineering structures. Transport graduates can be employed in design offices, construction companies and road or railway

administration units. A graduate graduating from studies will have the necessary knowledge enabling further education in the second degree studies in the field of "Transport".

Postgraduate studies accomplished in the Faculty of Civil and Environmental Engineering and Architecture

A. Hydrotechnics

Purpose of the Hydrotechnics studies. Studies aimed at improving skills. The aim of education is to acquire detailed knowledge and skills in the field of selected hydrotechnical issues, and thus to raise the level of professional competence in the field of hydrotechnics, with particular emphasis on hydraulic engineering.

Addresses of Hydrotechnics postgraduate studies. The studies are aimed at people professionally involved in issues related to the broadly understood hydrotechnics or interested in the above topics. The potential candidates for studies include:

- employees dealing with the administration and management of water resources in local government units,
- employees of various institutions and workplaces related to the design, operation and management of hydrotechnical facilities,
- graduates of universities of all types professionally dealing with issues of broadly understood water management.

Graduate profile. Graduates of postgraduate studies will improve their professional qualifications with theoretical basics of hydrotechnics - hydraulics, hydrology, soil mechanics, and learn about selected issues in constructing hydrotechnical structures. The acquired knowledge and skills will increase their competitiveness on the labour market.

B. Energy audit and certification of buildings

The studies are especially dedicated to people who want to expand their knowledge in the field of energy efficiency in construction.

Postgraduate studies "Audit and energy certification of buildings" are aimed at extending the knowledge gained during studies and during professional work. Modern construction materials and technologies enable their use in the design and implementation of buildings. This has many advantages in terms of obtaining the best solutions that protect the completed facility against excessive energy consumption during its operation.

The study program received a positive opinion from the Minister of Infrastructure and was approved by the Minister of Science and Higher Education. Therefore completion of studies allows for entering into the register of persons authorized to prepare energy performance certificates - kept by the Ministry of Infrastructure.

C. Environmental protection in industrial plants and municipalities

Purpose of education. Studies aimed at improving skills. The aim of education is to acquire detailed knowledge and skills to prepare environmental impact reports and applications for sector and integrated permits.

Areas and learning outcomes. A graduate of Postgraduate Studies "Environmental Protection in industrial plants and communes" receives a certificate of completion of Postgraduate Studies. The graduate obtains general knowledge in the field of broadly understood ecology, contemporary threats to the environment as well as processes and methods used to prevent its pollution, with issues related to the protection of water and soil, waste management and technologies of their processing, with environmental management systems, legal acts in environmental protection.

Study are addressed especially for:

- employees dealing with the administration and management of natural environment resources in local government units,
- employees of various institutions and workplaces related to the assessment of the state of the environment and its protection (water and soil protection, waste management, air protection, water and sewage management and others),
- graduates of universities of all types professionally dealing with ecology, nature protection and environmental protection.

D. Safety management of municipal infrastructure in the water and sewage management sector

Purpose of education. Studies aimed at improving skills. The aim of the education is to acquire detailed knowledge and skills concerning an innovative and comprehensive approach to the management of municipal infrastructure, including water and sewage infrastructure.

The studies are aimed at the management of companies, plants and other municipal sector units as well as people who would like to improve their qualifications and enrich their knowledge in the field of safety management.

Areas and learning outcomes. A graduate of postgraduate studies "Safety management of municipal infrastructure in the water and sewage management sector" receives a certificate of completion of postgraduate studies. The graduate obtains the knowledge, skills and competences allowing for professional use of the instruments of managing the municipal economy enterprise. A student is able to organize activities in the framework of management organization in a municipal unit and enterprise in crisis situations and during the modernization of managed infrastructure. The study program guarantees a multi-faceted approach to modern management.

Addressees of studies. The studies are aimed at the management of companies, plants and other units of the municipal sector as well as people who would like to improve their qualifications and enrich their knowledge in the field of municipal infrastructure safety management in private enterprises. The students of the study can be people with a diploma of graduating from higher education, both professional - first degree (bachelor's, engineering) and master's - second degree.

E. BIM (Building Information Modelling) technology in the design and implementation of construction investments

Purpose of education. The main goal of the studies is to prepare students to work in companies and institutions using BIM technology to:

- architectural design, construction and installation;
- managing the process of designing and implementing construction investments;
- preparation of tender documentation and cost estimation;
- building facilities management.

A graduate who completes the studies will acquire the knowledge and skills necessary to properly define the requirements of the client, plan the flow of information in the design and implementation of the investment, carry out the modelling process (3D, parametric, based on a point cloud, installations), teamwork and inter-industry cooperation, collision detection, dimensioning and detailing of structures, preparation of drawing documentation and lists, billing and costing (5D), development of schedules (4D), energy and environmental analyses (6D), use of models in the facility management process (7D). Student will also acquire social competences related to the creation and maintenance of appropriate relationships in the professional environment and private life.

Areas and learning outcomes.

Graduates who complete their studies will know and understand:

- advanced and in-depth theoretical foundations of modern methods, standards and technologies related to modelling and information management in construction processes in connection with various areas of professional activity (architectural, construction, installation, construction management),
- contemporary standards and development trends of professional activity in construction,
- basic rules for the protection of industrial property and copyright in the process of designing and implementing construction investments,
- advanced theories explaining the phenomena and processes related to integrated design and team work,
- various, complex methods and technologies of 3D scanning, modelling techniques and dimensioning of structures and installations,
- various, complex organizational solutions supporting the process of project, construction and building facilities management.

They will also be able to:

- independently plan one's own lifelong learning and direct others in this regard,
- monitor the development of BIM technology and its domestic and foreign conditions,
- make a diagnosis of the conducted professional activity (investor, designer, contractor, building administrator) and forecast its development,

- perform tasks and formulate and solve problems, using new knowledge, also from other fields,
- prepare a work plan for a team of employees, taking into account variable, not fully predictable conditions, and correct the plan according to the circumstances,
- perform complex tasks related to the process of designing and implementing investments in variable and not fully predictable conditions (by appropriate selection of sources and information derived from them and the use of appropriate methods and tools, including advanced information and communication techniques (ICT),
- manage a team of employees or a small organization that carries out complex design and executive tasks in variable and not fully predictable conditions,
- analyse and evaluate the conducted professional activity in the context of national conditions and development trends,
- design information flow in a team of employees or a small organization,
- communicate using specialized terminology, justify position,
- create and maintain proper relationships with colleagues and clients,
- adapt or modify simple methods, technologies and procedures in the conducted professional activity,
- analyse and evaluate professional competences and independently use the available opportunities to update and expand your professional competences.

Student will be also ready for:

- understanding non-technical aspects and effects of engineering activities, including its impact on the environment, and the related responsibility for decisions made;
- independent decision making, critical evaluation of own activities, the teams he/she manages and the organizations in which he/she participates; accepting responsibility for the effects of these actions;
- compliance with the rules applicable at work, relating to maintaining the quality of business and the culture of cooperation and competition;
- maintaining and creating appropriate relationships in the professional environment,
- promoting ethical principles in the field of professional activity and beyond.

Addressees of studies.

The offer of postgraduate studies "BIM technology in the design and implementation of construction investments" is addressed to architects, structural and installation designers, cost estimators, contractors, developers, public administration employees and administrators of building facilities.

Students' scientific groups in the Faculty of Civil and Environmental Engineering and Architecture

There are 9 students' scientific groups at Faculty of Civil and Environmental Engineering and Architecture for young scientist who is interested and wants to pursue his passions:

- Scientific Group of Civil Engineers – Construction section,
- Scientific Group "Da Vinci",

- Scientific Group of Road Engineers,
- Scientific Group of Surveyors "GLOB",
- Scientific Group of Environmental Engineering,
- Scientific Group of Structural Mechanics,
- Scientific Group of Bridge Engineers,
- Students' Scientific Group of Architecture "Zarys",
- HVAC Student Research Group Heating, Ventilation, Air-conditioning.

The Faculty of Civil and Environmental Engineering and Architecture has **14 departments**:

- Departments of Roads and Bridges,
- Departments of Building Structures,
- Departments of Structural Mechanics,
- Departments of Water Purification and Protection,
- Departments of Town Planning and Architecture,
- Departments of Architectural Design and Engineering Graphics,
- Departments of Building Engineering,
- Departments of Building Conservation,
- Departments of Heat Engineering and Air Conditioning,
- Departments of Infrastructure and Water Management,
- Departments of Geodesy and Geotechnics,
- Departments of Water Supply and Sewage Systems,
- Departments of Materials Engineering and Building Technology,
- Departments of Environmental and Chemistry Engineering.

Scientific disciplines in the Faculty of Civil and Environmental Engineering and Architecture

Moreover, in the **Faculty of Civil and Environmental Engineering and Architecture (FCEEA)** there are three disciplines where the scientific research is accomplished, as follows:

- 1. Architecture and Urban Planning.**
- 2. Civil Engineering and Transport.**
- 3. Environmental Engineering, Mining and Energy.**

Scientific and research equipment in the laboratories of the Faculty of Civil Engineering, Environmental Engineering and Architecture

The Faculty has laboratories equipped with the most modern equipment that allow to perform all necessary tests of building materials, soils, structural elements and construction models on a laboratory and real scale. In laboratories, it is possible to measure strength parameters, perform fatigue tests, test the behaviour of structures under static and dynamic loads, measure deformations, displacements, angles of rotation and forces, as well as noise and other acoustic parameters.

The department also has a well-equipped road laboratory. The research equipment at the Faculty's disposal allows testing various properties of road materials, as well as the surface, construction layers and substrate of existing roads.

The Faculty also has measurement stations and apparatus for analysing the state of the environment. Thanks to them, it is possible to check the quality and level of physicochemical and microbiological pollutants: natural, surface and ground waters, tap water, sewage, soil, waste, bottom sediments, sewage sludge, biomass and the atmosphere.

The equipment owned by the Faculty also enables the control of municipal infrastructure in the field of analysis of the functioning of water supply and sewage networks (flow meters, meteorological measurement stations, equipment for monitoring and inspection of water supply, sewage and industrial networks infrastructure) and research in the field of renewable energy (analysis of a wide spectrum of physical properties of biomass and biofuels).

Service and research offer from the laboratory of the Faculty of Civil and Environmental Engineering and Architecture

Individual units of the Faculty offer services to industry, business representatives and other interested parties in the following areas:

- designing structures of all types of facilities with any degree of difficulty,
- verification of designs and material and construction solutions,
- periodic inspections of engineering structures,
- carrying out construction expertise,
- assessment of the standard and service capacity of the existing engineering structures,
- development of repair technologies for concrete and reinforced concrete structures,
- supervising the construction implementation,
- preparation of maps for design purposes,
- consulting applications for ITB (in Polish: Instytut Techniki Budowlanej) technical approvals,
- static and dynamic model studies,
- construction elements, connections and finished construction products with the use of a universal, adjustable research system,
- fatigue tests of building structure elements, connections, vibroinsulation, machines and devices,
- tests of bridge structures under a static and dynamic test load,
- periodic measurements of building displacements and deformations,
- control measurements of cranes, bridges, viaducts and tower structures,
- tests of acoustic conditions in buildings and in the external environment, including noise measurements from road, rail, aviation and industrial plants,
- measurements of the effectiveness of acoustic screens,
- specialized material tests,
- assessment of acoustic insulation of building partitions in field conditions,

- consultations and cooperation in the implementation of new technologies and building materials,
- concrete design, production control, consultations and laboratory tests of concrete for its producers,
- comprehensive problem solving regarding concrete technology, testing of binding materials, aggregates, concrete products, concretes and mortars,
- inspections of inaccessible places in buildings, machines, installations, etc.,
- landslide monitoring,
- a wide range of road tests,
- consulting, expert opinions, projects in the field of architecture and urban planning, spatial planning and conservation of monuments,
- conducting conservation supervision over historic buildings,
- carrying out historical studies and architectural research,
- preparation of architectural and conservation documentation,
- developing programs for the protection of cultural heritage,
- analysis and assessment of risks related to the functioning of municipal systems,
- concepts for the construction, expansion and modernization of water supply systems,
- implementation of solutions for facilities and devices to control the flow of sewage in the sewage system,
- implementation of liquefied soil technology for the construction of infrastructure systems;
- implementation of the construction of multimedia chambers,
- environmental studies of reservoirs and the impact of surface waters and their catchments on the cleanliness of these reservoirs, monitoring of surface waters,
- bacteriological, microbiological, parasitological and physicochemical tests, incl. water, waste water, sediment and soil (e.g. heavy metal content),
- assessment of water quality and suitability for drinking and other purposes,
- technological research on water treatment,
- environmental impact assessment of industrial plants, sewage treatment plants, landfills,
- testing the suitability of sorption and ion exchange masses for operation,
- environmental impact assessments and reports of landfills,
- waste management in municipalities,
- studies of changes in sediments deposited in the environment, sanitary risk assessment.

1.2. National Technical University of Athens

1.2.1. General information

Introduction

The National Technical University of Athens (NTUA) is structured according to the continental European system for training engineers, with an emphasis on solid background. The duration of courses leading, after the acquisition of 300 credit units to a Diploma, of Master's level, is five years. The valuable work of NTUA and its international reputation are due to its well organized educational and research system, the quality of its staff and students, and the adequacy of its technical infrastructure. The graduate engineers who staffed public and private technical services and companies were and remain by general consent, equal to their European counterparts. Many have been elected to distinguished teaching and research positions in well-known universities all over the world.

The primary institutional component of the NTUA's mission, through the integrated complex of studies and research, is to provide advanced higher education of outstanding quality in science and technology. NTUA's code of operation and development, considered as one of the best European University Statutes, defines that the main strategy of NTUA in the new millennium, is not only to maintain its position as an outstanding and internationally recognized public university of science and technology, but also to strengthen that position as regarding all its basic operations. All other strategies, aims and actions must be compatible with this basic strategic choice.

In quantitative data:

- under NTUA auspice 9 Schools operate, with 512 faculty members, 4.090 external collaborators, 23.914 students, in 300.000m² of installations,
- over time, the baccalaureate grades required for admission in all of NTUA schools remain constantly the highest between all Greek academic institutions by specialty,
- according to QS World Universities Ranking 2016, NTUA is the leading academic institution in Greece and the only one in the top 400 institutions worldwide. The School of Civil Engineering is in the 33rd position of the world's best schools by specialty. NTUA is in 67th place worldwide among technological universities,
- at NTUA operates 194 laboratories, 140 of which are certified. In 2015, there were 1423 national and European research projects,
- NTUA Faculty members publish annually more than 3.000 scientific papers (in journals, conference proceedings, chapters in volumes etc.) which earn more than 20.000 citations.

Organization and Administration

Administrative Bodies

Rector

The administration of NTUA is headed by the Rector, the Vice Rector in charge of Finance, Planning and Development, the Vice Rector in charge of Research and Lifelong Education, and the Vice Rector of Administrative, Academic and Student Affairs. The Rector and the three Vice Rectors form the Rector's Council.

The Senate

The Senate is the highest collective body for elaborating and overseeing university policy and main actions. It consists of the Rector, the three Vice Rectors, the School Deans and the representatives of staff and students. The main responsibilities of the Senate are:

- the supervision of the way NTUA operates, ensuring that it does so within the law and in accordance with the "NTUA Statute",
- the general educational and research policy of NTUA, the elaboration, planning and strategy for its future development, and the regular review of its activities,
- the strengthening of the university's ties with the society's production of goods and services, the contribution to regional, national and international development, the continuing education and training for engineers, and the collaboration with Greek and foreign educational and training institutions and with scientific and social organizations.

Eight Senate Committees have been established with the mission to advise the Senate on particular affairs, ranging from Undergraduate Studies and Graduate Studies to Basic Research and Cultural activities. Each Committee comprises representatives from all Schools and is chaired by a member of the Rector's Council.

Legal Adviser Office

The Legal Adviser Office represents NTUA interests before all courts and other authorities. The Head of the Legal Office is a member of the State Legal Council. He is authorized to submit advices to NTUA officials and members of the community.

Studying at the National Technical University of Athens

Student Status

Greek high school graduates enter NTUA Schools after succeeding to the national "numerous clasus" entrance examinations. According to the exam records, NTUA students are in the range of the top 1 ~ 5% of the candidates for University education. There are no limits for the duration of studies. Students may apply to their School to suspend their studies.

Structure of Studies

The educational curriculum at NTUA is divided into independent academic semesters, each one equivalent to 30 credit units. The courses taught in the different Schools last one semester. Studies in all Schools last ten (five fall and five spring) semesters. The tenth semester is devoted to the Diploma Thesis. Each semester covers on average 30 credit units and lasts 18 weeks; 13 weeks are devoted exclusively to teaching, 2 for the Christmas or Easter break, and the last 3 of each semester for final examinations in that semester's courses.

Curriculum

The curriculum includes the titles and content of the mandatory and elective courses, the weekly hours of teaching (including every form of teaching) and the sequence or interdependence of courses. It is published every year in Greek and English. Handbooks are available from the School Offices. The General Assembly of the School is responsible for drawing up the curriculum, which comes under review every April. The School President sets up a program committee consisting of members of the General Assembly of the School, lasting for one year, which submits a report to the General Assembly based on the suggestions of the departments. The final curriculum authorization is given by the Senate.

Academic Tutors

Immediately following the publication of the list of registered students, the School Board appoints a School member as a tutor for each student.

Evaluation Questionnaires

NTUA evaluates the teaching process with questionnaires in order to pinpoint any weaknesses in the education offered and continuously improve its quality. Also to introduce new modes of teaching which will strengthen the active participation of students and to improve communication between academic staff and students. The questionnaires are optional and anonymous, and are offering vital information for achieving the above aims.

Quality Assurance

Starting in 1999, the National Technical University of Athens periodically conducts an evaluation of its educational and research services and facilities. It is carried out by an internal committee, consisting of academic staff representing all Faculties, graduate and postgraduate students and administrative staff, in collaboration with a Committee of External Evaluators from abroad. The purpose of this quality control is to collect, process and present all the available information on administration, education, research, infrastructure, facilities and services available, in order to identify potential problem areas, and improve the record of NTUA as one of the leading Technological Universities.

Undergraduate Studies

NTUA plans and organizes its educational program under the following principles:

- maintenance and enrichment of the basic five-year Diploma Degree course structure, which is equivalent with the Master's Degree, with a strong theoretical foundation in the applied sciences and technology, an appropriate range and number of courses, and high standards in the Diploma Thesis,

- strengthening studies, aiming at cohesion and academic depth, responding to current and future development needs, methodical adaptation to the educational process of active learning and linking studies with practical experience (professional or research-oriented),
- opening new horizons in scientific and technological education.

Requirements and Standards

Under the general principles which govern studies at NTUA, the university strives to ensure that the following demands and conditions are met:

- 25 to 26 teaching hours in total per week and 6 to 7 courses a semester,
- classes are normally held between the hours of 08:45 and 15:30 from Monday to Friday,
- class size is kept to a maximum of 80 students per lecturer,
- teaching includes theory and practice in a coherent presentation,
- academic tutorials and interim tests are assessed, to strengthen the step-by-step learning,
- information technology and PC labs form an integral part of the curriculum,
- regular detailed audit of textbooks by a special School Committee,
- distribution of textbooks, on time,
- a fixed timetable for courses, examination periods and announcement of results.

In the winter examination period (January-February), only the courses of the fall semester are examined. In the summer examination period (June-July), only the courses of the spring semester are examined. In September, students may retake exams in any courses which they have either failed or have not previously been examined on or in which they wish to improve their grade.

Design Projects

Design projects take place in all NTUA Schools during the semester courses or between the end of the final examinations in the spring semester and the start of courses in the fall semester. In the Schools of Civil Engineering, Rural and Surveying Engineering, and Mining and Metallurgical Engineering major projects are also in the curriculum.

Practical Training / Internship

The Internship's purpose is to connect education with the professional environment that the students will meet in the labour market when they complete their studies. NTUA was the first among the country's technology institutes which includes its students' Internship as an integral part of the educational process. The duration of the Internship is set at 1 or 2 months after the institutionalization of each school. It takes place every year from April to October. More than 1000 students of the NTUA every year are trained in their cognitive subjects through the Internship.

Diploma Thesis

The final Diploma Thesis has the level, content, and duration of the Master Thesis of equivalent Anglo-Saxon Universities. It gives the students the opportunity to integrate their

knowledge and to present their ability to carry out research on a topic of their specialty which was given during the five-year period of study. The principal thesis work is carried out exclusively during the 10th semester, when the student does not have any coursework. In the beginning of the 9th semester, the student applies to the School Office and selects the course within which the thesis is to be carried out under the supervision of a member of the academic staff who taught it or a course nearest the subject matter.

After completion of the Diploma Thesis, the student deposits the appropriate text and undergoes an oral examination, by a three-member examining committee. This committee is proposed by the General Assembly of the Department and confirmed by the General Assembly of the School or by the Executive Board of the School, if it has been so authorized. This can only be done after the student has successfully passed all the courses. The final copy of the thesis remains to the School Office, while 2 other copies must be submitted, one to the Departmental Library and the other to the Central Library. These copies are available for borrowing by anyone who is interested. The final mark of the Diploma Thesis is calculated as the average of the marks of the 3 examiners, rounded to the closest integer or half unit of an integer.

Marking Schemes and Diploma

Marking in all courses is made on a scale of 0-10, without using fraction of an integer, and with 5 as a passing mark. Thesis marking is an exception since it is allowed to use half marks (0.5), and the passing mark is 5.5. The overall mark for the Diploma is calculated by summing the following: the arithmetic average of all course marks taken by the student during his/her studies, with a weighted coefficient of four fifths ($4/5$), and the Diploma Thesis mark, with a weighted average of one fifth ($1/5$). The total quality of the student is assessed according to the following scale: Excellent 9 to 10, Very Good 7 to 8.99, Good 5.5 to 6.99, Satisfactory 5 to 5.49, Fail below 5.



Figure 1.1. Patio of National Technical University of Athens

Postgraduate Studies

NTUA holds a prominent place in the international academic community as a distinguished state university which promotes science and technology. This place is also due to the postgraduate degrees which it awards. They are of a high standard and enjoy international prestige. The main aims of the NTUA's postgraduate studies are to maintain and strengthen quality, to enhance international recognition of the degrees granted and to pursue cohesion between education, research advancement and scientific depth.

The postgraduate degrees currently offered by the NTUA include:

- Postgraduate studies organized in the framework of each School, which lead to the award of a "Doctoral Degree". Students follow a program of postgraduate courses and/or research, leading to an original and significant contribution in sciences and technology.
- Interdisciplinary Postgraduate studies, organized in the frame of several Schools of NTUA or jointly with other universities, which lead to the award of a "Postgraduate Degree of Specialisation", equivalent by law to a Master's degree. Students acquire this degree after one to two academic years, during which they follow specific courses divided into semesters or four - month terms and prepare a thesis. Students wishing to continue their research work towards a Doctoral Degree in related subjects may be allowed to do so in one of the collaborating Schools.

Interdisciplinary Postgraduate Programs

In the frame of the interdisciplinary approach, twenty postgraduate programs have been offered since 1998, leading to a Postgraduate Degree of Specialization and covering a wide range of research and professional potentials operating currently at NTUA. In all programs, the admission is very competitive. The minimum duration of studies and thesis presentation is one full year and the maximum is two years. The student must complete his/her thesis within this maximum period of two (2) years. Repeating an examination is generally not allowed.

The administration and management of each program (syllabus, student selection, teaching assignments etc.) is performed by its Academic Board, which consists of nine Faculty members from the co- operating Schools. Teaching is mainly performed by Faculty members, as well as by academic and industry experts, invited for lectures on specialized subjects:

- Water Resources Science and Technology – Coordination: School of Civil Engineering,
- Structural Design and Analysis of Structures – Coordination: School of Civil Engineering,
- Automation Systems – Coordination: School of Mechanical Engineering,
- Athens Postgraduate Program in Business Administration – Coordination: School of Mechanical Engineering,
- Energy Production and Management – Coordination: School of Electrical & Computer Engineering,

- Engineering – Economic Systems – Coordination: School of Electrical & Computer Engineering,
- Architecture – Space Planning – Coordination: School of Architecture,
- Protection of Monuments – Coordination: School of Architecture,
- Materials Science and Technology – Coordination: School of Chemical Engineering,
- Computational Mechanics – Coordination: School of Chemical Engineering,
- Environment and Development – Coordination: School of Rural & Surveying Engineering,
- Geoinformatics – Coordination: School of Rural & Surveying Engineering,
- Design and Construction of Underground Works – Coordination: School of Mining & Metallurgical Engineering,
- Marine and Ocean Technology – Coordination: School of Naval Architecture & Marine Engineering,
- Microsystems and Nanodevices – Coordination: School of Applied Mathematical & Physical Sciences,
- Mathematical Modelling in Modern Technologies and in Finance – Coordination: School of Applied Mathematical & Physical Sciences,
- Physics and Technological Applications – Coordination: School of Applied Mathematical & Physical Sciences,
- Applied Mathematical Sciences – Coordination: School of Applied Mathematical & Physical Sciences,
- Applied Mechanics – Coordination: School of Applied Mathematical & Physical Sciences,
- Offshore Structures, Systems and Processes for the Hydrocarbon Exploration and Exploitation – Coordination: School of Naval Architecture & Marine Engineering.

Participation of NTUA in other University Programs

The NTUA also participates through its Schools in many inter-university postgraduate degree courses coordinated by other universities.

Schools' Postgraduate Programs

Each one of the nine NTUA Schools is offering postgraduate studies, either within the School, sometimes involving graduate courses and in every case leading to the preparation of a Doctoral Thesis, or as coordinator of interdisciplinary postgraduate programs, leading to the abovementioned Postgraduate Degree of Specialization.

Doctoral Theses

The procedure for the preparation of a Doctoral Thesis guarantees substantial in-depth study and promotion of science and technology. The Doctoral Theses are designed by the cells of research, the Departments, and coordinated by the Schools. The total length for the preparation and the award of an NTUA doctoral degree is set by law at no less than 3 years and no more than 6 years, including the time spent in postgraduate courses. The candidate defends the doctoral thesis before an examination committee consisting of seven members of the faculty.

Student Exchange Programs

Student exchange programs allow students to study in other European countries for periods ranging from three months to one academic year. During their stay abroad, students must attend courses equivalent to those of their normal semester and pass examinations which count towards their degree. There is also the opportunity for a Master's Thesis to be written abroad with the agreement of the supervising professor of the NTUA School. Students are offered the possibility of subsidized professional employment in a foreign country during the summer vacation.



The Erasmus Program first began in 1987, and became the leader in studies in technical universities inside and outside the EU with which the NTUA has the appropriate agreement. Periods abroad range from three months to one academic year, with guaranteed recognition of studies. To cover the additional expense associated with cost-of-living differences abroad, Erasmus scholarships granted by the European Union are supplemented by the NTUA. Apart from the linguistic and cultural benefits offered by the program, students have the opportunity to gain international experience from other countries. Students who take part in Erasmus have usually completed their first year of studies, and the procedure for granting scholarships begins at least six months before travelling abroad.

The Tempus program involves cooperation between tertiary educational institutions in the European Union and the countries of Eastern Europe in the areas of research, technological development and education (exchanges of undergraduate, postgraduates, and research and teaching staff). NTUA has been involved in Tempus since 1991 in areas such as communication, information technology, telematics, metallurgy, mining engineering, naval architecture, industrial research and the environment.



NTUA is also involved in the International Association for the Exchange of Students for Technical Experience (IAESTE). Every year NTUA and seven other Greek universities send approximately 250 students for practical training in technical companies or University Laboratories of member countries of IAESTE, and accept a similar number of foreign students in Greece. The student work placements are funded by the companies themselves. Every year, they inform the authorities about places they have available and what conditions the candidates must fulfil. Applications are submitted in October and November of the previous year and the selection of successful candidates is made in February and March on the basis of objective criteria such as school, year of graduation, knowledge of the required foreign language and degree of success in the studies of the previous academic year. The student exchanges usually take place during vacations (July- September).



The aim of the Association des États Généraux des Étudiants de l'Europe (AEGEE) is to promote European awareness and cooperation among the members of the European student community. In this framework, AEGEE organizes conferences and events of European and scientific interest, and promotes exchanges between large numbers of students. It is an organization that operates at a European and regional level and includes activities such as summer universities, business management competitions, Community law competitions, seminars and conferences.

BEST (Board of European Students of Technology) is a nonprofit, nonpolitical students' organization "for students by students". It is a network of 64 Highest Educational Institutes of technological courses of 25 European countries, aiming to promote the idea of Europe among European students. The basic aims of this organization are the creation of strong ties between European



students, the understanding of different cultures, information about high technology issues, contact with the labour market, with the companies, and the development of students' abilities which will help them to work on an international level. To succeed through these goals BEST organizes, every year, a variety of academic activities, including educational seminars of technological interest, cultural exchanges, meetings with companies, sport meetings, excursions etc. BEST Athens is between the most powerful Local Teams of the Organization, while at the same time it has been established as one of the most important student organizations of European orientation. Participation in most of BEST activities is free of charge.



Especially related to the School of Civil Engineers is the International Association of Civil Engineering Students (IACES). Its purpose is to offer a collaboration network between civil engineers student enabling organized actions. IACES organizes member meetings in various European cities, where lectures, discussions and social activities take place.

The EESTEC Local Committee of Athens (Electrical Engineering Students' European assoCiation Local Committee Athens) is a voluntary, non-governmental organization of Electrical and Computer Engineering students, which operates in 28 countries and 53 polytechnic schools throughout Europe. EESTEC LC Athens is a member of the European organization EESTEC International, founded in 1984 in Eindhoven, Netherlands.



1.2.2. The School of Mechanical Engineering

The School of Mechanical Engineering of the National Technical University of Athens (Fig. 1.2) excels both in Greece and internationally, thanks to its advanced level of studies and to its internationally acclaimed research. Mechanical engineering covers a broad range of areas such as energy, the environment, transportation, machine design and the automatic control of technological systems. The activities of today's Mechanical Engineers require capabilities in research and development, design, testing and the manufacturing of products and systems, production organization and management. Our department ensures that young engineers will be able to contribute to the rapidly advancing technological development and distinguish themselves both in Greece and abroad.



Figure 1.2. National Technical University of Athens – School of Mechanical Engineering

Education & Learning Goals

The main education and learning goals of the School of Mechanical Engineering are:

- To educate Mechanical Engineers who can contribute to the Greek society, and who will be competitive both in Greece and internationally, capable of developing and utilizing breakthrough technologies, across a variety of fields.
- To emphasize modern skills.
Mechanical Engineers design and manufacture machines, products and processes, or manage projects and large systems. Therefore, they should be able to resolve design and management problems that include definition and modelling of the problem, model analysis and solving (detailed design) and implementation/manufacturing.
- To enhance the educational process. The educational process must become more meaningful and attractive to students, presenting a learning experience based more on hands-on activities than on passive presentation of knowledge.

- To strengthen course areas such as Biomedical technology, Renewable energy sources and energy saving, Intelligent systems for production, transportation, and energy, Robotics, Advanced materials and nanotechnology and Sustainable development and circular economy.

Research Goals

The main research goals are:

- To stimulate and encourage interdisciplinary research through intersectoral departmental university cooperation.
- To stimulate/encourage International research collaborations. International research collaborations have multiple benefits, both for faculty/researchers, such as interaction with other colleagues and research traditions, exchange of experience, ideas and methods, as well as for the School.
- To encourage a response to the challenges of basic and applied research.
- To publicize faculty research results. Research carried out -and especially the applied one- must be promoted both nationally and internationally.

Organizational and Administration Goals

The main organizational and administration goals can be described in brief as:

- To reinforce the strategic role of the School's Collective Bodies.
- To integrate School Internal and External Evaluations.
- To renovate and maintain the School premises.
- To exploit Information Technology, in order to simplify some procedures and make better use of the information technology by developing local applications.

Societal Engagement Goals

Finally, the societal engagements goals can be summarized as:

- To reinforce relations with other Universities and Research Centers.
- To strengthen relations with entities employing Mechanical Engineers.
- To enhance relations with our Alumni.
- To increase the visibility of the School's teaching and research efforts.
- To volunteer in assisting sensitive social groups.

Sections

The School of Mechanical Engineering has six sections:

- Section of Industrial Management and Operational Research
- Section of Thermal Engineering
- Section of Mechanical Design and Automatic Control
- Section of Nuclear Engineering
- Section of Fluids
- Section of Manufacturing Technology

Section of Industrial Management and Operational Research

The Sector of Industrial Management and Operational Research (SIMOR) activates in educational and research activities regarding the design, planning and control of production systems i.e., production management. SIMOR supports the Industrial Engineering Cycle of Studies. In addition, SIMOR has the organizational responsibility of ATHENS MBA jointly organized by National Technical University of Athens and Economic University of Athens.

SIMOR's laboratory units support the Production Engineering Cycle of Studies teaching process. In addition, the staff expertise and the integrity of the laboratory equipment has led to a series of successful implementations concerning research programs and service provision projects.

SIMOR's Teaching Faculty Members include 2 members ranked as Professor, 1 member ranked as Assistant Professor, 1 member ranked as Associate Professor, 5 members ranked as Lecturers and 2 members as PD 407 Lecturers.

In addition, to individual Laboratory Units 14 employees work as permanent staff with the properties of Scientific Collaborator. Finally, the Department maintains a total of Postgraduate Students/ Doctoral candidates.

Sector of Industrial Management and Operational Research comprises the following laboratories - studies:

- Metrotechnics Laboratory
- Laboratory of Industrial Engineering, which hosts the following units:
Industrial Software Unit, Energy Logistics Unit, Ergonomics Unit, Environmental Economics and Sustainability Unit.
- Operational Research Study
- Management Study

Metrotechnics Laboratory

The Metrotechnics Laboratory is an organizational unit of NTUA since 1962 when it was founded and it is for years the link between academic teaching and practical application of what is taught in classes of their course of Industrial Engineering Faculty of the school Mechanical Engineering of NTUA . Meanwhile, the Metrotechnics Laboratory operated since its inception in conducting a research project and services to businesses and organizations in the private and public sectors. Equipment and laboratory space are also used for preparing dissertations final year students, and the needs of graduate students for doctoral studies in the subject metrotechnics.

The Metrotechnics Laboratory has extensive experience in the area of precision measurement and large research projects . The laboratory is accredited according to ELOT EN ISO / IEC 17025: 2005 to provide testing services to industry.

The members of the lab have great experience in non - destructive testing and provide quality services:

- research projects requiring high-precision measurements of characteristics,
- to operators to perform precise measurements and the creation of laboratories measuring and control of their structures,
- in government organizations and private companies to perform precision measurements, and provide recommendations and advice on relevant issues in order to enable the measurement and improvement of quality of machining and other structures.

Laboratory of Industrial Engineering

The Industrial Engineering Laboratory (IEL) is an officially established laboratory of NTUA Founded in 1962, and it operates on the basis of the approved in the establishment of rules and in accordance with the rules of the NTUA.

Laboratory is active in research projects while it is the core of solving many problems of organization, administration, production and operational software for Greek industrial enterprises. In addition, the Industrial Engineering Laboratory is the link between academic teaching and the practical application of those lessons taught in the School of Mechanical Engineering of the NTUA.

Gradually and with the introduction of information technology in production, the laboratory became involved in the field of industrial software and its implementation in practice, to industrial users in the field of production planning initially, and then in issues pertaining to the organization of business processes and information systems in production.

The mission of the Laboratory is summarized in the following:

- promoting science in the fields it is involved in,
- support for teaching needs in the context of the curriculum of the School of Mechanical Engineering of NTUA,
- support of teaching needs for postgraduate programs of NTUA,
- conduct basic and applied research, independently or under funded research programs,
- providing services to industrial users and private or public organizations, in the form of performance measurement, analysis, processing and interpretation of the results, the drafting of reports and studies,
- the diffusion of knowledge through the publication of scientific articles, books, monographs,
- the organization of workshops, symposia and meetings with scientists from Greece and abroad,
- the collaboration with academic institutions and research centers, institutes and other scientific organizations that have similar or complementary interests,
- cooperation with private companies and public institutions with a view to the practical application of scientific research.

The laboratory's activities cover a wide area of interests and include supporting education Industrial Engineering courses provided by the School of Mechanical Engineering of NTUA

The staff of the laboratory (regular and postgraduate students) develop significant research activity in cooperation with research centers both Greek and foreign and Greek industrial enterprises and public organizations. The laboratory develops non-funded, basic applied research and applied research funded by cooperating enterprises or research projects in Greece or the European Union.

In order to efficiently carry out both its educational and research activities the laboratory is organized into four research units:

Industrial Software Unit (ILU): specializes in the study, development and implementation of systems and software in industrial enterprises or other organizations both in the private and public sector. The research efforts cover all the aspects of Supply Chain Management of businesses and organizations. The Unit is focused in the areas of information systems supporting not only production processes, from shop floor control to aggregate production planning, but also inter- and intra- business processes.

Energy Logistics Unit (ELU): Providing adequate and safe future energy supplies for organized societies, while addressing the environmental impact of energy production and use, is one of the key challenges facing our generation. Organizational and managerial issues as well as economic aspects of the new power generation methods, products and sources are also primary subjects of the current scientific race against consequent climate change and environmental degradation. The staff of ELU aim to address the above-mentioned issues. ELU belongs to the Sector of Industrial Management and Operational Research (SIMOR) of the Mechanical Engineering School of NTUA. Focusing mainly on fuels coming from renewable sources like biomass and municipal solid waste (MSW), ELU now provides an extended area of research covering new energy products like district-heating, district-cooling, tri-generation, poly-generation etc.

Logistics and Transportation Unit (LTU): is involved in research around the field of supply chain covering all aspects of supplier – customer relations. The unit focuses not only on optimizing distribution networks, associates and fleet but also on production planning and control and business modelling.

Environmental Economics and Sustainability Unit (ESU): focuses mainly in supporting – on a research and academic level – subjects relating to Sustainable Development and Sustainable Production and Consumption. The necessity of solving relatively specialized and targeted environmental problems in Greece, led to the establishment of ESU. It is usually believed that there can't be growth and/or development in a friendly and conventional environmental way combined with investments that cover social, environmental and economical aspects.

The Ergonomics Unit (ErgoU): main objectives are to provide education in Ergonomics, both at undergraduate and postgraduate level, to conduct basic and applied research mainly in the

areas of cognitive and usability engineering and to spread applications of Ergonomics in Greece through funded and non-funded applied Projects.

Section of Thermal Engineering

The Thermal Section covers the subjects of Thermodynamics, Heat and Mass Transfer, Refrigeration, Air-Conditioning, Internal Combustion Engines, Steam Generators and Thermal Installations, Thermal Stations, Solar Energy, Numerical Methods for Transport Phenomena. In the laboratories of Applied Thermodynamics, Heat Transfer, Heterogeneous Mixtures & Combustion Systems, Internal Combustion Engines, Refrigeration and Air-Conditioning, Solar Energy, Steam Boilers and Thermal Plants, Thermal Processes, Vehicle Refrigeration Technology training of the students and Diploma dissertations are carried out as well as research on Internal Combustion Engines, Thermodynamics, Heat Transfer, Unit Operations, Refrigeration, Air-Conditioning, Emission of Pollutants from Thermal Engines, Combustion, Two-Phase Flow of Gas-Solid particles, Mathematical Models of Combustion Points, Applications of Solar Energy.

Sector of Thermal Engineering comprises the following laboratories:

- Laboratory of Steam Boilers and Thermal Plants (LSBTP),
- Laboratory of Heterogeneous Mixtures & Combustion Systems,
- Laboratory of Applied Thermodynamics,
- Laboratory of Heat Transfer,
- Laboratory of Thermal Processes,
- Laboratory of Internal Combustion Engines,
- Laboratory of Solar Energy,
- Laboratory of Vehicle Refrigeration Technology,
- Laboratory of Refrigeration and Air Conditioning.

Laboratory of Steam Boilers and Thermal Plants (LSBTP)

The Laboratory of Steam Boilers and Thermal Plants has been working for the last 30 years on:

- the examination of phenomena which affect and determine the process of combustion in furnaces of conventional and non-conventional steam boilers,
- the formation of pollutants and the technologies for their reduction,
- the examination of heat transfer phenomena on the exchange surfaces of steam boilers,
- the testing and checking of heating systems as for their efficiency and their exhaust gas quality,
- the energy saving from Thermal Power Plants,
- the development of new technologies and combustion systems such as the burning in a Fluidised Bed,
- the prediction and coping with problems through the computational simulation of flow fields, of transfer and combustion phenomena,

- the energetic use of biomass (combustion, gasification),
- fuel cell technology,
- novel technologies for CO₂ capture in power production sector,
- hydrogen use in energy production.

The research efficiency of the Laboratory during the last decade has resulted in the development of innovative methods and technologies in the area of fuel usage, energy saving and reduction of atmospheric pollution. For reasons that are being explained separately in each case, the application of those technologies appears to have a special interest for our country.

Calculation models. One of the main research activity objectives of the Laboratory is modelling combustion phenomena. The development of a two-dimensional and the use of a three-dimensional calculation code for the simulation of solid and gas-fuel combustion were a result of this effort. These codes are the assemblage of sub models that solve problems of momentum, mass, and heat transfer in turbulent flows and chemical reactions. Each of the above-mentioned models constitute in fact a separate research area.

The contribution of the Laboratory to the area of heat transfer and especially the area of thermal radiation is innovative; the same applies to the area of NO_x and SO₂ formation and the procedures of natural desulphurisation of combustion gases.

Fluidised bed. Combustion in a fluidised bed is appropriate for taking advantage of low rank solid fuels or peripheral deposits of solid waste that exist in abundance in Greece. This is accompanied by a reduction of air emissions taking place at the same time. In this way, FB technology allows making the deposits that are rich in sulphur and also exist in excess, economically worthy. Another contemporary application of the fluidised bed technology is the incinerators of waste and sewage sludge with production of thermal power and electricity at the same time. Recently, advanced CFB design is being developed, the strategic importance of which is based on the capability for multi-fuel operation that enables remarkable CO₂ emission decrease compared to current applications.

Biomass & Waste. Biomass as a supplementary fuel in the Greek Thermal Power Plants appears to have the advantages of increased heating value and high volatile content while, at the same time, it is believed to be a fuel that does not affect the greenhouse phenomenon due to its life-cycle. Extensive series of experimental tests have been carried out in the Laboratory regarding the co-combustion of biomass species, which are characteristic of the Mediterranean region, with Greek brown coal. These investigations concerned both tests at the lab-scale installations and theoretical models to predict the combustion behaviour as well as the demonstration of this technique at industrial facilities and large-scale installations. Within the framework of a common project with the Public Power Corporation of Greece, partial replacement of lignite with olive kernel was performed in two units of the Megalopolis Power Station with exceptionally encouraging results. The Laboratory is also active in the field of thermal gasification of biomass or wastes with brown coal, participating in EU as well as

national funded projects focusing on biomass residue air and steam gasification in the lab-scale fluidised bed.

Combined cycles. The demand for continuous increase in the efficiency of Power Station Plants has caused a great movement around combined cycle technologies all over the world. Through its participation in international research programs, the Laboratory has conducted innovative work in this area such as an integrated calculation code for combined cycles, theoretical and computational research on pulverised coal combustion under pressure and experimental research of the Greek lignite catalytic combustion in a furnace that operates by using turbine exhaust gas as a fluidising and oxidant medium.

Advanced Technologies to Improve Brown Coal Performance. Extensive theoretical and computational work is carried out concerning the investigation of novel pre-drying concepts and the identification of their application potential at the Greek Thermal Stations utilizing high moisture brown coal. Moreover, the integrated approach of lignite drying and gasification for power production at high efficiencies and, thus, reduced CO₂ emission values are under investigation.

Co-generation. The Laboratory is active in the field of the promotion of combined heat and power generation concepts. It also participates in the design of a co-generation unit at the NTUA Zografou Campus.

Hydrogen. The Laboratory is active in the field of hydrogen technologies and techno-economic studies on fuel cell application potential. The work focused on the possibility of developing decentralized hydrogen production units. Furthermore, the legislative framework, the infrastructure and policy support measures, necessary codes and standards are also included.

CO₂ aspects. The Laboratory is active on novel technological scheme for CO₂ capture in the power generation sector. The work focuses on Oxyfuel, amine scrubbing and IGCC technologies. The laboratory is also active on legislative aspects related to the Emission Trading Scheme (ETS) and the Clean Development Mechanism (CDM).

Boiler design. A typical example of applying development through research was the design of four series of hot water steel boilers in the range area of 25 up to 400 kW. The design was based on a calculation program of each of the boiler parts.

Laboratory of Heterogeneous Mixtures & Combustion Systems

The Laboratory of Heterogeneous Mixtures & Combustion Systems (HMCS) is an officially established laboratory of the School of Mechanical Engineering of NTUA since 2002. The HMCS Lab has been working for the last twenty years on the investigation of combustion related phenomena and multi-phase, multi-component reacting flow problems in laboratory and industrial scale. The HMCS Laboratory is active in research projects and publications.

The Laboratory's activities cover a wide area of interest and include supporting education Thermal Engineering courses provided by the School of Mechanical Engineering of NTUA. The areas of interest of the Industrial Engineering Laboratory include:

- Support for teaching needs of the School of Mechanical Engineering of NTUA,
- Support of teaching needs to postgraduate programs of NTUA,
- Basic and applied research, independently or under funded research programs,
- Diffusion of knowledge through the publication of scientific articles and books;
- Organization of meetings with scientists from Greece and abroad.

The staff of the laboratory , both regular and postgraduate students, develops significant research activity in cooperation with other research centers in Greece or in the EU and with public organizations. The laboratory develops applied research funded by research projects in Greece or the European Union.

The scope of the H.M.C.S Laboratory is the generic research regarding:

- investigation of fundamental heterogeneous multi-phase, multi-component, reacting flows and related industrial processes,
- development of two-phase, reactive Computational Fluid Dynamics codes using Eulerian-Lagrangian and multi-fluid approaches,
- development of thermo-kinetic models for hydrocarbon oxidation, development of combustion chemistry models for thermal process optimization (e.g., diesel auto-ignition, cool flames) and pollutants emission control from combustion processes,

and the industrial research concerning:

- experimental aerodynamic and thermo-chemical characterization of prototype and industrial burners,
- modelling of particle induced mechanical erosion wear (e.g., in pipes, ducts, mills);
- development of multi-criteria assessment tools integrated with the Life Cycle Analysis for techno-economic & environmental impact assessment,
- process optimization – industrial energy auditing – energy saving solutions,
- optimization of pulverization methods using a prototype ring-type mill.

Laboratory of Applied Thermodynamics

The Laboratory of Applied Thermodynamics is one of the oldest laboratories in the National Technical University of Athens. The Laboratory of Applied Thermodynamics has the required expertise, manpower and necessary infrastructure to provide high quality teaching and scientific work. It has contributed actively to the industry, community groups, industries as well as individual contractors.

The main topics concerning the Laboratory of Applied Thermodynamics are:

- design, analysis, simulation and optimization of thermodynamic systems and cycles,
- design, analysis, simulation and optimization of air conditioning systems, evaporative light cycle with liquid and solid absorbents,
- design, analysis, simulation and optimization of heat exchangers,
- simulation and optimization of air conditioning units with solar thermal systems,
- design, analysis, simulation and optimization of refrigeration units and combined units injector absorption – injector,
- thermodynamic analysis of irreversible processes of biphasic binary mixture.

Section of Mechanical Design & Automatic Control

The main research areas of the current section concern topics regarding Mechanical engineering drawing, tolerances and fits, Design for manufacturing and for cost, Systematics of design, Machine elements, Hydraulics and pneumatics, Mechanisms, Dynamics of linear and non-linear systems, Machine dynamics and application, Rotor dynamics and balancing, elastic foundations of machines, Statics and dynamics of mechanical structures, Fatigue, Computational methods in structural analysis, finite and boundary elements, Metal light structures, Control systems theory and applications, Applied control, Robotics, Mechatronics, Aerospace dynamics and subsystems, Conveyors and elevators, Vehicle dynamics, Mechanics of tires, Technology of vehicles and their subsystems, Vehicle design, Processing of dynamic signal, Industrial measurements.

The section of Mechanical Design and Automatic Control comprises the following laboratories:

- Biomedical Systems Laboratory,
- Laboratory of Automatic Control & Machine and Plant Regulation,
- Laboratory of Dynamics and Structures,
- Laboratory of Vehicles,
- Laboratory of Machine Elements and Dynamics,
- Rapid Prototyping & Tooling – Reverse Engineering Laboratory.

Biomedical Systems Laboratory

Biomedical System Laboratory is a multidisciplinary research laboratory at the National Technical University of Athens composed of engineers, biologists and physicians working in the area of Systems Biology and Bioengineering. The main aim is to apply novel biological and engineering approaches for modelling biological systems, medical devices for proteomic profiling, and assay automation with applications in drug discovery and medical devices. The research also includes the design and build custom devices. Finally, biomechanics is employed for monitoring tissue mechanical properties in-vitro and real time.

Laboratory of Automatic Control & Machine and Plant Regulation

The main research topics of Robotics & Mechatronics problems lying in the exciting intersection of Mechanical / Aerospace, Electrical & Computer Engineering fields. In order to realistically address those types of problems we, mostly but not exclusively, adopt control theoretic concepts and utilize or develop analytic approaches coming from both the continuous and discrete domains. More specifically, our current research interests are in the area of applications of Nonlinear Control and Real Time Embedded Control Systems in Sensor Based Motion Planning & Control of multi-agent Robotic Systems: Manipulators & Vehicles (Mobile, Underwater and Aerial) and Bio – Mechatronics.

Vehicles Laboratory

The Vehicles Laboratory of N.T.U.A. in its current form was established by the legislation in 2001 is active on various areas regarding:

- Structural Analysis and Dynamic Behaviour of Vehicles,
- Suspension Systems of Vehicles,
- Electric and Hybrid Vehicles,
- Vehicles with Four Wheel Steering System.

The Vehicles Laboratory supports core and master courses providing laboratory exercises to more than two hundred students annually. Furthermore, it gives students the ability to conduct Diploma, Master, Doctorate and Postdoctoral Thesis under its supervision. It participates in research programs and provides services in the Domestic Construction Industry of Vehicles and Constructions. Since 2008 the Vehicles Laboratory provides theoretical and technical support to the Formula Student/ S.A.E of N.T.U.A.

The research areas can be summarized in the following topics:

- Optimum Design & implementation of mechanical constructions,
- Simulation – Vehicle Dynamics,
- Experimental identification of typical technical quantities of heavy vehicles,
- Traffic accident reconstruction.

Section of Nuclear Engineering

The main research areas of the current section concern topics regarding:

- Theory of nuclear fission reactors,
- Set-up and operation of nuclear power plants,
- Thermodynamic and thermohydraulic analysis of nuclear power reactors,
- Nuclear fusion,
- Materials for nuclear reactors,
- Interaction of radiation with matter, radioactivity detection methods, radiation shielding, radiation protection and dispersion of radioactive pollutants to the environment,

- Measurements of radioactive trace elements and detection of nuclear radiations.
- Technological applications of nuclear radiations,
- Measurements statistics, correlations, design of experiments and experiments simulation, experimental set-ups on-line to computers.

Moreover, the Section has able laboratory space and facilities for the training of the students and for research work on various of the above-mentioned subjects.

The section of Nuclear Engineering comprises the following laboratories:

- Laboratory of Nuclear Engineering,
- Laboratory of Engineering Measurements.

Laboratory of Nuclear Engineering

The research topics of the Nuclear Engineering laboratory include in brief:

- Low level Gamma Spectroscopy,
- Low level – low energy (5-200 keV) Gamma Spectroscopy,
- Two phase flow heat transfer in Nuclear Reactors with emphasis on transient phenomena,
- Investigation of the properties of thin liquid films during free isothermal and non-isothermal flow,
- Investigation into the relationship between Radon sources in the soil and indoor Radon concentration in Greek dwellings (in collaboration with the University of Athens),
- Continuous monitoring of Radon gamma-emitting daughters outdoors,
- Alpha Spectroscopy using PIPS detectors,
- Radon exhalation measurements of building materials and structural modules,
- Radon concentration measurements in soil gas,
- Neutron Activation analysis using Am-Be neutron source,
- X-Ray Fluorescence Analysis (XRF),
- Development of Unix Software for the Analysis of complex alpha and gamma spectra,
- Development of Computer Codes and GIS for mapping of Radiometric Data,
- Development of Hardware and Software techniques for Real-Time Data Acquisition Applications,
- Industrial Radiography.

Section of Fluids

The section of Fluids covers a wide range of subjects. Namely:

- Fluid properties and definitions (density, compressibility, viscosity),
- The fundamental laws of fluid mechanics,
- Ideal-fluid flow, boundary layer concepts, adiabatic flow, non-steady flow, shock waves, flow in pipes, hydraulic transient and water hammer,

- Energy conversion in turbomachinery and theory of turbomachines, hydraulic and thermal,
- Airfoil theories, cascades, subsonic and supersonic flow,
- Flight theory, propulsion systems,
- Environmental fluid mechanics,
- Bio-fluid mechanics, non-newtonian fluids.

Fluid section comprises the following laboratories:

- Laboratory of Aerodynamics,
- Laboratory of Bioengineering
- Laboratory for Innovative Environmental Technologies
- Laboratory of Thermal Turbomachines
- Laboratory of Hydraulic Machines

Laboratory of Aerodynamics

Main objective of the educational and research activities of the Laboratory of Aerodynamics is the experimental and theoretical (computational) analysis of flow problems that cover a broad range of applications. The Laboratory of aerodynamics since its foundation has actively participated in several Research projects, National and International (especially European). The continuous and systematic research activity on various research topics/applications has led to a numerous Journal and Conference publications. In parallel the laboratory is also active in providing consultancy services to the public or private sector (organizations, utilities and enterprises). The main research activities can be listed as:

- Aerodynamic Analysis and Aeroelasticity,
- Wind farms wake analysis/assessment,
- Aeroacoustics,
- Wind turbine noise emission and propagation,
- Design of Airfoils and Rotors,
- Internal Combustion Aerodynamics,
- Two-phase isothermal flows,
- Two-phase non-isothermal flows,
- Fundamental fluid mechanics experiments,
- Aeronautic and wind energy related experiments,
- Environmental and industrial experiments,
- Vehicle experiments,
- Flow control experiments,
- Biofluid experiments,
- [Go to Home Page](#),
- 3D flow separation on plane wing,
- Experimental and computational study of 3D separation and separation control using vortex generators.

Laboratory for Innovative Environmental Technologies

The Laboratory for Innovative Environmental Technologies belongs to the Fluids Section of the School of Mechanical Engineering, National Technical University of Athens.

Its mission is to support the educational scope of the School in the field of fluid flow specific to Environmental Technology applications, develop research activities in the field of Environmental Technology, collaborate with research and academic institutions whose scope is relevant or complementary to that of the Laboratory, collaborate with public entities and other social or scientific bodies and provide services to industry.

Laboratory of Thermal Turbomachines

The laboratory of Thermal Turbomachines has a substantial and modern infrastructure in a number of turbomachinery related research areas. It hosts a strong research group that works under contract and/or in collaboration for contract work with industrial outfits and organizations. Extensive research in the field of gas turbine performance modelling and diagnostics has resulted in comprehensive engine models for a large variety of engine configurations and the establishment of new diagnostic methods. Being part of a higher education institution, LTT supports a number of undergraduate and postgraduate courses and continually transfers the knowledge gained from research to educational activities.

Current research activities are oriented towards the advancement of diagnostic techniques, with the aim of increasing reliability of automated procedures and reduction of the impact of uncertainty factors introduced by the operating environment of gas turbines. Sample areas of activity are:

- development of probabilistic methods for gas turbine diagnostics,
- advanced diagnostics using Fusion methods,
- non-linear methods for on-board jet engine diagnostics,
- modelling of humidity and water injection effects in gas turbines,
- real time engine models and their exploitation for diagnostics. Integration of developed methods into industrial diagnostic systems.

The gained experience can be seen from the publications in this domain together with a large number of citations, which reveal a large part of the scientific achievements of the group.

Laboratory of Hydraulic Turbomachines

The Lab of Hydraulic Turbomachines (LHYT) aims to promote education and research, and to provide high level services to the public and private sector in the scientific areas of Hydraulic Turbomachines and Installations. The laboratory participates in various funded research activities in the framework of national and European projects. The main activities of the laboratory are focused around both theoretical and experimental investigations of Hydraulic Turbomachines and their components. The main scientific and technological areas of interest of LHT are:

- Flow Analysis in Turbines and Pumps,
- Development of advanced computational techniques and software for flow modelling,
- Rotor-Stator Interaction,
- Numerical analysis of transient phenomena and study of unsteady flow mechanisms,
- Laboratory testing and experimental analysis of performance curves,
- Numerical design optimization,
- Free Surface Flows in Pelton Turbines,
- Calibration of measuring instrumentation for Turbomachinery applications,
- Optimum sizing and design of pumping stations, hydraulic networks and small Hydroelectric Plants,
- Optimum design and optimum operation strategies of hybrid power production schemes from renewable sources with pumped storage.

The LHT conducts theoretical and applied research on a range of topics in the scientific area of hydraulic turbomachinery and hydraulic installations. The research activities are supported by PhD students, undergraduate students and scientific associates, and funded by public or private entities.

Section of Manufacturing Technology

The section of Manufacturing Technology and the corresponding Manufacturing Technology Lab (MTL) promotes the research in the fields of:

- Deformation Mechanics, Plasticity, Impact, Fracture,
- Manufacturing Processes (Metal forming, Metal removal processing, Casting, Powder metallurgy, Welding, Heat treatment, Dynamic deformation),
- Materials technology (Metals, Polymers, Ceramics, Composites),
- Machine tools (Friction/ Lubrication),
- Surface integrity, Structural plasticity/ Energy absorbing devices/ Crashworthiness,
- Manufacturing systems (Automation, Simulation, FMS, Robotics, CAM/CIM, Expert systems, Artificial intelligence),
- Workshop Technology,
- Metrology.

More specific the main topics of the research pertain:

Engineering Materials. The engineering materials are used in the construction of manmade structures and components. An engineering material should be able to withstand the applied loading without permanent failure and/or without being excessively deformed. The most important types of engineering materials include: metals, polymers, ceramics and composites.

MTL is actively engaged in researching the following areas related to engineering materials: Crashworthiness, Coatings, Development of novel materials and Smart materials.

Machine Tools. Machine tools are fundamental in the modern manufacturing industry and often dictate the technological capabilities of any company.

MTL is actively engaged in researching the following areas related to machine tools: Metrology of machine tools, 3D Printing, Path planning, Automation of composites manufacturing.

Manufacturing Processes. A manufacturing process involves a series of steps that transforms raw-materials into finished parts or products. MTL is actively engaged in researching the following areas related to manufacturing processes: High precision processes, Powder based processes, Plasticity, Numerical simulation, Modelling and optimization.

Manufacturing Systems. A manufacturing system can be defined as a transformation of various inputs (materials, equipment, people, information etc.) to various outputs (tangible or intangible products) whose value depends on their functionality, quantity, quality etc. This transformation needs to be able to be performed efficiently using measurable indices and criteria.

MTL is actively engaged in researching the following areas related to manufacturing systems: Process planning, Automated quality control, Control of manufacturing systems, Virtual and Augmented Reality, Human-Robot collaboration.

1.3. Hochschule Furtwangen University

1.3.1. General information

As one of Germany's leading universities, Furtwangen University (HFU) is recognised for its excellence in the following areas:

- high quality and innovation in teaching,
- strong practical focus through collaboration with industry,
- international focus,
- applied research,
- continuing education and lifelong learning,
- cooperation and motivation,
- social responsibility and safeguarding of the future.

Furtwangen University's core focus is on employment-oriented education and training based on academic principles. Traditional boundaries between subject fields are removed in interdisciplinary projects. HFU is a leader in the specialist areas of engineering, computer science, information systems and management, business administration and engineering, media, international business and health.

Our university understands the importance of cooperation and strong partnerships with industry. Ongoing information exchange with our partners in companies and organisations

guarantees a practical focus in teaching, research and professional development. We also work with those partners to develop new study programme models and relevant funding programmes for our students.

We support international education, research and cultural exchange by working in collaboration with universities and companies around the world. We develop our degree programmes with a focus on international opportunities and demands, and guarantee that they will be recognised around the world. The inclusion of international developments in our course content and the teaching of foreign languages and intercultural skills, as well as the provision of funding for travel abroad, all help to prepare graduates for work in an international environment. Our international profile is further strengthened by our worldwide collaborations and partnerships: study modules abroad; joint-degree agreements; recruitment of international students, staff and professors; and international research cooperation agreements.

We actively support cooperation between our university and partner companies in the area of applied research and technology transfer as it is an essential catalyst for innovation and the sustained relevance of our teaching. Lecturers are actively involved in application-oriented research, development and project work ensuring the relevance and quality of course content. Both students and companies are also encouraged to take advantage of results.

Our university enthusiastically supports lifelong learning, offering continuing education courses for academic and professional qualifications. We explore new approaches and develop innovative, customer-oriented programs and courses for companies, organizations and graduates.

We are experts in crossing borders: in cooperative work between students, staff, and professors; in interdisciplinary projects bringing together different faculties and departments within the university; and between teaching, research and professional development. Our visiting lecturers act as important links between the university and industry. A focus on service, transparency and continuous improvement characterizes all processes throughout our university. Motivation, personal aptitude and professional dedication, as well as research and development experience, all guarantee academic and technical expertise.

1.3.2. Institute of Precision Machining

For more than 20 years, the Institute of Precision Machining (KSF) has been dealing with the constantly growing problems in the machining of new materials and the increasing demands on machining, mainly in the field of grinding process, but also in the field of unconventional machining processes (vibration- and laser-assisted). In addition to research, teaching is an important field of activity, and we also offer the possibility of doctoral studies. We provide our industrial partners from Germany and abroad with concrete and innovative approaches to solutions for practical problems. In the working group "Grinding Technology", founded in

1997, currently about 25 and in the working group "Carbide, Ceramics", founded in 2015, more than 10 renowned companies are working together with the aim to optimize and further develop specific manufacturing processes. The activities of KSF might be listed as follows:

- optimization of chip removal finishing processes (geometrically defined and undefined cutting edges),
- optimization of precision machining,
- solution approaches in machining and grinding processes for industry,
- tool and machine tools development,
- organization of training seminars for industry,
- training and supervision of students through their projects and final thesis (bachelor and master),
- awarding and supervision of PhD thesis,
- cooperation with other research institutes worldwide,
- literature research for industrial partners.

Training programs for industry

KSF offers two training programs for industry including:

- Grinding and dressing technology: In this program experts from industrial sections participate to gain practical and theoretical knowledge in the field of grinding and dressing. This course is divided into two sections including theoretical fundamentals of the grinding and dressing process and practical training of this process held at the workshop on the grinding machines.
- External cylindrical grinding: Due to the complexity of cylindrical grinding operation, a special training course was planned at KSF for industry. Like the grinding and dressing course, this training course composes of both theoretical and practical section.

Courses offered by KSF

The following courses are presented by KSF for bachelor and master students:

- Manufacturing technology I and II,
- Machine tools,
- Precision manufacturing,
- Precision measurement systems,
- Design of mechanical elements,
- Fundamentals of mechanical engineering II.

Research and scientific activities

The KSF is divided into three main groups in the research activities including:

- Machining technology: High speed cutting, micro machining, non-conventional machining, difficult to cut materials, tool geometry, sustainable and green manufacturing, modelling of process,
- Grinding and precision manufacturing: High efficiency deep grinding, difficult to cut materials, micro grinding, non-conventional grinding and hybrid manufacturing, dry grinding, modelling of grinding process, measurement systems and process monitoring,
- Laser technology: micro structuring, conditioning of grinding tools, functional surfaces, hybrid machining, and additive manufacturing.

Study program

The KSF institute also offers a master study program, Precision Manufacturing and Management, from 2020, which is a career-oriented program to teach both technical and management skills. The integrated research modules link KSF's very strong research capability to the master's program.

FELIX, ELearning program of HFU

FELIX stands for Furtwangen ELearning and Information eXchange and is the university's central learning platform. Students can find instructional materials around events as well as important information and announcements from faculty and service institutions in FELIX. FELIX supports teachers in the organization of teaching and helps with communication between teachers and students. The following possibilities are offered by FELIX through following three main tabs:

- Groups: offers the ability to create groups with other HFU members. You will also find groups there in which you are already a member.
- In the "Courses" tab the students can find their courses. For students this is the most important FELIX tab.
- In the "VidCo" tab information about the online conference systems in use at HFU can be found.

1.4. Centoform s.r.l.

CENTOFORM, set up in 2001, is a Vocational and Education Training Centre (VET) recognized with Quality Accreditation on training by Emilia Romagna Region, Italy, a region characterized by a strong dynamic economy with a sectoral focus on Mechanical engineering and important university research networks. During 19 years of activity the VET Centre created an operative multiregional and international network with SMEs, public institutions, VET schools, social partners, universities, and R&D centres.

It is a partner of Confindustria, the main Italian industrial association, and it works in collaboration with representatives and clusters of productive sectors at national and European level. It operates in 2 Italian regions: Emilia-Romagna (Northern competitiveness region) and Apulia Region (Southern convergence region).

The staff (23 employees and 13 external professionals) is composed of VET senior project managers, administrative staff, senior and junior consultants with expertise in training, career guidance, tutorship in apprenticeships, research, management and financial reporting of Italian, European and international funds, and projects.

Centoform main activities are the following:

- Design and delivery of vocational training courses and programmes financed by the European Social Fund (ESF), on the market and interprofessional Italian funds,
- Design of orientation projects for youth and enterprises in job market and training related issues (apprenticeship, WBL): Centoform deals with apprenticeship-related projects for young people and other forms of in-company training since several years. Since 2016 Centoform is an official member of EAfA – European Alliance for Apprenticeships,
- It works on the development of WBL and Dual System in VET and schools through the coordination of a local network of schools and companies applying WBL as learning approach to education,
- Partnership and Network building at national and international level. Design and management of International projects: Centoform is involved as applicant and partner in several Erasmus+ KA2 VET Strategic Partnerships projects running from 2015, either on Innovation and Exchange of good practices in VET and in Higher Education. Since 2018 Centoform is also an official member of the regional Europe Direct Network 2018-2020.

IFTS Training Programme in Mechanical Design “Technician for Mechanical Design and Industrial Design”

Centoform is the coordinator of IFTS (Istruzione e Formazione Tecnica Superiore) training programme in Mechanical Design “Technician for Mechanical Design and Industrial Design” held in Cento (FE). It is a post-secondary education course (EQF Level IV), financed by ESF regional funds, that releases a High Technical Specialization Certificate in Drawing Techniques and Industrial Design. IFTS aims at strengthening technical and technological skills and know-how. The course lasts 800 hours: 480 hours of lectures, 300 hours of internship and 20 hours for Project Work. The curriculum includes basic technical and scientific subjects, practical applications, training periods at private companies or public bodies, other professionally oriented activities, and real work experience. The course can be accessed by young people and adults, and more generally by those who do not hold a secondary school diploma, have fulfilled compulsory education and training, or do not hold any certification and are willing to acquire competences in professional settings or develop useful skills for professional retraining. The topics covered are the following: Manual technical drawing; CAD mechanical design using Solidworks and any second software (NX or Inventor); Virtual Product Design (VDP) and Smart Manufacturing applied to machines; Feasibility and functional requirements of mechanical products; Prototyping and Styling; Lean Thinking and Lean Production; Circular economy: Design for Manufacturing/Disassembly/Recycling; Security Elements; English language; Technical informatics.

ITS TEC Foundation Training Programme in Energy Efficiency “Higher technician for sustainability and energy efficiency of the building-territory system - BIM executive design”

Centoform is a founder member of ITS TEC (Istituto Tecnico Superiore Territorio Energia Costruire) Foundation course “Superior technician for sustainability and energy efficiency of buildings - Executive BIM design” held in Ferrara.

ITS TEC Foundation is part of the national network of Higher Technical Institutes (ITS), new technology schools that offer biennial post-diploma courses (tertiary non-academic education – EQF level 5), alternative to the university but connected to it, to form the upper classes to enter the strategic sectors of the economic-production system, maintaining highly specialized skills and innovation capacity in companies.

ITS is composed of high technical schools, universities, companies, public authorities, research centers and training centers. In Emilia-Romagna there are 7 ITS Foundations which are part of the Polytechnic Network, created with the aim of enhancing the professional, technical, technological and scientific culture and intercepting and responding promptly and effectively to the requests for skills of the production system in the technological areas strategic for economic development and competitiveness. The Foundations issue the Diploma of Higher Technician in the technological areas defined by national law, level 5 EQF (European Qualifications Framework).

Based on the regional planning, the ITS Territory-Energy-Building Foundation carries out 2 courses in the technological area of energy efficiency:

- A.** The course to obtain the diploma of "Higher technician for sustainability and energy efficiency of the building-territory system - BIM executive design" (site of Ferrara). It lasts 2000 hours: 1200 hours of lectures, laboratory exercises and project work (20 hours) and 800 hours of internship. The covered topics are: analysis, design and professional realization of buildings by applying the method and technologies of green buildings; management of activities related to BIM design, energy saving and evaluation, energy certification, high efficiency building envelopes, thermotechnical plants powered with alternative energies, environmental impact assessment, integration of different construction technologies, construction process optimization adopting efficiency, quality, safety and reduction of the environmental impact criteria.
- B.** The course to obtain the diploma of "Higher technician for the management of sustainable energy systems 4.0" (site of Ravenna).

IFTS Training Programme in Circular Economy “Junior Expert in Circular Economy”

The new blended learning course “Junior Expert in Circular Economy” (EQF level 4) trains 25 European young people who are qualified with a school diploma (e.g. upper secondary school, or vocational school certificates) and preferably are neither in employment nor education or training.

The course equips the participants with the necessary tools and skills needed for sustainable development and circular transition in economy and society. Following the 3 Rs (reduce, reuse

and recycle), they gain skills in the analysis, evaluation and improvement of manufacturing processes, impact assessment methods, total quality management for environmental sustainability, entrepreneurship and digital literacy.

The course is taught in English and is composed of 800 hours: 480 hours of interactive online classes complemented with a live training in Ferrara, Italy (currently scheduled for September-October 2021) and 320 hours of internship (currently scheduled for June-August 2021).

2. Ways of linking the education process with scientific research – current state

2.1. Rzeszow University of Technology

Full-time students

At the Rzeszow University of Technology, there are no top-down conditions regarding the way of combining research results with teaching activities. However academic teachers try to follow a widely accepted model of the four ways of linking research and teaching [2.1].

This model identifies the following forms of research-based learning [2.2]:

- Research-led: where students learn about research findings, the curriculum content is dominated by faculty research interests, and information transmission is the main teaching mode,
- Research-oriented: where students learn about research processes, the curriculum emphasizes as much the processes by which knowledge is produced as learning knowledge that has been achieved, and faculty try to engender a research ethos through their teaching,
- Research-based: where students learn as researchers, the curriculum is largely designed around inquiry-based activities, and the division of roles between teacher and student is minimized,
- Research tutored: where students learn in small group discussions with a teacher about research findings.

Based on the presented model, linking the education process with scientific research at Rzeszow University of Technology takes place mainly through:

- conducting scientific research by academic teachers and sharing them with students (information from articles written and read by teachers, knowledge obtained from participation in conferences, etc., providing students with access to various databases containing books and articles with the results of the latest scientific research),
- engaging students in their own research and / or research carried out by other academic employees (activities in student's scientific clubs, writing joint articles, carrying out research-based diploma theses),
- implementation of research results into newly created or modernized education programs.

Most of the teachers agree that the level of implementation of scientific work to the education process depends directly on the lecturer's approach and the resources provided. The limitations in availability of research resources is one of the main problems in 'practical'

implementation of research results. In many cases, the equipment assigned to research and teaching varies significantly. Furthermore, companies which often cooperate with the university, are not willing to provide didactic aids, which would result in the use of the researcher-teacher of results in real production. Another serious limitation is that some of the teaching subjects may not be directly related to the teacher's research interests. In general, scientific work often requires a lot of learning from various disciplines (areas) that may not be part of the taught subjects and in many cases may exceed it. For each teacher, some activities may be correlated with scientific work and others may not.

Erasmus students

Scientific research conducted by employees of the Rzeszow University of Technology are also used during the didactic process with Erasmus+ students. They can be divided into 4 basic groups:

A. Employees' own research – the results of scientific research and scientific experiments used in the didactic process are the result of employees' own research and research resulting from the implementation of doctoral and habilitation theses.

- research of energy saving possibilities in a car with a recovery system in a real transient cycle,
- visualization of the boundary layer flow around the glider wing infrared,
- air quality (during the research, the air quality was analysed on the basis of tests from the pollution monitoring stations in Rzeszow and Bilbao, as well as on the basis of students' own research).

B. Scientific research as a result of research and development works (B+R), for example:

- experimental modal analysis of beam and the turbine blade using the Unholtz-Dickie vibration system,
- experimental material tests of samples made of steel and aluminium alloy,
- experimental analysis of the velocity of the fatigue crack propagation in a compressor blade subjected to resonant vibrations.

C. Scientific results obtained during the implementation of European grants, for example:

- Project: Integrated Ground and on-Board system for Support of the Aircraft Safe Take-off and Landing, GABRIEL, Grant agreement No 284884. The research covers the optimization of the trajectory of transport aircraft during the take-off and climb phase to cruising altitude, minimizing CO₂ and noise emissions,
- Project: SESAR 2020 PJ06 ToBeFREE, Trajectory based Free Routing, Grant agreement No 734129. Results regarding the optimization of light transport aircraft routes in the Free Route Airspace (FRA) controlled space,

- Project: SESAR 2020 PJ10 PROSA, IFR RPAS Integration, Grant agreement No 734143. Analysis of the possibility of integrating light unmanned aerial vehicles with manned flights in the controlled space of communication airports (TMA - Terminal Manoeuvring Area).

D. Scientific research conducted at the student's request, e.g. necessary for the completion of the diploma thesis. During their studies at the Rzeszow University of Technology, students carried out a significant amount of research in line with their interests. The result of these studies in most cases was a positive implementation of diploma theses. Examples of such topics are as follows:

- identification of flow conditions in micro scale centrifugal compressors using computational fluid dynamics,
- airplane control in the absence of some measurement signals,
- analysis of the causes of operational failures of selected components of airplanes and aircraft engines.

2.2. National Technical University of Athens

Full-time students

Regarding full-time studies in the National Technical University of Athens (NTUA), systematic relationship between research results and teaching activities does not exist. However, cells of research do exist throughout the university schools and laboratories, being occasionally incorporated in the teaching process. Such examples of linkage between the education process and scientific research are:

- optional courses with highly specialized subjects in which the teaching staff shares part of their own scientific research. These courses are available during the last two years of undergraduate studies (studies in NTUA are five years),
- laboratory exercises aiming to familiarize students with new technologies,
- seminars from specialists guests from the industry domain incorporated in subject related courses,
- visits organized in industrial facilities related to the context of courses, giving students an insight to cutting-edge technologies.

Auxiliary activities existing in the NTUA that link the education process with scientific research are:

- courses with specific emphasis in innovation in a wide range of subjects e.g. “Design of Innovative Mechanical Products” provided at the 9th semester of the School of Mechanical Engineering,

- special emphasis on the innovative character of the diploma theses,
- innovation competitions, e.g. “Green Challenge 2020, held for NTUA students and annual awards given from schools for the most innovative works,
- students groups with innovative orientation like Prom Racing, Board of European Students of Technology (BEST), Prometheus ECO Racing NTUA, White Noise Team, Euroavia and others.

Most of the teaching staff and the students agree that a more potent connection between the education process and scientific research needs to be established. However, limited research resources and lack of adequate equipment can cause serious limitations in some cases. Moreover, not all courses are equally easy to be connected with the scientific research of the teacher, and a more versatile approach should be utilized in order to systematically include research results within the course contents.

Another aspect that should be taken into account regarding the linking of the education process with scientific research is the role of companies that cooperate with the university. The character of their cooperation is not mainly based on the education of the university students, which can arise from mutual research results. On the contrary, companies usually benefit from the scientific work that is produced by university students, without helping them to upgrade their education level. Finally, in a few cases, some teaching approaches may exclude the linkage of the education process with scientific work.

Erasmus+ students and interns from abroad

Research outcome of NTUA teaching staff is also used in didactic processes with Erasmus+ students and interns from abroad. Some of the most significant are:

- Several courses are conducted in the English language.
- Interns from all over the world conduct research in various subjects at NTUA.
- Several educational Erasmus+ projects e.g.: “Giving A Voice to Deaf People in Metal Sector”, with reference **2019-1-TR01-KA202-076675**.
- Participation in the process of creating scientific work and publishing their work in scientific journals.
- Development of special software, such as the use of gamification in engineering education and training [2.3].
- Participation in various international workshops and conferences.
- Hosting events fueled by latest scientific research, like “CO₂OLING THE EARTH SUMMER SCHOOL II”.

2.3. Hochschule Furtwangen University

Full-time students

There is no regular connection between the education process and scientific research at the Hochschule Furtwangen University (HFU). However, full time students at HFU may get know with the scientific research activities through the following approaches:

- Conducting their bachelor or master thesis or their research works at the research centers of HFU, during which they will be committed in a part of the current research projects.
- Participating in the training courses, which are held at the research centers. In these courses the latest results of the scientific research are presented.
- Laboratory exercises at the research center of HFU.
- The seminars organized by both UFH and Industry. In these seminars, the students will get an overview of the latest advances in technology.

The full time students also may get known with the last scientific results in the regular courses during a semester. In this regards the professors which are active in research will combine their course materials with the latest results of their own scientific research. Although this depends on the teaching method of the professor and is not a defined method. The following courses are some examples of such courses:

- Production techniques (Fertigungstechnik): in this course the latest research activities in the field of machining and grinding process are presented in addition to the fundamentals of production techniques. This course is closely connected with the activities in the KSF institute at the HFU. The KSF is also active in the field of online monitoring of the machining and grinding processes and the research results are presented in the courses by the corresponding professor, who is the leader of the KSF institute.
- Precision manufacturing: it is attempted to update the material being presented in each semester with the latest methods of the manufacturing from other researches in the world.
- Machine tools: the fundamental of machine tools are the focus of this course, which is combined with some innovative developments in the machine tools from other researchers or industrial sections.

In general, depending on the lecturer, the level of connection between training and scientific results can vary. In many cases the scientific results are lacking in training courses. Some of the reasons in this regard are as follows:

- the lack of a platform, which enhances the contribution of research staff in training process,
- a training discipline has not yet been established to teach, present, and share the latest scientific and applied science achievements,
- confidential agreement between the research institute and industrial partners.

In this regard, an approach to link the education process with the scientific research seems to be essential.

Erasmus+ students

The students spending some part of their education at HFU under the Erasmus+ program can also participate in scientific research activities through the following activities:

- the English language courses and seminars at the research institutes of HFU,
- performing their final thesis (bachelor or master) in the research area of HFU,
- participating in scientific research projects as the part time students who contribute partially in the project procedure.

2.4. Universities in Italy

In Italy the Law no. 240 of 30th December 2010 named 'Rules on the organisation of universities, academic staff and recruitment, as well as delegation of powers to the Government to incentivise the quality and efficiency of the university system' claims that Universities are the primary site of free research and free education within their respective systems and are places of learning and critical processing of knowledge; they operate organically combining research and education for the cultural, civil and economic progress of the Italian Republic.

Moreover, Article 5 defines Universities as 'facilities of residential character, of national importance and of high cultural qualification, which provide students with educational and guidance services and integrate the educational programme of universities'. Despite this, in Italian universities scientific research is not very well connected to the education processes. Current research findings are not usually included in traditional lectures and students do not usually receive a training on how to perform and implement research.

Schools provide entry-level skills for the university system, thus linking to the education-research-innovation triangle. International comparative studies have shown a connection between the outcomes of different levels of educational systems, indicating that to improve tertiary education outcomes, educational policies should also consider inadequacies in earlier levels of education.

Higher education, both undergraduate and postgraduate, represents the basis of the more comprehensive research and innovation system. In 2016, tertiary education levels in Italy were among the lowest compared to the average of European countries: the share of

graduates in the 30-34 age group is 26% of the population against a European average of 39% (Eurostat 2017[2.4]). Also PhDs, the highest level of tertiary education, play a crucial role in driving innovation and supporting economic growth. In terms of the number of people with a Ph.D. degree, Italy is at the bottom of the ranking [2.5].

Furthermore, Italy does invest less than other European countries so much in scientific research. The Italian system presents some critical issues, such as the insufficient aptitude for the application of results and collaboration of companies, which find difficult to link their own research activity with input from public research centre. The motivation may also lie in a certain resistance of Italian public research to adopt new organizational models and new incentive mechanisms, as happens in other countries, and by the limited investment by companies in research and development activities [2.6].

Finally, Italy is characterized by a considerable fragmentation of the R&D system and an overlapping between the actions developed. The same fragmentation also concerns the sources of research funding. In short, the governance of the public research system, meant as methods and managerial tools aimed at integrating and coordinating the processes of generation, dissemination and application of knowledge, appears poorly structured, making it difficult to achieve the strategic objectives for the Country.

Full-time students

Italian university students usually get in contact with research mainly in the following cases:

- laboratory exercises at the research centers of the various departments,
- participation to research projects implemented by their professors (however, this depends on the professor only),
- participation to seminars and exhibitions organized by universities, companies and business support associations,
- conduction of their bachelor or master thesis of their research work supported by a professor,
- optional courses focused on research methods,
- during the internship to be realized within the bachelor's or master's degree.

For example, the research activities of the **Engineering Department of the University of Ferrara (ENDIF)**, one of the main universities with whom Centoform VET centre collaborates, cover a wide spectrum of research fields and this is undoubtedly one of the strengths of the Department allowing to access a large number of opportunities for research funding.

Researches address both theoretical and experimental issues and activities and some of them involve the two anechoic chambers: one for electromagnetic compatibility and immunity and one for applied acoustic and vibro-acoustic investigations.

Students of the Bachelor's and Master's Degree, interested in carrying out a thesis in which the use of National Instruments technologies will be required, belonging to the Department, will be able to register for free in training courses provided by the Company at its Training

Centres as part of the LabVIEW Staff Program. The training activities are carried out with Certified National Instruments staff.

The University of Bologna, one of the most important Universities in Italy, offers within its Engineering Department, Bachelor and Master Degree's courses with practice laboratories. For instance, the Master's Degree in Automation Engineering [2.7] has laboratory for industrial robotics and a laboratory for business plans development, where students can exercise in transforming a research in an entrepreneurial opportunity. The Architecture Department has some interdisciplinary laboratories and supporting tools for researchers and PhD students. One of these is the DiMoRe (Digital Modeling and Virtual Representation), a laboratory that provides support to the teaching activities of the degree courses of the Department of Architecture and of the PhD in Architecture and Design Cultures [2.8].

In addition, the University of Bologna also provides an incubator for spin-off and start-up [2.9], which support students, from all Departments, to transform their ideas into business project and matching opportunities with local enterprises.

The University of Roma Tre, over the past few years, has significantly increased its interest in the issues of themes of economic exploitation of academic research and the link with the business world. The interest, in fact, has focused mainly on activities that use research results as a distinctive element and that find their natural outlet in the organizational form of enterprise as opposed to the current management forms of university activities. Therefore, on the basis of these principles, the University of Roma Tre has launched a plan for the administrative, organizational and financial support of the initiatives, identifying mechanisms to stimulate the design of new businesses and/or forms of technology transfer and providing elements for assessing the degree of "economic maturity" of new initiatives that, directly linked to research carried out in the University, could be subjected primarily to internal assessment for the connotation of spin-offs of the University. The outcome of this process has led to the establishment of three spin-offs, CHITechnologies Srl, MBS Srl and TRS Srl - operating respectively in the ICT, Biotech and Security sectors - whose structure is characterized, in addition to the presence of the University itself and some of its researchers, also for the participation of industrial partners and seed funds [2.10].

Erasmus+ students

Incoming students can attend classes from Bachelor's degrees and Master's degrees, carry out an internship or even work on the final thesis. They can come to Italian universities for a semester or a whole academic year.

They can participate in scientific research activities through the following activities:

- the English language courses and seminars at research institutes,
- perform their final thesis (bachelor or master) in the research area,
- participate in scientific research projects and publish their work in scientific journals.

2.5. General conclusions

Linking scientific research and teaching process is undoubtedly one of major topics of international interest. The links may take many different forms and may be found in all types of university. University authorities as well as University teachers are aware of the fact that the „teaching-research nexus” is central to higher education. However, there are a number of issues that should be taken into consideration and/or improvement:

- Despite being aware of this fact, systematic relationship between research results and teaching activities does not exist.
- There are important disciplinary variations in teaching-research relations that should be taken into account.
- How scientists understand teaching and research activities can be critical to understanding how they relate. Also the degree of staff involvement must not be neglected.
- It seems that the types of research and their connection with didactics should be adapted to the appropriate type of studies (first-cycle, second-cycle and doctoral studies).
- Effective teaching-research links are not automatic and have to be constructed.
- University resources should be taken into account. Institutions with different resources may have different views on the teaching-research linkage, which reflects their available resources.
- It seems that academic departments play a crucial role in developing the links between research in the discipline and student learning.

References

- [2.1] Healey, M., Jordan, F., Pell, B., Short, Ch.: The research–teaching nexus: a case study of students' awareness, experiences and perceptions of research. *Innovations in Education and Teaching International*, 2010, 47:2, pp. 235–246.
- [2.2] Obwegeser, N., Pantelis, M. Papadopoulos: Integrating research and teaching in the IS classroom: Benefits for teachers and students. *Journal of Information Systems Education*, 2016, 27(4), pp. 249–258.
- [2.3] Markopoulos A.P., Fragkou A., Kasidiaris P.D., Davim J.P.: Gamification in engineering education and professional training. *International Journal of Mechanical Engineering Education*, 2015, 43(2), pp. 118–131.
- [2.4] EUROSTAT, 2017. Education Administrative Data from 2013 Onwards. ISCED 2011. Codice database: educ_uoe_fine06.

- [2.5] National Committee for the Research (CNR), Research and Innovation Report, Science and Technology Policy Analysis and Data, 2018,
http://www2.dsu.cnr.it/relazione_ricerca_innovazione/volume/Relazione_sulla_ricerca_e_innovazione_in_Italia_webformat.pdf
- [2.6] Montanaro P, Torrini R., The public research system in Italy, 2014,
<https://www.bancaditalia.it/pubblicazioni/altri-atti-convegni/2014-innovazione-italia/Montanaro-Torrini.pdf>
- [2.7] Course structure diagrams for students enrolled a.y. 2020-21
<https://corsi.unibo.it/2cycle/AutomationEngineering/course-structure-diagram/piano/2021/8891/000/000/2020>
- [2.8] <https://da.unibo.it/it/ricerca/laboratori-di-ricerca>
- [2.9] <https://site.unibo.it/idea/en>
- [2.10] https://www2.crui.it/crui/osservatorio/3_GdL3_Rapporto%20Def.pdf
- [2.11] Italian Parliament, Legge 30 dicembre 2010, 240, Gazzetta Ufficiale, 10, 14th January 2011. Suppl. Ordinario, 11, <https://www.camera.it/parlam/leggi/10240l.htm>
- [2.12] University of Ferrara, Engineering Department of the University of Ferrara (ENDIF) – Research website, <https://de.unife.it/en/research>
- [2.13] Fondazione CRUI, The enhancement of scientific research: technology transfer offices (TTOs), university incubators, spin-offs/start-ups and patents/licenses.

3. The results of the surveys

EDURES project partners prepared and sent questions to four groups of people (students, academics, graduates and employers) in order to obtain knowledge regarding their opinions and expectations in the area of research results implementation in teaching. The chapter presents the abovementioned questions, responses of surveyed people and conclusions resulting from the surveys. It will help to develop further project results properly.

3.1. Surveys for students

3.1.1. Surveys content

The following questions were attached to the survey.

I am: **(single choice)**

- ☐ an undergraduate (a bachelor) student,
- ☐ a Master student,
- ☐ a PhD student.

Please indicate your discipline: **(single choice)**

- ☐ construction / civil engineering,
- ☐ mechanical engineering,
- ☐ other discipline in technical sciences,
- ☐ other discipline in non-technical sciences.

Please enter the name of the university you are studying at. **(open answer)**

Do you know any scientific research performed at your university? **(single choice)**

- ☐ yes, I know a lot of them,
- ☐ yes, I know only a few,
- ☐ no.

Which research results of your university would you like to know the most? **(single choice)**

- ☐ research results of individual researchers relevant to the course studied,
- ☐ research results relevant to local technological firms,
- ☐ research results which help me prepare my diploma thesis,
- ☐ research results of scientific groups,
- ☐ other.

What activities will prepare you for your future job which will require you to generate innovations? **(multiple choice)**

- ☐ lectures,
- ☐ classes,
- ☐ laboratories,
- ☐ projects,
- ☐ apprenticeships,
- ☐ student internships,
- ☐ participation in the activity of students' scientific groups,
- ☐ getting to know the results of research conducted at the University,
- ☐ performing lab exercises focused on research,
- ☐ thematic courses / seminars / webinars,
- ☐ participation in students' conferences,
- ☐ other.

How would you mostly like to use your research and your supervisor's research for the purposes of your future diploma thesis? **(single choice)**

- ☐ by the implementation of the diploma thesis results in the area of the supervisor's scientific interests who will guide me through my research activities,
- ☐ I would like to write a scientific paper,
- ☐ I would like to present my research and get to know the research of my supervisor during seminar/conference,
- ☐ I am not interested in research activities,
- ☐ other.

How do you rate the idea of building a website which will present results of scientific research carried out by University employees? **(single choice)**

- ☐ not at all important,
- ☐ slightly important,
- ☐ moderately important,
- ☐ very important,
- ☐ extremely important.

Do you agree to take part in classes partly based on recent research results? **(single choice)**

- ☐ disagree,
- ☐ somewhat disagree,
- ☐ neither agree or disagree,
- ☐ somewhat agree,
- ☐ agree.

Are you familiar with the student access to scientific articles of publishing houses available at your university? **(single choice)**

- ☐ Yes, I know about it and I know how to use it,
- ☐ Yes, I have heard about the access but I have never used it,
- ☐ No, I have not heard about it and I would like to know how to use it,
- ☐ No, I have not heard about it and I am not interested in such access.

What would you like to do, in the context of research, within your classes as a part of teaching programme? **(multiple choice)**

- ☐ I would like to take part in scientific investigations conducted at my university as part of my studies,
- ☐ I am interested in conducting research activities within my future diploma thesis,
- ☐ I am interested in preparation of scientific articles with other students and/or employees of my university,
- ☐ other.

Have you participated in classes which were based on results of scientific investigations? **(single choice)**

- ☐ yes,
- ☐ no,
- ☐ I do not know.

Do you think that presenting recent research results to students by academics is important? **(single choice)**

- ☐ not at all important,
- ☐ slightly important,
- ☐ moderately important,
- ☐ very important,
- ☐ extremely important.

What might allow you to know the research results of your University better? **(open question)**

3.1.2. Results of the survey for students

The chapter presents the results of the survey for students.

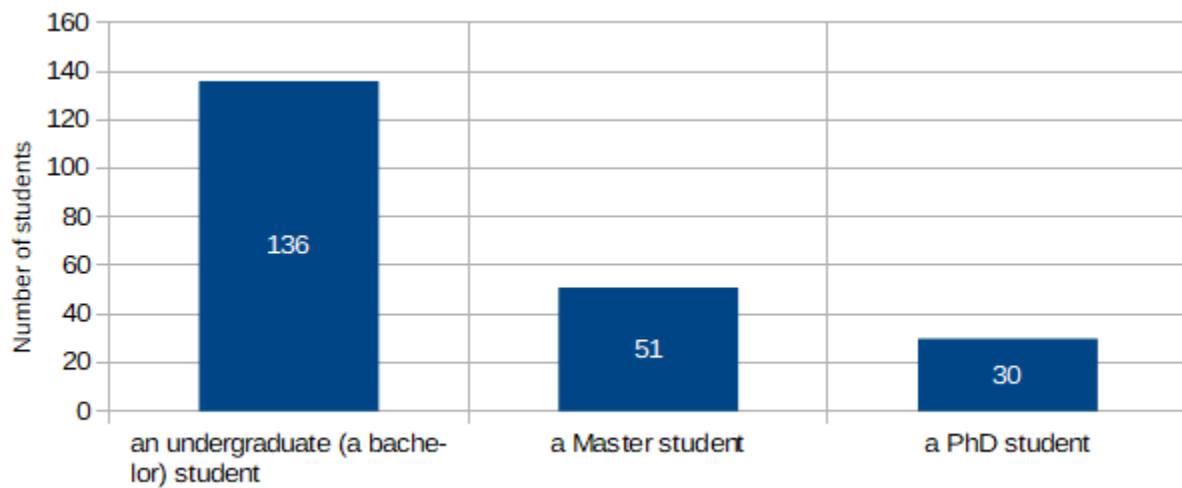


Figure 3.1. Academic degree of students who filled the survey

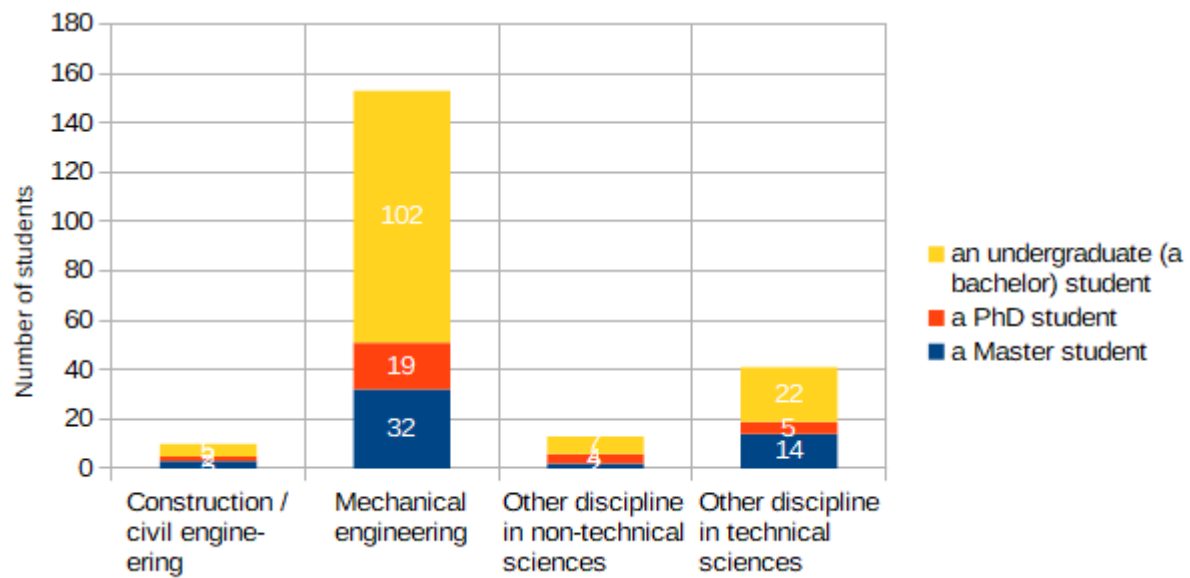


Figure 3.2. Discipline of students who filled the survey

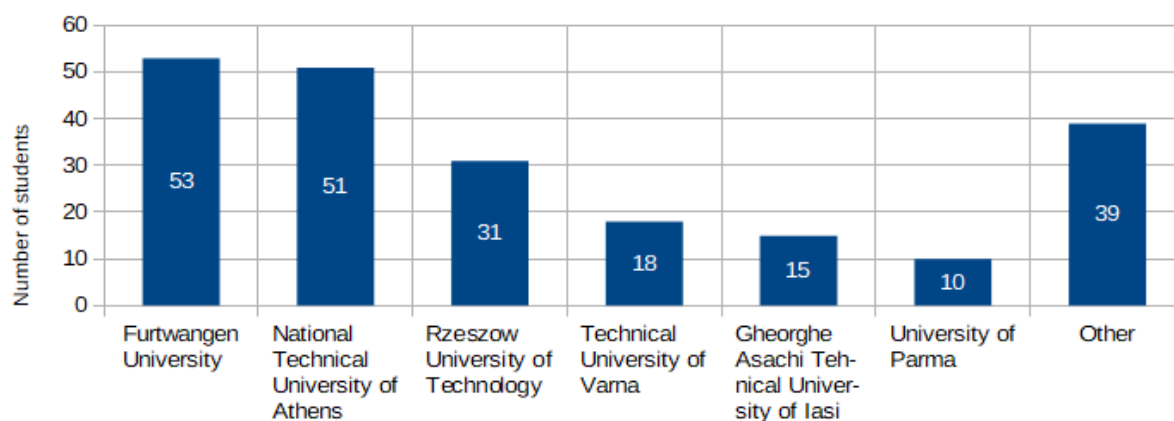


Figure 3.3. University of students who filled the survey

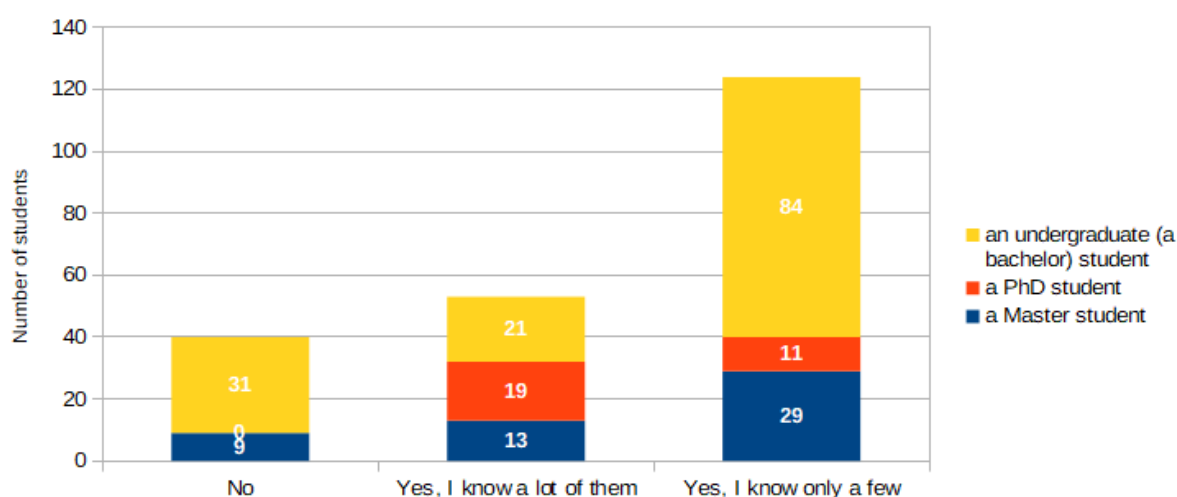


Figure 3.4. Students knowledge about any scientific research performed at their university (taking into account degree of students)

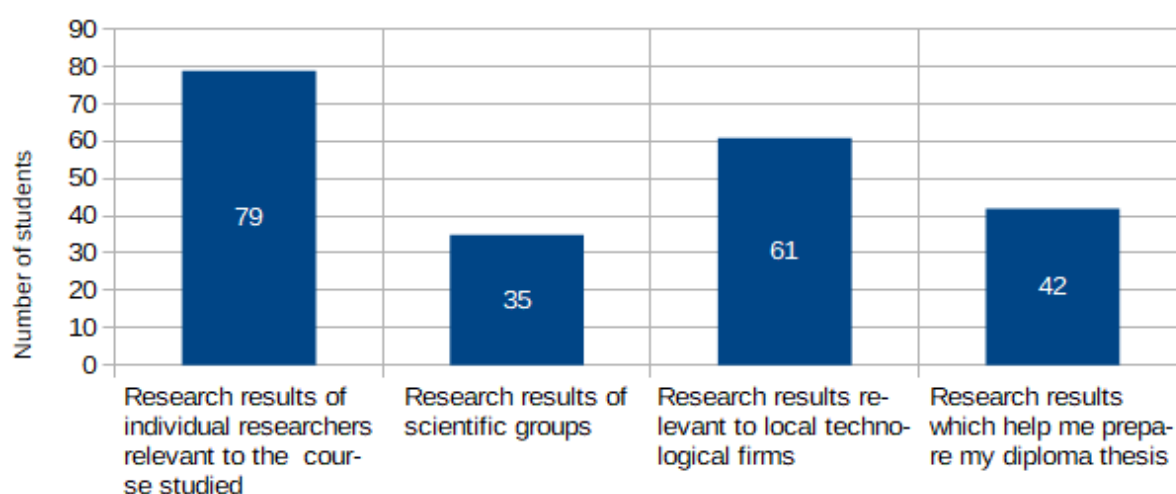


Figure 3.5. Research results which students would you like to know the most

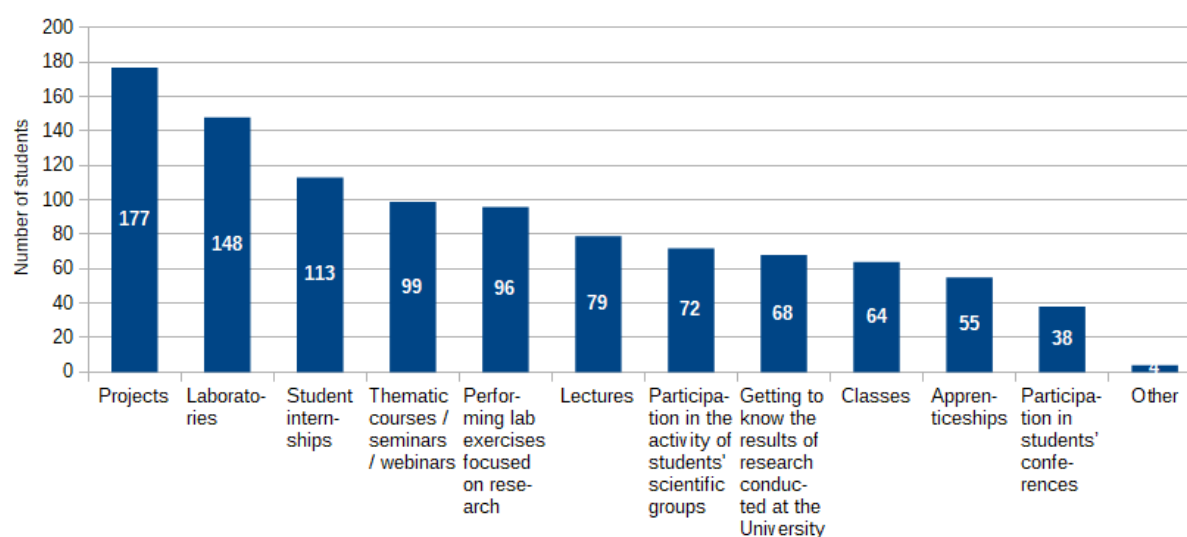


Figure 3.6. Activities which prepare students for future job and are required to generate innovations

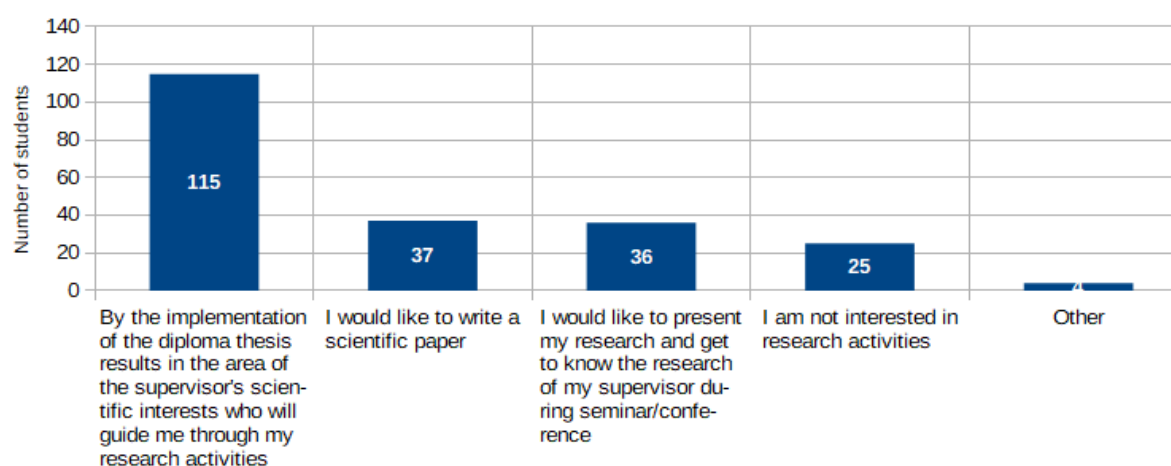


Figure 3.7. Students opinion about the preferable use of their research and supervisor's research for the purposes of their future diploma thesis

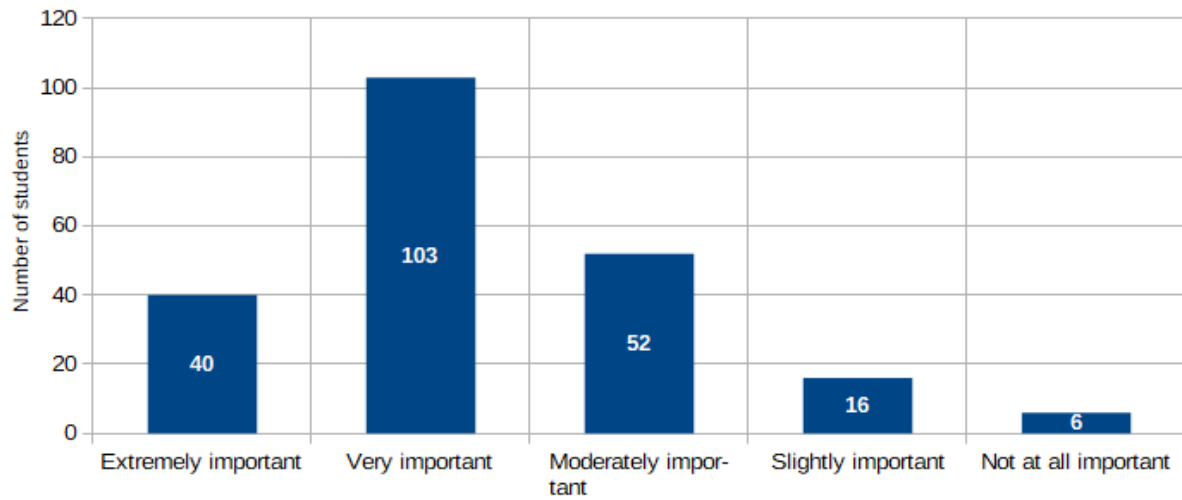


Figure 3.8. Students opinion about the idea of building a website which will present results of scientific research carried out by University employees

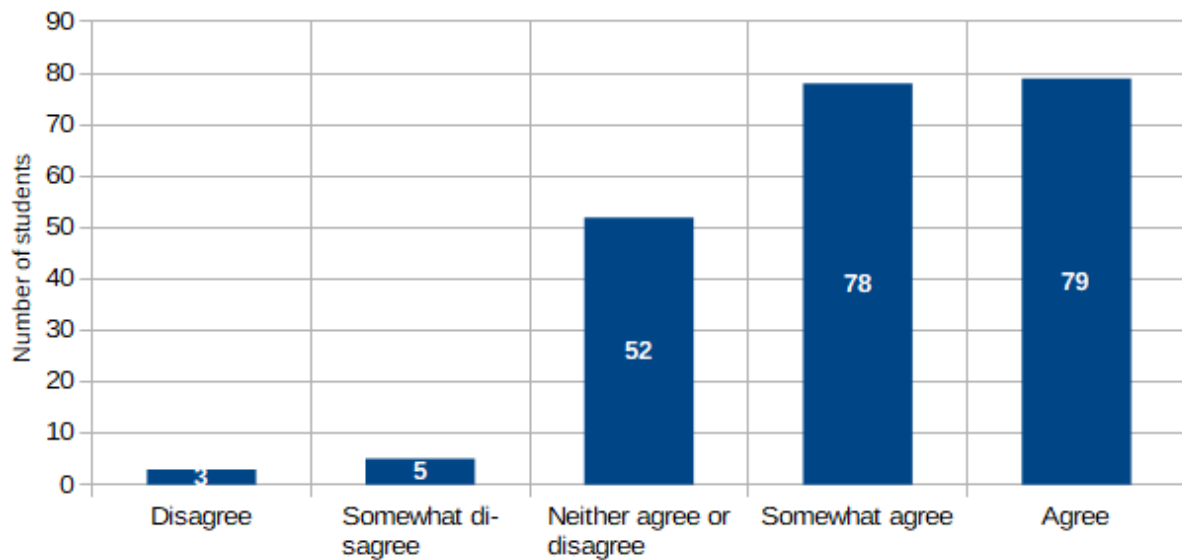


Figure 3.9. Student declaration about their participation in classes partly based on recent research results

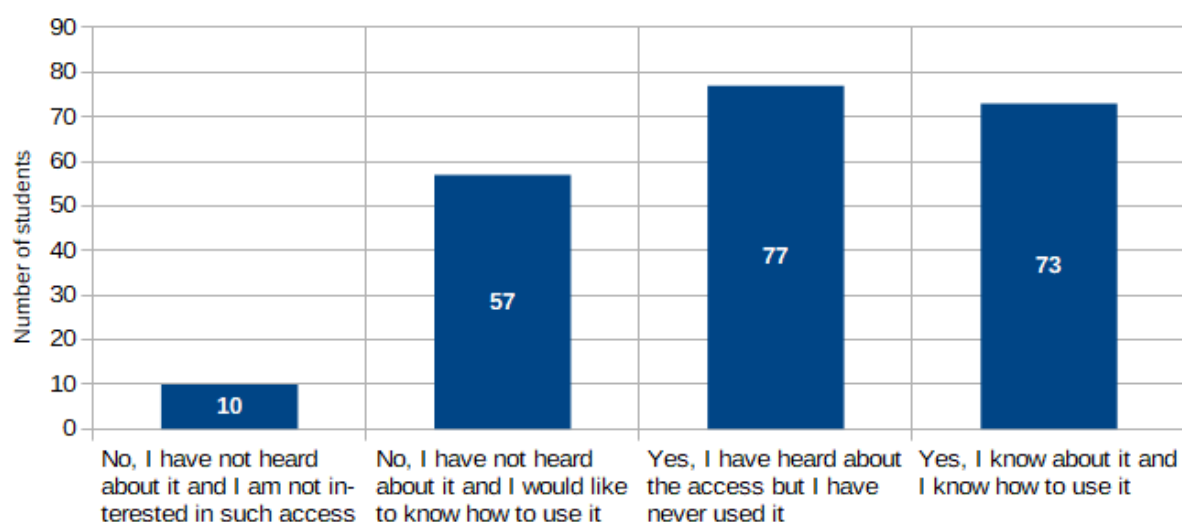


Figure 3.10. Student awareness about the access to scientific articles of publishing houses available at their university

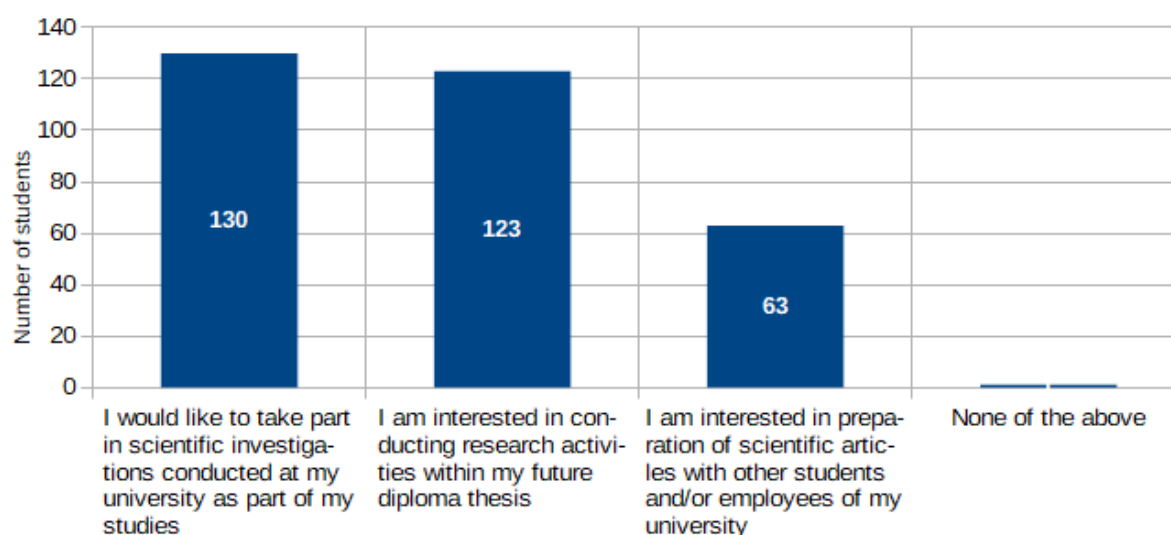


Figure 3.11. Students opinion about their possible research activity as a part of teaching programme

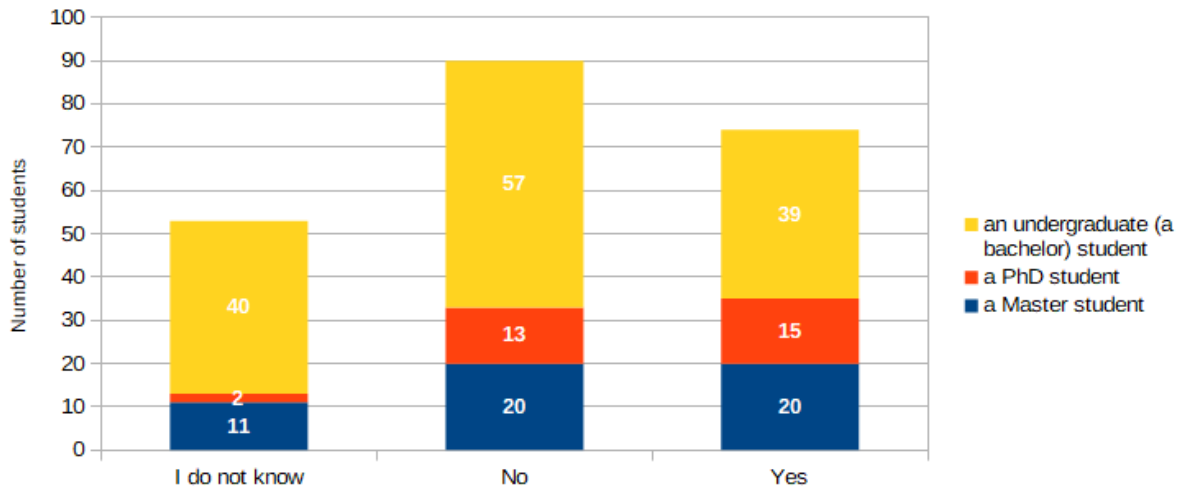


Figure 3.12. Students declaration about their participation in classes which were based on results of scientific investigations (taking into account degree of students)

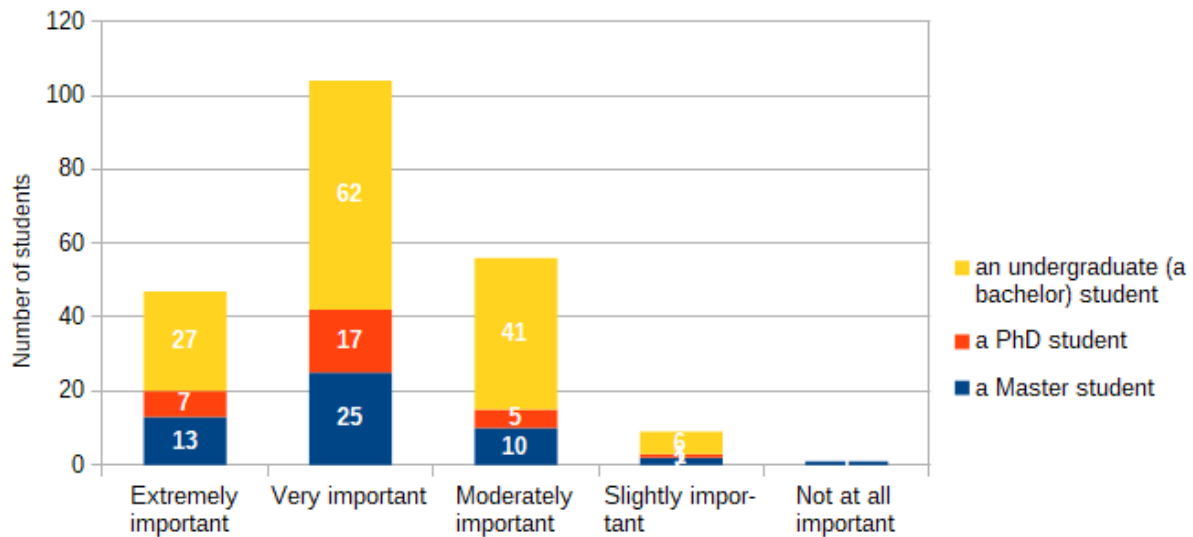


Figure 3.13. Students opinion about the importance of presenting them the recent research results by academics (taking into account degree of students)

3.1.3. Analysis of the results of the survey for students

From the analysis of the surveys for students, the following conclusions may be placed:

- The biggest group of respondents taking part in the survey was related to an undergraduate (a bachelor) students (Figure 3.1). Most of them were related to discipline of mechanical engineering (Figure 3.2).
- The students were mainly associated with universities from Germany (Hochschule Furtwangen University), Greece (National Technical University of Athens), Poland (Rzeszow University of Technology) and Italy (Universities of Varna and Parma, Figure 3.3).

- C. Most of the students stated that they know at least few scientific research performed at their university. This knowledge is possessed not only by master and PhD students, but also by undergraduate (a bachelor) students (Figure 3.4).
- D. The students the most would you like to know research results of individual researchers which are relevant to the course studied (Figure 3.5). Research results relevant to local technological firms is in second place and research results which help to prepare diploma thesis is in third place. Research results of scientific groups turned out to be the least important for students.
- E. In the opinion of the respondents, the most important activities which prepare students for future job and are required to generate innovations are (Figure 3.6):
 - projects,
 - laboratories,
 - student internships,
 - thematic courses/seminars/webinars,
 - performing lab exercises focused on research.
- F. The students would mostly like to use their research and supervisor's research for the purposes of their future diploma thesis by the implementation of the diploma thesis results in the area of the supervisor's scientific interests who will guide them through the undertaken research activities (Figure 3.7). A much smaller group of students is interested in writing a scientific paper or disseminating their research during seminars and conferences.
- G. Most of the students stated that in theirs opinion the idea of building a website which will present results of scientific research carried out by University employees is very important (Figure 3.8).
- H. Most students would agree to take part in classes partly based on recent research results (Figure 3.9).
- I. Most students have at least heard that student have access to scientific articles of publishing houses available at their university, but there is a relatively large group who have not heard about it and they would like to know how to use it (Figure 3.10).
- J. In the context of research activity as a part of teaching programme the students (Figure 3.11):
 - would like to take part in scientific investigations conducted at the university as part of their studies,
 - are interested in conducting research activities within my future diploma thesis.
- K. The smallest group is interested in preparation of scientific articles with other students and/or employees of their university.
- L. The majority of students have answered that they have not participated in classes which were based on results of scientific investigations or know nothing about it (Figure 3.12). However, one third of the respondents stated that they had taken part in such activities and it concerns all three degrees of students.

- M. The majority of students (70%) answered that presenting recent research results to students by academics is at least very important (Figure 3.13).
- N. In the last question of the survey students were asked what might allow them to know better the research results of their University. Most often they replied that this could be achieved by:
- a conference held at the university,
 - a type of institute journal highlighting the scientific findings of the institute's researchers,
 - a website that provides access to all the research done within the University,
 - posting information about the results on social pages (LinkedIn, Facebook, etc.) and in a website,
 - through the lectures and laboratories,
 - more collaboration of academic staff with students,
 - student internships for work in ongoing research.

3.2. Surveys for academics

3.2.1. Surveys content

The following questions were attached to the survey,

I am an academic: **(single choice)**

- ☐ in the group of research staff,
- ☐ in the group of research and teaching staff,
- ☐ in the group of teaching staff (no research activities).

Please indicate your discipline. **(single choice)**

- ☐ construction / civil engineering,
- ☐ mechanical engineering,
- ☐ other discipline in technical sciences,
- ☐ other discipline in non-technical sciences.

Please enter the name of the university you are working at. **(open answer)**

Do you think that linking teaching activities with scientific research results is important in the educational process of your discipline? **(single choice)**

- ☐ not at all important,
- ☐ slightly important,
- ☐ moderately important,

- ☐ very important,
 - ☐ extremely important.
-

Do you agree that the results of research in your discipline are sufficiently integrated into the educational process? **(single choice)**

- ☐ disagree,
 - ☐ somewhat disagree,
 - ☐ neither agree or disagree,
 - ☐ somewhat agree,
 - ☐ agree.
-

Why is it important to include scientific research topics into educational process? **(multiple choice)**

- ☐ to gain skills that are otherwise unattainable,
 - ☐ to encourage people to think outside the box and solve problems independently,
 - ☐ to increase the chance of finding an interesting job,
 - ☐ to encourage students to continue their education (doctoral school) and/or to undertake research work,
 - ☐ it is not important,
 - ☐ other.
-

What forms of classes do you use in order to present your research results? **(multiple choice)**

- ☐ I use my research results within lectures,
 - ☐ I use my research results within labs,
 - ☐ I use my research results within realisation of seminars with students performing their diploma theses,
 - ☐ I have not used my research results in teaching so far
 - ☐ other.
-

What barriers do you see in implementing research results into teaching? **(multiple choice)**

- ☐ limitations resulting from the study program,
 - ☐ differences in my research aims and teaching outcomes of my courses,
 - ☐ formal barriers in submitting a new form of classes,
 - ☐ inadequate or maladjusted laboratory/lecture room equipment,
 - ☐ other.
-

Do you think that your research results could be used within diploma theses? **(single choice)**

- ☐ Yes, by submission of a diploma thesis topic in the area of the employee's scientific interests and scientific collaboration with a student,
 - ☐ Yes, by writing an article (student(s) with their supervisor),
 - ☐ No, I do not think,
 - ☐ other.
-

How would you like to implement recent research results of your university into teaching process (please indicate max. 3 most important solutions)? **(multiple choice)**

- ☐ I think that the content of teaching programmes should be changed by new courses/teaching outcomes which, inter alia, build scientific skills of students,
 - ☐ I suggest extending possibilities of internet-based systems which are used by my university with new functionalities (e.g. with new search engines of employees' publications, with new search engines regarding proposed diploma thesis topics, etc.),
 - ☐ I think that expanding students' scientific groups is crucial,
 - ☐ E-learning platforms should be developed by adding new tools useful in presentation of scientific achievements and building students' scientific skills,
 - ☐ I suggest creating a website containing information on research conducted by lecturers and students,
 - ☐ I suggest launching courses/webinars with the presence of students during which the results of scientific research are presented,
 - ☐ other.
-

What tools do you use in order to present results of research to students? **(multiple choice)**

- ☐ presentations during classes,
 - ☐ self-made test stands,
 - ☐ discussions,
 - ☐ I do not present research results,
 - ☐ other.
-

Have you published any scientific articles in collaboration with master or undergraduate students? **(single choice)**

- ☐ yes, only one paper,
- ☐ yes, more than one paper but less than 5,
- ☐ yes, more than 5 papers but less than 10,
- ☐ yes, more than 10 papers but less than 30,
- ☐ yes, more than 30,
- ☐ no, I have not published with master or undergraduate students yet and I am not interested in this activity,
- ☐ no, I have not published with master or undergraduate students yet but I am interested in this activity.

3.2.2. Results of the survey for academics

The chapter presents the results of the survey for academics.

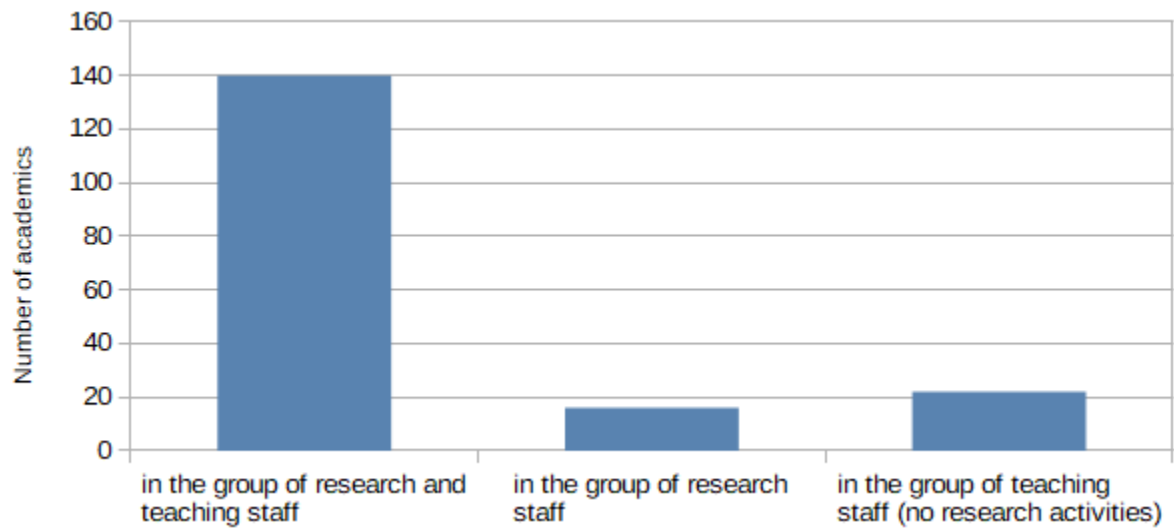


Figure 3.14. Groups of academics who filled the survey

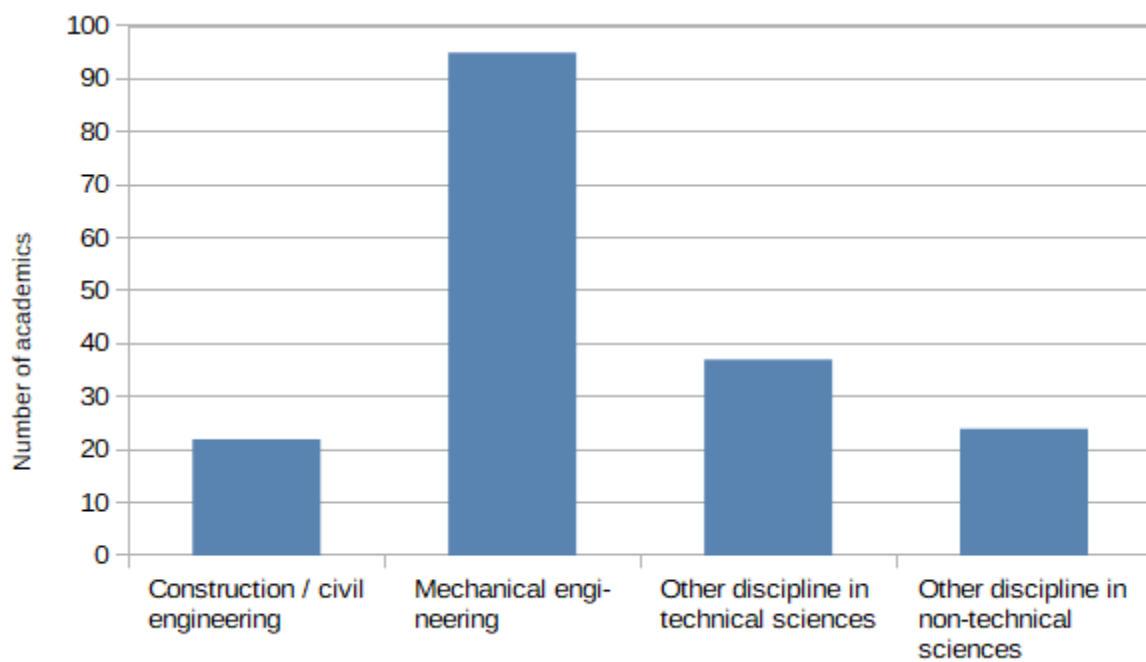


Figure 3.15. Discipline of academics who filled the survey

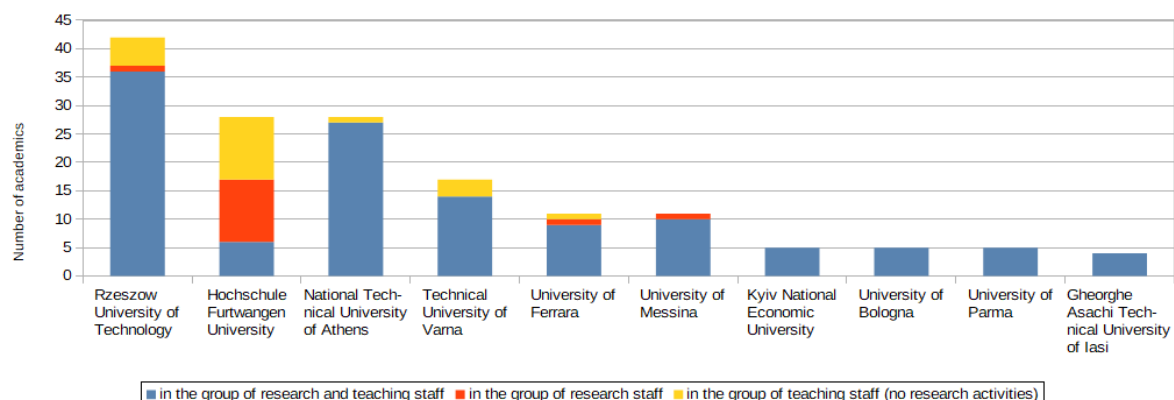


Figure 3.16. First ten universities from which the academics filled the survey (taking into account disciplines of academics)

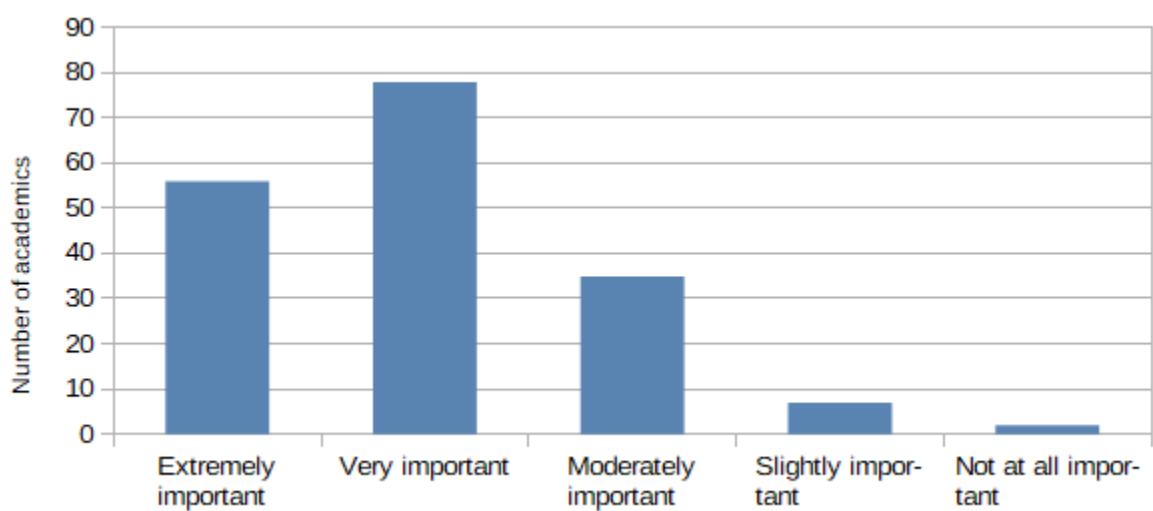


Figure 3.17. Importance of the linking teaching activities with scientific research results

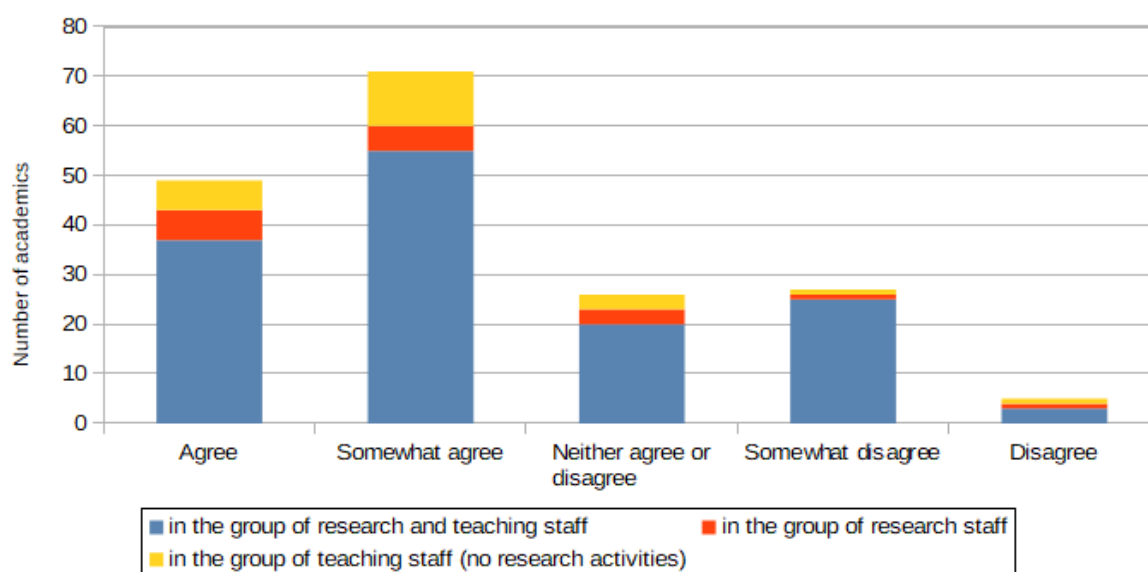


Figure 3.18. Question: Do you agree that the results of research in your discipline are sufficiently integrated into the educational process? (taking into account disciplines of academics)

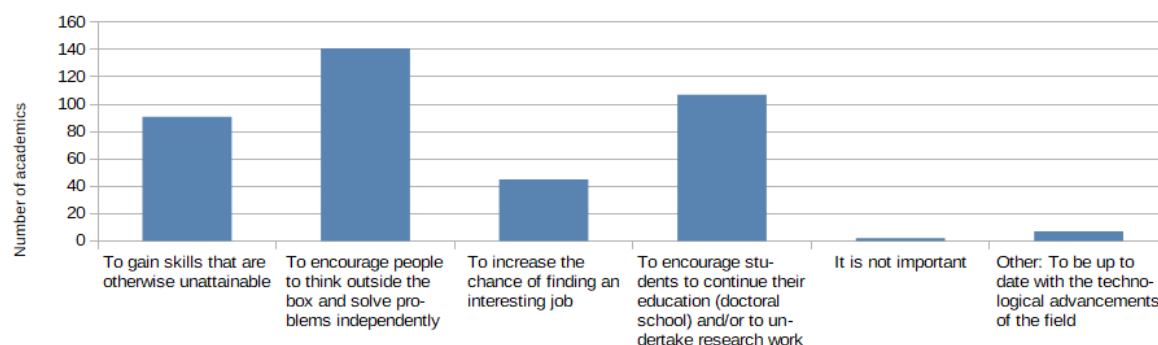


Figure 3.19. Question: Why is it important to include scientific research topics into educational process? (taking into account disciplines of students)

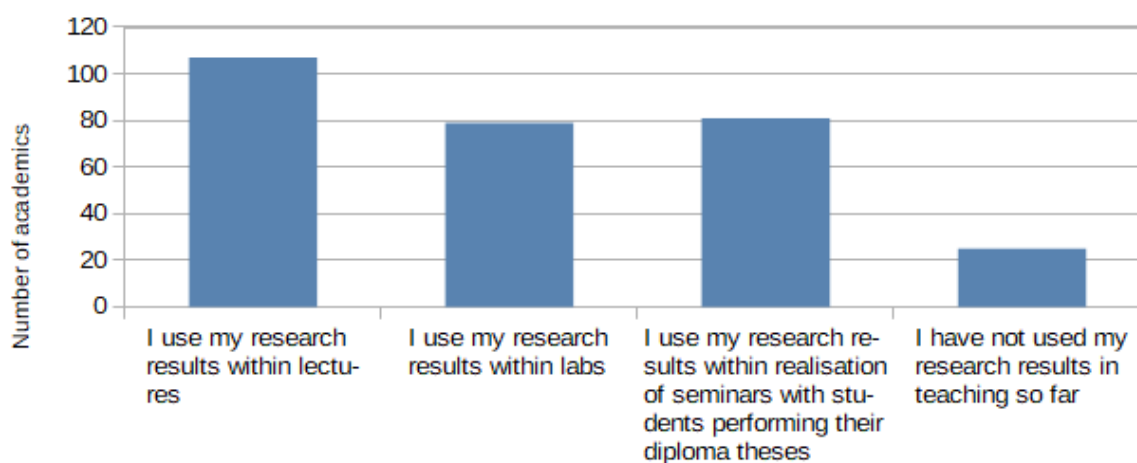


Figure 3.20. Forms of classes where academics present their research results

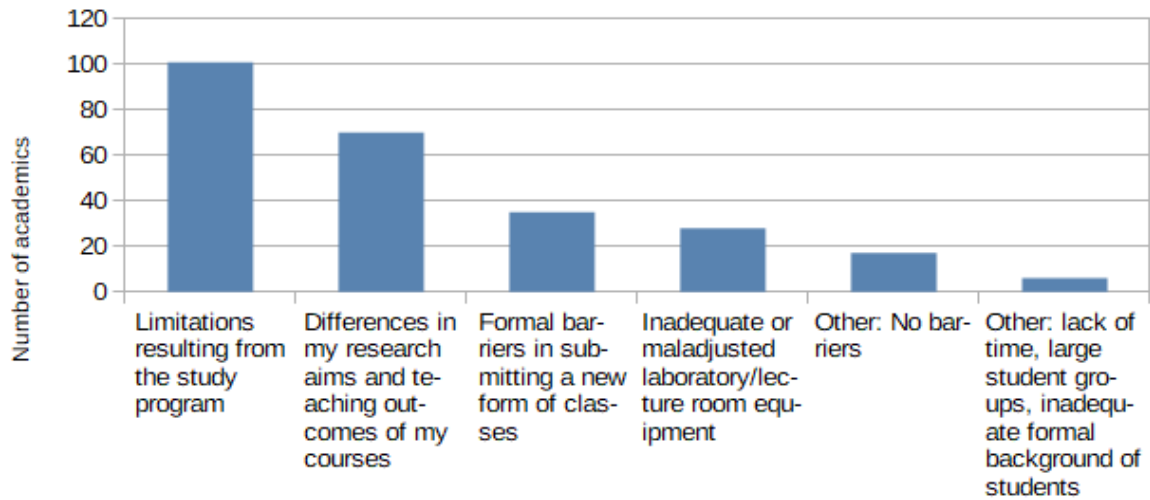


Figure 3.21. Question: What barriers do you see in implementing research results into teaching?

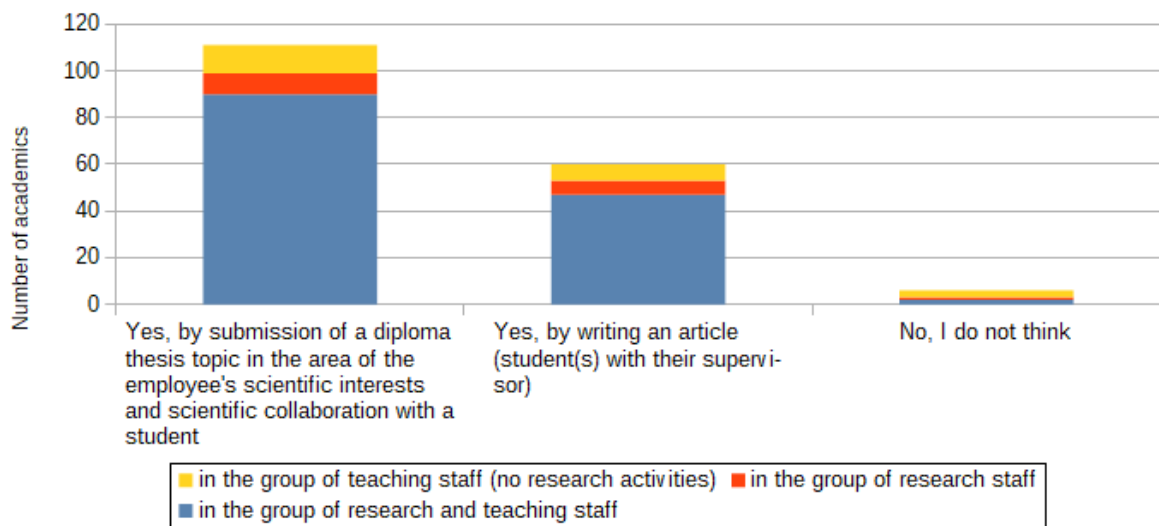


Figure 3.22. Question: Do you think that your research results could be used within diploma theses?

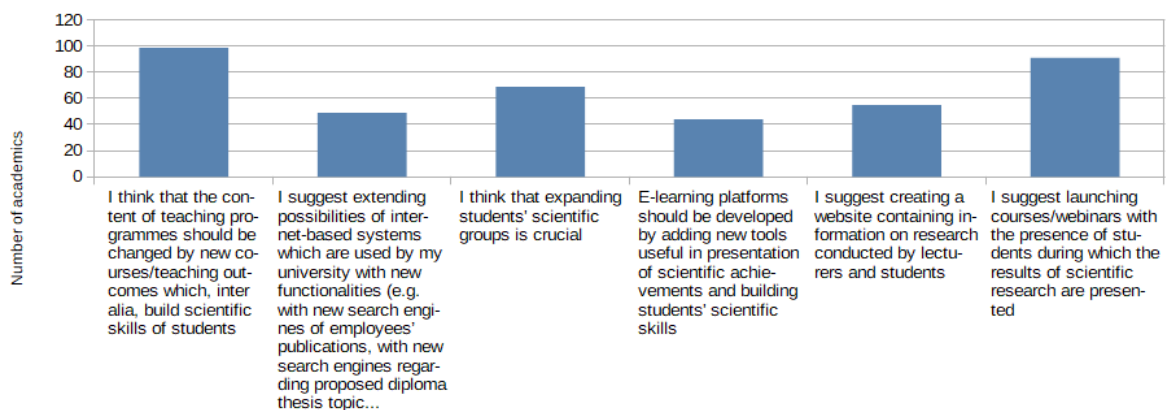


Figure 3.23. Question: How would you like to implement recent research results of your university into teaching process?

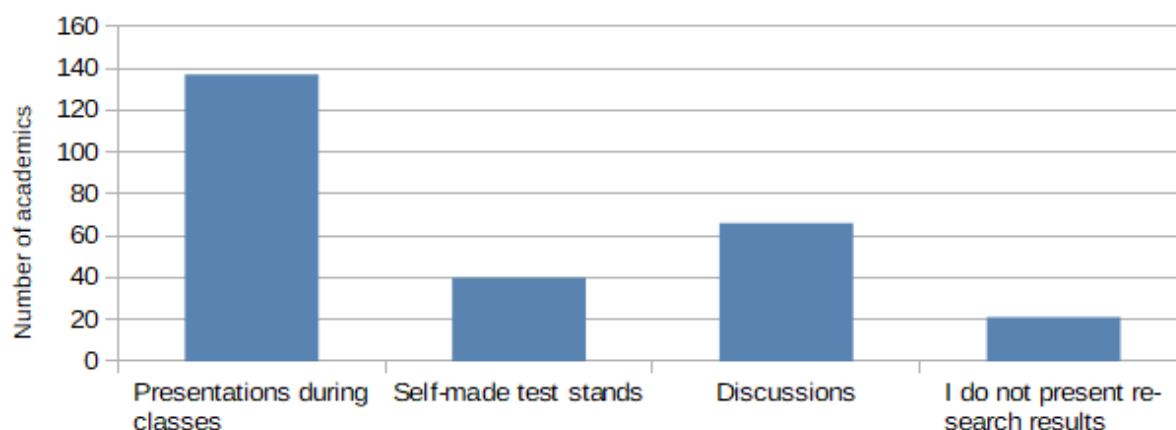


Figure 3.24. Question: What tools do you use in order to present results of research to students?

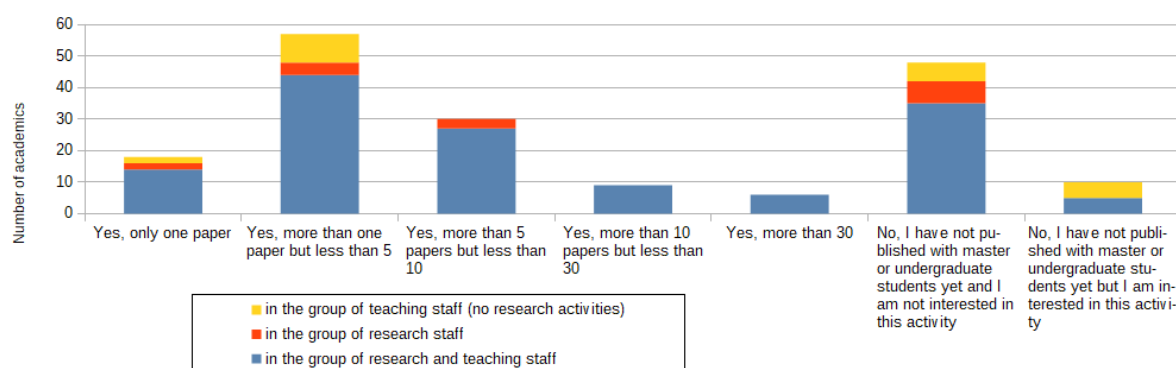


Figure 3.25. Question: Have you published any scientific articles in collaboration with master or undergraduate students?

3.2.3. Analysis of the results of the survey for academics

From the analysis of the surveys for graduates, the following conclusions may be issued:

- The group of research and teaching staff constituted the largest number of respondents (Figure 3.14). Most of them were people associated with the discipline of mechanical engineering (Figure 3.15).
- The survey participants were mainly associated with universities from Poland (Rzeszow University of Technology), Italy (Universities of Varna, Ferrara and Messina, Bologna and Parma), Germany (Hochschule Furtwangen University) and Greece (National Technical University of Athens). In the case of the Hochschule Furtwangen University, a large group of respondents were research or teaching staff (Figure 3.16).
- The respondents think that linking teaching activities with scientific research results is very important in the educational process of their discipline (Figure 3.17).

- D. The largest group of respondents somewhat agree that the results of research in their discipline are sufficiently integrated into the educational process (Figure 3.18).
- E. The most of respondents stated that it is important to include scientific research topics into educational process (Figure 3.19):
 - to encourage people to think outside the box and solve problems independently,
 - to encourage students to continue their education (doctoral school) and/or to undertake research work,
 - to gain skills that are otherwise unattainable.
- F. The most frequently used form of classes in order to present research results are lectures, then seminars and labs (Figure 3.20).
- G. The three the most frequently mentioned barriers that respondents see in implementing research results into teaching are (Figure 3.21):
 - limitations resulting from the study program,
 - differences in the research aims and teaching outcomes of courses,
 - formal barriers in submitting a new form of classes.
- H. The respondents think that their research results could be used within diploma theses by submission of a diploma thesis topic in the area of the employee's scientific interests and scientific collaboration with a student or by writing an article (student(s) with their supervisor, see Figure 3.22).
- I. According to the respondents, three the most important ways to implement recent research results into teaching process are (Figure 3.23):
 - the content of teaching programmes should be changed by new courses/teaching outcomes which, inter alia, build scientific skills of students,
 - launching courses/webinars with the presence of students during which the results of scientific research are presented,
 - expanding students' scientific groups is crucial.
- J. Results of research are most often presented to students by (Figure 3.24):
 - presentations during classes,
 - discussions,
 - self-made test stands.
- K. The majority of respondents have published at least one scientific articles in collaboration with master or undergraduate students, but there is also a large group of researchers who are not interested in publishing with students (Figure 3.25).

3.3. Surveys for graduates

3.3.1. Surveys content

The following questions were attached to the survey.

Please select university you have graduated from. **(single choice)**

- ☐ Rzeszów University of Technology,
 - ☐ National Technical University of Athens,
 - ☐ Furtwangen University,
 - ☐ other.
-

Please indicate a discipline linked to your field of study. **(single choice)**

- ☐ construction / civil engineering,
 - ☐ mechanical engineering,
 - ☐ other discipline in technical sciences,
 - ☐ other discipline in non-technical sciences.
-

Did you know about any research conducted at your university during your studies? **(single choice)**

- ☐ yes,
 - ☐ no,
 - ☐ I do not remember.
-

Did you have an access to research results (papers of academics, experiments and test stands, scientific groups and their achievements) of the university you graduated from? **(single choice)**

- ☐ yes, to a small extent,
 - ☐ yes, to a large extent,
 - ☐ no,
 - ☐ I did not search such results.
-

Did research results of your university enable you to enrich your knowledge or skills? **(single choice)**

- ☐ yes,
 - ☐ no,
 - ☐ hard to say.
-

Did research results of your university enable you to develop your career? **(single choice)**

- ☐ yes,
- ☐ no,
- ☐ hard to say.

Did research results of your university enable your firm to develop something new? **(single choice)**

- ☐ yes,
- ☐ no.
- ☐ hard to say.

Do you think that conducted research could be used in diploma theses? **(single choice)**

- ☐ yes, mainly by implementation of the diploma thesis in the area of the employee's scientific interests,
- ☐ yes, university research should be linked to the topics of diploma theses,
- ☐ yes, there is a need to write an article by the student together with the supervisor
- ☐ no, I don't,
- ☐ other.

Do you use the knowledge and skills resulting from scientific research in your current workplace? **(single choice)**

- ☐ yes, to a large extent,
- ☐ yes, to a small extent,
- ☐ no, I do not use any knowledge and skills resulting from scientific research in my current workplace and I do not need it,
- ☐ no, I do not use any knowledge and skills resulting from scientific research in my current workplace but I do need it,
- ☐ hard to say.

How, from the time perspective, do you evaluate the relationship between practical, theoretical classes and these which build scientific knowledge and skills of students of your university? **(single choice)**

- ☐ the proportions were right,
- ☐ there should be more practical elements (including research activities),
- ☐ there should be more practical elements (excluding research activities),
- ☐ there should be more theoretical elements,
- ☐ hard to say,
- ☐ other.

3.3.2. Results of the survey for graduates

The chapter presents the results of the survey for graduates.

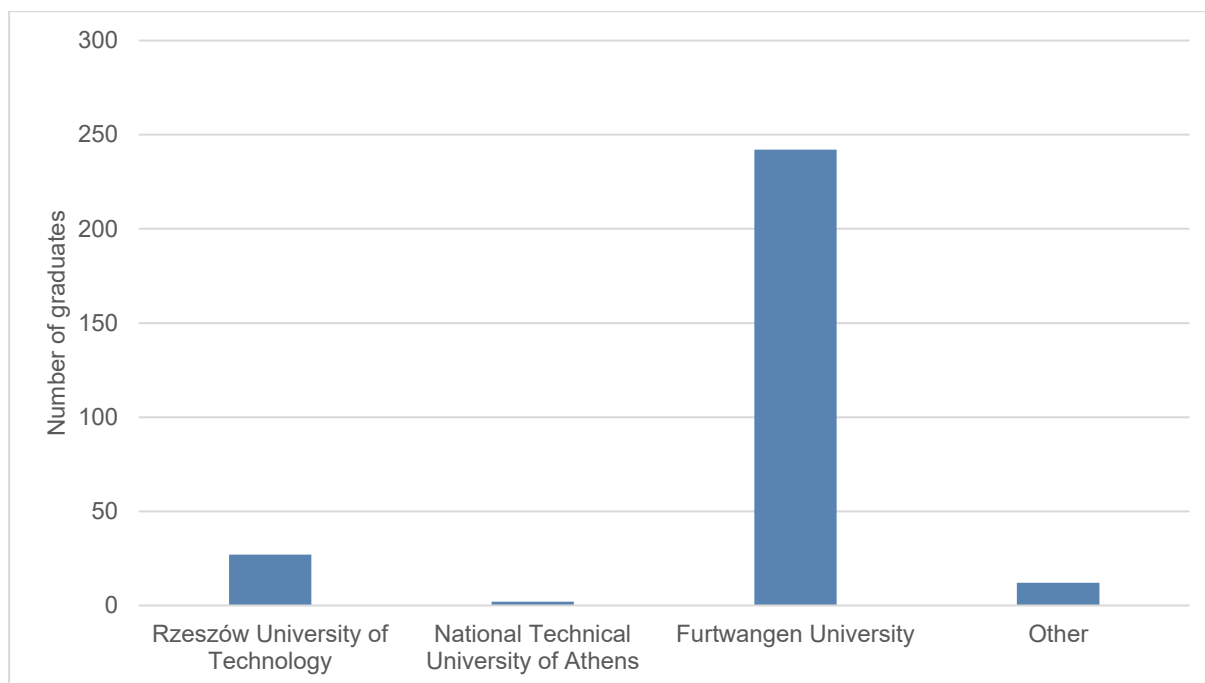


Figure 3.26. Universities of graduates

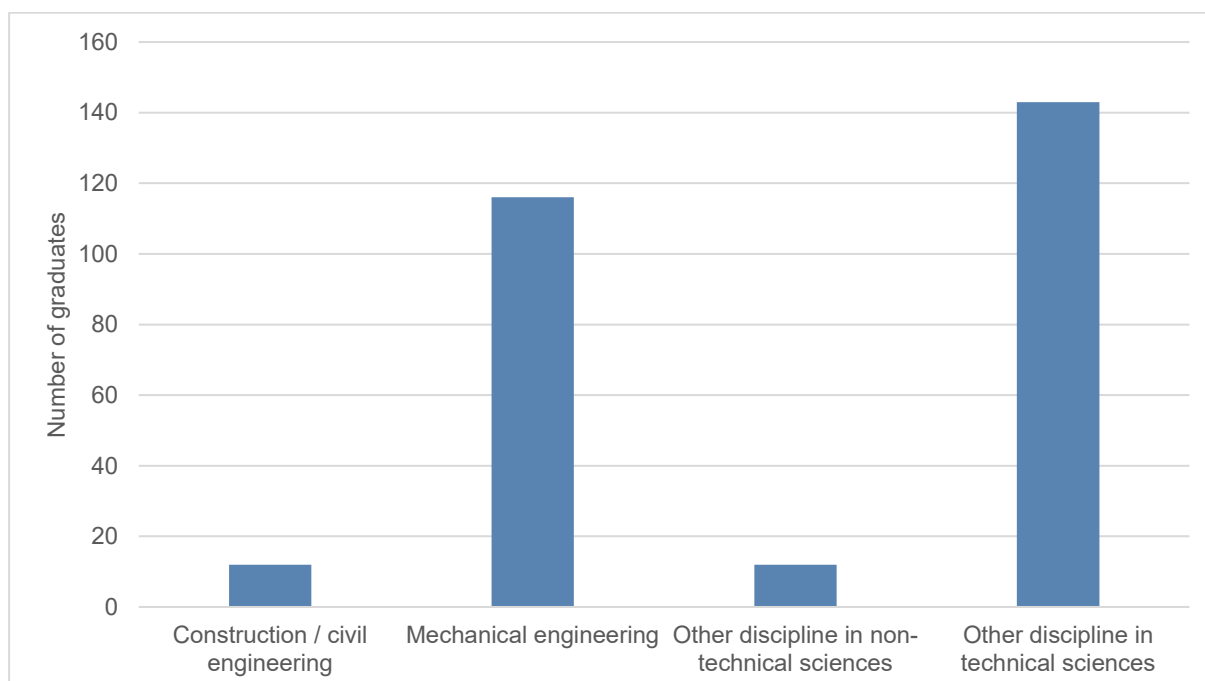


Figure 3.27. Disciplines of graduates

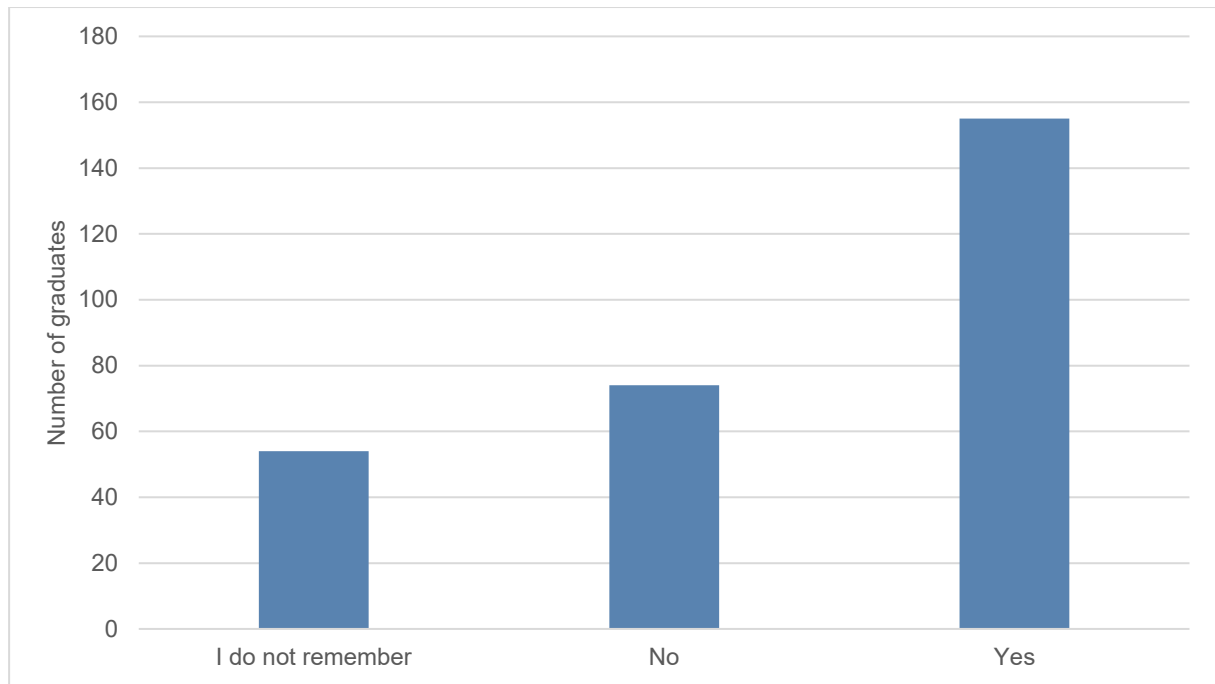


Figure 3.28. Question: Did you know about any research conducted at your university during your studies?

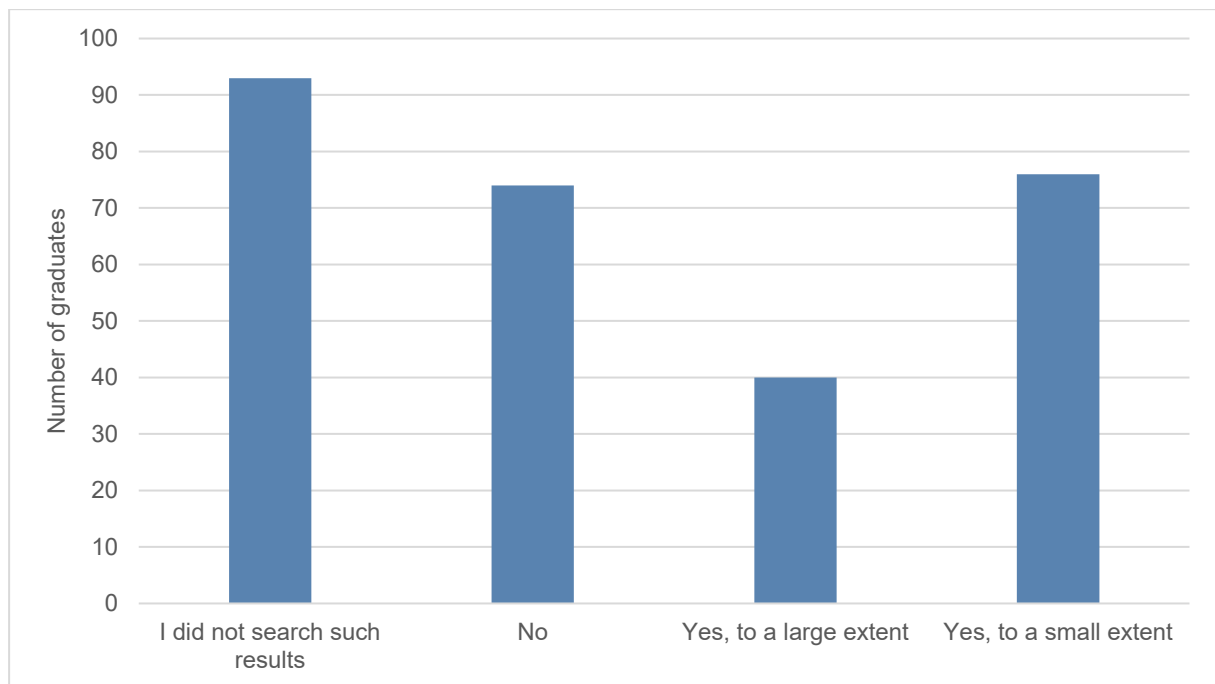


Figure 3.29. Question: Did you have an access to research results (papers of academics, experiments and test stands, scientific groups and their achievements) of the university you graduated from?

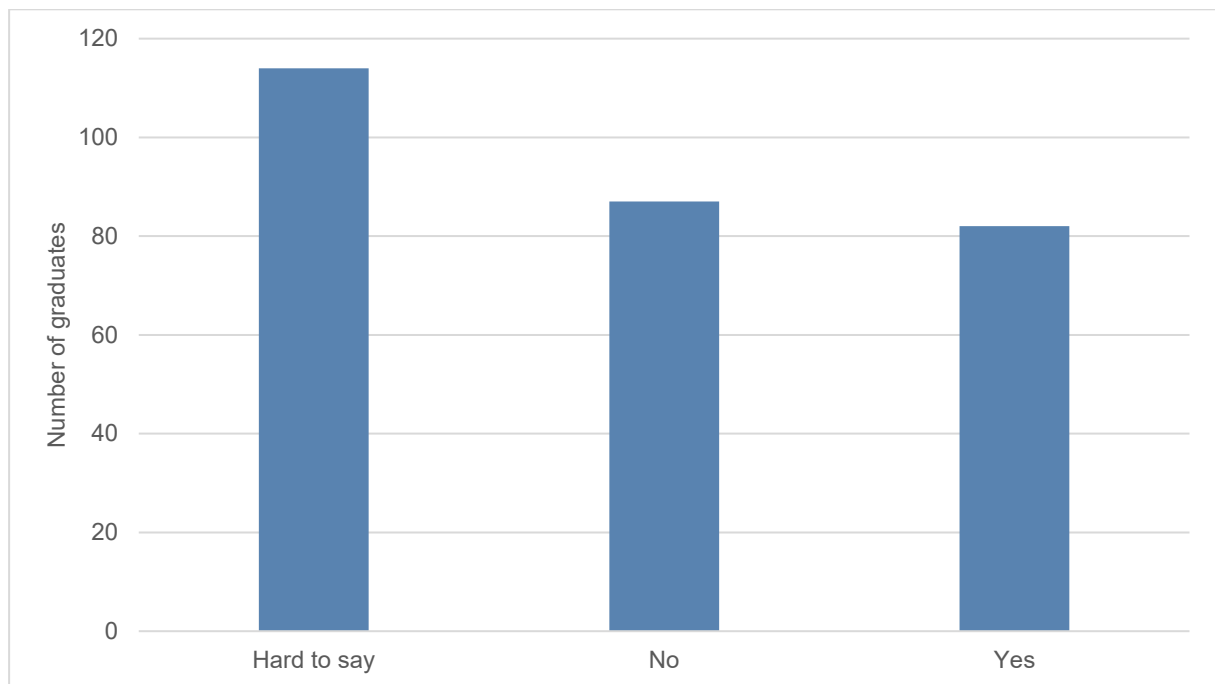


Figure 3.30. Question: Did research results of your university enable you to enrich your knowledge or skills?

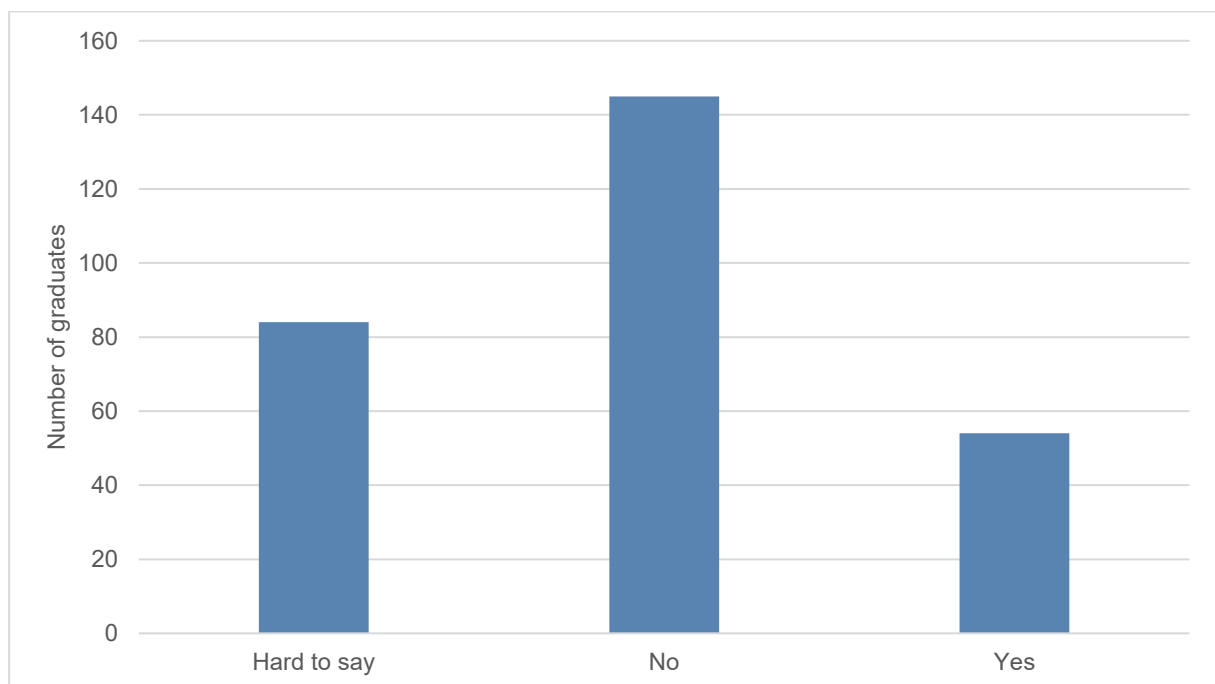


Figure 3.31. Question: Did research results of your university enable you to develop your career?

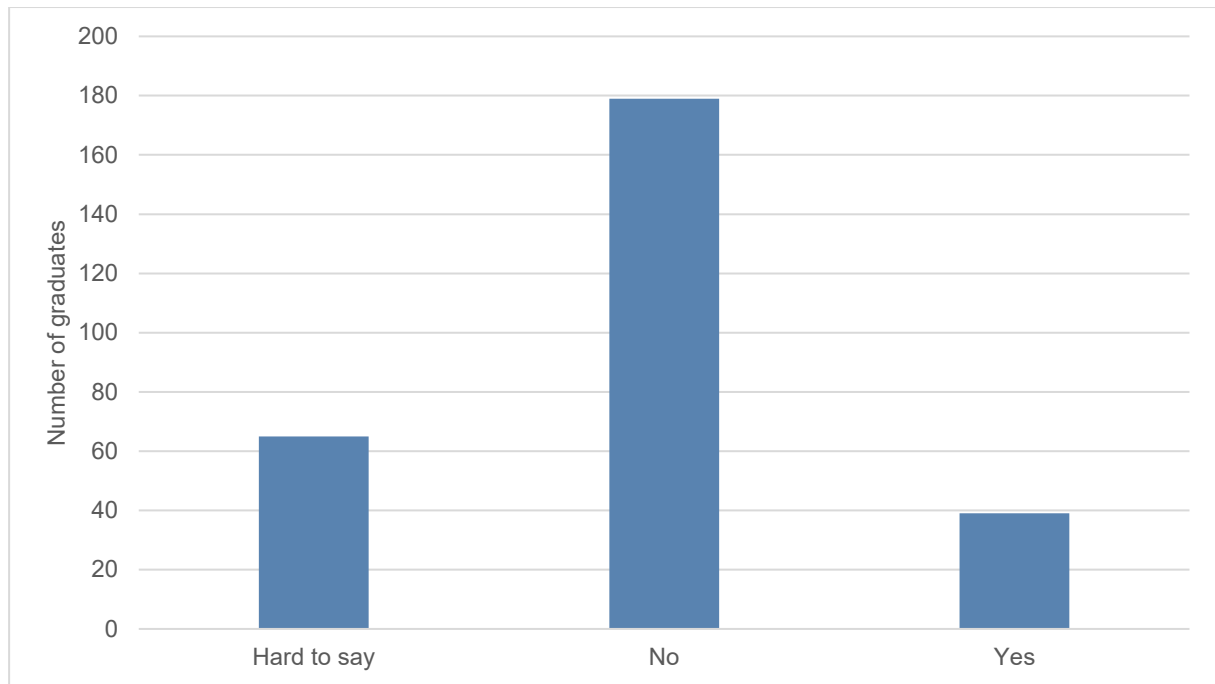


Figure 3.32. Question: Did research results of your university enable your firm to develop something new?

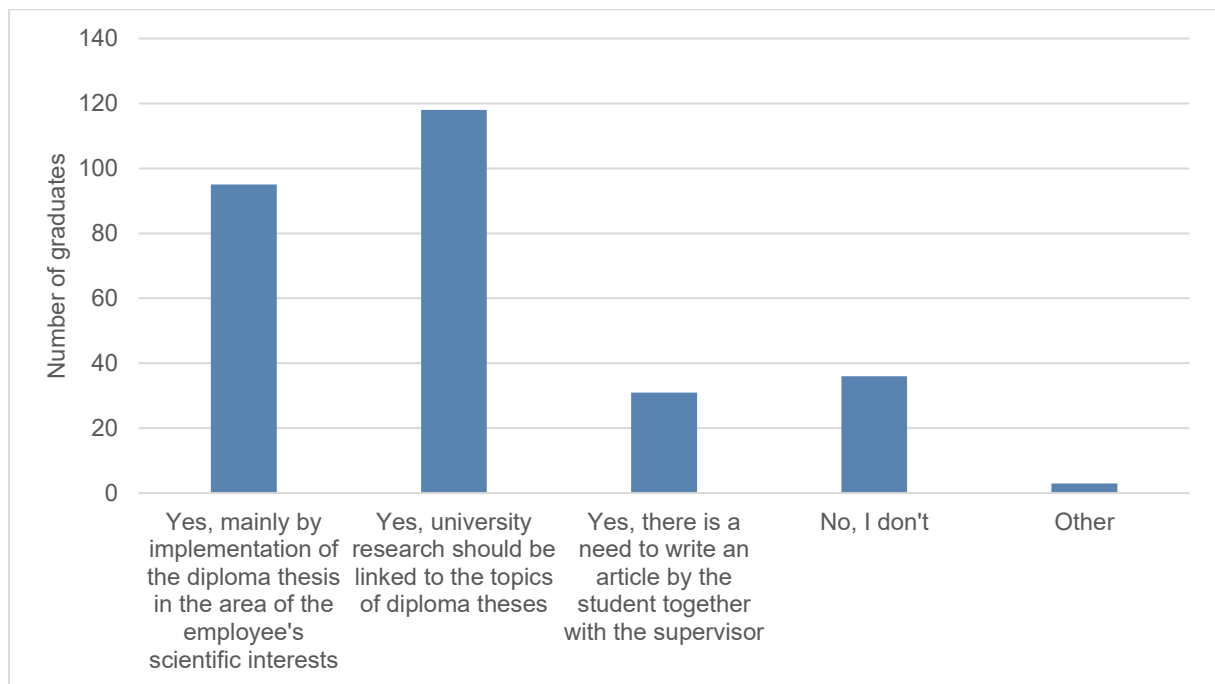


Figure 3.33. Question: Do you think that conducted research could be used in diploma theses?

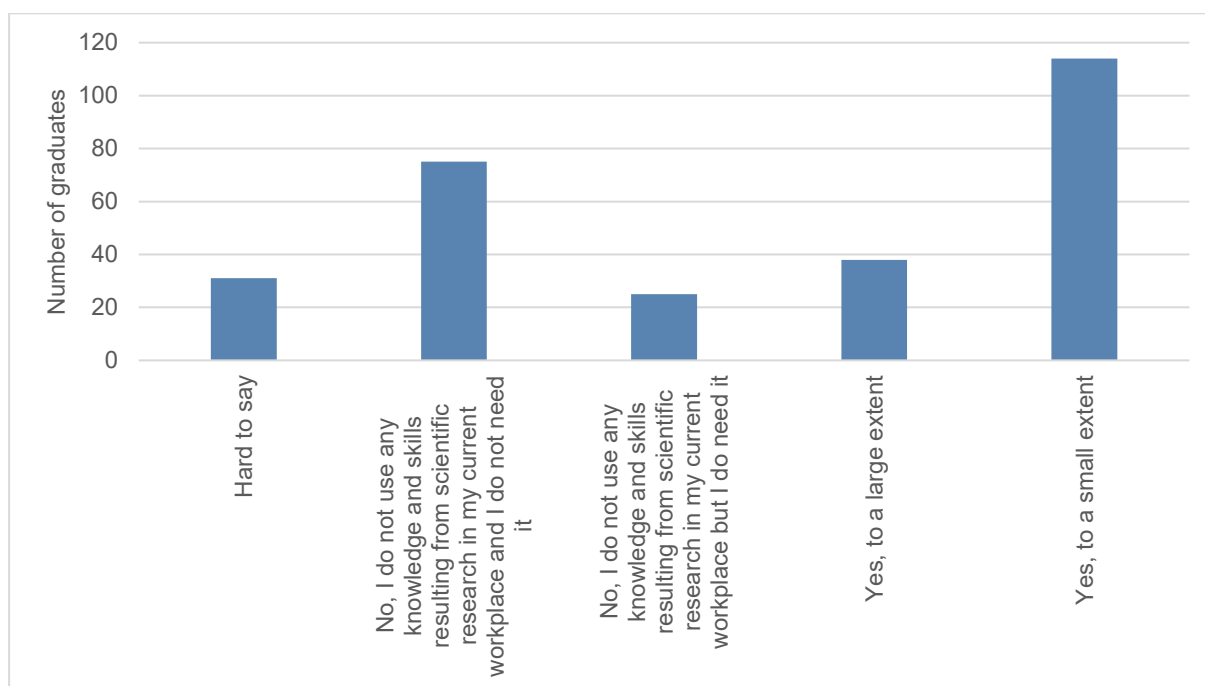


Figure 3.34. Question: Do you use the knowledge and skills resulting from scientific research in your current workplace?

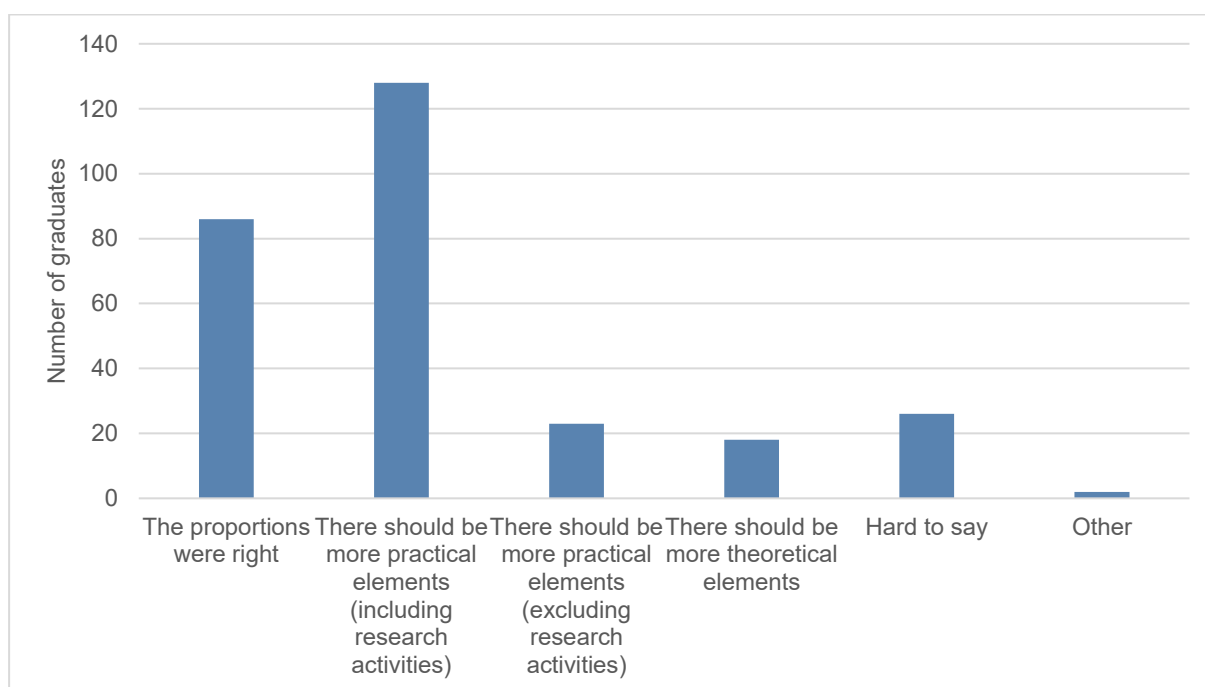


Figure 3.35. Question: How, from the time perspective, do you evaluate the relationship between practical, theoretical classes and these which build scientific knowledge and skills of students of your university?

3.3.3. Analysis of the results of the survey for graduates

From the analysis of the surveys for graduates, the following conclusions may be issued:

- A. The most graduates who completed the survey studied at Furtwangen University (Figure 3.26).
- B. The most respondents represent the other discipline in technical sciences. However, the large group of graduates who took part in the survey also specialize in mechanical engineering (Figure 3.27).
- C. The most graduates knew about research conducted at their university during their studies. However, there is also the large group of respondents who have no such knowledge (Figure 3.28).
- D. The most respondents did not search for any research results of the university they graduated from. There is also the large group of graduates who did not have the access to such results or have it to a small extent (Figure 3.29).
- E. There are ambiguous results that research results of graduates' universities enrich knowledge or skills of graduates. The largest group of respondents selected the option: hard to say. Moreover, a similar number of people chose yes and no options (Figure 3.30).
- F. The most graduates indicated that research results of their university did not enable them to develop their careers (Figure 3.31).
- G. The most respondents said that research results of their universities did not enable their firms to develop something new (Figure 3.32).
- H. The largest group of graduates indicated that research could be used in diploma theses. The most of respondents said that research activities should be linked to the topics of diploma theses (Figure 3.33).
- I. The largest group of respondents think that they use the knowledge and skills resulting from scientific research in their current workplace to a small extent. Moreover, there is the large group of graduates who do not use any knowledge and skills resulting from scientific research in their professional work (Figure 3.34).
- J. The most respondents think that there should be more practical elements, which also include research activities, during their studies (Figure 3.35).

3.4. Surveys for employers

3.4.1. Surveys content

The following questions were attached to the survey.

Please select your country. **(single choice)**

- ☐ Germany,
- ☐ Greece,
- ☐ Italy,
- ☐ Poland,
- ☐ other.

Please indicate your industrial sector. **(single choice)**

- ☐ construction / civil engineering,
- ☐ mechanical engineering,
- ☐ other.

Do you expect any research qualifications from graduates of a technical university? **(single choice)**

- ☐ yes, my organization has an R&D department and we need such qualifications,
- ☐ yes, my organization does not have an R&D department but we would expect research qualifications from graduates of a technical university in order to test our products and look for new solutions,
- ☐ no,
- ☐ hard to say.

Do you think employers should have an influence on the teaching programs and research of higher education institutions? **(single choice)**

- ☐ no, it is a role of higher education institutions to define teaching programs and scope of research,
- ☐ Yes,
- ☐ hard to say.

Would you encourage your employees to study at a university which offers research skills to students? **(single choice)**

- ☐ yes,
- ☐ no,
- ☐ hard to say.

Which of the following accurately describes in your opinion a graduate of a university in comparison to a graduate of a high school? **(multiple choice)**

- ☐ creativity,
 - ☐ extended knowledge and skills,
 - ☐ research qualifications,
 - ☐ activity and initiative,
 - ☐ independence and problem-solving attitude,
 - ☐ ability to search for information,
 - ☐ responsibility and organizational skills,
 - ☐ the ability to synthesize facts, draw conclusions,
 - ☐ teamwork skills,
 - ☐ other.
-

Would you be interested in knowledge of your employees graduating from higher education institutions regarding innovations/patents/publications produced by local universities? **(single choice)**

- ☐ yes, definitely. My firm is open for knowledge regarding innovations,
 - ☐ yes, in the area which is important for my firm,
 - ☐ no,
 - ☐ hard to say.
-

Do you know any research results produced at regional universities that have had in your opinion a strong impact on manufacturing firms? **(single choice)**

- ☐ yes, I know many of them (more than 10),
- ☐ yes, I know some (between 5 and 10),
- ☐ yes, I know few (up to 5),
- ☐ no, I don't

3.4.2. Results of the survey for employers

The chapter presents the results of the survey for employers.

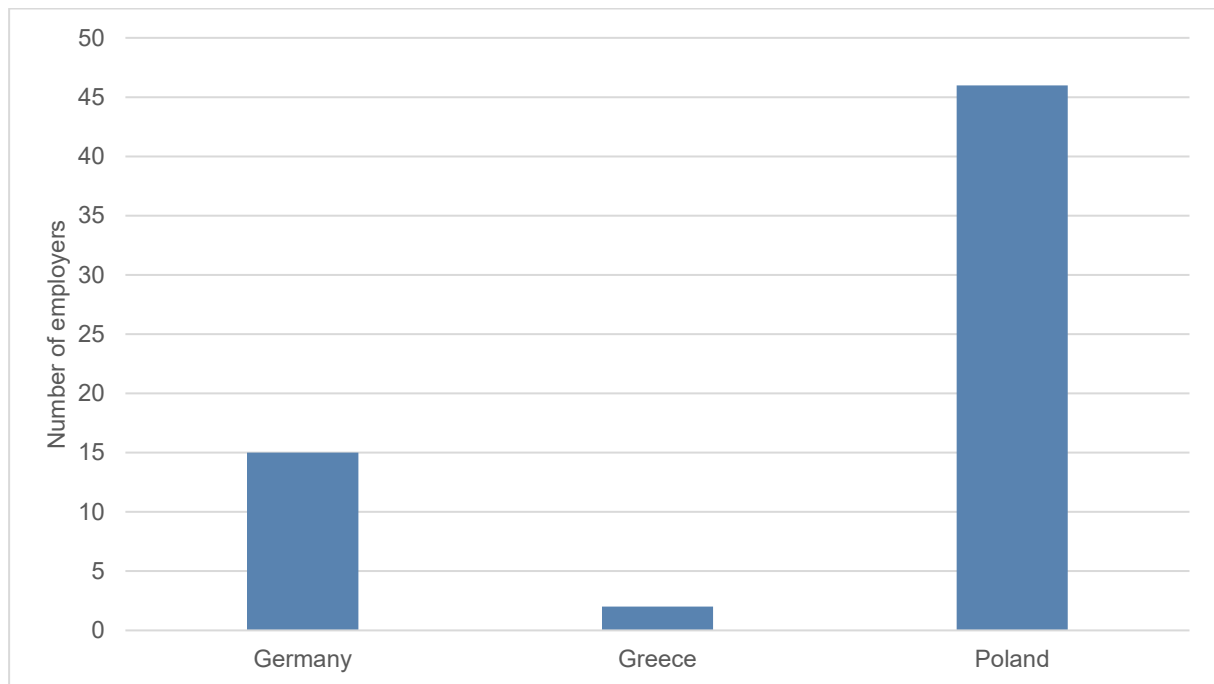


Figure 3.36. Countries of employers

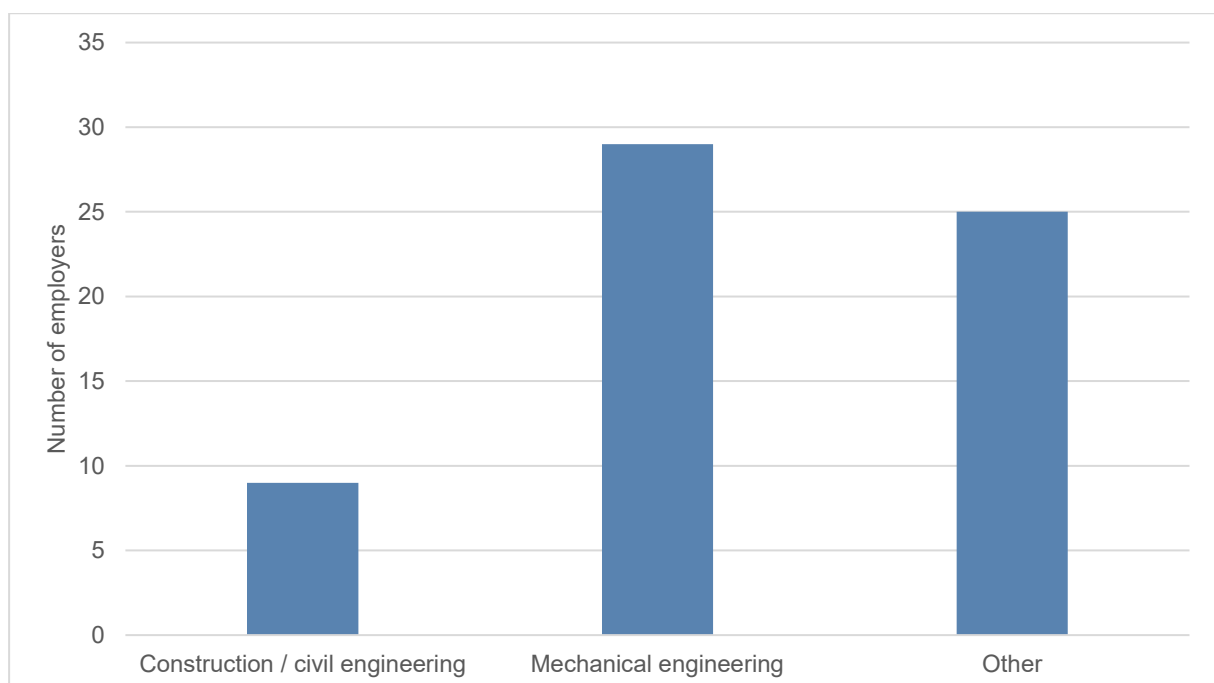


Figure 3.37. Disciplines of employers

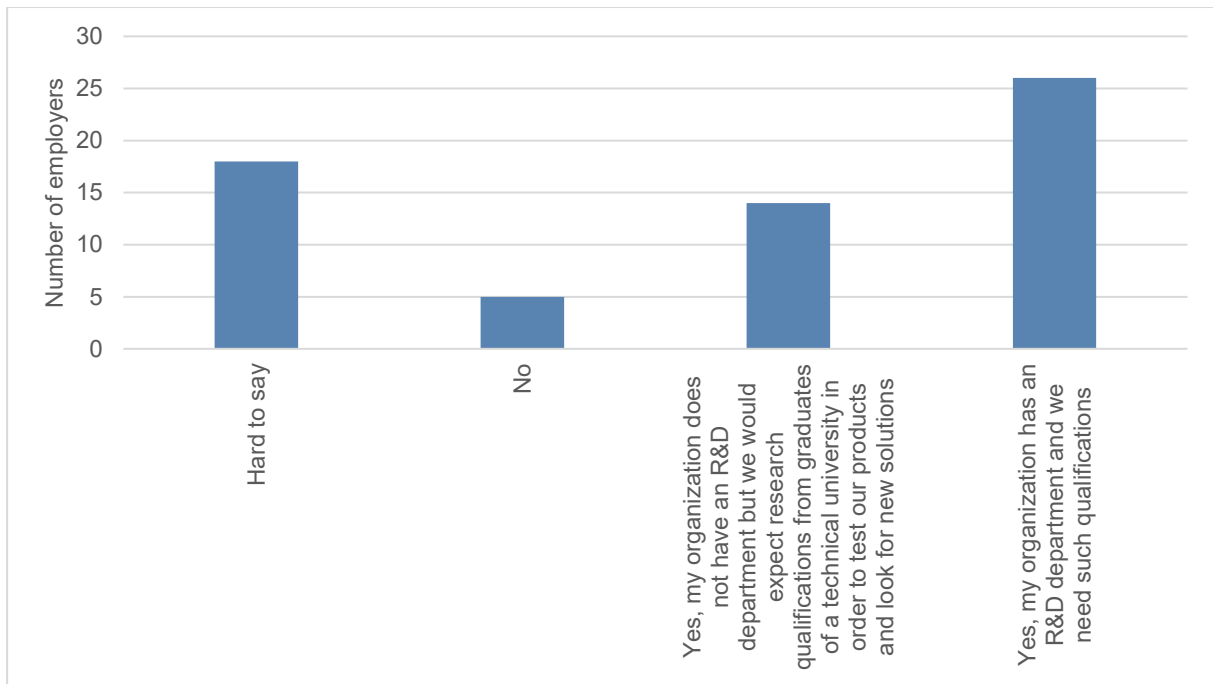


Figure 3.38. Question: Do you expect any research qualifications from graduates of a technical university?

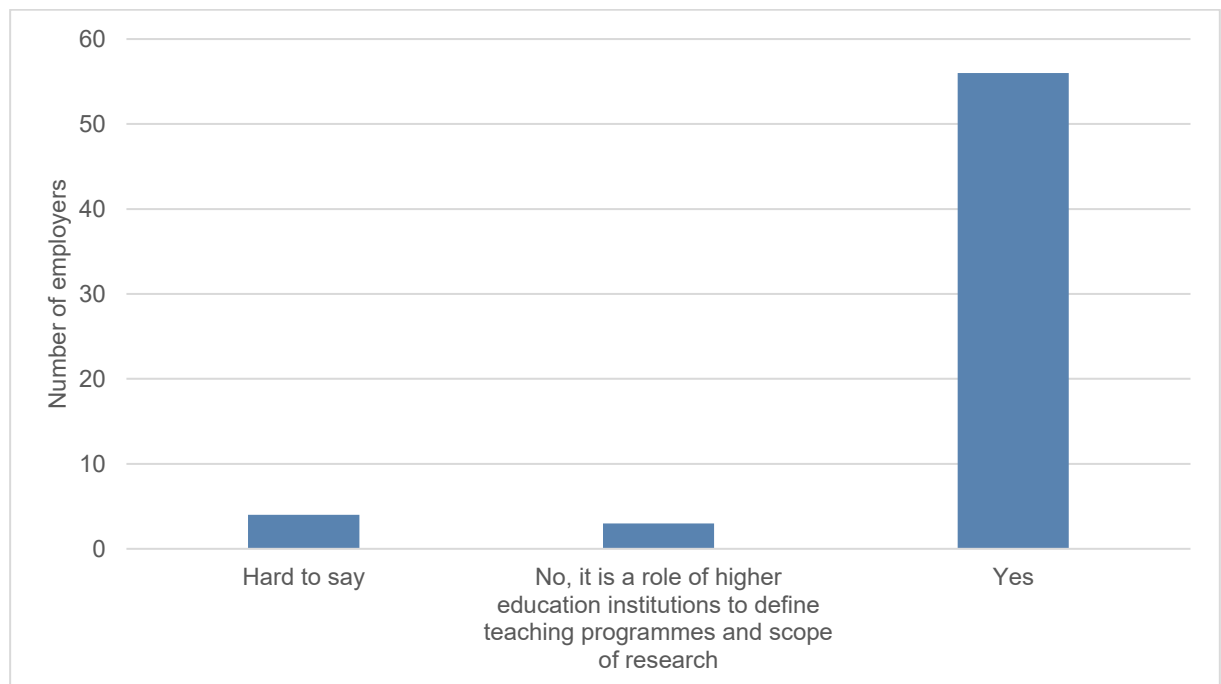


Figure 3.39. Question: Do you think employers should have an influence on the teaching programs and research of higher education institutions?

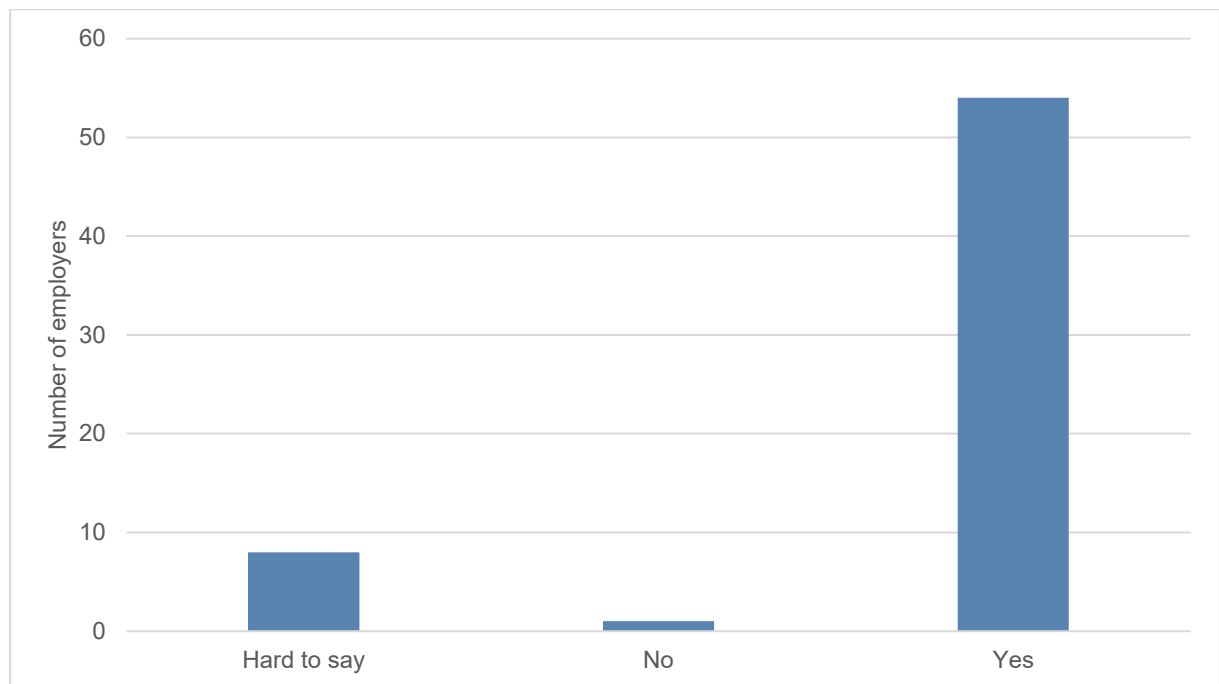


Figure 3.40. Would you encourage your employees to study at a university which offers research skills to students?

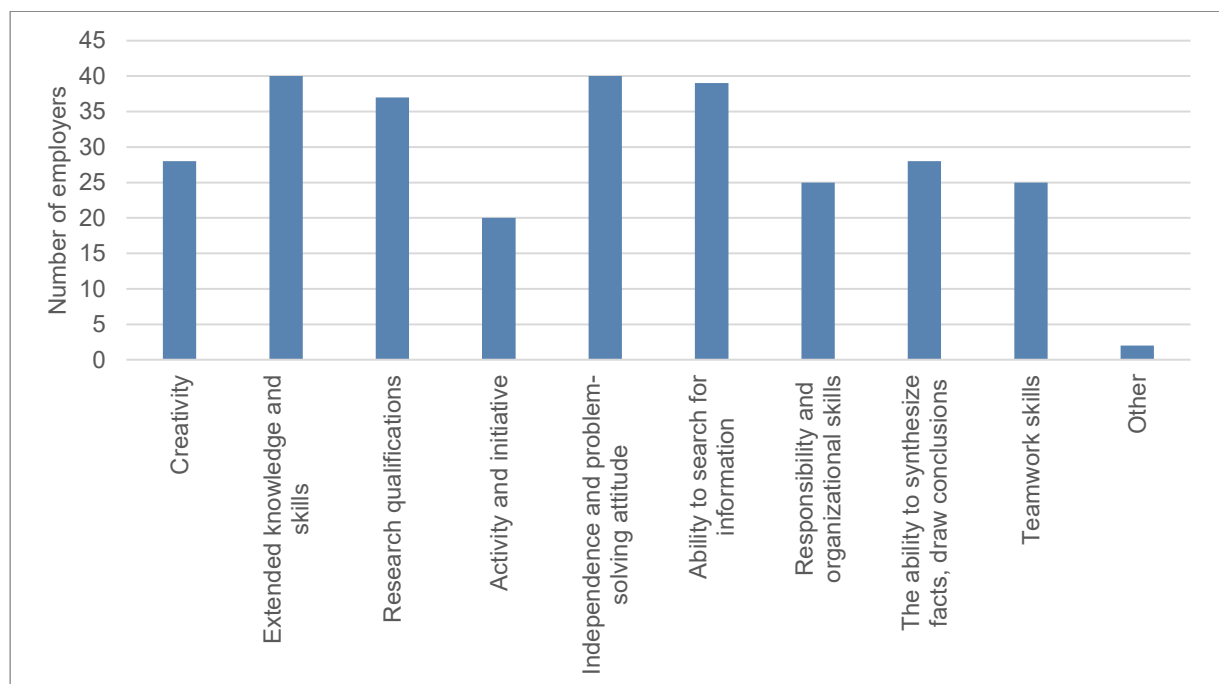


Figure 3.41. Which of the following accurately describes in your opinion a graduate of a university in comparison to a graduate of a high school?

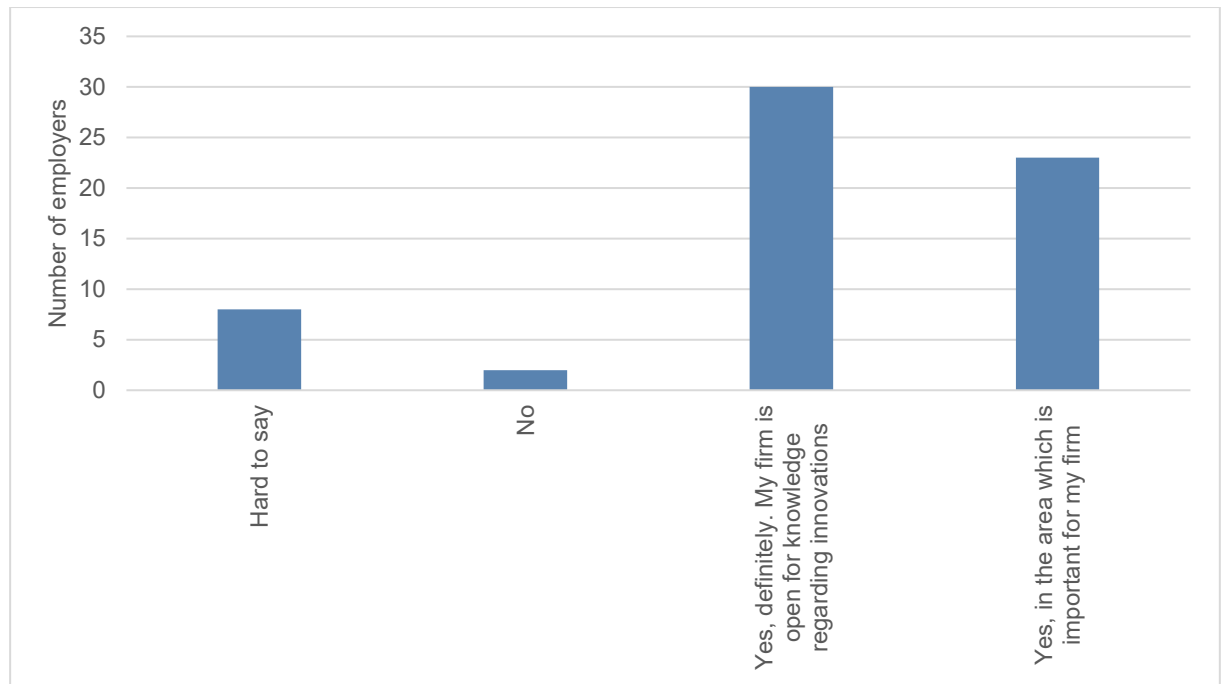


Figure 3.42. Would you be interested in knowledge of your employees graduating from higher education institutions regarding innovations/patents/publications produced by local universities?

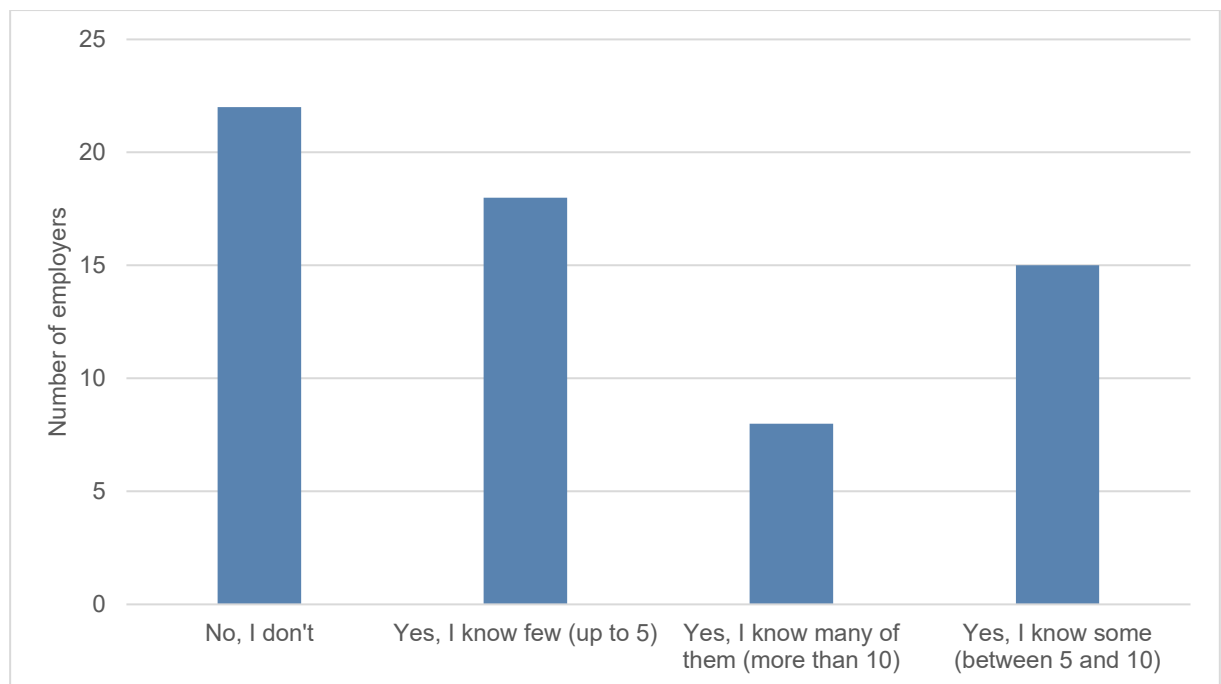


Figure 3.43. Do you know any research results produced at regional universities that have had in your opinion a strong impact on manufacturing firms?

3.4.3. Analysis of the results of the survey for employers

From the analysis of the surveys for employers, the following conclusions may be raised:

- A. The most of employers who took part in the survey were from Poland (Figure 3.36).
- B. The most of employers who completed the survey represent the mechanical engineering. Moreover, a large group of respondents work in IT companies, which are included in the other group of disciplines (Figure 3.37).
- C. The most employers expect research qualifications from graduates of technical universities (Figure 3.38).
- D. The most respondents think that they should have an influence on the teaching programs and research of higher education institutions (Figure 3.39).
- E. The most employers would encourage their employees to study at a university which offers research skills to students (Figure 3.40).
- F. Large number of employers think that research qualifications are obtained when studying at technical universities. Moreover, graduates of technical universities have extended knowledge and skills and independence and problem-solving attitude according to respondents (Figure 3.41).
- G. The most respondents are interested in knowledge of their employees graduating from higher education institutions regarding innovations/patents/publications produced by local universities (Figure 3.42).
- H. The most employers do not know any research results produced at regional universities that have a strong impact on manufacturing firms or know only few of them (Figure 3.43).

4. Methodology of using the research results in the education processes

4.1. Scientific research results presentation Toolbox

4.1.1. Development of the best practices summary for using case studies in engineering education & hints on how to introduce this form into classes teaching staff

A case study involves an up-close, in-depth, and detailed examination of a particular case or cases, within a real-world context. Case studies can be used in a variety of fields, hoping that learning gained from studying one case can be generalized to many others. On the other hand, case studies tend to be highly subjective and it is sometimes difficult to generalize results to a larger population. Hence there are some pros and some limitations.

Namely the main strengths of employing case studies are:

- allows researchers to investigate things that are often difficult to impossible to replicate in a lab,
- allows researchers to collect a great deal of information,
- give researchers the chance to collect information on rare or unusual cases,
- allows researchers to develop hypotheses that can be explored in experimental research,

while the major limitations are:

- cannot necessarily be generalized to the larger population,
- cannot demonstrate cause and effect,
- may not be scientifically rigorous,
- can lead to bias.

Case study 1: failure of Hip Joint due to fatigue

Basic background

Nowadays, engineering is extensively employed in medicine in order to provide state-of-the-art technologies in fields like prevention, diagnosis, therapy and rehabilitation. Nevertheless, as a working environment, the body can be deemed extremely hostile since body fluids are essentially an aerated solution, containing approximately 1wt% NaCl at 37°C. Hence, the body fluids are corrosive for metals, leading not only to uniform corrosion, but also to crevice attack and pitting. Moreover, particulate debris will be generated by the articulation of bearing surfaces of devices such as hip prostheses, which subsequently will be accumulated in surrounding tissues, releasing enzymes that will result in the death of surrounding bone cells (osteolysis).

Thus, there are minimum requirements regarding the choice of utilized materials. In specific, some major requirements are:

- corrosion resistance,
- fatigue resistance,
- biocompatibility with any surrounding tissues or body fluid,
- resistant to friction and wear.

To meet performance benchmarks, the development of applicable design attributes has to consider the following points as a minimum:

- physical, mechanical and chemical properties of the instrument materials
- the potential deterioration of the material characteristics due to sterilization and storage
- the effect of contact between the instrument and body environment, or the implant and other instruments
- shape and dimensions, to include their possible effects on the body
- wear characteristics of materials and the effect of wear products on the instrument or body
- insertion, removal and interconnecting parts
- extent of fluid leakage and/or diffusion of substances into or out of instruments
- the accuracy and stability of instruments with a measuring function
- the ability of the implant, instrument or fragment of an instrument to be located by means of an external imaging device

The Hip Joint

In 1961, Sir John Charnley revolutionized modern total hip replacement with the introduction of his “low friction arthroplasty”.

40 years later, current designs continue to be based on his principles of using a relatively small metallic femoral head and a polymeric socket.

Back to 60’s surgical grade 316L stainless steel was mainly used, but nowadays a range of more exotic alloys systems are also utilized.

The device “parts” are a ball, which is inserted into the top of the femur, with a stem for stability (see Figure 4.1).

The stem may be composed of titanium or a cobalt-based alloy and the ball or “head” is generally cobalt chrome or ceramic. The stem is often inserted with a bone cement but may also have a sintered porous surface coating which allows bone ingrowth (osteointegration) for mechanical locking. The socket is composed of a metal shell (usually titanium or cobalt chrome) which bone grows into, and a plastic (ultra-high molecular weight polyethylene) liner, which articulates with the new ball.

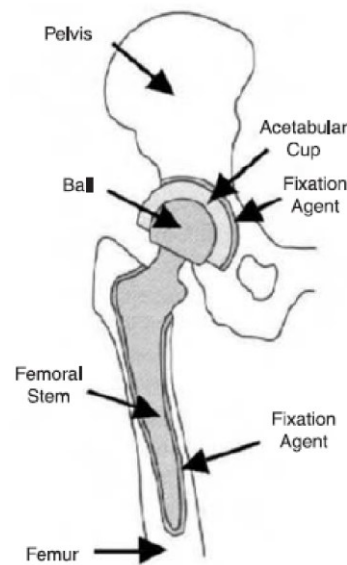


Figure 4.1. Sketch of total replacement hip device

Fatigue Failure of Prosthetic Hip Components

When a patient has been diagnosed with a diseased or damaged hip joint, total hip replacement is accepted as a standard method treatment. However, complications may arise from in-service (usually fatigue) failure of the femoral component. Fatigue is known to depend on factors ranging from design and material of the device, through the surgical technique employed during implantation, to the weight and level of activity of the patient.

Key aspects:

- A metallic total hip component was developed in the early 1970s. It had a trapezoidal cross section to its stem and neck, which was intended to impart improved mobility, stability and stem strength over previous hip designs.
- It was fabricated from 316 surgical grade stainless steel in a hot forged and lightly cold-worked condition.
- At one New York hospital, 805 patients received this implant over a 6-year period prior to 1979. Of this population, at least 21 patients had to have remedial treatment for a fractured femoral component. This represented a failure rate over four times higher than that reported for other femoral component designs.
- To investigate the reason for such high failure rates, a failure analysis was conducted on all 21 fractured parts.

Fracture generally occurred within the proximal third of the stem. Optical microscopy revealed a dominant crack initiation site at the posterior corner on the medial side of the stem. A second crack had initiated on the lateral side of the stem, and exhibited clam-shell markings typically found on fatigue fracture surfaces. The boundary between the two crack fronts was identified by a step near the central portion of the trapezoidal cross section (see Figure 4.2) [4.1].

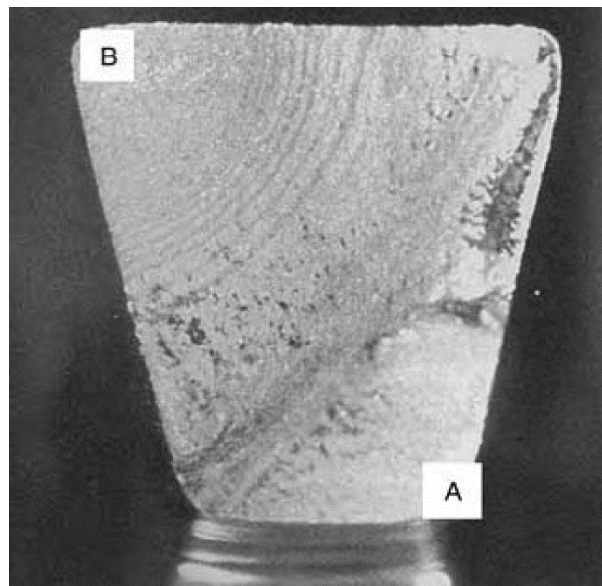


Figure 4.2. Optical micrograph of fracture surface on femoral stem of total hip device. Crack growth from medial corner (A), and clamshell markings emanating from lateral corner (B).

The proposed explanation for the fracture of the femoral stem

Residual tensile stresses induced by large compressive overload on the medial side of the stem resulted in the growth of a fatigue crack prior to a second crack nucleation on the lateral side. With crack growth, there is a progressive reduction in residual tensile stresses, along with an increase in the extent of crack closure, ahead of a fatigue crack subjected to cyclic compressive loads. As a result, the medial cracks slowed down or stopped after a certain amount of crack advance. The nucleation of medial cracking increased the stress level to which the lateral side of the stem was exposed. With time and cyclic loading in service, the two crack fronts eventually met up. This coalescence of crack fronts produced a step on the fracture surface.

Rimnac et al. [4.2] concluded that the failure of the femoral stem was a consequence of the combined effects of the trapezoidal cross-sectional design and of the materials properties of the stainless steel used to fabricate the component.

Case study 2: accident with a pressure die-casting machine

Basic background

Pressure die-casting is a process similar to injection molding of plastics, which is widely used for mass production of small to medium sized castings by aluminum or zinc alloys. Pressure die-casting results good surface finish, while inserts of other metals such as steel pins and screw threads can also be incorporated. The main steps of the process are:

- the machines comprise a set of water-cooled metal dies and cores that are clamped firmly together,
- a measured quantity of the molten alloy is injected under high pressure,
- the clamping force has to be sufficient to prevent any liquid from escaping,
- a short time is allowed for solidification, during which period the dies have to remain clamped,

- when the casting is solid and able to support itself, the dies are opened and the casting is ejected,
- after cleaning the opened mold, the faces of the cavity are recoated with a release agent and then clamped together again ready for the next casting.

Key aspect of the process is the cycle time. Different sizes of casting require different time cycles that have to be properly set according to the mass of metal injected and the time necessary for the heaviest section to solidify. Too long a time slows down the production rate, on the other hand, if the time is too short for complete solidification, castings either break up when the dies are opened or become distorted by the ejector pins.

There are two process types in die casting:

- the liquid metal is drawn from near the bottom of the reservoir and injected with minimum turbulence, in order to eliminate dross and avoid air entrapment,
- the metal is ladled out of a large melting pot and a “shot” sufficient to make the casting poured into a receiver and then injected. Castings made in this way are very likely to carry air into the mold and, although the outer skin of the casting may be free of porosity and well formed, the air and any other gases evolved during solidification end up within the thicker sections. At the same time, the internal gas pressure thus set up may sometimes be sufficient to cause parts of the casting to swell when first taken from the mold while the outer skin is still soft and relatively weak.

The accident’s key points

- The accident occurred when two men were operating a machine of the latter type making castings in an aluminum alloy.
- Both were experienced workers, very familiar with the machine, so much so that they were left to work on their own, virtually unsupervised, during a night shift.
- One of them suffered severe facial burns when liquid metal squirted out from between the dies as he was waiting with tongs ready to remove the finished casting as soon as the dies opened.
- He and his colleague who had poured the shot into the injector reservoir claimed he was wearing a visor, but a jet of metal struck his clothing just below this and ricocheted up into his eye.

A more in-depth analysis

The casting was to form a pair of matching spacers for a motor mount (see Figure 4.3). The spacer at the right shows where liquid alloy had burst out from the face at the sprue end the narrow blocks at the far end are “sinks” to catch any dirt or residues swept before the liquid as it is injected. These would be broken off the finished casting and put back into the melting pot, along with the sprues.

A microsection taken through the casting revealed extensive voids due to air entrapment within in the body of the casting. This was confirmed by x-radiography before sectioning (see Figure 4.4). The metallographic structure revealed the pressure of this entrapped air had forced liquid alloy through the skin of the casting. For this to occur the dies must have been partially opened in order for the internal air pressure to rupture the unsupported skin. This

was clearly the source of the liquid metal that squirted out as the dies were unclamped. The position of the dies where this metal was ejected would have been just below the eye level of someone standing at the side of the machine waiting to remove the finished casting as soon as the dies opened.



Figure 4.3. Pair of aluminium alloy die castings on common sprue, as removed. Notice the broken skin in the end face at the right-hand side where liquid metal has burst out after dies opened. [4.1]

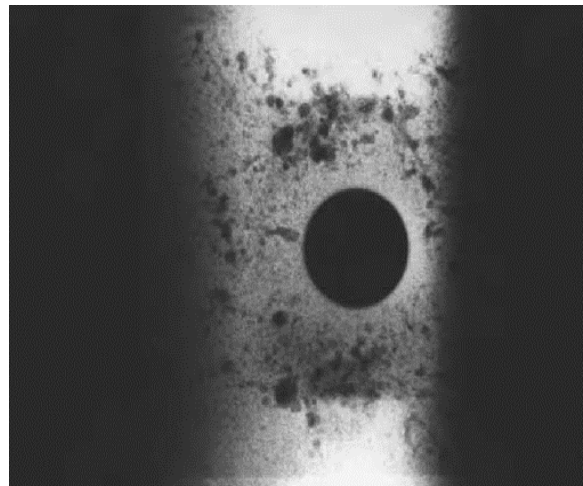


Figure 4.4. X-radiograph of right-side casting showing excessive porosity caused by air entrapped as liquid metal was injected [4.1]

Explanation

On the morning after the accident, it was discovered that the timing cycle on the machine had been altered from the setting when these particular dies had been installed the previous day. The number of castings made up to the time the accident occurred was about 10% greater than what should have been possible in the number of hours the two men on the night shift had been working. It appears that they had decreased the cooling time of the machine cycle in order to produce their expected quota of castings in less time and thus take a longer break. It was the first time they had made this particular casting. In view of the evidence of the way the skin had burst open it seems they were unlucky with this particular casting in that more air than usual had been carried in by the turbulence as the metal was injected and the dies had opened before the skin was thick enough to withstand the internal pressure.

Outcome

The operators were to blame for the cause of the accident but the management was held responsible on the grounds that:

- the two workers were inadequately trained and had been left on their own to work unsupervised for the entire 8-h night shift,
- the time cycle setting controls should have been locked or otherwise made tamper-proof so that adjustments could only be made by authorized personnel.

The subsection 4.1.1 was created mainly based on the work of Lewis et al. (2003) [4.1].

Case study 3: Gluing case study

Subject: Environmental management

Topic: The impact of conventional manufacturing techniques on the environment and the search for BAT - on the example of adhesive bonding

Lecturer: B. Ciecińska

The lecturer's publications were used as teaching materials:

- A. Ciecińska B.: Surface pretreatment for adhesive bonding by conventional methods and lasers: a comparative study on human and environmental safety. Procedia Manufacturing, 2021.
- B. Ciecińska B.: Using Lasers as Safe Alternatives for Adhesive Bonding. Emerging Research and Opportunities. IGI Global, Hershey, NY, 2020.
- C. Chapter 1: Adhesive bonding: Types of Adhesives and the Preparation of the Adhesive Mixture.
- D. Chapter 3: The Importance of the Surface Preparation Method.
- E. Chapter 4: Technological Methods of Surface Pre-Treatment: Traditional Approach.
- F. Chapter 6: Evaluation of Possibilities to Apply Lasers for Adhesive Bonding.

Presentation

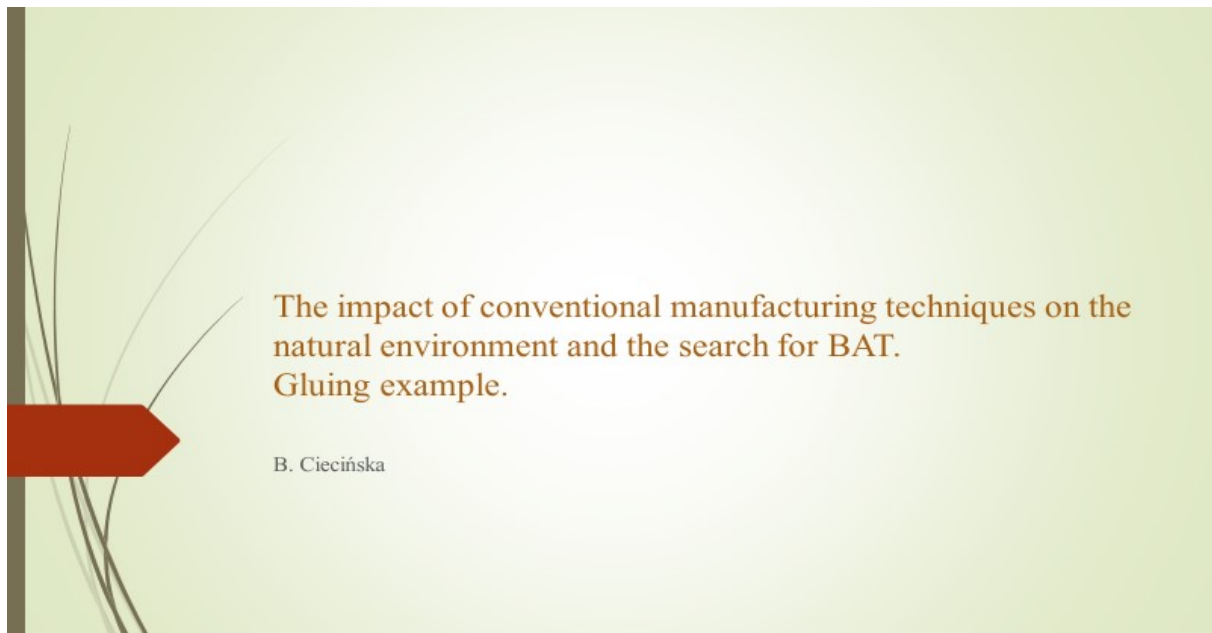


Figure 4.5. Title of the presentation

Comment

Various semi-finished products and various manufacturing techniques are used in the production of machine parts. One of them is joining elements by gluing.

There are many industries in which gluing is widely used: automotive, aviation, household appliances and utility products, paper, footwear, toys and others.

Various chemical substances are used to connect in this way, not always indifferent to the environment and human health. Therefore, the question arises whether there are ways to eliminate environmentally harmful chemicals without compromising the operational properties of the products.

The widely used purpose of bonding as an assembly technique is also due to number of advantages of the joining. The following can be distinguished: the materials to be joined can be different (e.g. metal with plastic), the joint is light, durable, does not require additional fasteners (screws, rivets), the creation of the joint does not require additional structural elements (holes), the restrictions on the shape and size of the product are small, the price of the joint is low, and many others.

Due to the lack of additional stresses at the bonding point, bonding is considered instead of welding or soldering.

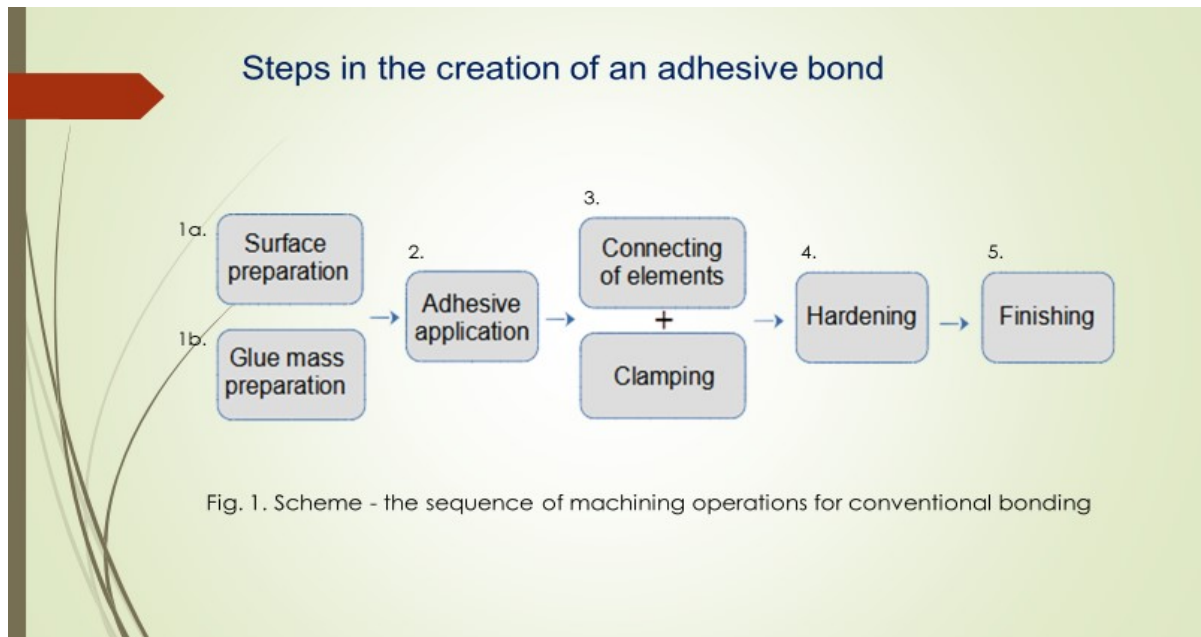


Figure 4.6. Steps in the creation of an adhesive bond

Comment

An adhesive joint is formed in an operation involving a number of steps: preparation of the surface before the application of the adhesive, preparation of the mass (resin + hardener), application of the adhesive, joining of the elements together with possible pressing against each other, hardening (under various conditions), optional finishing treatment.

The sequential activities shown in Figure 1 generate specific production requirements. Based on technical information regarding the types of used substances and materials, their physical and chemical properties, equipment, devices, a list of negative environmental aspects was identified and sorted out according to the steps of the bonding operation.

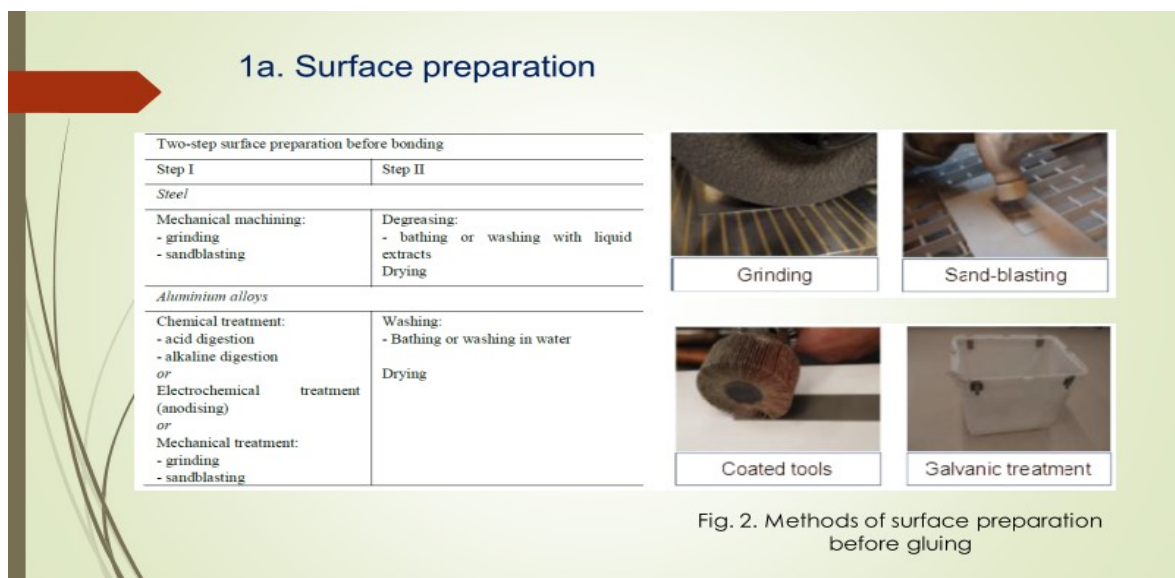


Figure 4.7. Surface preparation

Comment

The surface preparation (the first step in adhesive bonding) can be realized by different methods. In case of use of chemicals for degreasing, the following environmental aspects can be distinguished: the use of concentrated acids (sulphuric acid, nitric acid, hydrofluoric acid), alkalis, mixtures of substances including chromium compounds e.g. $\text{H}_2\text{Cr}_2\text{O}_7$; petroleum derivatives (e.g. petrol), trichloroethene, aromatic hydrocarbons, ketones, metal vapors.

In case of use of chemicals for pickling or anodising, possible environmental aspects are connected with the use of concentrated acids (e.g. H_2SO_4) or concentrated alkalis (e.g. NaOH). When abrasive treatment is required and corundum or grinding wheels are used.

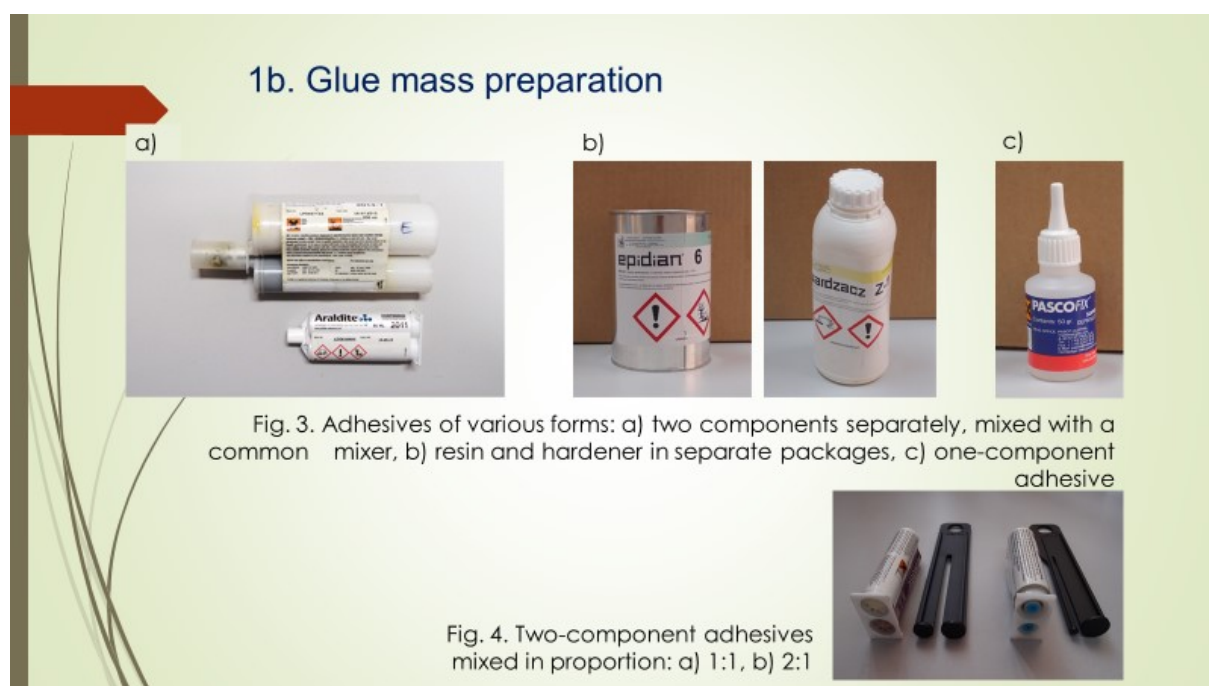


Figure 4.8. Glue mass preparation

Comment

Next step in bonding operation is preparation of the adhesive mass, when the environmental aspect consist of use of different chemicals for bonding: epoxy, cyanoacrylate, methacrylate, phenolic, phenol-formaldehyde resins, polyvinyl chloride based resins, polyurethane; hardeners, e.g. triethylenetetramine; others containing e.g. diluted sulphuric, hydrochloric, orthophosphoric acid; primers; sealers, fillers, modifiers (e.g. styrene in epoxy resins).

These adhesives are commercially available in various packages, and for their use additional equipment is required. If the resin and the hardener are delivered separately, they should be properly portioned and mixed. An additional container and stirrer will be hazardous waste in the environmental context.

2. Adhesive application

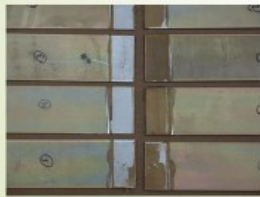
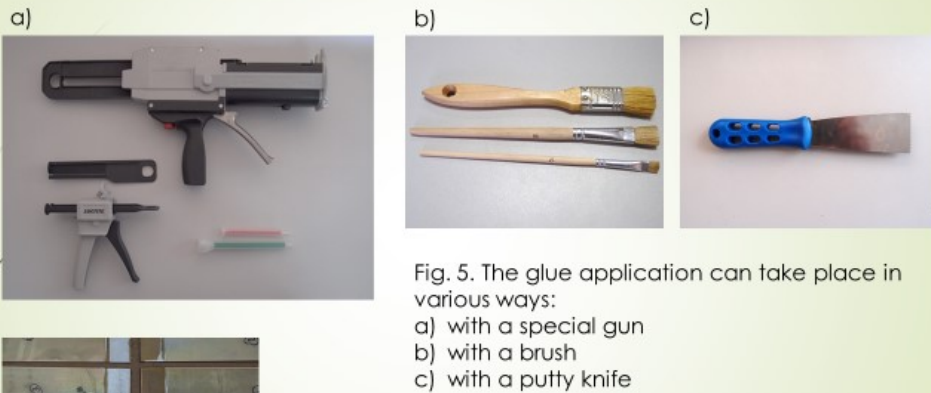


Figure 4.9. Adhesive application

Comment

The finished glue mass is applied to a cleaned and dry surface in various ways. Adhesives in two-component packages are squeezed by the mixing tip directly onto the surface. Sometimes there is also a need to grind high-density glue. Adhesives mixed in a different way (in specially designed vessels) are applied with a brush or putty knife, depending on the consistency of the mass. The strength of the joint later depends on the accuracy of applying the mass. It is important not to leave any empty spaces, also avoid the formation of air bubbles and foreign particles from getting into the joint.

3. Connecting of elements and clamping



Fig. 7. A special handle for positioning the glued elements
Fig. 8. Prepared elements for gluing
Fig. 9. Connection made



Figure 4.10. Elements connecting and clamping

Comment

Glue alone is not sufficient for gluing. We said before that there should be a surface preparation step before applying the glue. Similarly, after applying the glue, you must provide the appropriate conditions for the formation of an adhesive joint.

Many adhesives take a certain amount of time to form chemical bonds. During this time, the connection should be kept unchanged. Different glue holders are used to prevent the elements from moving relative to each other. Then the stationary elements can be permanently connected.



Figure 4.11. Hardening and finishing

Comment

The last two stages consist of hardening and finishing require the use of warming-up devices and tools for example for removing excess adhesive.

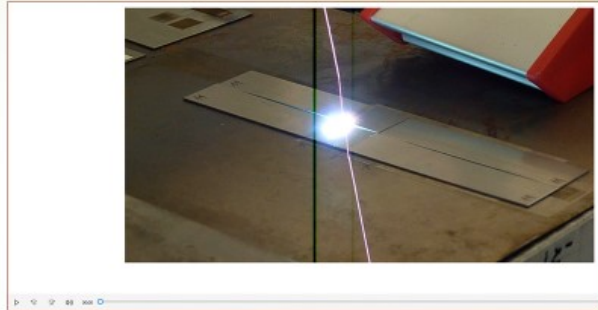
Some adhesives do not require additional equipment to harden the joint. Curing punctured at ambient temperature.

Additional tooling may be needed to remove excess adhesive for aesthetic or strength reasons.

Laser use possibility



Fig. 14. A laser can be used to prepare the surface before gluing.
a) Laser head with hood for removing ablation products
b) A sample



Movie 1. The laser surface treatment is very interesting. The screen shows the reflected laser beam - but it cannot be seen with the naked eye

Figure 4.12. Laser use possibility

Comment

The problem of using a wide variety of chemicals that are harmful or hazardous at the initial stage of the bonding operation can be solved by implementing a different method of the surface preparation. Experimental results show that both obtaining a suitably rough surface and its activation and improved wettability are possible as a result of the laser treatment. Experimental studies show that after laser surface preparation and bonding these surfaces with an adhesive, results comparable to or even better than the existing technology can be obtained.

Analysis of hazard and human risk in traditional method

Operation	Environmental aspect	Environmental effect and hazard
1. Surface preparation	Use of chemicals for degreasing: concentrated acids (sulphuric acid, nitric acid, hydrofluoric acid), alkalis, mixtures of substances including chromium compounds e.g. $H_2Cr_2O_7$, metal vapours, petroleum derivatives (e.g. petrol), trichloroethene, aromatic hydrocarbons, ketones	<ul style="list-style-type: none"> - Toxic or harmful effects on humans through skin, eyes, mouth and mucous membranes (possible asthma, cancer, allergies, poisoning, burns depending on exposure), danger of loss of consciousness through inhalation of vapours (e.g. acetone) and further accident consequences - Risk of explosion or fire - Environmental load of hazardous liquid waste (contaminated liquids) - Consumption of clean rinsing water - Vapour emissions to air - Energy consumption for heating the cleaning baths - Risk of electric shock in case of an equipment failure

Operation	Environmental aspect	Environmental effect and hazard
1. Surface preparation	Use of chemicals for pickling, anodising: concentrated acids (H_2SO_4), concentrated alkalis (NaOH)	<ul style="list-style-type: none"> - In case of a contact with strongly corrosive substances - burns to skin, eyes, respiratory system - Danger of electroshock in case of heater malfunctions - Possible mutagenic, carcinogenic, toxic, sensitising effects - Possible fire, explosion hazard as a secondary aspect - pollution of the atmosphere with combustion products, possibility of getting into surface water and soil, also during fire extinguishing action - Environmental load of contaminated liquids after bathing or rinsing - Consumption of clean rinsing water - Vapour emissions to air - Electricity consumption for heating the baths
	Use of corundum or grinding wheels	<ul style="list-style-type: none"> - Workplace dustiness - Environmental burden of waste in form of the used corundum or grinding wheels - Energy requirement to power the equipment (to a lesser extent) - Minor risk of accidents due to a wear of grinding wheels

Figure 4.13. Analysis of hazard and human risk in traditional method

Comment

Most environmental problems and threats to human life and health can be identified at the first stage of surface preparation. Different materials should be prepared in a specific way. Hence the multiplicity and variety of means, substances and equipment necessary to perform the surface preparation activities. In the table the use of chemicals for degreasing, pickling, anodizing are presented. (Please, let's read carefully the environmental and human risks of using so many chemicals.) The third area discussed concerns abrasive machining. (Please read this part of the table carefully).

Operation	Environmental aspect	Environmental effect and hazard
2. Preparation of the adhesive mass	Use of chemicals for bonding: - epoxy, cyanoacrylate, methacrylate, phenolic, phenol-formaldehyde resins, polyvinyl chloride based resins, polyurethane - hardeners, e.g. triethylenetetramine, others containing e.g. diluted sulphuric, hydrochloric, orthophosphoric acid - primers - sealers, fillers, modifiers (e.g. styrene in epoxy resins)	- Risk to human health: possible sensitisation, mutagenic effects, carcinogenicity, irritation to eyes, skin, gastrointestinal tract, sometimes acute poisoning, nervous system disorders, disorientation (depending on the type of substance) - Possible fire hazard (flammable vaporous) - Vapour emissions to air - Waste load from packaging, additional mixing equipment (spatulas, containers)
3. Application of the adhesive	Use of manufacturer's containers and mixing tips for application	- The burden of hazardous packaging waste
4. Connection of elements	Use of clamps for fastening components	- Waste load from used components (minor aspect)
5. Clamping	As above	As above
6. Hardening	Use of warming-up devices	- Electricity requirement
7. Finishing	Use of tools e.g. for removing excess adhesive	- Waste burden (minor aspect)

Figure 4.14. Analysis of hazard and human risk in traditional method - continuation

Comment

The remaining steps of the gluing operation also involve certain risks. Some of the hazards are recurring, which means that there are multiple sources of the same problem in one bonding process. Examples include air emissions, the use of harmful substances, and the generation of troublesome and hazardous waste.

New kind of hazard and new risk during laser surface preparation

Operation	Environmental aspect	Environmental effect and hazard
Laser beam surface treatment and cleaning	Use of a laser device	<ul style="list-style-type: none"> - Risk to eyes, skin by directing the beam towards the face or hands - aspect dependent on production practices - Possible emission of chemical substances into the atmosphere due to evaporation of e.g. pollutants from surfaces - Possible irritation of respiratory tract by dispersed dust. - Possibility of poisoning by vapours emitted into the atmosphere when working with plastics - Electricity requirement (a less important aspect) - Need for protective atmosphere gases in the processing zone - a less important aspect, not present in the processing of most materials in the context of bonding



a)



b)

Fig. 15. Due to the risk of exposure to the invisible laser beam, it is necessary to properly mark the site and use protective glasses

Figure 4.15. New kind of hazard and new risk during laser surface preparation

Comment

Experimental studies support the claim that nuisance chemicals and other environmental problems can be eliminated. One way is to replace the existing activities with laser treatment. The obtained adhesive joints are characterized by comparable or even better static shear strength, and the surface roughness before bonding is satisfactory. The use of a laser can therefore bring particular benefits in the first step - surface preparation.

However, you need to be aware that the implementation of a new production method and the use of new procedures, substances and devices may generate a different, not always positive, impact on the environment. An example is the laser which, as a tool, has specific features that should be considered in the risk assessment.

Let's read the content in the table carefully.

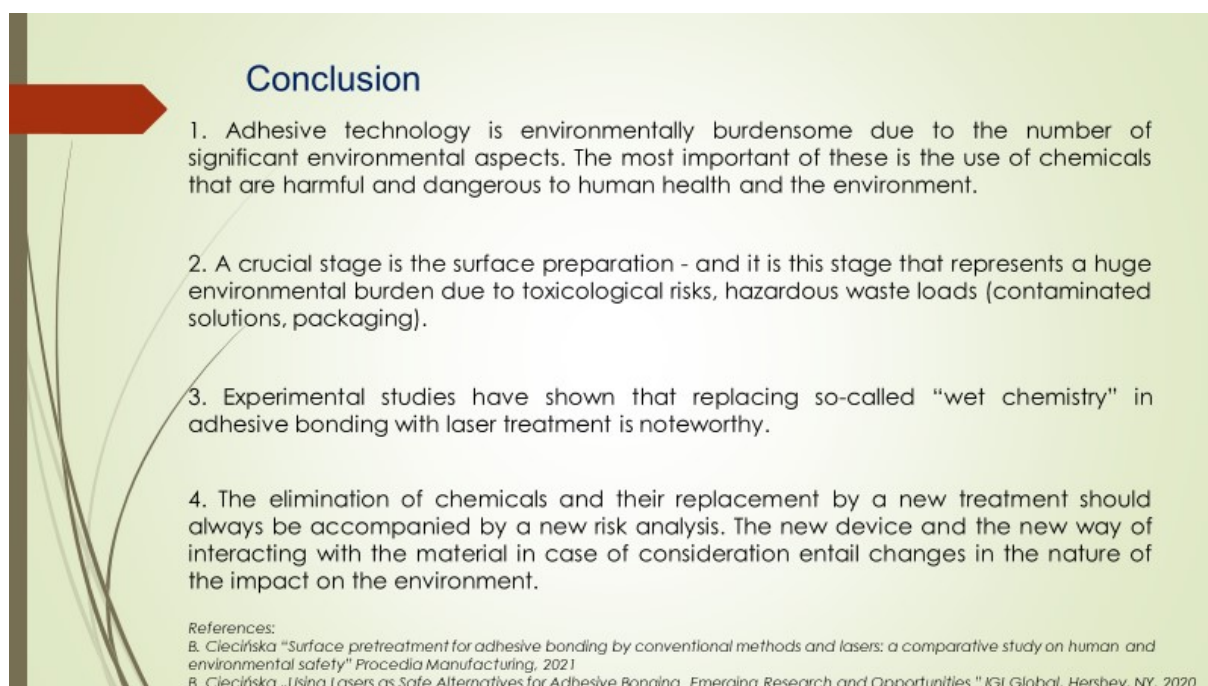


Figure 4.16. Conclusion of the case study

Comment

Adhesive technology is environmentally burdensome due to the number of significant environmental aspects. The most important of these is the use of chemicals that are harmful and dangerous to human health and the environment. The choice of these substances depends on the material to be prepared for bonding, but undoubtedly there are many of them, and they are diverse in their chemical structure and the nature of their impact on people and the environment. A crucial stage is the surface preparation - and it is this stage that represents a huge environmental burden due to toxicological risks, hazardous waste loads (contaminated solutions, packaging). In order to protect the environment and employees, it is necessary to respect the proper method of handling such chemicals, which in turn requires the implementation of good manufacturing practices. These practices, however followed, will not eliminate the environmental aspects present in the process.

In a production context, changing technology requires a series of decisions. It is important to confirm that the new manufacturing method will not be poorer - from the point of view of product quality, its strength, durability, aesthetics, production costs, and many other criteria of technology effectiveness assessment.

Therefore, it can be concluded that laser surface preparation technology can be considered in the context of the search for the Best Available Technology for adhesive bonding.

The elimination of chemicals and their replacement by a new treatment should always be accompanied by a new risk analysis. The revised environmental aspects and human safety problems are presented in this article. A new risk is generated by the laser. It is a device which, by the nature of the used physical phenomena, is not very cheap at present. However, the energy beam it emits has undoubted advantages: it is consistent over time, monochromatic, does not wear out and is not contaminated. Commercially available laser devices offer

a choice of wavelengths, operating modes (continuous, pulsed), and power, so that both the device and its operating parameters can be selected to allow the processing of a given structural material.

The new device and the new way of interacting with the material in case of consideration entail changes in the nature of the impact on the environment. Due to the significant risk of negative impact on the eyes and skin (tissue damage), human protection from the laser beam becomes the most important requirement. Previous chemical handling practices are superseded by the need to use enclosures and goggles to protect the eyes. Good practice should also include handling of the product being exposed to the beam to protect the skin from burns. A direct environmental effect is the emission of vaporised or molten material into the atmosphere. Therefore, laser equipment should be used with industrial filters, and personal protective equipment such as face masks against dust or organic substances is sometimes necessary.

4.1.2. Development of best practices summary for using graphical visualization in engineering education & hints on how to introduce this form into classes teaching stuff.

Infographics are visual representations of information, data, or knowledge meant to present complex information quickly and clearly. Infographics use many different strategies to present information, including graphs, charts, maps, diagrams, and pictures (and often a mixture of several of these). Interpreting, critiquing, and producing infographics are great ways for students to learn and practice key science literacy skills. When students interpret infographics, they practice reading and understanding graphs, charts, diagrams, and maps; finding patterns in data and interpreting their meaning; and arguing from evidence to support their interpretation of the infographic.

Statistics can say a lot about a subject, but figures alone don't always make for the most compelling reading material. Instead, adding graphics and short text explanations can make a string of numbers much easier to understand and remember. Infographics also help increasing awareness of an issue. Encouraging change isn't always easy, but an eye-catching infographic can educate your audience about an important issue while teaching them how and why to take action.

Depending on the focus of your classroom and the level of your students, you could use infographics in a number of learning activities:

- try introducing a new module by using an eye-catching infographic to convey the basics or generate interest,
- encourage students to read statistics, interpret data, and draw conclusions from an infographic,
- rather than having students read a textbook passage or a news article, use an infographic to start a discussion or lead a classroom debate.

Example No1: Raising awareness on energy consumption

World energy supply and consumption refers to global production and preparation of fuel, generation of electricity, energy transport and final consumption. It is a basic part of economic activity. Energy production is 80% fossil, while half of this is produced by China, the United States and the Arab states of the Persian Gulf. The Gulf States and Russia export most of their production, largely to the European Union and China where not enough energy is produced to satisfy demand. Energy production increases slowly, except for solar and wind energy which grows more than 20% per year.

The reasons for increasing energy consumption include economic development, rising population and technological developments. As energy plays an important role in the lives of humans and in the activities of the economy, both as a scale of economic and social development and as a basic humanitarian need, energy consumption per capita of a country is regarded as an important indicator of economic development.

All energy sources have some impact on our environment. Fossil fuels—coal, oil, and natural gas—do substantially more harm than renewable energy sources by most measures, including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and global warming emissions. Therefore, it is very important that we conserve energy, and raise awareness on this issue.

The following graphs will provide a general view regarding the global energy consumption and production over time, the energy consumption during a year and its distribution in different energy sources, the per person energy consumption and other important and key information.

Energy consumption

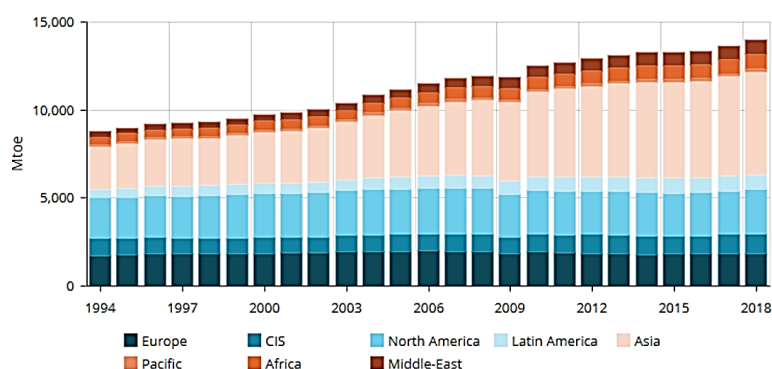


Figure 4.17. Global energy consumption over time [4.3]

As we can notice in Figure 4.17, Asia's energy consumption significantly increased the last 20 years, on the contrary to the other parts of the world where the energy consumption remained stable. At the same time Middle-East and Africa increased their energy consumption notably, as the result of their economic growth.

Energy production

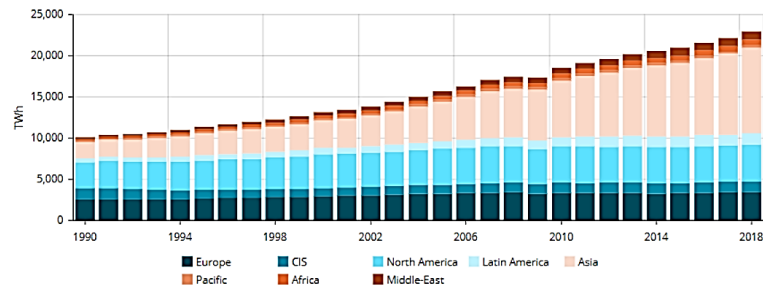


Figure 4.18. Global energy production over time [4.3]

The Figure 4.18 shows the worldwide energy production. Accordingly, to the consumption, energy production has also raised in Asia, whereas it remained stable in the other parts of the world.

Energy consumption 2018

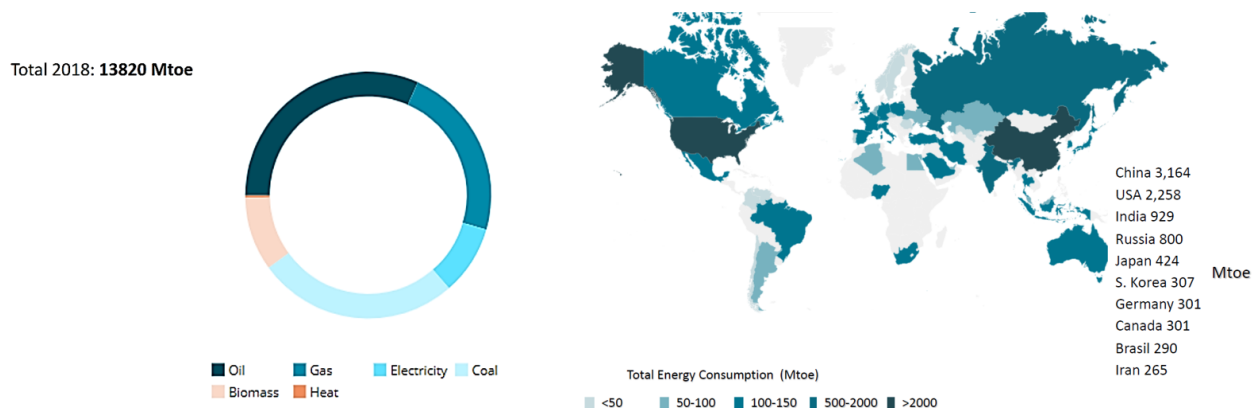


Figure 4.19. Energy mixture and regional energy consumption in 2018 [4.3]

In 2018, and according to Figure 4.19, the total energy consumption was approximately 13820 Mtoe (million tones oil equivalent). More specific, in 2018 the main energy types that were consumed were oil and coal followed by gas. Significant was also the energy consumption in biomass and electricity, and finally a small amount was heat. The regional distribution is also very interesting, since China and USA are the only countries that consume over 2000 Mtoe, consuming in total more than 5000 Mtoe, approximately 40% of the global energy consumption. India on the other hand, with practically the same population with China, has almost 70% less energy consumption than China.

World consumption and energy mixture

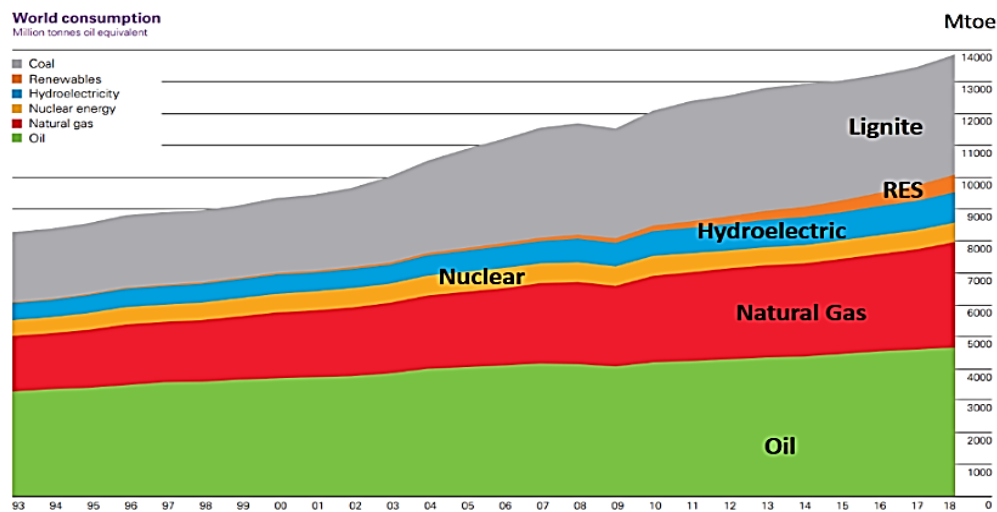


Figure 4.20. World consumption energy mixture [4.4]

Subsequently to the previous plots we can see in Figure 4.20 the energy world consumption over time. Mainly we notice that from the 90's there is a slight increase in oil consumption and natural gas. On the other hand, lignite (coal) and renewable energy sources were extensively utilized the last decade, as the result of the change in more sustainable and eco-friendly energy resources. Finally nuclear and hydroelectric power consumption remained stable through the years.

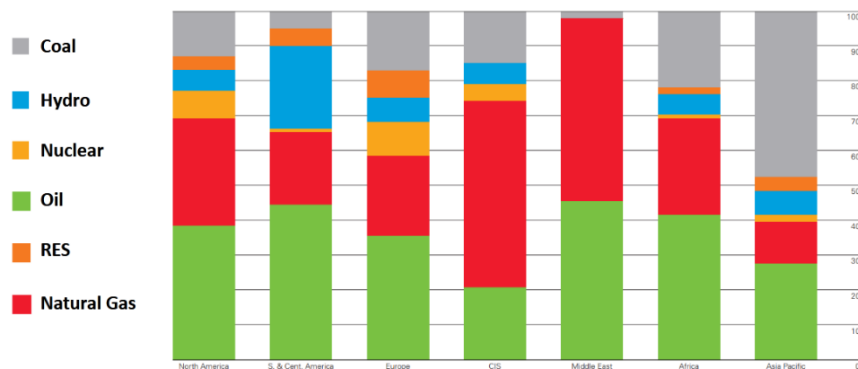


Figure 4.21. Regional energy mixture [4.4]

In addition to the previous diagrams, in Figure 4.21 we can see how different world regions meet their energy needs by utilizing different energy sources. America and Africa consume mainly Oil, while Middle East uses oil and natural gas in the same percentage. In contrast, Asia uses mostly coal, followed by oil. It is remarkable that Europe has incorporated in its energy mixture renewable energy sources, which represent almost 20% of Europe's total energy production. We also notice that Central and South America consumes a large percentage of hydroelectric energy, in comparison with the others. Finally, the most economically developed

continents, especially Europe and North America, consume also a noticeable amount of nuclear power.

Per person energy consumption

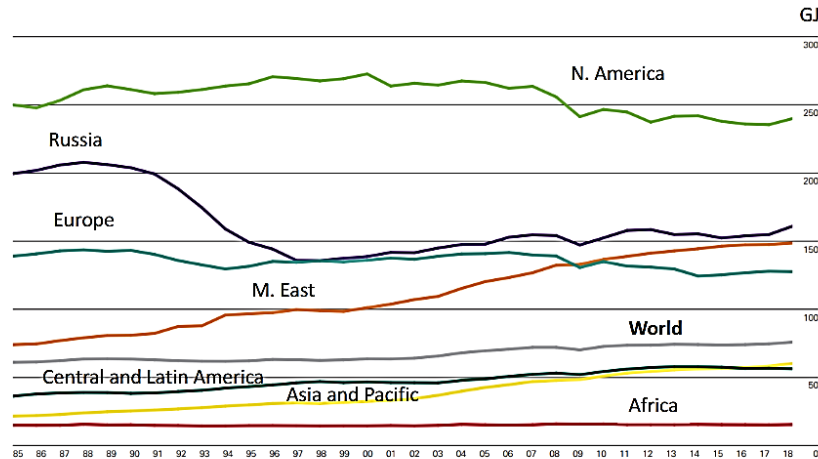
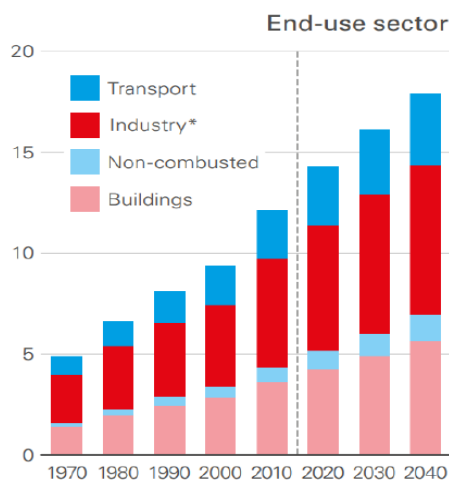


Figure 4.22. Energy consumption per person over time [4.4]

Based on Figure 4.22, it becomes clear that the energy consumption per person is undoubtedly larger in North America, as a result to the prosperous lifestyle. We also notice that Russia reduced significantly the energy consumption from the 90's until now. Middle East on the contrary, uses more and more energy per person through the years, possibly due to their radical economic growth. Europe remains stable with slight ups and downs, same as Africa, which although uses the lowest percentage of energy between all the others.

Energy consumption sectors

Primary Energy Consumption (btoe)



The final plot of Figure 4.23 pertains to the distribution of energy consumption in the different sectors of economy over time. Namely, from 1970 and based on predictions up to 2040 the main energy consumer is the industry, followed by the energy consumption by the buildings, while, transportations and non-combustion consumption consist the sectors with the lower consumptions. Hence, it is obvious, that by incorporate and adopt more energy efficient production lines and more eco-friendly buildings, a major step towards a less energy consuming and feasible reality and economy can be taken.

Figure 4.23. Energy Consumption Sectors [4.4]

Example No2: Manufacturing in European Union (EU)

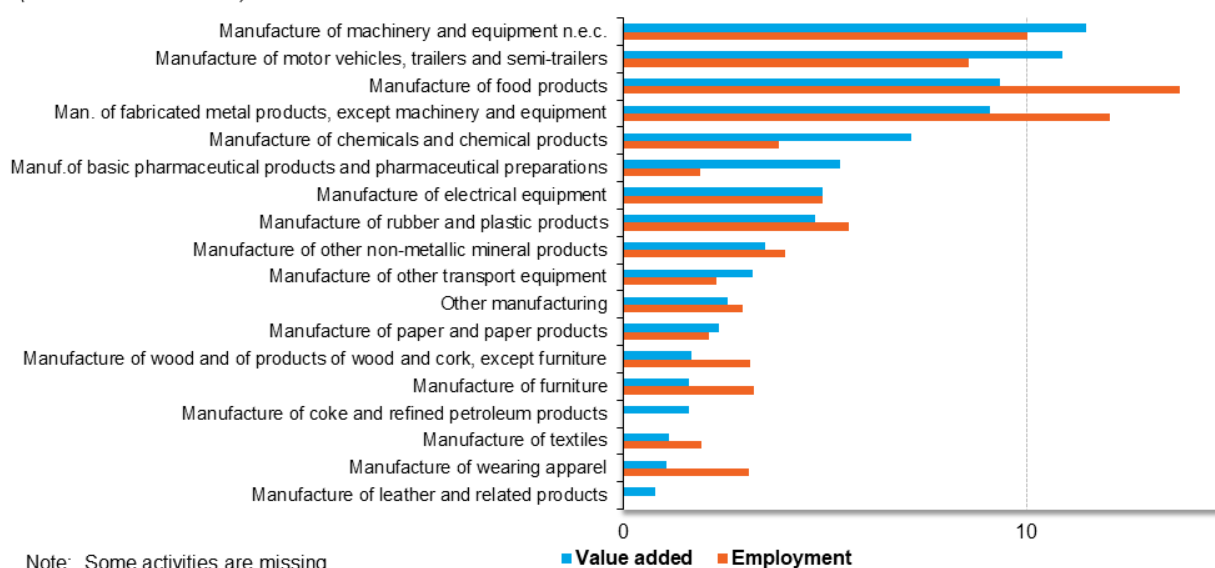
The example is based on: Statistical classification of economic activities in the European Community (NACE) Rev. 2 Section C.

The manufacturing sector includes a vast range of activities and production techniques, from small-scale enterprises using traditional production techniques, such as the manufacture of musical instruments, to very large enterprises sitting atop a high and broad pyramid of parts and components suppliers collectively manufacturing complex products, such as aircraft. An analysis of the manufacturing sector as a whole gives an idea of the scale of this sector. It should be noted, however, that indicators of its inputs (for example, labor or capital goods), its performance, or its size structure are effectively an average across very different activities. While this can also be said of other large and diverse sectors, such as distributive trades and transport services, the manufacturing sector is probably the most varied activity within the non-financial business economy at the NACE section level of detail.

Sectoral Analysis

Sectoral analysis of Manufacturing (NACE Section C), EU-27, 2017

(% share of sectoral total)



Note: Some activities are missing

Note: Ranked on value added.

Source: Eurostat (online data code: [sbs_na_ind_r2])

eurostat 

Figure 4.24. Sectoral analysis of Manufacturing in EU for 2017 [4.5]

Based on Figure 4.24, the largest EU-27 subsectors in 2017 in terms of value added were the manufacture of machinery -equipment and the manufacture of motor vehicles, trailers and semi-trailers. At the same time, in terms of employment, the manufacture of food products, and the manufacture of fabricated metal products, except machinery and equipment were the largest sectors

Country overview

Relative importance of Manufacturing (NACE Section C), EU-27, 2017

(% share of value added and employment in the non-financial business economy total)

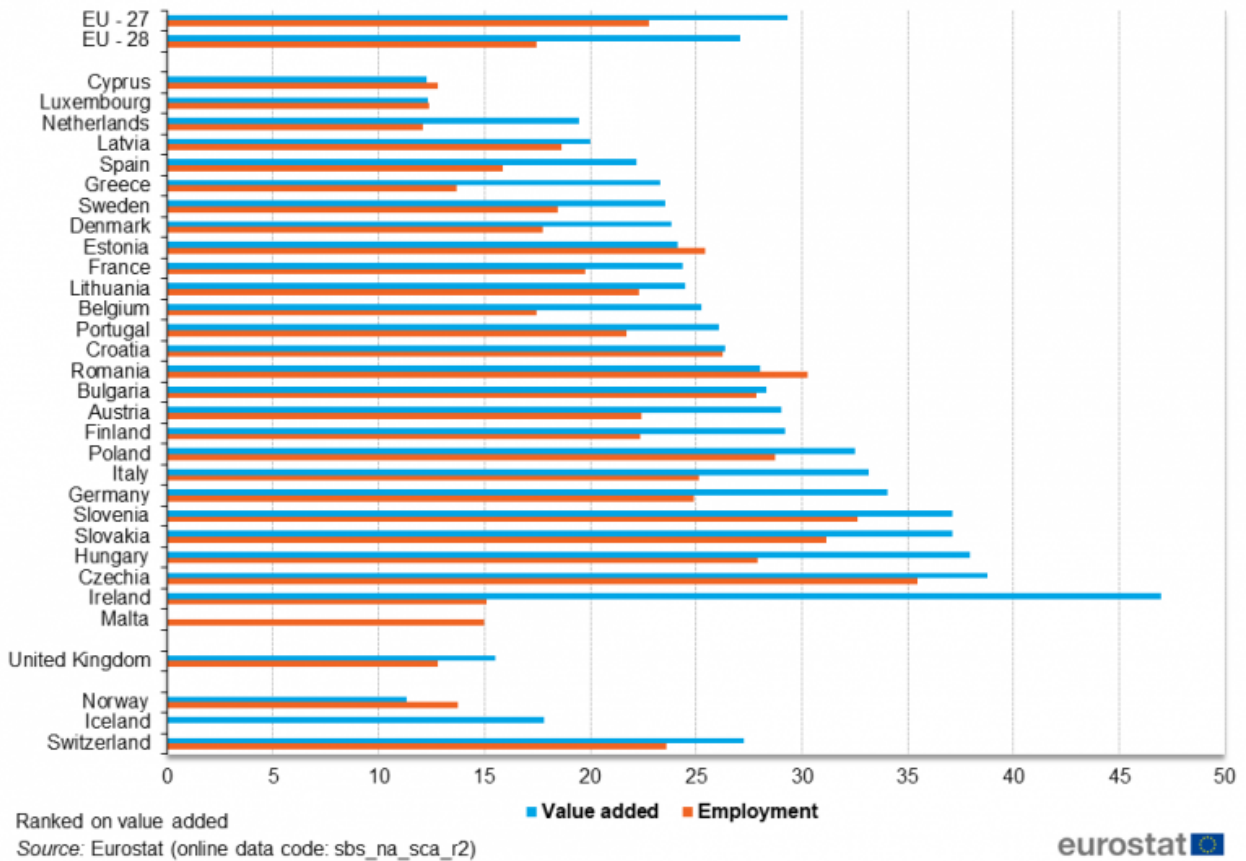
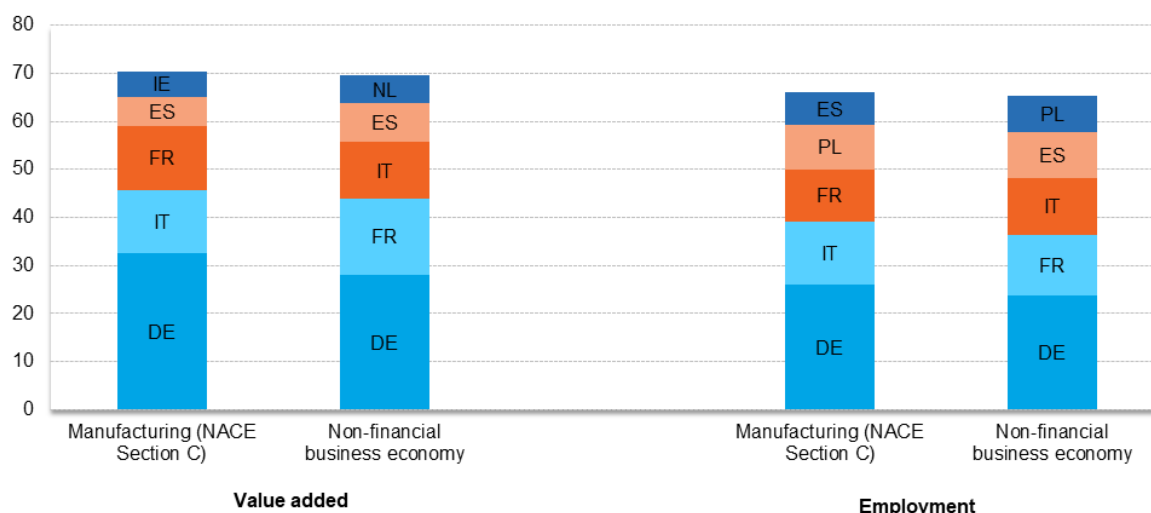


Figure 4.25. Regional analysis of Manufacturing in EU for 2017 [4.5]

Because of the tradable (export and import) nature of manufactured goods it follows that the relative importance of manufacturing within the non-financial business economy varies greatly between EU Member States and also that specialisations at the subsector level are sometimes very pronounced. As we can see in Figure 4.25, the share of manufacturing within the non-financial business economy's value added varied in 2017 from 12.3% in Cyprus and 12.4% in Luxembourg to more than 37.0% of the total in Slovenia, Slovakia, Hungary and Czechia, with Ireland having the highest share (47.0%). The range in employment terms was similar, from 11.3% in the Netherlands to 35.4% in Czechia.

Concentration of value added and employment, Manufacturing

(NACE Section C), EU-27, 2017 *(cumulative share of the five principal Member States as a % of the EU-27 total)*



Source: Eurostat (online data code: sbs_na_sca_r2)

eurostat 

Figure 4.26. Concentration of value added and employment, manufacturing in EU for 2017 [4.5]

Among the five largest EU Member States, Germany stood out as its manufacturing sector contributed almost one third (32.5%) of the EU-27's value added in 2017, above its 28.0% share of value added in the EU-27's non-financial business economy as a whole. Italy also recorded a larger share (13.3%) of the value added generated in the EU-27's manufacturing sector than it did for the non-financial business economy as a whole (11.7%), while the reverse was true for France, Spain and the Netherlands (see Figure 4.26).

Size Class Analysis

Based on the NACE, in 2017 "Large enterprises" (employing 250 or more persons) contributed more to the EU-27's manufacturing sector than is typical for the non-financial business economy as a whole — in 2017, some 61.5% of the manufacturing sector's value added was generated by 15400 large enterprises and these employed 44.5% of the manufacturing employment; for comparison, the non-financial business economy average for large enterprise was a 44.1% share of value added and a 33.0% share of the employment (see Figure 4.27).

Relative importance of enterprise size classes, Manufacturing (NACE Section C), EU-27, 2017 (% share of sectoral total)

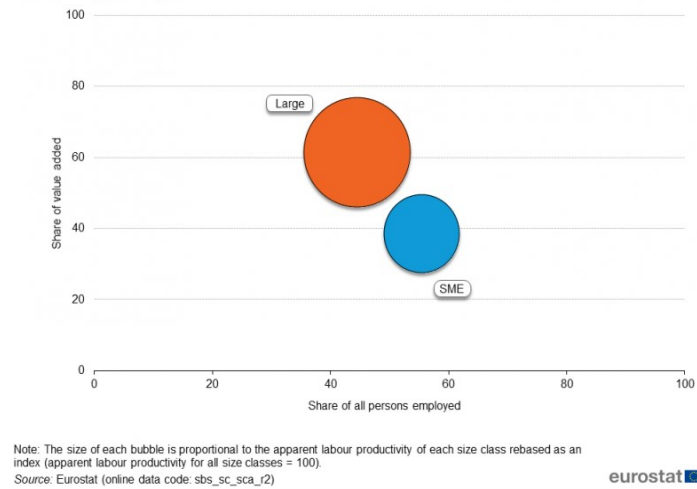
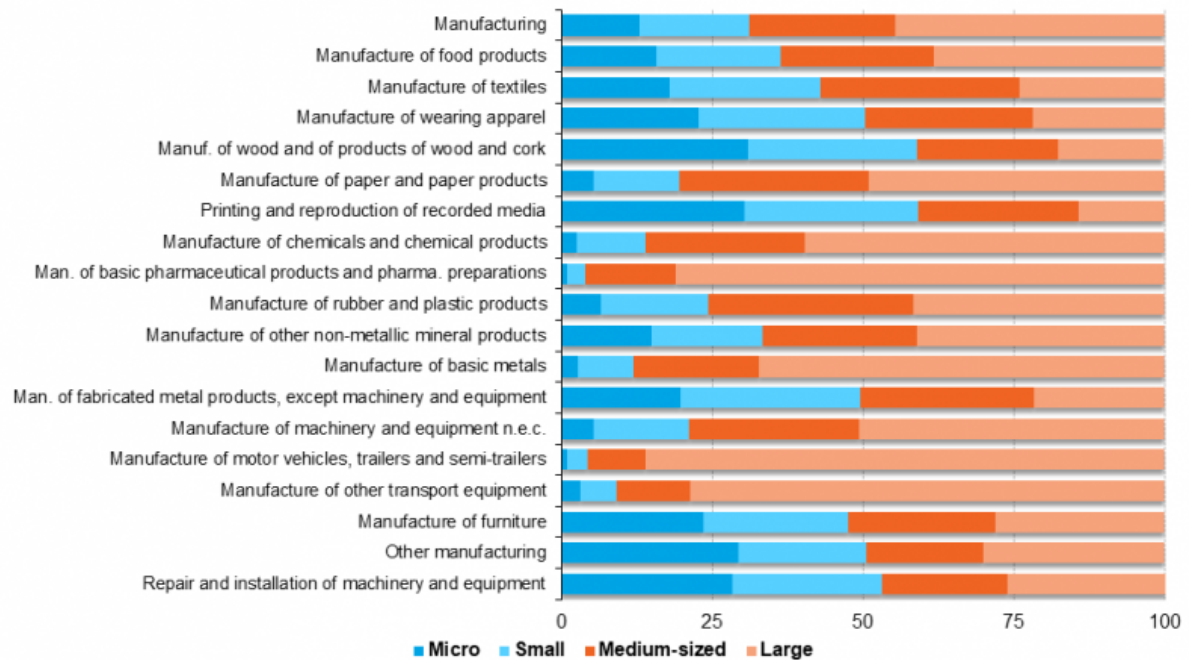


Figure 4.27. Relative importance of enterprise size [4.5]

Sectoral analysis of employment by enterprise size class, Manufacturing (NACE Section C), EU-27, 2017 (% share of sectoral employment)



Note: Activities which are not shown are incomplete. For the purpose of the article some percentages have been calculated for confidential data, which causes a lower reliability.
Source: Eurostat (online data code: sbs_sc_ind_r2)

eurostat

Figure 4.28. Sectoral analysis of employment by enterprise size class [4.5]

Finally, in Figure 4.28 a sectoral analysis of employment by enterprise size class is presented. The contribution of large enterprises (employing 250 or more persons) to EU-27 value added in 2017 was concentrated in the manufacture of coke and refined petroleum products, of motor vehicles, trailers and semi-trailers, of basic pharmaceutical products and

pharmaceutical preparations, and of other transport equipment. The contribution of medium-sized enterprises (employing 50 to 249 persons) to EU-27 value added in 2017 was highest (across the manufacturing sector) in textiles, rubber and plastic products, fabricated metal products except machinery and equipment and manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials. In the manufacture of fabricated metal products except machinery and equipment, small enterprises (employing 10 to 49 persons) contributed 28.5% of the subsectors' value added. In none of the manufacturing subsectors did micro enterprises (employing fewer than 10 persons) contribute the largest share of value added among the four size classes; their greatest contribution was 16.9% of the value added generated in the manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials and 15.2% manufacture of furniture.

Example No3: Infographics in engineering education

Figures 4.29-4.31 present two infographics showing selected issues implemented at the Faculty of Mechanical Engineering and Aeronautics of the Rzeszow University of Technology.

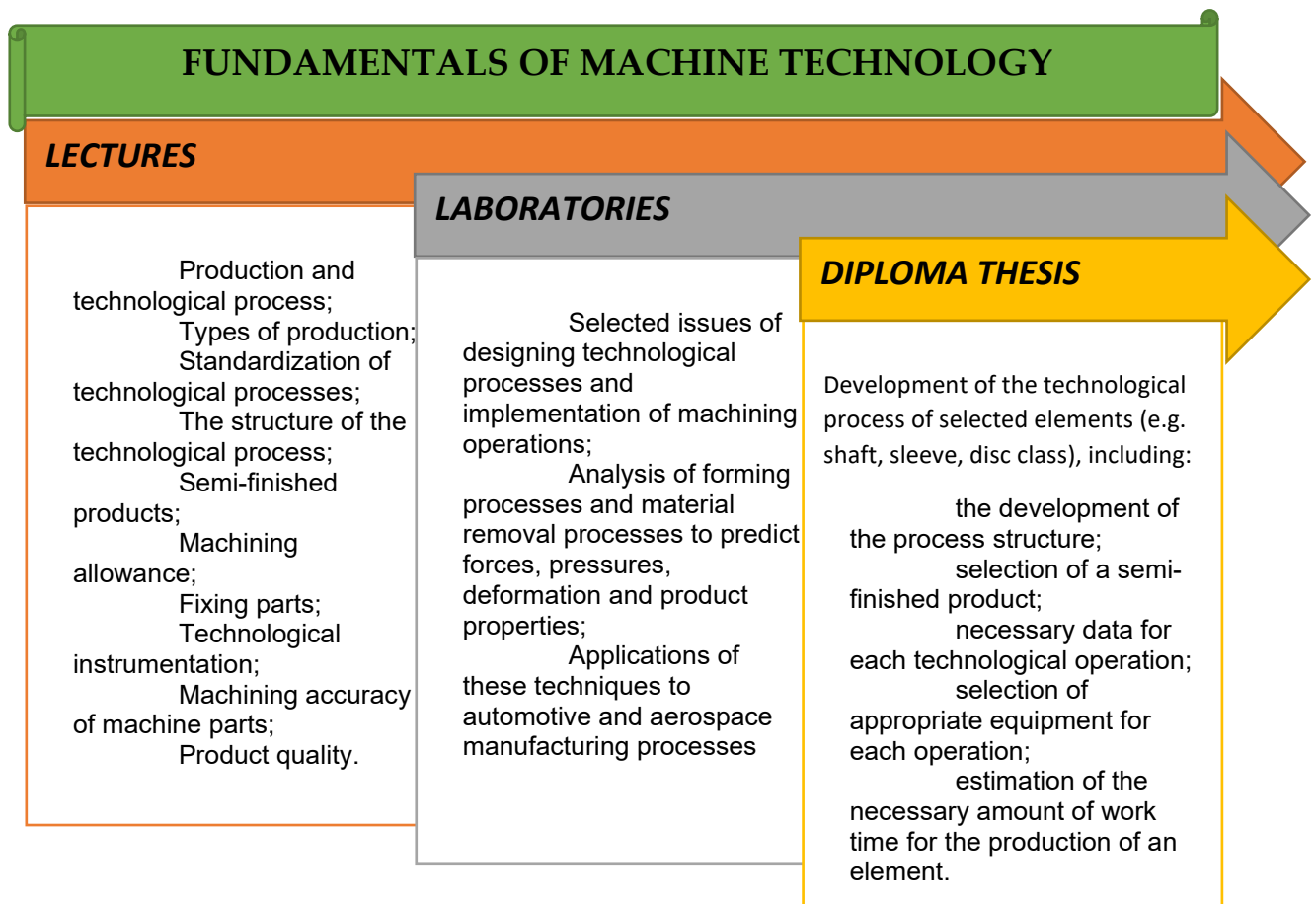


Figure 4.29. Infographics of the subject “fundamentals of machine technology”

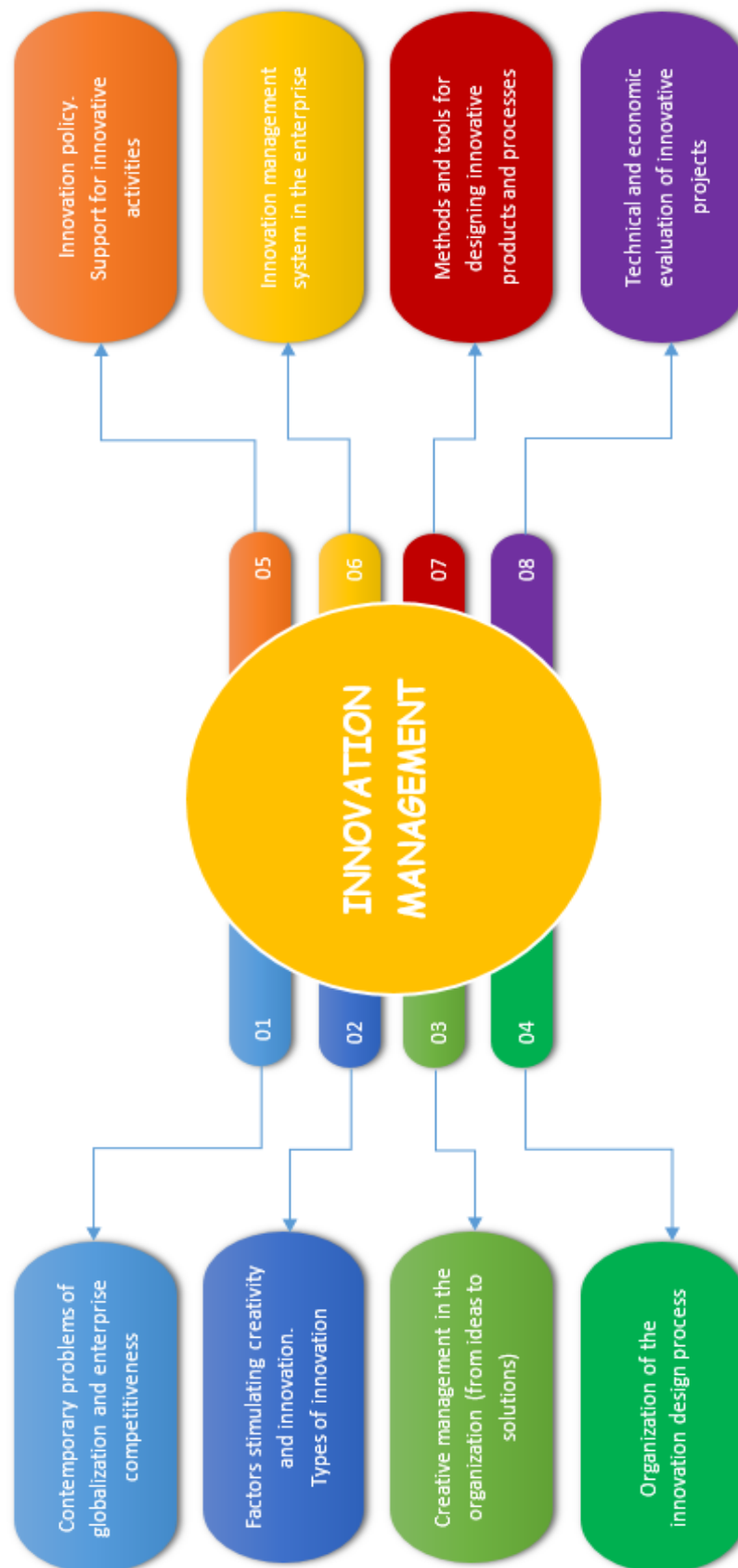


Figure 4.30. Lectures infographics of the subject “innovation management”

Figure 4.29 presents the basic issues of the subject: “fundamentals of machine technology”. They are divided into 3 areas: lectures, laboratories and diploma thesis. Obtaining a credit for a course consisting of a lecture and laboratories is necessary for students. On the other hand, students have the opportunity to expand their knowledge in this field through the implementation of bachelor’s and master’s theses. The topics of such works are often the result of collaboration with the industry.

Figure 4.30 presents the topics of the lectures on "innovation management". It contains 8 groups of issues carried out during 15 teaching hours. Thanks to the graphic form, students can easily familiarize themselves with the basic content that will be implemented during lectures on a given subject. Then, Figure 4.31 shows the field of studies currently offered by the Faculty of Mechanical Engineering and Aeronautics.

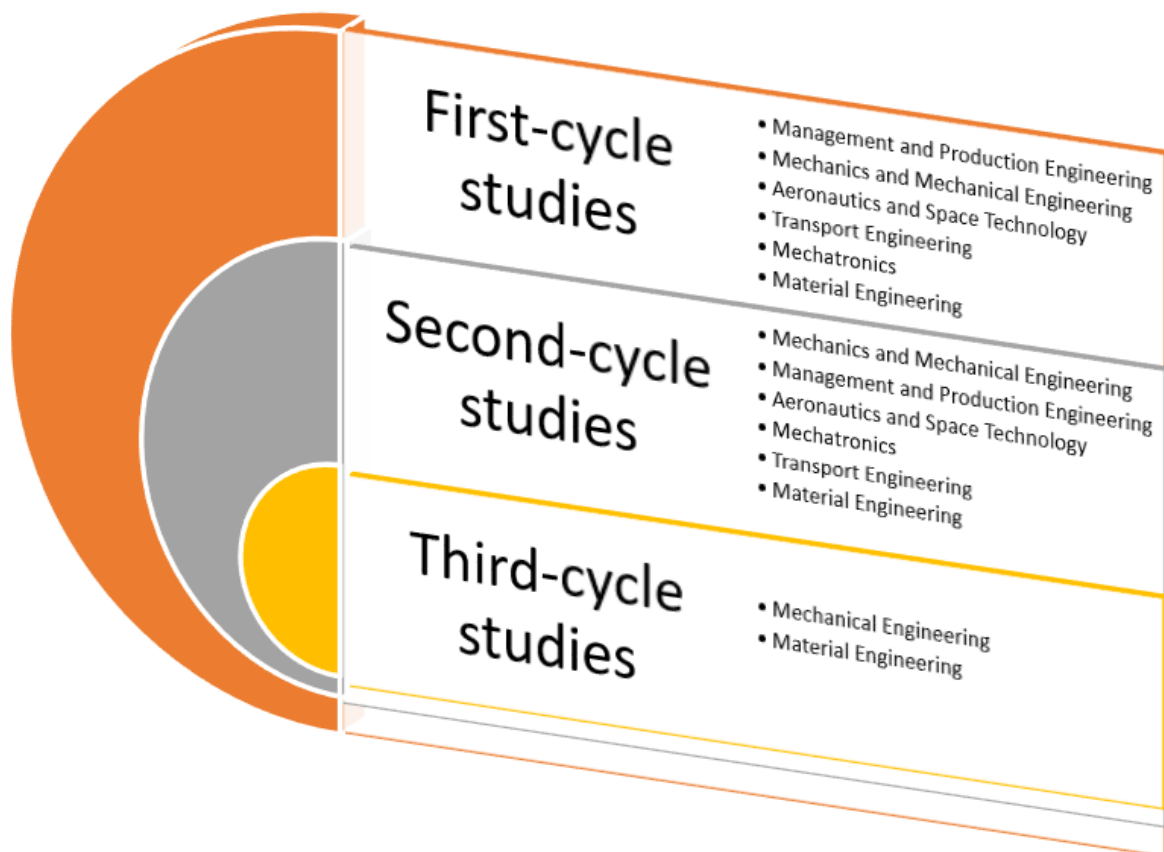


Figure 4.31. Field of study offered by the Faculty of Mechanical Engineering and Aeronautics

Mind mapping in education is an effective tool for students and educators seeking to maximize the learning experience. A mindmap is a learning tool that allows users to create and share visual representations of things like lectures, notes, and research. In fact, mind mapping in education is useful for a wide variety of tasks, and can be easily tailored to the user's needs.

The benefits of mind mapping in education are endless; teachers can significantly improve their lectures, and students can better understand and retain knowledge in a way that suits their specific needs. Incorporating mind mapping in education allows teachers to improve their presentations through visual software such as:

- XMind (desktop, mobile, web), <https://www.xmind.net/>
- Coggle (web), <https://coggle.it/>
- Mindomo (desktop, mobile, web), <https://www.mindomo.com/>

For many teachers and administrators, gathering and forming plans and ideas for faculty and students can be tedious. It often requires multiple documents, charts, and links that do not fit on a single page. Lessons and presentations typically require multiple media outlets, with teachers switching back and forth from presentations to documents to videos. This can be confusing to students, stressful on teachers, and ultimately create more work than is required. Mind mapping is an attractive solution to this by confining lesson information into one space. Not to mention, the visual platform is beneficial for students as well. Students can better comprehend the topics at hand as a result of mind mapping's visual nature. Teachers can create thorough lesson plans, present them from one central platform, and easily share them with students.

Some major advantages of using mindmaps are:

- mind maps help student grasp complex topics and ideas,
- studying with mind maps leads to better information retention,
- mind maps help professors and students capitalize on their research and action it in a way that benefits both them and the wider education community.

Example No1: Additive manufacturing

Additive manufacturing (AM) is a technology that is rapidly developing and being Integrated into manufacturing and our day-to-day lives. Many people have heard of its emergence into the commercial world, though it has been labeled by different names, such as three-dimensional (3D) printing, rapid prototyping (RP), layered manufacturing (LM), and solid freeform fabrication (SFF). Conceptually, AM is an approach where 3D designs can be built directly from a computer-aided design (CAD) file without any part- specific tools or dies. In this freeform layer-wise fabrication, multiple layers are built in the X–Y direction one on top of the other generating the Z or third dimension. Once the part is built, it can be used for touch and feel for concept models, tested for functional prototypes, or used in practice. AM is much more than a process that can be used to make personalized novel items or prototypes. With new developments in AM, we live in an age on the cusp of industrialized rapid manufacturing taking over as a process to produce many products as well and make it feasible to design and create new ones. This will cause the manufacturing process of many things to change as well as cause a new style of customer- to-manufacturer interaction. Integration of 3D printing will

make it so people can contribute to the design process from almost any location and will break the barriers of localized engineering and take it to a global scale. Just as the Internet has given us the ability to spread and access information from any location, digital designing and CAD have given people the ability to make, change, and critique designs from essentially anywhere. With AM, those designs can be made and tested from almost any location with very little lead time. The capabilities of AM machines have surpassed the abilities of CAD, making the design and visualization of a part the more difficult process compared to that for building it. As a new generation grows up with CAD technology and the abilities and availability of AM machines grow, the process of designing a product will mature from being just done by a select group of engineers to being created by the consumer and company together; this technique will enable manufacture of products from anywhere in the world in a timely manner.

Advantages

AM will have a profound effect on the manufacturing process of many goods in many different industries. Advantages include its ability to make parts that could not be made before. AM is a start-to-finish process that can make the entire part and does not require multiple machines or processes. It can build complex geometries effectively that are very difficult, costly, or impossible using other methods. This gives the designer a lot more freedom when making a part. Many times, the optimal design is not feasible with the types of manufacturing processes available presently. With AM, there is essentially no restriction besides the size of the part has to fit in the machine. Now the designer only has to make it, so the part or item can be installed or be operational for its application.

Another benefit to this is the single tool involvement, since no other tooling cost is required except of the AM machine. Though some parts must be machined after to have the right surface finish, for the most part much less tooling is required. This eliminates a huge cost of production. The only other cost is maintenance of the machine. AM also saves material because it is an additive technique as opposed to reduction. A reduction manufacturing method is one such as milling where the product starts as a block with dimensions larger than the final product. Then, material is removed until the final dimensions are achieved. The waste material is then either disposed of or recycled, which the manufacturer usually has to pay for. With AM, material is added until the product is made. Therefore, little to no material is lost, so there is up to a 75% reduction in material use and can lower the production time and cost by 50%.²⁶ These huge savings are one of the reasons AM has sparked so much interest with manufacturers.

Challenges

Additive manufacturing, however, cannot fully compete in present with conventional manufacturing, especially in the domain of mass production, primarily because of some major drawbacks. More specific there are limitations in size: Additive manufacturing processes often use a liquid polymer or a powder that is inlaid with resin or plaster to build object layers. The use of such materials for additive manufacturing means that large objects cannot be produced, primarily due to a lack of material strength. Further, large objects become impractical when considering the extended amount of time required to complete the build process. Moreover, the presence of imperfections consists another significant challenge. The parts produced using additive manufacturing processes often have a rough and ribbed surface finish. This appearance is primarily due to the plastic beads or large powder particles being

stacked on top of each other. This unfinished look requires further surface preparation by either machining or polishing. Finally, the cost is a parameter that has to be considered. The initial cost of additive manufacturing equipment can be high. Entry-level 3D printers average approximately \$5000 and can go as high as \$50,000 for higher end models. This does not include the cost of accessories, resins, and other materials required for operation. In Figure 4.32 the main advantages and challenges of AM are listed.

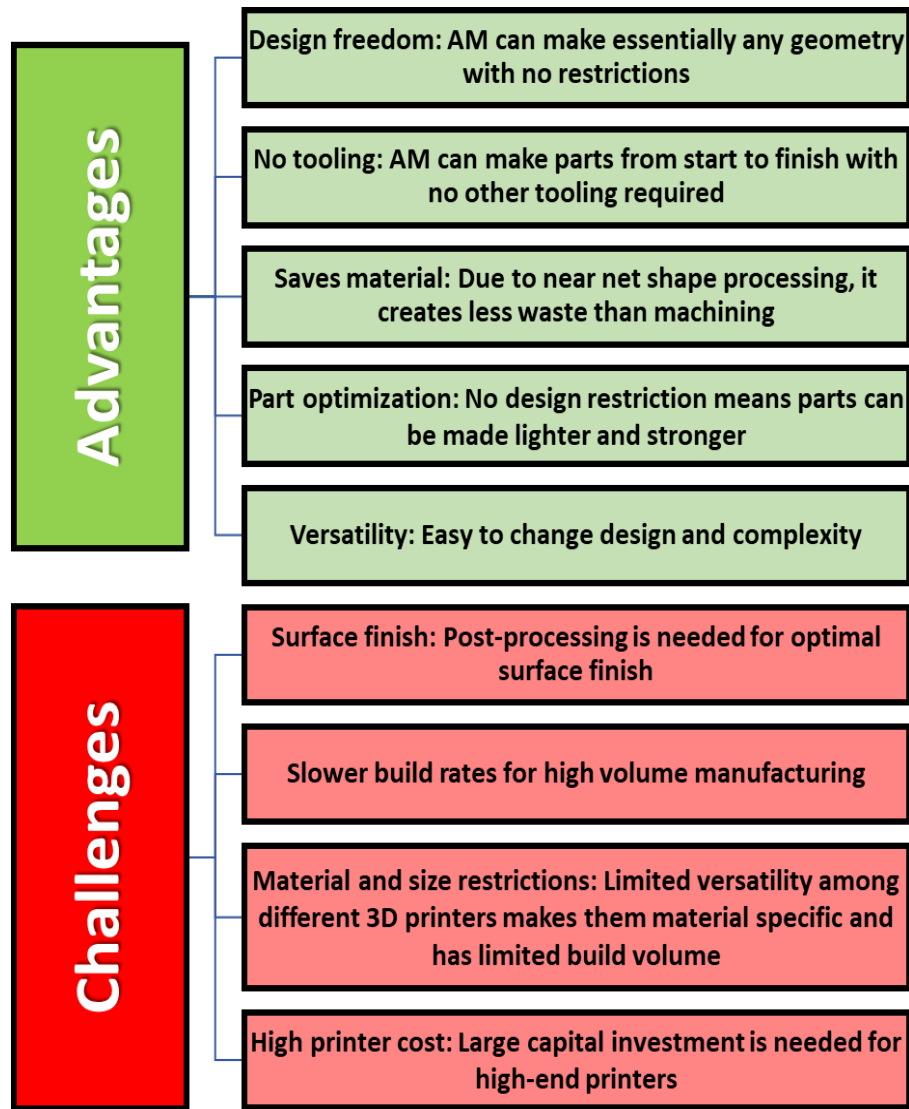


Figure 4.32. Main advantages and challenges of Additive Manufacturing Technology

Types of Additive Manufacturing

In Figure 4.33 the main methods of AM are presented.

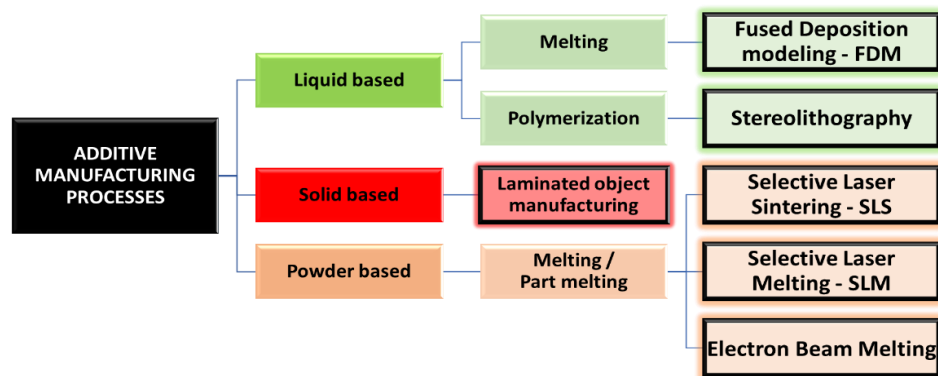


Figure 4.33. Main types of Additive Manufacturing methods

Fused Deposition Modeling. The patent for fused deposition modeling (FDM) (U.S. Patent 5121329) was awarded in 1992. In this technique, liquid thermoplastic material is easily extruded from a movable FDM head and then deposited in ultra-thin layers onto a substrate. Basically, the material is heated to one degree above its melting point so that it solidifies immediately following extrusion and also easily cold welds to the previous layers. The materials that have been used for this additive manufacturing technique include polycarbonate (PC), acrylonitrile butadiene styrene (ABS), polyphenyl sulfone (PPSF), PC–ABS blends, medical-grade polycarbonate, wax, metals, and even ceramics. The noticeable disadvantages of this technique include the following:

- a seam line between the layers,
- the need for supports,
- longer build-up time, sometimes requiring days to build complex parts,
- delamination arising as a direct consequence of fluctuation in temperature,
- low resolution of the Z-axis compared to other additive manufacturing techniques.

The observable advantages of this process include the following:

- no chemical post-processing required,
- less expensive equipment due to no resins having to be cured,
- use of materials resulting in an overall cost-effective process.

Stereolithography (SLA). Stereolithography, initially developed by 3D Systems, Inc. (Rock Hill, SC), was the first and most widely applied rapid prototyping process. The patent for SLA (U.S. Patent 4575330) was awarded in 1986. In essence, it is a liquid-based process that consists of the curing or solidification of a photosensitive polymer when an ultraviolet laser makes contact with the resin. The process begins with construction of a model using CAD software. The model is then translated to a STL file in which the pieces are cut into “slices,” with each slice containing the information required for each layer. The thickness of each layer as well as its resolution depend on the equipment used. A platform is created to hold the piece and to support any overhanging structures. An ultraviolet laser applied to the resin initiates

solidification at specific locations of each layer. When the layer is finished the platform is lowered. When the process is finally done any excess resin is drained and subsequently reused. Variation of stereolithography is the Digital Light Processing (DLP) 3D printing. Sustained progress through the years in stereolithography resulted in the development of an advancement of this process that offered much higher resolution and was known as micro-stereolithography. In this process, a layer thickness of less than 10 microns is easily achieved. The technique of micro-stereolithography helps provide three-dimensional microstructures. Promising applications of this novel technology are ultra-dense routing for three-dimensional structural electronic substrates having width, thickness, and space dimensions extending down to the level of microns.

Selective Laser Sintering (SLS). The patent for selective laser sintering (SLS) (U.S. Patent 4863538) was awarded in 1989.^{64,65} This additive manufacturing process uses a high-power laser to fuse small particles of the build material (metal, ceramic, polymer, glass, or any material that can be easily pulverized). The fabrication powder bed is heated to just below the melting point of the material with the primary objective of minimizing thermal distortion and to concurrently facilitate fusion to the previous layer. Each layer is then drawn on the powder bed using a laser to sinter the material. The sintered material forms the part while the unsintered powder remains in place to support the structure; it can be cleaned away and recycled once the part of interest has been built. This process of selective laser sintering offers the freedom to build complex parts that are often more durable and provide better functionality compared to other existing and preferentially used additive manufacturing processes. Further, in this process no post-curing is required, and the build time is noticeably fast. A great variety of materials can be used. The materials normally chosen include plastics, metals, combination of metals, combination of metals and polymers, and combination of metals and ceramics. Other materials that have been used are composite materials and reinforced polymers. For the specific case of metals, it is necessary to have a binder. The binder is often made of a polymer, which is removed during heating or mixing of metals that have very different melting points. This particular technique has been used to build parts of alumina having high strength, with polyvinyl alcohol being used as the organic binder. Overall, this additive manufacturing technique can be categorized as complicated, as several build variables must be carefully controlled. The observable disadvantages specific to this process include the following:

- accuracy is strictly limited by the size of the particles of the chosen material,
- oxidation must be avoided by executing the process in an inert atmosphere or vacuum,
- the process must occur at a constant temperature near the melting point of the chosen material.

Selective Laser Melting (SLM). Selective laser melting (SLM) is an additive manufacturing (AM) technique to produce complex three-dimensional parts through solidifying successive layers of powder materials on the basis of a CAD model. SLM is associated with complete melting of the powder material rather than sintering or partial melting of the powder particles which is the dominant mechanism in the selective laser sintering (SLS) process. In this process (carried

out under a protective atmosphere), a metal base plate is used to anchor the part during the building process. A layer of powder (most commonly from metals) is spread on top of the base plate and is subsequently melted by a laser beam projected from above. The laser scans the powder bed according to the shape defined in a CAD file (that has been sliced into many different layers). After each layer has been scanned, the powder bed is moved down over a distance of one layer thickness, followed by an automated levelling system that distributes a new layer of powder. The laser then melts a new cross-section. The process is repeated to form the desired solid metal part (comprised of hundreds or possibly thousands of thin layers). Many advantages are associated with the SLM process, including high density and strength of the parts, negligible waste of material (unused powders can be recycled), possibility of producing complicated shapes (e.g., a steel mold with curved internal cooling channels, which is common to other AM methods), ability to process a wide variety of metals and their mixtures (due to the powder-based nature of SLM); and no need for any distinct binders or melt phases, so the process can directly produce single material parts (e.g., steel, Ti, or Al alloys), rather than first producing a composite green part that requires such secondary processing steps as debinding and furnace sintering (as done with some other AM methods). Selective laser melting is a newly developed process faced with various challenges. For example, SLM suffers from melt pool instabilities leading to imperfections such as low-quality down-facing surfaces, greater upper-surface roughness, and the risk of internal pores. The resulting coarse and grainy surface finish may require a secondary machining or polishing process. Additionally, high temperature gradients in SLM increase the risk of delamination and distortion due to large thermal or residual stresses. From an economical aspect, the high cost of a high-power laser source, long processing times, and a small palette of available materials are the main obstacles. Despite these challenges, SLM is increasingly becoming a competitive manufacturing alternative.

Electron Beam Melting (EBM). The process of electron beam melting (EBM) is quite similar to selective laser sintering. This relatively new and innovative additive manufacturing process has grown rapidly as a result of its technological significance and resultant far-reaching applications. In this process, an electron laser beam is used to melt the powder. The laser beam is powered by a high voltage of the order of 30 to 60 kV. To minimize or eliminate environmental interactions, such as oxidation, this process is conducted in a high-vacuum chamber when building metal parts. This process has been used extensively to build metal parts, and it has the ability to process a wide variety of pre-alloyed metal powders. A potential future application of this technique is manufacturing in outer space, which is particularly achievable as the technique is often done within a high-vacuum chamber.

Laminated Object Manufacturing. The patent for laminated object manufacturing (documented in U.S. Patent 4752352) was awarded in 1988. The simplest LOM technique uses adhesive-coated sheet materials. The adhesive, which is either precoated onto the materials or deposited on the surface immediately prior to bonding, allows the sheets to be attached to each other. The 3D parts are then manufactured by sequential lamination and the cutting of two-dimensional (2D) cross-sections using a laser beam. The velocity and focus of the laser

beam are adjusted so the cutting depth corresponds to the thickness of the layer. By careful selection of both the velocity and focus, damage to the underlying layers is either minimized or avoided. A variety of materials, including paper, metals, plastics, fabrics, synthetic materials, and even composites, have been tried. Most importantly, this technique is relatively inexpensive, and toxic fumes are not generated. It offers the advantage of being automated, thus requiring minimal operator assistance. The primary limitation of this technique can be associated with accuracy problems along the Z-axis resulting in instability in dimensions. This technique can also cause internal cavities, thus influencing the quality of the end product. To totally reduce waste, post-production is necessary, and in a few cases secondary processes are necessary to generate parts that are functional. The noticeable advantages of this technique include the following:

- low cost,
- no need for post-processing or support structures,
- no deformation or phase change during the process,
- the possibility of building large parts.

Four observable disadvantages of this technique are:

- fabrication material is subtracted, thus causing wastage,
- the surface has low definition,
- the material is directionally dependent with regard to both machinability and mechanical properties,
- complex internal cavities are difficult to build.

Finally in the following mindmap of Figure 4.34 the main application fields of AM is presented.

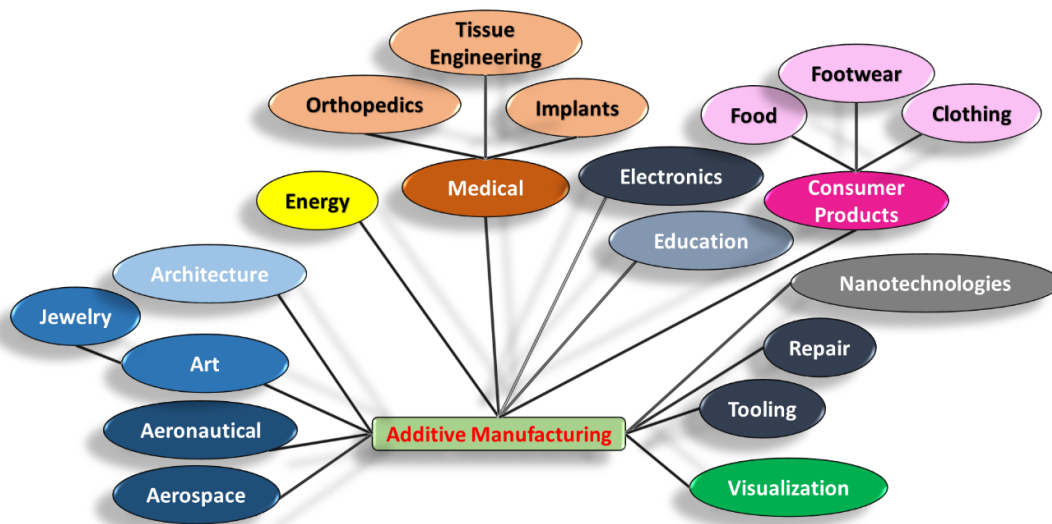


Figure 4.34. Main field of additive manufacturing and the many domains for research

Example No2: Manufacturing Process Selection

The selection of a particular manufacturing process or, more often, sequence of processes, depends on the geometric features of the parts to be produced, including the dimensional tolerances and surface texture required, and on numerous factors pertaining to the particular workpiece material and its manufacturing properties. To emphasize the challenges involved, consider the following two cases:

- Brittle and hard materials cannot be shaped or formed without the risk of fracture, unless they are performed at elevated temperatures, whereas these materials can easily be cast, machined, or ground.
- Metals that have been pre-shaped at room temperature become less formable during subsequent processing, which, in practice, is often required to complete the part; this is because the metals have become stronger, harder, and less ductile than they were prior to processing them further.

There is a constant demand for new approaches to production problems and, especially, for manufacturing cost reduction. For example, sheet-metal parts traditionally have been cut and fabricated using common mechanical tools such as punches and dies. Although still widely used, some of these operations are now being replaced by laser cutting, thus eliminating the need for hard tools, which have only fixed shapes and can be expensive and time consuming to make. The laser path in this cutting operation is computer controlled, thereby increasing the operation's flexibility and its capability of producing an infinite variety of shapes accurately, repeatedly, and economically. However, because of the high heat involved in using lasers, the surfaces produced after cutting have very different characteristics (such as discoloration and a different surface texture) than those produced by traditional methods. This difference can have significant effects not only on the appearance of the material, but especially on its subsequent processing and in the service life of the product. Moreover, the inherent flexibility of laser cutting is countered by the fact that it is a much slower operation than traditional punching. In process selection, several factors can have a major role, such as the part size, shape complexity, and dimensional accuracy and surface finish required. For example:

- Flat parts and thin cross sections can be difficult to cast.
- Complex parts generally cannot be shaped easily and economically by such metalworking techniques as forging, whereas, depending on the part size and the level of complexity, the parts may be precision cast, fabricated from individual pieces, or produced by powder-metallurgy techniques.
- Dimensional tolerances and surface finish in hot-working operations are not as fine as those obtained in operations performed at room temperature (called cold working), because of the dimensional changes, distortion, warping, and surface oxidation that occur at the elevated temperatures involved.

Casting processes

The first metal castings were made during the period from 4000 to 3000 B.C., using stone and metal molds for casting copper. Various casting processes have been developed over time, each with its own characteristics and applications to meet specific design requirements. A large variety of parts and components are made by casting, such as engine blocks, crankshafts, automotive components and powertrains, agricultural and railroad equipment, pipes and plumbing fixtures, power-tool housings, gun barrels, frying pans, jewellery, orthopaedic implants, and very large components for hydraulic turbines. Expendable molds, which typically are made of sand, plaster, ceramics, and similar materials and generally are mixed with various binders (bonding agents) for improved properties. A typical sand mold consists of 90% sand, 7% clay, and 3% Water. These materials are refractories (that is, they are capable of withstanding the high temperatures of molten metals). After the casting has solidified, the mold is broken up to remove the casting. The mold is produced from a pattern; in some processes, such as sand and shell casting, the mold is expendable, but the pattern is reused to produce several molds. Such processes are referred to as expendable-mold, permanent-pattern casting processes. On the other hand, investment casting consumes a pattern for each mold produced; it is an example of an expendable-mold, expendable pattern process.

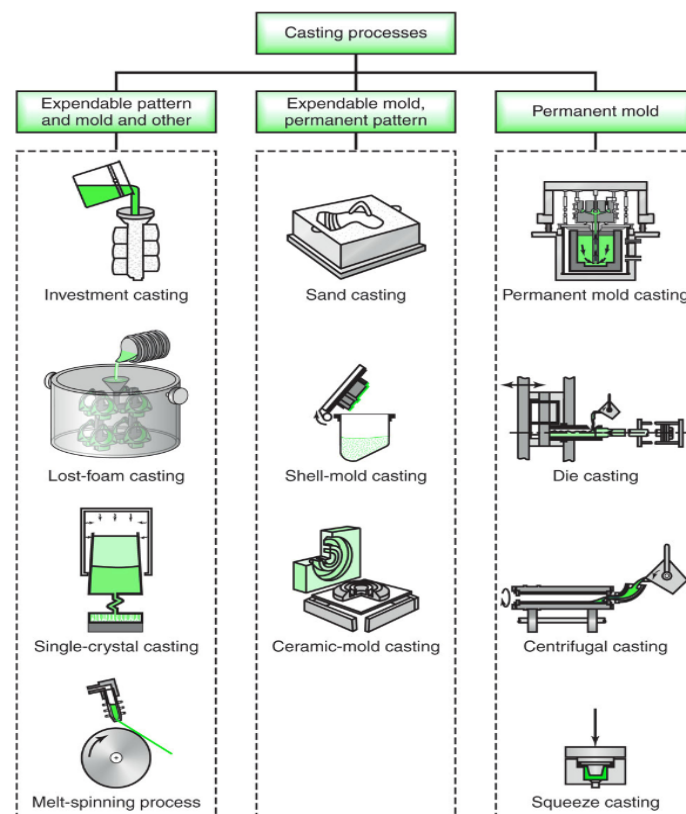


Figure 4.35. Casting Processes [4.10]

Permanent molds, which are made of metals that maintain their strength at high temperatures. As the name implies, they are used repeatedly and are designed in such a way that the casting can be removed easily and the mold used for the next casting. Metal molds

are better heat conductors than expendable non-metallic molds; hence, the solidifying casting is subjected to a higher rate of cooling, which in turn affects the microstructure and grain size within the casting. In Figure 4.35 the main casting processes are presented.

Composite molds, which are made of two or more different materials (such as sand, graphite, and metal) combining the advantages of each material. These molds have a permanent and an expendable portion and are used in various casting processes to improve mold strength, control the cooling rates, and optimize the overall economics of the casting process.

Bulk Deformation Processes

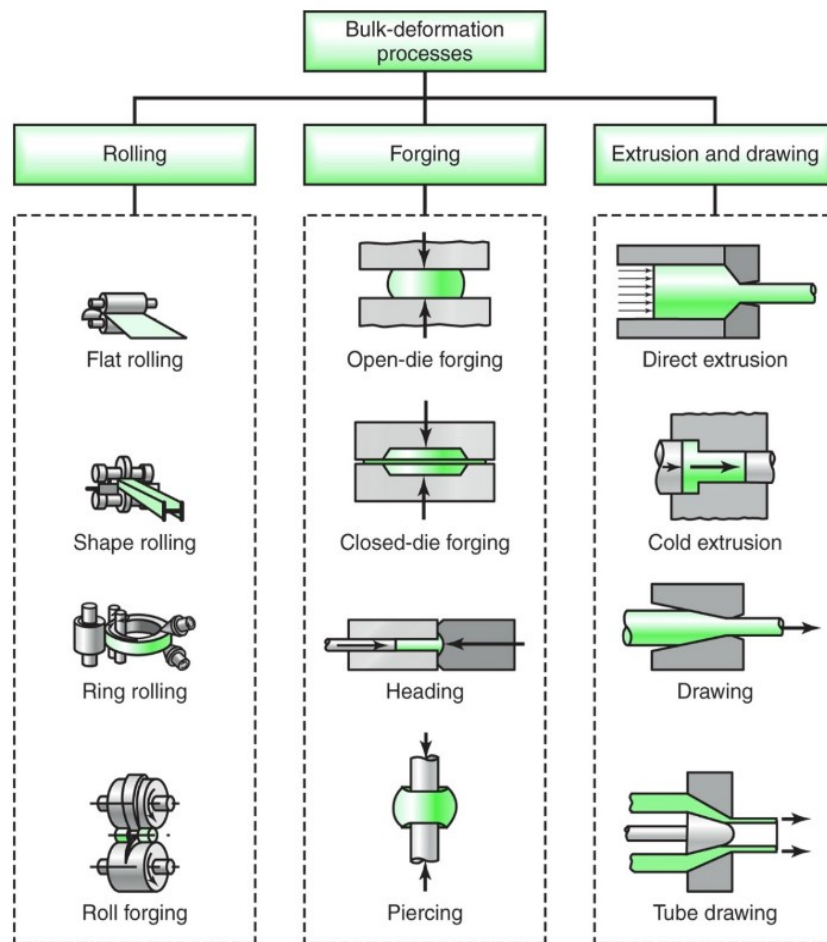


Figure 4.36. Bulk deformation processes [4.10]

Bulk deformation processes include Rolling, Forging and Extrusion – drawing (see Figure 4.36). Rolling is the process of reducing the thickness or changing the cross section of a long workpiece by compressive forces applied through a set of rolls. This process is similar to rolling dough with a rolling pin to reduce its thickness. Rolling, which accounts for about 90% of all metals produced by metalworking processes, was first developed in the late 1500s. Modern steelmaking practices and the production of various ferrous and nonferrous metals and alloys now generally involve combining continuous casting with rolling processes. This greatly

improves productivity and lowers production costs. Non-metallic materials also are rolled to reduce their thickness and enhance their properties. Typical applications are in the rolling of plastics, powder metals, ceramic slurry, and hot glass.

Forging is a basic process in which the workpiece is shaped by compressive forces applied through various dies and tooling. One of the oldest and most important metalworking operations, dating back at least to 4000 B.C., forging first was used to make jewellery, coins, and various implements by hammering metal with tools made of stone. Forged parts now include large rotors for turbines; gears; bolts and rivets; cutlery; hand tools; numerous structural components for machinery, aircraft, and railroads; and a variety of other transportation equipment. Unlike rolling operations that is generally produce continuous plates, sheets, strips, or various structural cross sections, forging operations produce discrete parts. Because the metal flow in a die and the material's grain structure can be controlled, forged parts have good strength and toughness, and are very reliable for highly stressed and critical applications. Simple forging operations can be performed with a heavy hammer and an anvil, as has been done traditionally by blacksmiths. However, most forgings require a set of dies and such equipment as a press or a powered forging hammer.

Forging may be carried out at room temperature (cold forging) or at elevated temperatures (warm or hot forging) depending on the homologous temperature. Cold forging requires higher forces (because of the higher strength of the workpiece material), and the workpiece material must possess sufficient ductility at room temperature to undergo the necessary deformation without cracking. Cold-forged parts have a good surface finish and dimensional accuracy. Hot forging requires lower forces, but the dimensional accuracy and surface finish of the parts are not as good as in cold forging. Forgings generally are subjected to additional finishing operations, such as heat treating to modify properties and machining to obtain accurate final dimensions and a good surface finish. These finishing operations can be minimized by precision forging, which is an important example of net-shape or near-net-shape forming processes. As we shall see throughout this book, components that can be forged successfully also may be manufactured economically by other methods, such as casting, powder metallurgy, or machining. Each of these will produce a part having different characteristics, particularly with regard to strength, toughness, dimensional accuracy, surface finish, and the possibility of internal or external defects.

In extrusion, a cylindrical billet is forced through a die in various cross sections in a toy press. A wide variety of solid or hollow cross sections may be produced by extrusion, which essentially are semi-finished parts. A characteristic of extrusion is that large deformations can take place without fracture because the material is under high triaxial compression. Since the die geometry remains unchanged throughout the operation, extruded products typically have a constant cross section. Typical products made by extrusion are railings for sliding doors, window frames, tubing n having various cross sections, aluminum ladder frames, and numerous structural and architectural shapes. Extrusions can be cut into desired lengths, which then become discrete parts, such as brackets, gears, and coat hangers. Commonly

extruded materials are aluminum, copper, steel, magnesium, and lead; other metals and alloys also can be extruded, with various levels of difficulty. Because a chamber is involved, each billet is extruded individually; thus, extrusion is a batch, or semicontinuous, process. Extrusion can be economical for large as well as short production runs. Tool costs generally are low, particularly for producing simple, solid cross sections. Depending on the ductility of the material, extrusion is carried out at room or elevated temperatures. Extrusion at room temperature often is combined with forging operations, in which case it generally is known as cold extrusion. It has numerous important applications, including fasteners and components for automobiles, bicycles, motorcycles, heavy machinery, and transportation equipment.

In drawing, an operation that was developed between 1000 and 1500 A.D., the cross section of solid rod, wire, or tubing is reduced or changed in shape by pulling it through a die. Drawn rods are used for shafts, spindles, and small pistons and as the raw material for fasteners (such as rivets, bolts, and screws). In addition to round rods, various profiles can be drawn. The term drawing also is used to refer to making cup-shaped parts by sheet-metal-forming operations. The distinction between the terms rod and Wire is somewhat arbitrary, with rod taken to be larger in cross section than wire. In industry, wire generally is defined as a rod that has been drawn through a die at least once, or its diameter is small enough so that it can be coiled. Wire drawing involves smaller diameters than rod drawing, with sizes down to 0.01 mm for magnet wire and even smaller for use in very low current fuses.

Sheet Metal Forming Processes

In Figure 4.37 the main sheet metal forming processes are presented. Shearing is a metal fabrication process that's used to trim and remove unwanted material from sheet metal. It involves the use of a machine or tool, such as a bench shear, to slice through sheet metal with extreme precision. Shearing doesn't require the use of heat — sheet metal is typically sheared while cold or at room temperature — nor does it produce waste in the form of chips, making it an attractive choice for manufacturers. Shearing is performed by slicing through sheet metal with a blade-affixed machine or tool. Sheet metal is first secured between the tool's or machine's blades. Most shearing tools and machines have a squaring arm to control the location of the cut. After placing the sheet metal in the proper position with the squaring arm, the top blade drops to slice through the sheet metal. As the top blade comes down, the bottom of the sheet metal is pressed into a lower blade. There are several types of shearing tools and machines, one of the most common being a bench shear. Also known as a lever shear, a bench shear is a cutting tool that's mounted to a working surface, such as a workbench. It's small, lightweight and easy to use, though it requires the use of a stable and secure surface for mounting. Guillotine machines are also used to perform shearing. Also known as a power shear, it's a more complex shearing machine that's powered either mechanically or hydraulically. The powered blade allows guillotine machines to slice through sheet metal faster and more effectively than a bench shear.

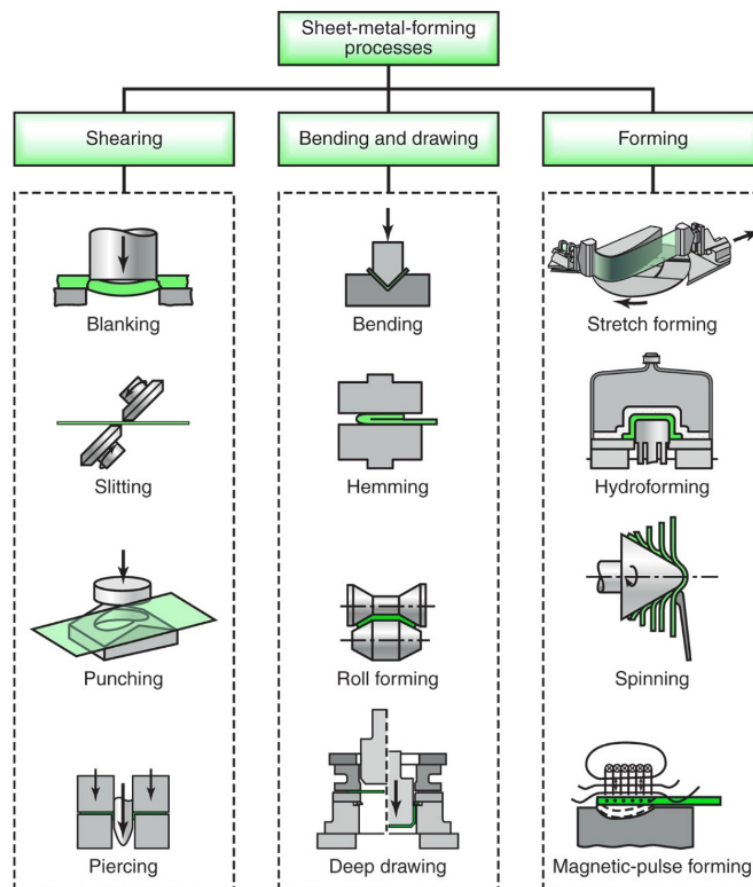


Figure 4.37. Sheet metal forming processes [4.10]

Bending in sheet-metalwork is defined as the straining of the metal around a straight axis. Bending operations are performed using punch and die tooling. The two common bending methods and associated tooling are V-bending, performed with a V-die; and edge bending, performed with a wiping die. In V-bending, the sheet metal is bent between a V-shaped punch and die. Included angles ranging from very obtuse to very acute can be made with V-dies. It is often performed on a press brake, and the associated V-dies are relatively simple and inexpensive. Edge bending involves cantilever loading of the sheet metal. A pressure pad is used to apply a force to hold the base of the part against the die, while the punch forces the part to yield and bend over the edge of the die. In edge bending is limited to bends of 90° or less. More complicated wiping dies can be designed for bend angles greater than 90° . Because of the pressure pad, wiping dies are more complicated and costly than V-dies and are generally used for high-production work. Drawing is a sheet-metal-forming operation used to make cup-shaped, box-shaped, or other complex-curved and concave parts. It is performed by placing a piece of sheet metal over a die cavity and then pushing the metal into the opening with a punch. The blank must usually be held down flat against the die by a blank holder. Common parts made by drawing include beverage cans, ammunition shells, sinks, cooking pots, and automobile body panels.

In sheet metal forming processes, the geometry of the formed part follows the geometry of the die. Due to the complexity of the production process of most parts, several choices regarding the selection of techniques, machines, and tools exist. The machines and tools used for production can sometimes be very expensive. Due to the complicated geometry of most parts, the forming process is often carried out in several operational steps by using different types of production technologies. One operation can also include several forming processes simultaneously and several sequential forming processes are usually necessary to achieve the desired shape. For sheet metal forming processes, different parameters such as tools, machines, material properties and tribology influence the product quality and cost. Some of these parameters influence each other directly. The manufacturability of producing a sheet metal part depends on many factors such as material properties, applied forming technique and its process parameters. The material properties can be evaluated by means of standard material characteristics such as tensile yield strength, ultimate elongation and tensile strength obtained from testing. The main challenge is to find the best way of producing the part most effectively and economically with the existing machines and forming techniques. Different types of sheet metal forming processes that are commonly used in manufacturing industries.

Polymer Processing

In Figure 4.38 the main polymer-processes are presented.

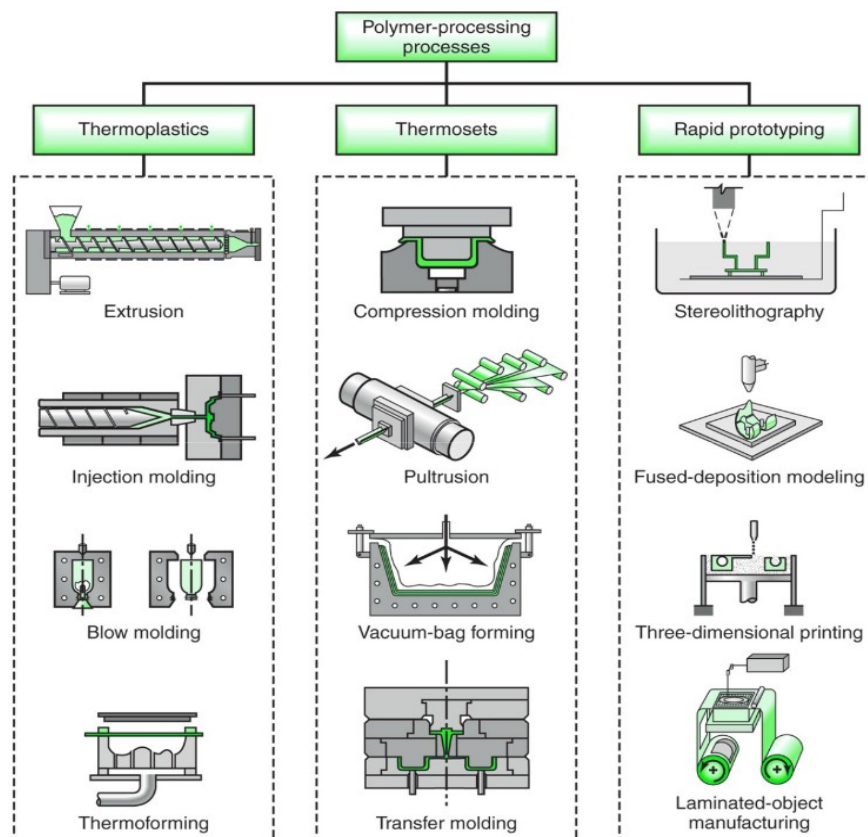


Figure 4.38. Polymer processing processes [4.10]

The processing of plastics and elastomers involves operations similar to those used in the forming and shaping of metals. The processing of rubbers and elastomers began in the 1800s with the discovery of vulcanization by C. Goodyear in 1839. Plastics began to be developed in the 1920s, and rapid progress in the 1940s and onward led to important advances in the design and manufacture of various processing equipment to make numerous consumer and industrial products in large quantities. In the 1970s, reinforced plastics began to be introduced, leading the way for rapid progress in the use of composite materials with unique properties and attendant challenges in producing them. Thermoplastics melt and thermosets cure at relatively low temperatures. Hence, unlike metals, they are relatively easy to handle and require much less force and energy to process. Plastics in general can be molded, cast, formed, and machined into complex shapes in few operations, with relative ease, and at high production rates. They also can be joined by various means and coated (generally for improved appearance) by various techniques. Plastics are shaped into discrete products or as sheets, plates, rods, and tubing that may then be formed by secondary processes into a variety of discrete products. The types and properties of polymers and the shape and complexity of components that can be produced are influenced greatly by their method of manufacture and processing parameters. Plastics usually are shipped to manufacturing plants as pellets, granules, or powders and are melted (for thermoplastics) just before the shaping process. Liquid plastics that cure into solid form are used especially in the making of thermosets and reinforced-plastic parts. With increasing awareness of our environment, raw materials also may consist of reground or chopped plastics obtained from recycling centers. As expected, however, product quality is not as high for such materials.

Joining Processes

Joining is an all-inclusive term covering processes such as welding, brazing, soldering, adhesive bonding, and mechanical fastening. In Figure 4.39 the main joining processes are presented. These processes are an essential and important aspect of manufacturing and assembly operations, for one or more of the following reasons:

- even a relatively simple product may be impossible to manufacture as a single piece,
- a product may be, is easier and more economical to manufacture as individual components, which are then assembled into a product,
- products need to be designed to be able to be taken apart for maintenance or replacement of their parts.
- different properties may be desirable for functional purposes of the product. For example, surfaces subjected to friction, wear, corrosion, or environmental attack generally require characteristics that differ significantly from those of the component's bulk.

Transporting the product in individual components and assembling them later may be easier and less costly than transporting the completed item. Metal or wood shelving, large toys, and machinery are assembled after the components or subassemblies have been transported to the appropriate site.

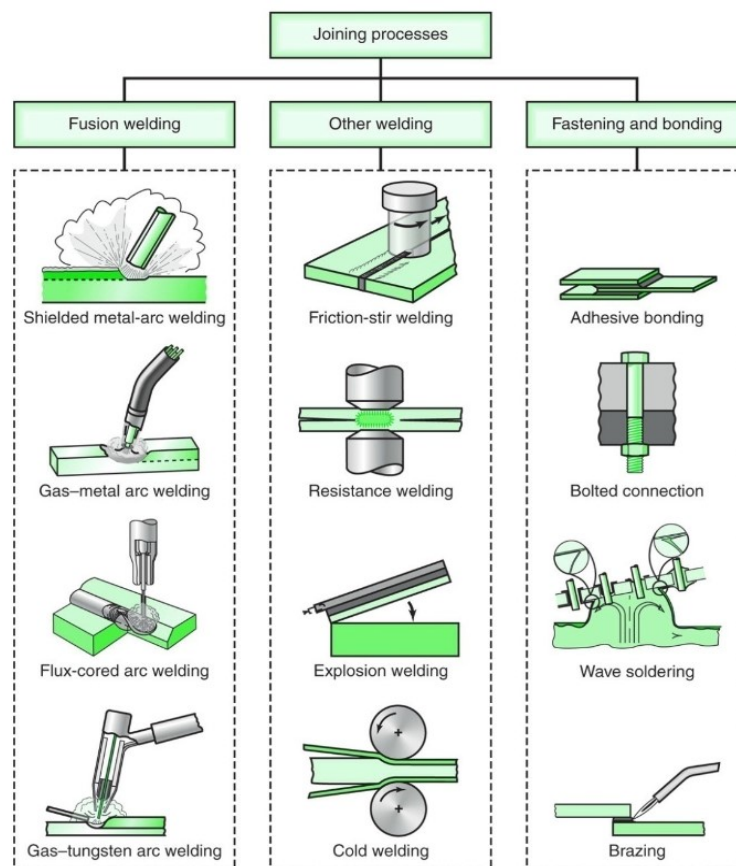


Figure 4.39. Joining processes [4.10]

Fusion Welding is defined as the melting together and coalescing of materials by means of heat, usually supplied by chemical or electrical means; filler metals may or may not be used. Fusion welding is composed of consumable- and non-consumable electrode arc Welding and high-energy-beam Welding processes. The Welded joint undergoes important metallurgical and physical changes, which, in turn, have a major effect on the properties and performance of the welded component or structure. In solid-state welding, joining takes place without fusion; consequently, there is no liquid (molten) phase in the joint. The basic processes in this category are diffusion bonding and cold, ultrasonic, friction, resistance, and explosion welding. Brazing uses filler metals and involves lower temperatures than welding. Soldering uses similar filler metals (solders) and involves even lower temperatures.

Adhesive bonding has unique applications that require strength, sealing, thermal and electrical insulating, vibration damping, and resistance to corrosion between dissimilar metals. Mechanical fastening involves traditional methods of using various fasteners, especially bolts, nuts, and rivets. The joining of plastics can be accomplished by adhesive bonding, fusion by various external or internal heat sources, and mechanical fastening.

Machining and finishing

Machining is a general term describing a group of processes that consist of the removal of material and modification of the surfaces of a workpiece after it has been produced by various

methods. Thus, machining involves secondary and finishing operations. It also should be recognized that some parts may be produced to final shape (net shape) and at high quantities by forming and shaping processes, such as die casting and powder metallurgy. However, machining may be more economical, provided that the number of parts required is relatively small or the material and shape allow the parts to be machined at high rates and quantities and with high dimensional accuracy. In general, however, resorting to machining suggests that a part could not have been produced to the final desired specifications by the primary processes used in making them and that additional operations are necessary.

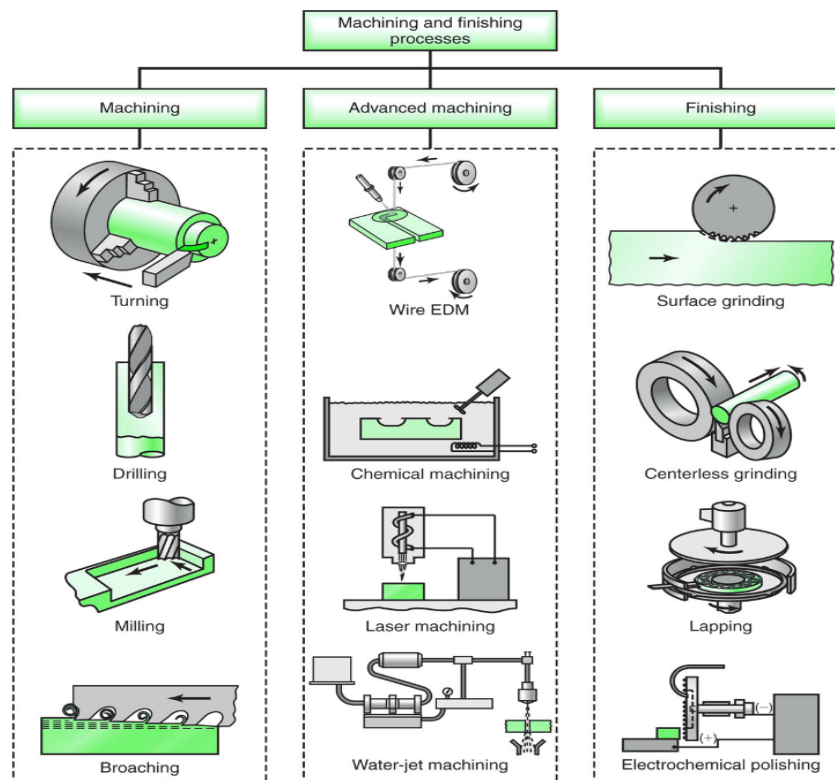


Figure 4.40. Machining and finishing processes [4.10]

In Figure 4.40 the main machining and finishing processes are presented. Furthermore, in spite of their advantages, material-removal processes have the following disadvantages:

- They waste material (although the amount may be relatively small).
- The processes generally takes longer than other processes. They generally require more energy than do forming and shaping process.
- They can have adverse effects on the surface quality and properties of the product.

Machining consists of several major types of material removal processes: cutting, which typically involving single-point or multipoint cutting tools, each with a clearly defined shape; brasive processes, such as grinding and related processes; advanced machining processes utilizing electrical, chemical, laser, thermal, and hydrodynamic methods to accomplish this task.

4.1.3. Guidelines on how to organize project oriented classes and shape such skills as teamwork, problem solving, creativity, critical thinking etc.

One of the challenges facing higher education is the development of methodologies which empower learners to respond innovatively to the problems and challenges they face now and will face in the future [4.11]. The knowledge of the learning pyramid is also helpful in this (Figure 4.41).

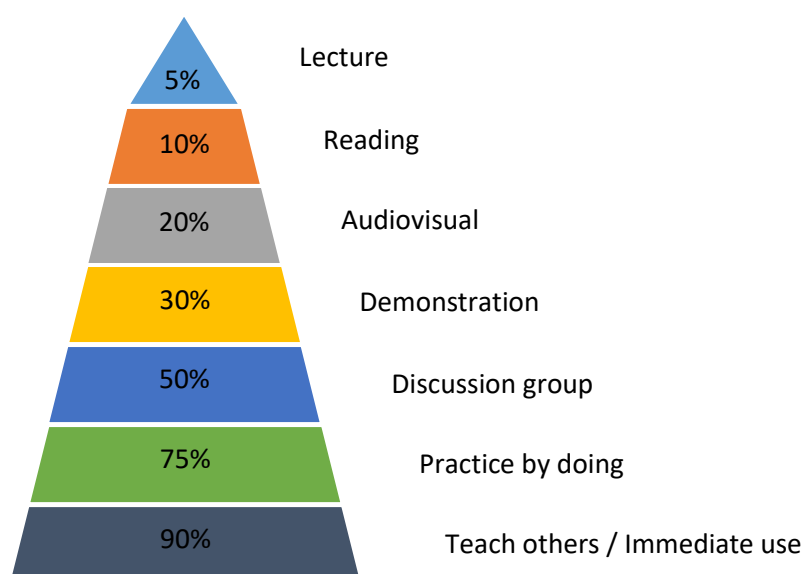


Figure 4.41. The learning pyramid [4.12]

To summarize the numbers presented on Figure 4.42 learners retain approximately [4.13]:

- 90% of what they learn when they teach someone else/use immediately,
- 75% of what they learn when they practice what they learned,
- 50% of what they learn when engaged in a group discussion,
- 30% of what they learn when they see a demonstration,
- 20% of what they learn from audiovisual,
- 10% of what they learn when they've learned from reading,
- 5% of what they learn when they've learned from lecture.

The best results, as much as 50% of learning the material, can be obtained during the seminar form of classes, in which students will be inspired to exchange views. As much as 75% of the material will be mastered through well-planned projects, preferably team ones. The best results are achieved when students use the acquired knowledge systematically and pass it on to other students on their own in a form that they understand.

Institutions of higher education have been trying to provide students with both hard skills, namely cognitive knowledge and professional skills [4.14], and soft skills, such as problem-solving and teamwork [4.15]. However, these skill related goals are not easy to be achieved as traditional learning has been playing a prevailing role where teachers are “the transmitter of

the knowledge” while students act as “the receptor of the information”. As a result, it is difficult for students to fully engage in educational practices, which may lead to a superficial understanding of disciplinary knowledge [4.16]. In order to change this situation, it is suggested that students are provided with the opportunity to participate in real problem-solving and knowledge construction in authentic professional contexts (lower parts of the learning pyramid). One attractive way to achieve this goal is through project-based learning (PBL). Markham et al. [4.17] describe PBL as “a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured among complex, authentic questions and carefully designed projects and task”. A PBL environment would usually possess five key features [4.18]:

- it begins with a driving question or a problem to be solved,
- students initiate and participate in authentic situated inquiry in order to explore the driving question, learn and apply important ideas in relevant disciplines,
- students, teachers and members of the community engage in collaborative activities to derive solutions for the driving question,
- scaffolding takes place with the help of learning technologies that engage students in the process of inquiry; and finally,
- students create tangible outputs that address the driving question.

Moreover, PBL methodology emphasizes activities which [4.19]:

- are long-term,
- are student-centered,
- are based on collaborative team learning,
- are integrated with real world practices,
- have productive outcomes,
- have an impact on skills like self-management, teamwork, leadership, time management, communication and problem-solving,
- use technology-based tools.

In order to meet the implementation needs, a PBL curriculum model has been developed, which is based on the PBL learning principles and on the curriculum theories of alignment and social construction. The PBL curriculum model is linked to the PBL learning principles, but the seven elements have been identified as: objectives and knowledge, types of problems and projects, students’ learning, progression and size, academic staff and facilitation, space, and organization, and, finally, assessment and evaluation. All components are elementary in a basic PBL-curriculum and must be aligned to a certain degree. Depending on subject areas, cultural and national requirements, there might be more elements to consider and numerous dimensions for each element. In each of the curriculum elements, there are several dimensions as illustrated in table 4.1. Between the two approaches, there are mixed modes, and most of the PBL practice is defined as some kind of a mixed mode [4.20].

PBL goes beyond generating student interest. Well-designed projects encourage active inquiry and higher-level thinking. The students' abilities to acquire new understanding are enhanced

when they are connected to meaningful problem-solving activities. The students are helped to understand why, when, and how those facts and skills are relevant. It's important to note that throughout the project, the students have to employ their innovative skills and improvise the technique. During PBL, the students have to learn to jump from common-sense ideas to more substantiated ideas based on practical experience and theoretical reflection – after all, that's what engineering is all about [4.21].

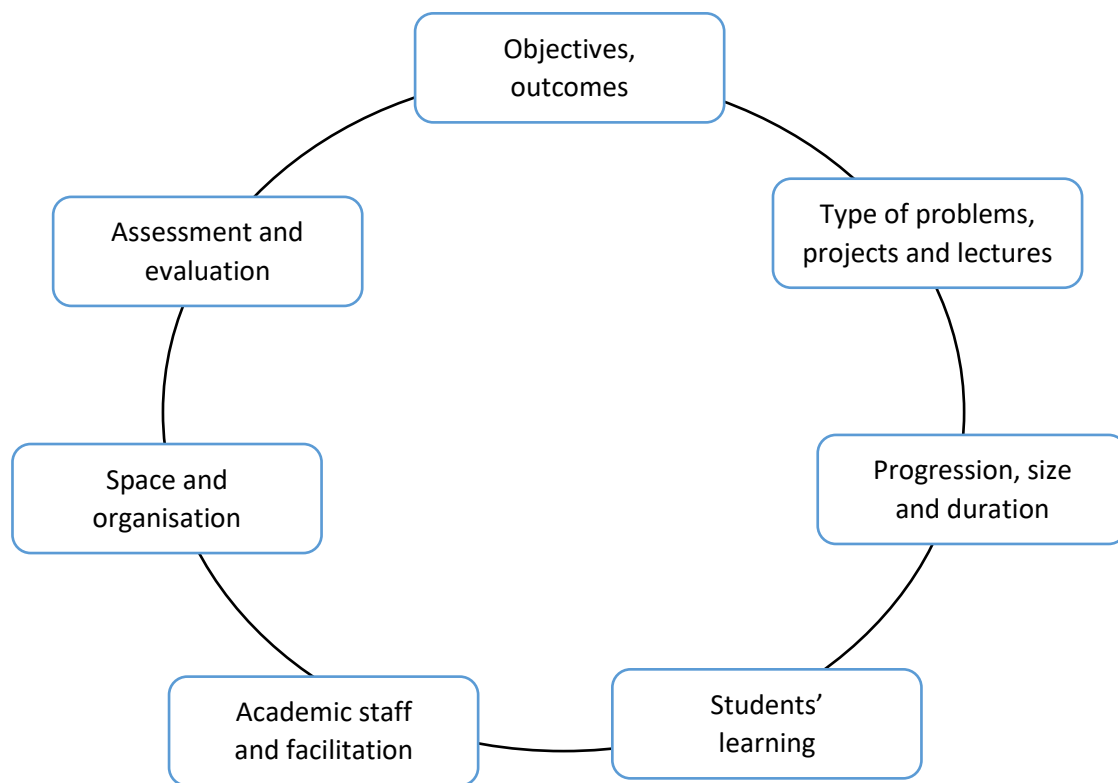


Figure 4.42. PBL Curriculum model [4.20]

The students develop a number of skills by their involvement in PBL efforts. There are most of all:

- **Teamwork:** „Behaviours under the control of individual team members (effort they put into team tasks, their manner of interacting with others on team, and the quantity and quality of contributions they make to team discussions” [4.22].
- **Creative thinking** (Creativity onwards): „It is both the capacity to combine or synthesize existing ideas, images, or expertise in original ways and the experience of thinking, reacting, and working in an imaginative way characterized by a high degree of innovation, divergent thinking, and risk taking” [4.22].
- **Critical thinking:** „It is a fundamental skill that develops early learning exercises and varied activities, depending on the actual educational situation (static context) and critical thinking development stage (dynamic context). Critical thinking is based on knowledge, analyzing differences and comparisons, namely the establishment of similarities and differences, observing and identifying cause-effect relationships,

extracting ideas from examples (inductive) support ideas with examples and evaluation on the value of truth, utility, positive or negative effects” [4.23].

- **Problem-solving:** „The process of designing, evaluating and implementing a strategy to answer an open-ended question or achieve a desired goal” [4.22].

Table 4.1. Dimensions of PBL curriculum elements [4.20]

Curriculum element	Discipline and teacher centered approach	Innovative and learner centered approach
Outcomes	Traditional discipline objectives	PBL and interdisciplinary methodological objectives
Type of problems and projects	Well-defined problems Disciplined projects Lectures determine the project	Ill-defined problems Problem projects Lecture to support the project
Progress, size and duration	No visible progression Minor part of curriculum	Visible and clear progression Major part of course / curriculum
Students’ learning	No supporting courses Acquisition of knowledge Collaboration for individual teaching	Supporting courses Construction of knowledge Collaboration for innovation
Academic staff and facilitation	No training Teacher controlled supervision	Training courses Facilitator / process guide
Space and organisation	Administrative support to courses Lecture rooms	Administrative support to PBL curriculum Group rooms for facilitate teamwork
Assessment and evaluation	Individual assessment Summative course evaluation	Group assessment Formative evaluation

Teamwork is the co-operation and communication between a group of committed individuals who combine and contribute their talents, experience and personal qualities. The attributes needed for effective teamwork are as follows [4.24]:

- Commitment to team success and shared goals.
- Interdependence – team members need to create an environment where together they can contribute far more than as individuals.
- Interpersonal Skills includes the ability to discuss issues openly with team members, be honest, trustworthy, supportive and show respect and commitment to the team and to its individuals.
- Open Communication and positive feedback - actively listening to the concerns and needs of team members and valuing their contribution and expressing this helps to create an effective work environment.
- Appropriate team composition is essential in the creation of a successful team. Team members need to be fully aware of their specific team role and understand what is expected of them in terms of their contribution to the team and the project.

- Commitment to team processes, leadership & accountability - team members need to be accountable for their contribution to the team and the project. They need to be aware of team processes, best practice and new ideas.

Critical and Creative Thinking is for teaching students to think for themselves and be more resilient. Both skills help prepare them with skills, strategies and dispositions.

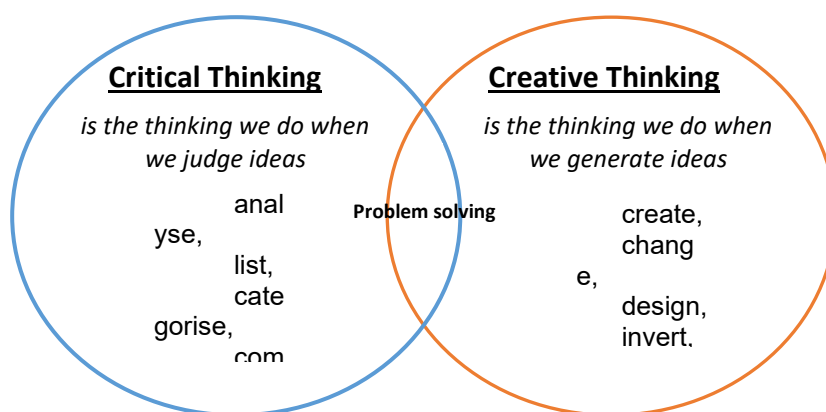


Figure 4.43. Critical thinking vs. Creative thinking [4.25]

Despite the differences shown in Figure 4.43 critical and creative thinking are strongly linked. Students require explicit support to develop the breadth and depth of their thinking and to take intellectual risks. This attention to thinking helps students to build self-awareness and their capacities for reflection. Developing critical and creative thinking capability is an essential element of developing successful, confident and innovative members of the community.

Problem-solving is necessary on every job. It is important that students develop the skills to resolve problems and have the personal resilience to meet the challenges and pressure that may be the result of a problem. Problem-solving requires a variety of both analytical and creative thinking skills. Which of them are used depends on the role in the organization and the problem. Over the years many authors have proposed conceptual models of problem solving but In general, these models consist of a sequential process, involving four to six steps. The following is a five-step model that most students can easily remember and implement, which is directly applicable to many areas of the curriculum as well as to everyday life [4.26]:

1. Understand the problem.
2. Describe any barriers.
3. Identify various solutions.
4. Try out a solution.
5. Evaluate the results.

The problem solving method is based on the principles of active learning. The student gets totally involved in the activity which helps in enhancing his/her knowledge, understanding and skills in real life situation and ultimately in developing a holistic personality.

4.1.4. Guidelines on the tools which can be used within preparation of classes

Didactic printed or online materials and presentations regarding technological areas usually consist of:

- text and equations,
- images, drawings, photos, figures, etc.,
- videos,
- audio recordings.

Functions of software dedicated for text and equations preparation are as follow:

- translation,
- editing,
- proof reading.

Functions of software dedicated for images, drawings, photos preparation concern:

- merging of separate recordings,
- adding descriptions,
- adding animations.

Functions of software dedicated for videos and recordings are:

- editing,
- changing formats,
- merging of separate recordings,
- improving video and sound quality.

In the tables below, 4.2, 4.3, 4.4, 4.5 and 4.6, names of examples of various tools for improving digital teaching materials were presented.

Table 4.2. The exemplary tools useful in text editing/equation preparation

Tool name	Weblink
Microsoft Word	https://www.microsoft.com/en-gb/microsoft-365/word
Apache OpenOffice	https://www.openoffice.org/?redirect=soft
LibreOffice	https://www.libreoffice.org/
FreeOffice	https://www.freeoffice.com/
LaTeX – A document preparation system	https://www.latex-project.org/
WPS Officee	https://www.wps.com/

Zoho Writer	https://www.zoho.com/writer/
ONLYOFFICE	http://onlyoffice.com
Formulator MathML Editor	http://www.mmlsoft.com/index.php/products/mathml-weaver
Office Suite	https://www.officesuite.com/?&tz=Europe/Warsaw
Online, collaborative LaTeX editor	https://www.overleaf.com/

Table 4.3. The exemplary tools useful in video editing tasks

Tool name	Weblink
Shotcut	http://shotcut.com
Video editor in Photos	https://www.microsoft.com/en-us/p/microsoft-photos/9wzdncrfjbh4?activetab=pivot:overviewtab
Moviemaker	https://www.microsoft.com/en-us/p/movie-maker-10-free/9mvfq4lmz6c9?activetab=pivot:overviewtab
IMovie	https://www.apple.com/imovie/
VSDC	http://www.videosoftdev.com/
VideoPad Video Editor	https://www.nchsoftware.com/videopad/index.html
DaVinci Resolve	https://www.blackmagicdesign.com/products/davinciresolve/

Table 4.4. The exemplary tools useful in screen recording and capturing

Tool name	Weblink
Apowersoft Free Online Screen Recorder	https://www.apowersoft.com/free-online-screen-recorder
Bandicam	https://www.bandicam.com/free-screen-recorder/
Ultra Screen Recorder	https://www.microsoft.com/en-us/p/ultra-screen-recorder-for-free/9n7d4xkg96km?activetab=pivot:overviewtab

Wink	https://www.debugmode.com/wink/
Gadwin PrintScreen	https://gadwin.com/printscreens/
Screencastify	https://www.screencastify.com

Table 4.5. The exemplary tools useful in images, photos, drawings preparation

Tool name	Weblink
Photos	https://www.microsoft.com/en-us/p/microsoft-photos/9wzdncrfjbh4?activetab=pivot:overviewtab
Adobe Photoshop	https://www.adobe.com/pl/products/photoshop.html
Inkscape (vector graphics)	https://inkscape.org/
Paint.NET	https://www.getpaint.net/
Gimp (GNU Image Manipulation Program)	https://www.gimp.org/
PIXLR	https://pixlr.com/pl/
Canva	https://www.canva.com/photo-editor/

Table 4.6. The exemplary audio editing tools

Tool name	Weblink
Audacity	https://www.audacityteam.org/
WavePad Audio Editing Software	https://www.nch.com.au/index.html
PODIUM FREE	https://zynewave.com/podium-free/
Adobe Audition	https://www.adobe.com/pl/products/audition.html
Audiotool	https://www.audiotool.com/
Acoustica – Audio Editing	https://acondigital.com/products/acoustica-audio-editor/

4.2. Guide on How to find research results

4.2.1. Preparing the list of on-line sources for research results

Locating relevant data and information sources and knowing how to reference them accurately are fundamental skills for academic research and writing. Accurate referencing not only locates the research context and sets the scope of the work but also identifies the writer as a genuine member of the academic community. Most postgraduate students and early career researchers understand the importance of accurate referencing in their work; nevertheless, sourcing and referencing remains a difficult and time-consuming process. At N.T.U.A. there are many ways that provide access to the necessary information.

NTUA Library and Information Center

Mission of the NTUA Library and Information Center is to serve the teaching staff and students of the University, as well as the scientists or students of other Universities by providing access to information.

For that purpose, Central Library of NTUA offers the Information literacy (IL) workshops, which provides students with the necessary competences:

- for the proper use of the available information resources and the services provided by the library.
- to prepare the Institution's undergraduate and post-graduate students in order to manage and evaluate the vast volume of information they are exposed to.
- to teach the students how to prepare an individual or group paper within a particular class, and how to work on their final thesis or dissertation.

Heal-link

Through this Portal HEAL-Link members have full-text access to journals, e-books and to bibliographic databases. Authentication and Authorization Infrastructure (AAI) through shibboleth is supported by a few publishers. Access is allowed through IP address recognition and My-HEAL-Link, which is a personalization service, does not conflict with this process. Legislation for Copyright issues is applied to the electronic publications the same way that it is applied for printed.

Heal-link main objectives are:

1. The collaboration among its members, by establishing common policy, on journals subscriptions (print and electronic), with aid to promote rational growth of journals collections among partners, savings and access to a greater number of electronic sources in order to meet the educational and research needs of the users of the participating institutions.

2. The creation and function of the Catalog of bibliographic records (Union Catalogue) of Hellenic Academic Libraries and the use of the entries in the Catalog of each member of the Consortium.
3. The joint subscription to electronic resources and services, and managed remote access to electronic resources and information services, including electronic journals.
4. Developing and establishing standards for any kind of librarian work.
5. The responsibility for continuing training of its members' library staff.
6. The collaboration on providing available material to each participating library through interlibrary loan and other methods and practices to ensure and facilitate the material availability among the partners.
7. The cooperation with similar institutions and organizations home and abroad in order to ensure the participation of HEAL-Link on international developments in library cooperation and copyright management.
8. To undertake any other initiative that promotes and develops Hellenic Academic Libraries through joint activities and initiatives.

NTUA Library & Information Center consists of Institutional Repository,
Electronic Journals, Electronic Books and Databases

Institutional Repository

In Institutional Repository, every student who obtains an NTUA diploma or degree shall submit mandatorily to the Central Library a copy, in electronic form, of their final work (dissertation, master dissertation, PHD thesis) and of the relevant accompanying material. There is also the Historical Library which contains digitized rare collections. There you can also find Greek Scientific and Technical Bibliography (1830-1940) including material published in Greece since the foundation of the Greek state until 1940. The aim of the bibliography is to facilitate researchers studying the history of science and technology. Some other useful journals are Archimedes, a monthly journal of the Greek Polytechnic Association from 1899 to 1947, Prometheus and Pyrforos which was published by the National Technical University of Athens from May 1992 to 2003. As part of the NSRF actions in 2013, it was digitized and is now hosted on the electronic journals' platform of the Central Library of the NTUA.

Electronic journals

Some electronic journals, provided by Heal-link, are the following:

- Polytechniaka Nea: The aim of the magazine is to inform the research and academic community about technological issues, research and development projects of the National Technical University of Athens.
- Akademiai Kiado (formerly part of ALPSP Learned Journal Collection).
- American Chemical Society (ACS).
- American Institute of Physics (AIP).
- American Physical Society (APS).
- American Society of Civil Engineers.
- Association for Computing Machinery (ACM).

- Cambridge University Press.
- Elsevier (Scencedirect).
- Emerald (MCB).
- Institute of Electrical and Electronics Engineers (IEEE).
- Institute of Physics (IOP).
- John Benjamins Publishing Company (formerly part of ALPSP Learned Journal Collection).
- Kluwer Law International (Temporarily unavailable).
- Lippincott Williams & Wilkins.
- Oxford University Press.
- Periodical Archive Online (ProQuest).
- Project MUSE.
- PsycARTICLES (APA).
- Royal Society of Chemistry (RSC).
- Sage.
- Springer Nature.
- Taylor & Francis.
- Wiley.

There are also some Publishers/providers that offer open access to all or part of their journals, such as DOAJ (Directory of Open Access Journals), ERCIM, HighWire Press (Free Access), Hikari Ltd. (Open Access), NUMDAM (Open Access), Project Euclid (Open Access).

Electronic books

Electronic books, also provided by Heal-link, can be found at the following:

- **eBook Collection (EBSCOhost):** It includes over 3700 books and covers all thematic categories. This is the collection of NetLibrary, which is now hosted by EBSCO.
- **Elsevier Book Series:** Full text to approximately 170 titles of book series, 91 of those are now available through the platform of Emerald.
- **Elsevier Handbooks:** Full text to approximately 20 titles of handbooks.
- **Elsevier Reference Works:** Full text to 58 titles of encyclopedias.
- **Referex Engineering:** Full text to approximately 400 titles of electronic books of the following collections: Chemical, Petrochemical and Process Engineering, Mechanical Engineering and Materials Collection, Electronics and Electrical Engineering.
- **Emerald e-Book Series:** Full text to approximately 140 titles of e-book series of the collections of Emerald Business, Management and Economics και Emerald Social Sciences. Three of the series titles (Innovation and Leadership in English Language Teaching, Syntax and Semantics, Studies in Writing) purchased by Brill and is now available only through its platform.
- **IEEE Proceedings:** Full text access to the conference proceedings of the IEEE.
- **Springer e-Books:** Full text to more than 2500 titles of electronic books.

- **Springer Full eBook Package (Copyright Years 2005 – 2017):** Full text to approximately 45000 titles of electronic books containing monographs, book series and reference works (encyclopedias, atlases, handbooks etc.).
- **Taylor & Francis Group eBooks:** Full text to approximately 500 titles of electronic books related to Archaeology, Classical studies and Law.
- **Wiley Online Books Collection:** Full text to more than 20.000 titles of electronic books.

Electronic books with open access, can be found at:

- **“Kallipos” Hellenic Academic Ebooks:** The “Kallipos” Repository gathers books, handbooks and learning objects, which were either produced within the framework of the “Hellenic Academic Electronic (Text)books” project or submitted in the course of an open call for Open Access scientific content. The “Kallipos” repository aims at the organized presentation, storage and long-term preservation of open-access (text)books and learning objects for the academic and research community.
- **Directory of Open Access Books (DOAB):** Full text to more than 15.000 electronic books of 300 publishers.
- **OAPEN Library:** Full text to more than 8.000 electronic academic books of several distinguished publishers, mainly in the area of humanities and social sciences.
- **Open Research Library (ORL):** It is a platform for open access eBooks with more than 20.000 titles in categories such as: architecture, computers, mathematics, science, transportation, technology and engineering.
- **Open Access eBooks on JSTOR:** Full text to more than 5.000 electronic books.
- **Project Muse Open Access Books:** Full text to more than 550 electronic books of several distinguished university presses.
- **SiELO Books:** Full text to more than 500 electronic books.
- **Taylor & Francis Group Open Access eBooks:** Full text to 400 electronic academic books of Taylor & Francis.

Heal-link also provides access in the following digital resources:

- **Art Index Retrospective (H.W. Wilson):** The database by H.W. Wilson is available through the EBSCOHOST platform. It offers 55 years (1929-1984) of art literature, including indexing of nearly 600 publications, many of which are peer-reviewed, and citations of over 25.000 book reviews.
- **Brill Dictionary of Ancient Greek Online:** English translation of Franco Montanari’s Vocabolario della Lingua Greca. With an established reputation as the most important modern dictionary for Ancient Greek, it brings together 140.000 headwords taken from the literature, papyri, inscriptions and other sources of the archaic period up to the 6th Century CE, and occasionally beyond.
- **Brill’s Companions to Classical Studies Online I-IV:** A series of English handbooks, on a wide variety of subjects and persons from the Classical Antiquity and their reception

in European culture. Designed for students and scholars, the books explain what sources there are, what methodologies and approaches are appropriate in dealing with them, what issues arise and how they have been treated, and what room there is for disagreement.

- **Encyclopedia of Ancient Greek Language and Linguistics Online:** A unique work that brings together the latest research from across a range of disciplines which contribute to the knowledge of Ancient Greek, offering a systematic and comprehensive treatment of all aspects of the history and study of Ancient Greek. It is an indispensable research tool for scholars and students of Greek, of linguistics, and of other Indo-European languages, as well as of Biblical literature.
- **Grove Art:** An art resource, scholarly updated, that covers global art and architecture from prehistory to present day. It includes 30.000 signed and peer-reviewed articles contributed by over 7.000 scholars from around the world, accompanied by images, bibliographies, and links to additional resources.
- **Grove Music Online:** An art resource that is scholarly updated and covers global art and architecture from prehistory to present day. It includes 30.000 signed and peer-reviewed articles contributed by over 7.000 scholars from around the world, accompanied by images, bibliographies, and links to additional resources.
- **International Aristotle Bibliography:** A comprehensive research tool that gives access to over 50.000 books, journal articles, book chapters, book reviews and dissertations on the philosopher Aristotle and his influence. The bibliography covers more than 100 years of publication in a broad range of languages.
- **Lexicon of Greek Grammarians of Antiquity:** A useful tool for scholars of Greek and Latin antiquity, as the first point of reference for information on the ancient grammarians, in particular for research into the history of philology, grammar and ancient scholarship. More than 300 grammarians are currently available online.
- **New Pauly Online:** Access to the German encyclopaedic work for the ancient world Metzler's *Der Neue Pauly* and to its English version Brill's *New Pauly*. The encyclopaedic coverage and high academic standard of the work and its interdisciplinary and contemporary approach have made the *New Pauly* an unrivalled modern reference work for the antiquity. There is an extensive coverage of Greco-Roman antiquity covering more than two thousand years of history, while emphasizing the long and influential aftermath of antiquity and the process of continuous reinterpretation and revaluation of the ancient heritage, including the history of classical scholarship.
- **New Pauly Supplements I:** A collection of reference works that complement and enrich the encyclopaedic work *New Pauly Online*. It brings together 6 major reference works for the study of the ancient world and its reception in later centuries. The collection consists of the following titles: 1. *Chronologies of the Ancient World*, 2. *Dictionary of Greek and Latin Authors and Texts*, 3. *Historical Atlas of the Ancient World*, 4. *The Reception of Myth and Mythology*, 5. *The Reception of Classical Literature*, 6. *The History of Classical Scholarship*.

- **Portico:** Access to the journal titles that have been “triggered” and are available through Portico. Portico is a service which offers a permanent archive of electronic scholarly journals, thereby providing protection against the potential loss of access (e.g., cessation of a publisher’s operations, discontinuation of a title by a publisher, termination of license agreement etc.) to e-content of HEAL-Link Collection.
- **SCOPUS:** Access to the bibliographic and citation database of Elsevier, with simultaneous search to more than 21.500 titles of scientific journals, to more than 116.000 e-books and to the World Wide Web. It offers the possibility of automatic linking to the full text of the articles of the subscribed titles to HEAL-Link. The SCOPUS database includes also citation indexes in all the sectors of science and technology. Authors can search for the references that have been made to their work and identify their own h-index.
- **Supplementum Epigraphicum Graecum Online:** A collection of newly published Greek inscriptions and studies on previously known documents. SEG presents complete Greek texts of all new inscriptions with a critical apparatus, it summarises new readings, interpretations and studies of known inscriptions, and occasionally presents the Greek text of these documents.
- **Thesaurus Linguae Graecae (TLG):** Full-text access to literary works, dated from the Homer (8 c. B.C.) to 1453 A.D. Today, TLG contains more than 110 million words from over 10.000 works associated with 4.000 authors. To access the TLG database, in addition to the IP addresses that have already been registered to the provider, each user is necessary to create an account.

Some other services of the NTUA Library are Wireless Free Internet and Virtual Private Network (VPN)

The Wi – Fi service provides to all the members of the university and to visitors the ability to access the data network of the institution via the wireless technology Ethernet. Access to this service is granted only to the authenticated users, whose username and password are registered in the main server of LDAP and is allowed to:

- Members of the community of N.T.U.A. via their password for the Dialup service (remote Telephone Access to the data network) of the institution.
- Visitors via username / password, which is valid only for one day and only in closed space where meetings or presentations take place (e.g., Ceremony room, multimedia rooms). The password is provided after an application from the organizer of the meeting – presentation.
- The Central Library and its annexes provide free wi-fi from the NTUA network using a daily password to all its visitors. Please contact the Help-desk of the library for more information.
- The Virtual Private Networks – VPN service of NTUA offers the ability to the users of the institution to connect through third networks and have access in a secure way to NTUA’s network and services. The connection takes place with the use of the appropriate software (OpenVPN), which creates a channel of communication between

the user's PC and the NTUA network. The user's PC acquires an IP address of the NTUA's network. For as long as the connection is active all the network movement of the user comes through this new channel. The data that are been trafficking are encoded with the use of SSL protocol, making the connection secure. The use of the VPN service from the users that are connected from remote networks (e.g., visitors in other networks) or from alternative access networks (e.g., ADSL connections) offers the following advantages:

- Access to data and services available only through the NTUA network, such as the subscriptions of the Central Library and the e-mail servers of the institution.
- Secure access to the services of NTUA and the internet even when the security of the network is not guaranteed.

4.2.2. Development of guide on results searching

Most postgraduate students have developed library search skills during their undergraduate training, although few have developed strategies for methodical and efficient searching. At a postgraduate level and beyond, writers need to adopt a critical stance in order to challenge and develop the discourse in their field. Sources can be evaluated as to their relevance, currency and credibility and the ideas presented in these sources should be extended, challenged or revised. Furthermore, the source material is often so vast that a high level of organizational skill is required to keep track of information, readings and your developing argument. Even finding a previously used reference can prove a challenge.

In order to find research results in an efficient way, there are some basic steps that should be followed:

- determine **the extent and the kind of information** you need,
- discover **where to look** for information related to the topic,
- learn how to **evaluate information** using critical thinking,
- document the new knowledge attained in a way that allows you to **demonstrate your personal judgment**.

At the same time, you should always keep in mind that each case is unique, and should be treated this way.

As there are different bibliographic sources, there are pros and cons each one has. The most important of them, are the following:

Books

- + Pros: cover a wide range of topics, they start from basic topics and move on to more advanced ones, provide a general point of view.
- Cons: extended, general, sometimes not up-to date.

Research Articles

- + Pros: specific topic – to the point, brief (usually under 20 pages), detailed with an in-depth analysis.
- Cons: quality issues, great volume of research articles, require pre-existing knowledge.

Review papers

- + Pros: state of the art, provide an in-depth analysis of a specific topic, include adequate number of references.
- Cons: sometimes they are too extensive, details may be omitted, limited number and topics.

The following example of finding research result for a case study in selective laser melting (SLM) of ferrous alloys, will help to clear things out

The first step is to find the appropriate keywords; hence, the topic must be divided in logical sub-sections, which will lead the search. In our example we see that SLM is an Additive Manufacturing process, and namely, a Powder Bed Fusion Method, while different types of alloys can be utilized (e.g., titanium, aluminum or ferrous alloys). At the same time the studies can be experimental and/or numerical, while the results may pertain to the surface quality, the dimensional accuracy, temperature and stress fields, keyhole formations etc. This thinking coherence is presented in the Figure 4.44.

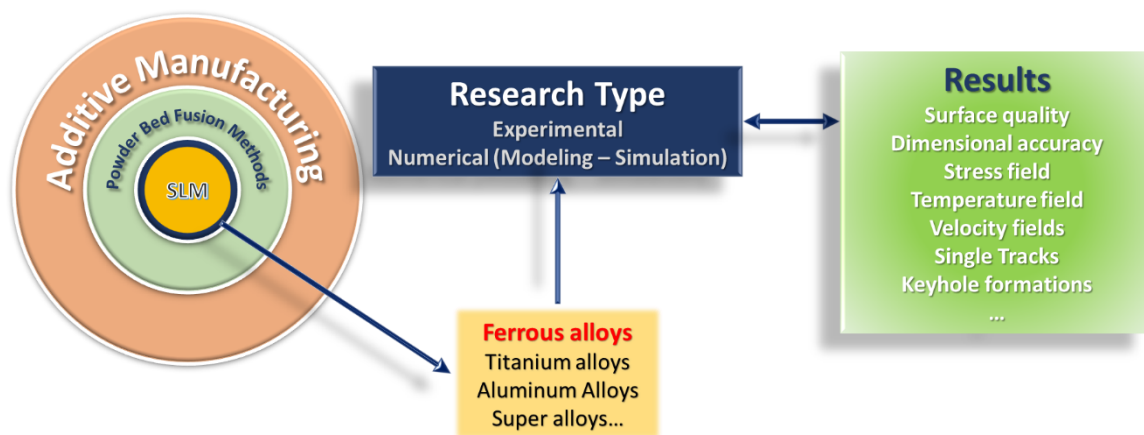


Figure 4.44. A basic thinking coherence

Hence, some representative keywords were emerged: For example for book search words like “Additive Manufacturing” , “Ferrous alloys”, “Numerical Modeling” , “Design of Experiments” can be used. For review paper search keywords like “Selective Laser Melting”, “Additive Manufacturing of ferrous alloys”, “Research progress on SLM”, “A review on SLM” are suitable. Finally, for research papers keywords like “SLM , Ferrous alloys (316L...” , “Experimental investigation”, “Numerical study”, “Stress/temperature/ velocity fields”, “Keyhole/single tracks” can be used.

Book search

Usually on every topic there is a huge amount of books, which consequently will lead to a huge amount of search results. For example, if we use the keyword “Additive Manufacturing” within books, the output will be 6905 results (see Figure 4.45).

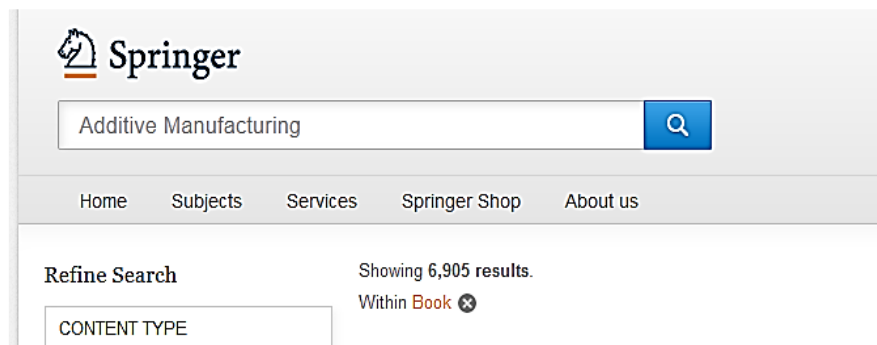


Figure 4.45. Screenshot from Springer website

So, we should use refined search, in order to limit the options in a more practical number, by defining for example the topic and the date of the desirable results.

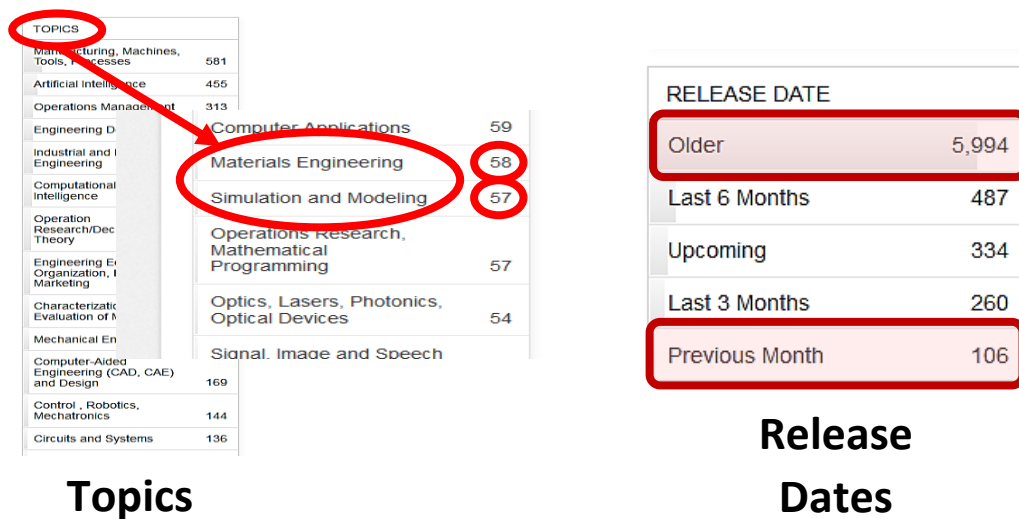


Figure 4.46. Screenshot from Springer website

So now, the options have been significantly limited, and through a more detailed search we can come up with a manageable number of books (see Figure 4.46).

Find articles with these terms

Selective Laser Melting

Q

Advanced search

3,267 results

Refine by:

Years

☐ 2021 (396)
 ☐ 2020 (453)
 ☐ 2019 (352)

Show more

Article type

☒ Review articles (3,267)
 ☐ Research articles (22,456)
 ☐ Encyclopedia (829)
 ☐ Book chapters (3,787)

Show more

Review article

Selective laser melting of Ti6Al4V alloy: Process parameters, defects and post-treatments

Journal of Manufacturing Processes, 28 January 2021, ...

Anil Kumar Singla, Mainak Banerjee, ... Deepak Kumar Goyal

Review article

Research progress on selective laser melting (SLM) of magnesium alloys: A review

Optik, 16 January 2020, ...

Wan-neng Zhang, Lin-zhi Wang, ... Yu-ming Chen

Want a richer search experience?

Sign in for article previews, additional search fields & filters, and multiple article download & export options.

Sign in

Figure 4.47. Screenshot from ScienceDirect website

We face the same challenge as we search for a review paper, since more than three thousand results appear (see Figure 4.47). Again, we need for a Refine Search and a reasonable hypothesis is that material would be a good criterion. Thus, by including the terms “ferrous” we find a specific review regarding the powder bed based additive manufacturing methods of ferrous (see Figure 4.48).

Find articles with these terms

Selective Laser Melting ferrous review

Q

Advanced search

990 results

sorted by relevance | date

Refine by:

Years

☐ 2021 (76)
 ☐ 2020 (83)
 ☐ 2019 (52)

Show more

Article type

☐ Review articles (155)
 ☐ Research articles (245)
 ☐ Encyclopedia (55)
 ☐ Book chapters (245)

Show more

Publication title

☐ Geochimica et Cosmochimica Acta (67)
 ☐ Metal Powder Report (29)
 ☐ Fuel and Energy Abstracts (27)
 ☐ Physica C: Superconductivity and its Applications (25)
 ☐ Biophysical Journal (12)
 ☐ Progress in Materials Science (11)

Research article

A review of particulate-reinforced aluminum matrix composites fabricated by selective laser melting

Transactions of Nonferrous Metals Society of China, August 2020, ...

Pei WANG, Jürgen ECKERT, ... Sergio SCUDINO

Review article

Selective laser melting of Ti6Al4V alloy: Process parameters, defects and post-treatments

Journal of Manufacturing Processes, 28 January 2021, ...

Anil Kumar Singla, Mainak Banerjee, ... Deepak Kumar Goyal

Want a richer search experience?

Sign in for article previews, additional search fields & filters, and multiple article download & export options.

Sign in

Review article

Review on residual stress in selective laser melting additive manufacturing of alloy parts

Optics & Laser Technology, 15 April 2020, ...

Ze-Chen Fang, Zhi-Lin Wu, ... Chen-Wu Wu

Research article

A critical review of powder-based additive manufacturing of ferrous alloys: Process parameters, microstructure and mechanical properties

Materials & Design, 7 February 2018, ...

Haniyeh Fayazfar, Mehraz Salarian, ... Ehsan Toyserkani

Figure 4.48. Screenshot from ScienceDirect website

In general Review articles are ideal, especially in the beginning of studying a specific topic since they usually cover a wide range of related topics, while they also include practical Graphs, Diagrams and Tables. Nevertheless, Research articles consist the main volume of the bibliographic research since they pertain to the topic of our interest specifically, whilst they can act as guidelines for our research. Again, the main problem is the volume of the conducted work – available articles. More specific, by searching in ScienceDirect “Selective Laser Melting Steel” more than eleven thousand results emerged (see Figure 4.49).

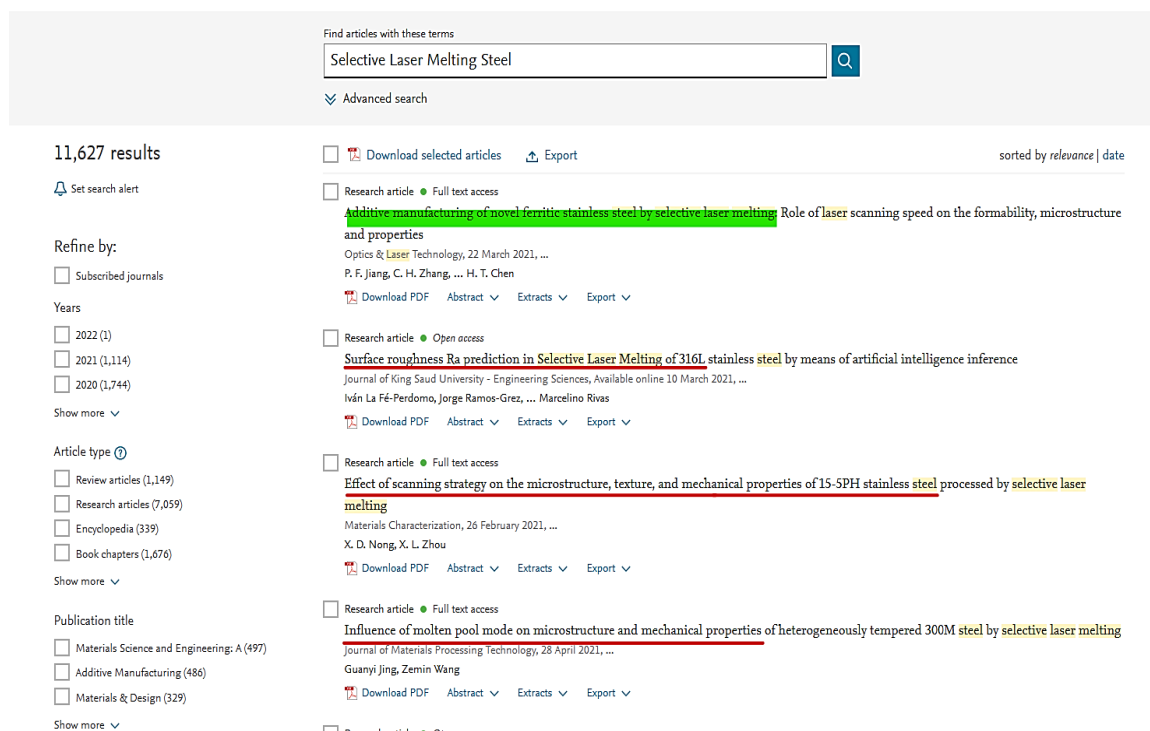


Figure 4.49. Screenshot from ScienceDirect website

Again, by specifying our search, we can limit the volume of the research articles. For example, we see that papers pertain to different sub-topics in SLM of ferrous alloys, like Surface Roughness, Effect of Scanning Strategy, Influence of molten pool modes in microstructure properties etc., hence, according to our specific interest we have and will focus on these particular papers.

Concluding, the main advice to follow while searching for research results, are the following:

- understand the research topic,
- find representative keywords,
- begin the research from the general to the specific sub-topics,
- the research has to include Books – Review Papers – Research Articles,
- you should be up-to date following the state of the art,
- use the bibliography as guidelines to substantiate your work,
- avoid plagiarism and have a critical point of view,
- always include the proper references.

How to rank papers with regard to criteria set, what criteria to take into consideration when ranking papers?

Journal ranking is widely used in academic circles in the evaluation of an academic journal's impact and quality. Journal rankings are intended to reflect the place of a journal within its field, the relative difficulty of being published in that journal, and the prestige associated with it. They have been introduced as official research evaluation tools in several countries. Traditionally, journal ranking "measures" or evaluations have been provided simply through institutional lists established by academic leaders or through committee vote. These approaches have been notoriously politicized and inaccurate reflections of actual prestige and quality, as they would often reflect the biases and personal career objectives of those involved in ranking the journals; also causing the problem of highly disparate evaluations across institutions. Consequently, many institutions have required external sources of evaluation of journal quality.

The Journals' Universe

There are more than 26k journals worldwide, so it is a necessity the existence of a practical and quantitative tool to help authors decide where to submit their manuscript. Any metric only tells a part of the story of a journal's quality and impact. Additionally, each metric has its limitations so should never be considered in isolation.

A brief history of Journals' metrics

The Journal Impact Factor was the first metric created for scholarly journals. Eugene Garfield first conceived of the idea of an impact factor in 1955 that is used to determine the impact a particular journal has in a given field of research and also to determine in which journal an author might wish to publish. The Journal Impact Factor is reported each year in Journal Citation Reports, and it was the only metric available for many years. Once the Internet made gathering statistics easier, other metrics were created, such as the Eigenfactor, which is the next popular metric, followed by SJR and SNIP.

A closer look into journals' metrics

There are different metric sources, such as Web of Science, Scopus and Google Scholar.

There are also different metrics, such as Impact Factor, 5-Year Impact Factor, Eigenfactor, Immediacy Index, SJR, SNIP, Citescore, Google Scholar Metrics, h-index.

- **Impact Factor** (Web of Science): The Impact Factor is the average number of times articles from the journal published in the past two years have been cited in the JCR year. The Impact Factor is calculated by dividing the number of citations in the JCR year by the total number of articles published in the two previous years.
- **5-Years Impact Factor** (Web of Science): The 5-year Impact Factor is the average number of times articles from the journal published in the past five years have been cited in the JCR year. It is calculated by dividing the number of citations in the JCR year by the total number of articles published in the five previous years.
- **Eigenfactor** (Web of Science): the Eigenfactor is based on weighted citations in the JCR year to papers published within the previous 5 years. Citations are weighted according to the prestige of the citing journal, with citations from highly ranked journals making a larger contribution to the Eigenfactor than those from poorly ranked journals.
- **Immediacy Index** (Web of Science): The Immediacy Index is the average number of times an article is cited in the year it is published. The Immediacy Index is calculated by dividing the number of citations to articles published in a given year by the number of articles published in that year.
- **SJR (Scopus)**: The SCImago Journal Rank (SJR) Indicator is based on weighted citations in Year X to papers published in the previous 3 years. Citations are weighted by the prestige of the citing journal, so that a citation from a top journal will have more impact than a citation from a low-ranked journal.
- **SNIP - Source-Normalized Impact per Paper** (Scopus): The Source Normalized Impact per Paper (SNIP) measures average citations in Year X to papers published in the previous 3 years. Citations are weighted by the citation potential of the journal's subject category, thereby making the metric more comparable across different disciplines.
- **CiteScore** (Scopus): The number of citations made in the current year to articles in the previous 3 years of the journal, divided by the total number of articles in the previous 3 years of the journal.
- **Google metrics** (Google Scholar): The main Google Scholar journal metric is the H5 index and is based on articles published in the last 5 complete calendar years. This is similar to the h-Index but also includes the top cited h articles (h-core) and the median of the citation counts (h-median)
- **h-Index** (Web of Science / Scopus / Google Scholar): the h-index attempts to measure the productivity and citation impact of the published body of work of an author. The h-index indicates the number of papers, h, that have been cited at least h-times (e.g. an h-index of 15 means that 15 papers have been cited at least 15 times each.)

Furthermore, there are also **National Rankings**, for example:

ERA Australia journal lists, Brazil's Qualis, Colombia's Publindex, Finland's Julkaisufoorumi (JUFO), Norwegian Scientific Index, Germany VHB Index, France CNRS ranking, Italian ANVUR ranking, List of HEC-Pakistan Recognized Journals, Indian National Academy of Agricultural Sciences, Polish ranking of journals.

Journals' metrics have also limitations:

- Larger journals have more usage potential. Those journals which publish a high number of articles each year and those with a 'long tail' of volumes going back many decades offer many more choices to readers. It would therefore be misleading to compare them to a journal which is relatively new or which only publishes a handful of articles each year.
- Downloading an article is not the same as reading it...
- Review articles tend to be cited more often and can impact results.
- The practice of self-citing can impact results.
- Some journal editorial policies, such as requiring authors to add citations to articles in that journal, may inflate an impact factor.
- With metrics that compare across disciplines, disciplines with traditionally fewer journals can be at a disadvantage. Comparing journals within the same disciplines is important.
- International journal coverage can be poorly represented.
- Books or book chapters may be poorly represented, if at all.
- Different metrics use different sources to compile lists of journals. A particular metric may not include certain journals.
- Different metrics use different publication ranges, which may vary from 2-5 years.
- Different metrics focus on different disciplines or fields of study, and may not include all disciplines or fields.
- It is also important always to keep in mind that the number of citations an article has received may not predict the quality of the article!

Summarizing:

- Different metric sources and different metrics.
- The National Rankings have to be also considered.
- Journal metric indexes are indications but not a panacea since any metric only tells a part of the story of a journal's quality and impact.
- It is important to compare journals within the same disciplines.
- The number of citations an article has received may not predict the quality of the article.

4.3. Scientific Writing Cookbook

4.3.1. Pocket Guide on “How to write scientifically?”

The aim of the guide

All scientists are under pressure to write the papers and finally publish them. Universities are periodically checking the number of points researchers have collected as well as the importance of their work via different commonly accepted indexes and papers' citations. Published articles are usually put on-line and available through many research results oriented indexing services. The amount of scientific knowledge constantly increases and competition among scientific research centers around the world has become really stiff.

Well known sentence that comes from scientists nightmares is “Publish or perish!”. This short guide's main aim is to help young scientists and students to write better scientific articles. The guide presents a practical approach to scientific writing that focuses on two main aspects:

- understanding what editors and referees consider that is worth to publish;
- understanding what makes the research article the compelling one.

To be successful in both cases it is important to follow some best practices this guide takes into consideration and summarizes. These best practices are related to typical structure of the scientific article, the process of preparing its content (typical steps), hints related to article review as well as typical activities of manuscript evaluation.

Typical structure of a scientific article

The structure of research articles are driven by conventions that started to appear in the XVII century when the first issue of Philosophical Transactions has been published in England. Of course there is no one binding structure but there are some common patterns that can be followed. It could also be a case the structure will be slightly different from domain to domain. Therefore every scientist should stick to the one in his domain most publications comply with. It is also important to check the specific requirements of the target journal before finalizing the structure of any article you write.

Activity 1

Search on-line for 2-3 highly cited articles from your domain of research. Read them quickly to find the headings of the sections:

- How is each paper organized?
- What are the main headings and subheadings?

Draw conclusions and make brief notes.

The generic structure of the articles presented in this guide is focused on publications related to experimental research. Bear in mind that papers related to other research paradigms or non-research publications may have different structures. In the experimental research domain the most common structure is AIMRaD. This abbreviation is for Abstract, Introduction, Materials and methods, Results, and Discussion. In order to better understand such structure the hourglass shape can be used (see Figure 4.50). What is important in this diagram are the width and shape of the segments. The most significant component that is the “beef” of the articles is a Results section. It means that other parts should be related to this section with regard to data as well as conducted analysis results presented in it. The results section governs the whole structure and contents of the article. However it is not enough to have interesting research results in order to attract the audience. The Introduction section plays the role of “a bait” that should make your readers interested in what you have done and would like to present. Spend some time on elaborating the content of starting point that will develop among the potential readers vested interest in your research results. Usually Introduction starts with the broad focus and ends with statement of the aim or purpose of the research, or its principal findings. In between the Introduction start and end there is background information connected with previous work results to emphasize the relevance of the problem solved and approach taken.

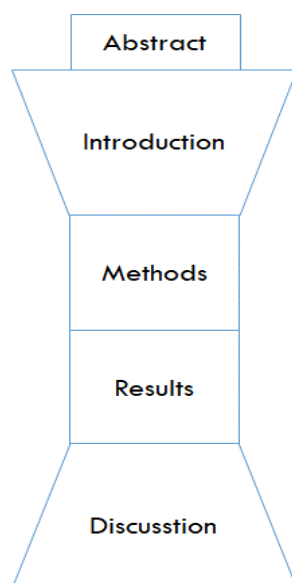


Figure 4.50. The AIMRaD structure of experimental research papers

The Methods section presents how the results have been obtained in terms of methods, techniques and tools used in the frame of research methodology suitable for specific domain.

The Discussion section width is similar to that of Results. However it ends with the same width as Introduction started. At the end, a paper should address broader issues that have been taken into consideration at the beginning. The idea at the end is to show the importance of research results in the wider perspective.

Activity 2

Is the presented shape similar to shape of the research articles in your domain? Analyze 1-3 highly cited papers from your domain, and answer this question. If the presented shape does not fit your domain paper suggest your own that expresses specificity of your research area.

Activity 3

Determine which part of a research article the following statements have been written in. Use the following letters: **I** for Introduction, **M** for Materials and methods, **R** for Results, or **D** for Discussion.

Example: It is very likely that . . . because . . . (D)

. . . data presented on the figure. . . ()

The aim of the paper is to. . . ()

. . . was used to determine . . . ()

As the study's results have shown. . . ()

The selected distribution of the random variable. . . was verified by . . . ()

It could be explained by . . . ()

The analysis was conducted with the use of. . . ()

. . . it is well visible, that these two variables are highly correlated . . . ()

Initial Steps of Manuscript Preparation Process

There are many different ways to prepare a research paper manuscript for submission to a journal, but the process can often be very time-consuming and usually involves reworking and tracking changes.

The activity that initiates the development of a scientific article is usually the selection of the research results that you intend to present in the article. As we know the

As we know, scientific articles can be written by a single author or a team of authors, but usually the concept of developing a scientific article is submitted by one person.

After selecting the set of results, the composition of the team of authors should be determined. Only people who have a creative and significant contribution to the creation of a scientific idea, the acquisition and analysis of data, the preparation of results as well as the writing and substantive improvement of the article may be recognized as authors of a scientific study. At this stage, the scope of work for individual authors should be determined and the order in which the names of authors are given should be determined, e.g. based on their contribution to the preparation of the publication. The order in which surnames are given should be accepted by all authors.

It should be discussed with potential co-authors whether the selected set of results is sufficient to write the article, or whether any additional results should be included.

Then you should define the story the data tells. The main message of the article should be answered. In other words, a vision statement is necessary. The vision of the article should be contained in one sentence that contains information about the achievement that you want to describe in the article. The vision of the article together with the context (background and motivation) of the conducted research allows us to answer the question of how important the story told by the article is and for whom this story is important. This leads to the definition of the target audience of the article and, consequently, to the selection of the journal to which you want to send the work.

The choice of a journal should be made based on the defined areas of research that the journal deals with and the rank of achievement presented in your article. The research topic of your article must fall within the target journal's area of interest, and the importance of the achievement presented in the article should be matched with the journal's prestige and reach. If your work is ground-breaking for researchers around the world, you should choose the most prestigious, highest-cited journal with a global reach. If, on the other hand, your research is relevant to the local (national) environment, then a local journal is a good choice. Usually, in addition to specific areas of interest, journals have defined formatting rules, the maximum number of pages, the format of tables and figures, or the order of the main chapters of the article. Therefore, it is important to read the guidelines for authors before starting to write an article. Instructions for authors can most often be found on the journal's website. Familiarising yourself with the journal's requirements at this stage will save you a lot of time in working on the manuscript. If you are convinced that you can prepare the publication in accordance with the guidelines and your article meets the journal's requirements, you can start editing the article.

Typically a research paper starts with a title followed by an abstract and an introduction. However, you shouldn't write your article in that order. If you do so, and then show the methods, analyse the results or draw conclusions from the research, it may turn out that you will have to rewrite the previously developed parts.

A good way to start an article is by developing a set of figures and tables that tell the story of your article. Prepared figures and tables should be arranged in the form of a diagram presenting the scenario of your publication. You can also use the presentation software and prepare a slide show that you would like to encourage the reader to read your publication. Such a presentation should start with a vision and then include a description of the methods used, the data collected, the analysis of the results and preliminary conclusions and ideas for discussing your achievement. Preparing the presentation will allow you to make sure that the history is not missing any element (drawing or table) and that all the prepared elements are necessary. The slides of the presentation prepared in this way form the backbone of your article.

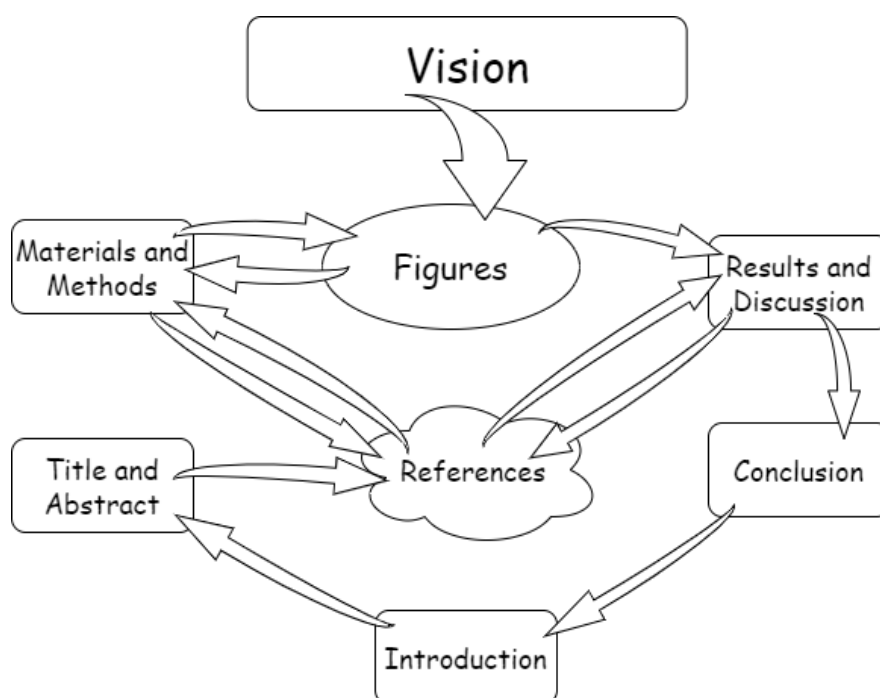


Figure 4.51. Steps to Writing a Scientific Paper [4.33]

Now you can proceed to the preparation of the Materials and Methods section (or its equivalent), the task of which is to show how the results presented in the work were achieved. The description of the research methods used should be precise enough to enable the reproduction of the results presented in the manuscript. If you have used a new research method, it must be accurately presented in this section, while if you have used known methods, it is enough to provide the literature source in which the method used is described.

After presenting the research methods used, you can proceed to the editing of the Results and Discussion section, highlighting the most important achievements presented in the manuscript. Depending on the article template provided by the selected journal, this section of the article may cover separate chapters Results and Discussion or be a combination of both. In this part, the obtained results should be successively described, the interpretation of the results in relation to the scientific hypothesis under consideration should be given, and the significance of the results for the research field should be demonstrated.

The Discussion of Results is an introduction to the next section, Conclusion. Here you should summarise all the most important achievements presented in the article. Conclusion should reassure you that the reader has understood the essence of your research and the significance of its results.

Now you can write Introduction. The Introduction is a story about your article. It shows the characteristics of your research, their motivations, assumptions made and the location of the research done in the research field. Introduction is a bird's-eye view of the problem under study: it shows a broad perspective (context) of the conducted research, describes previous

research achievements (literature review), and finally presents assumptions about the impact of your achievement on the research area.

Abstract plays a special role in a scientific article. Abstract, alternatively called Summary, should encourage the reader to read the entire article, so it must be written with particular care. Abstract should briefly present the assumptions and scope of the research, the methods used, and the most important results and conclusions. The abstract is usually limited to 150-300 words. Most journals require an additional set of keywords.

Remember to attach a Bibliography to the article in the format recommended by the journal. Thanks to the attached bibliography, the reader can see the previously published results of research in a given field. It is important that all bibliography items are quoted in the text of the article.

Note that the article you are working on still has no title. The leitmotif is still the vision you defined at the beginning of your work. Now that all the sections have been worked out, it's time to decide on a title that will showcase your publication. The title must reflect the essence of the article and show what is most important in the article.

Now you can put all the pieces together to create a complete FIRST draft.

Sections of the article and how to prepare them

Results Section

As has already been stated, the results section is the heart of every research article. Before you start writing an article you should be sure with regard to the main points of your results you would like to present. Therefore the first task you should carry out is to analyse the results and formulate the story your results “tell” as well as a take-home message the readers of your paper will receive. This message is about the insights the readers can get from reading the paper and then discuss with colleagues, think over, remember and maybe use in their own research activities. It may also be a trigger for research done by others with your results playing the role of starting point. To elaborate a story you should focus on data you have collected during research which are stored in tables and presented on figures. When deciding on the story the paper will carry, it is worth to answer the following questions:

- Which data will constitute the foundation of the paper and therefore should be included?
- What are the important points that will shape the story?
- What are the main take-home messages?

The questions can be even more detailed such as examples presented below.

- What may the results I’ve collected say?
- Is it possible to draw conclusions based on these results? What would they be? What data says in the specific context my article is written in?
- Who will benefit from reading my article? What are the main characteristics of my article audience?

- What is the value proposition of my results? Assuming that the paper will not be published what the readers will miss or will be lacking?

When you will be answering these questions, take notes. Summarise your findings. Having these done you can start refining your data. Data refinement is needed for clear data presentation which constitutes the most important element of every scientific article.

Main aim of data presentation is to illustrate the story, justify the hypotheses you have set and would like to support/reject or record data. Data is used to share and legitimise new knowledge which is created through research. Data presentation styles may vary and there is no one commonly accepted by all the journals. The most important guideline here is that the reader should not need to consult the text of the paper to understand the data presented in the table or figure. All the reader needs to understand should be shown in the table/figure or in the title/legend. To finally decide on the data presentation style you should read the so-called Author Guidelines that are provided by the journal you intend to submit your paper to. You can also review articles already published in the journal of your choice and analyse how the data presentation looks like, what are the patterns and best practises.

There are many sources that explain what is a good data presentation in the form of figures or tables. This is quite extensive knowledge and because of the scope of this guide it is hard to discuss this topic in a detailed manner. However there are some general hints concerning the selection of presentation form for data. Usually we have two options – table or figure. The tables are useful in the following situations:

- recording raw or processed data,
- enable comparisons between elements in many directions,
- making calculations or components of calculated data clear,
- showing data values and their precision.

When using figures you probably would like to:

- enable comparisons between few elements,
- show the “big picture” or the trends in data series,
- show the shape that allows us to comprehend the story instead of specific numbers.

These hints may be summarised with the following statements:

- When you are working with numbers use a table, but when you are focused on shapes use figures.
- When the patterns are the main issue use figures but when you are concentrating on data values use tables.
- When accuracy of value is of main importance use table, otherwise use figure.

After data is properly refined and presented an author may start writing about the results.

One of the most important hint for writing this section is to be very specific and focus only on main points of the research results. It also means that authors should write about important findings that will be taken into consideration in the Discussion section that may be separated

or combined in the single section with Results. Always check the instructions provided by Journal, you would like to publish in, what is preferable organization of these sections. However keeping the Results and Discussion sections separate is more common.

Sentences written in the Results section usually have the following functions:

- stress the most important findings,
- explain/comment on the results (but not discuss the results, this will be done in the Discussion section),
- point at the places (tables and figures) where the results related data can be found.

Activity 4

For selected 1-2 highly cited papers from your domain of research read the Results sections and draw conclusions how do they comply with the hints presented in this guide. Are sections Results and Discussion merged or separated? What presentation forms have been selected for results data? Are they clear and understandable? Are they self-contained?

Methods Section

The purpose of this section is to prove the credibility of the research conducted and the results obtained. This is done by explaining how the research was planned, organized, and done and how the results have been finally obtained. In this way, the reader will be able to determine for themselves whether the results actually present what the author of the article claims given the methods applied. This section is also used in assessing whether the methods used conform to accepted standards of research in a particular field. Methods that have been used before and have been described in publications do not have to be discussed in detail. It is sufficient that the articles in which they are described are cited. However every novel method should be fully described and detailed explanation of its usage should be provided.

Since the Methods section is used to assess the credibility of the findings described in the Results section, it is important to point out the important links between these two sections. This can be done with the use of the following strategies:

- Similar structure of both sections and/or similar or identical subheadings,
- Short introductory statements in the Methods section that refer to the results and aims.

Reasonable approach to have the logic of Methods section clear is to use the first sentence of the new paragraphs in it to introduce what you will be talking about and relate it what has been done. In all the strategies, the main idea is to show semantic connection between methods and results sections' content.

Final hint concerns the language used in Methods section.

Activity 5

Look at the Methods section of your selected papers from your domain of research and answer the following questions:

- What headings/subheadings are used in the section?
- What is the relationship of subheadings with: the *Introduction*, *Results* sections?

Is the section easy for you to follow and relate with Results? Why? Or why not?

Introduction Section

When readers of your article will read it they probably will start with Introduction. The most important questions they would like to answer are:

- Have you made any contribution to the domain's knowledge?
- Are your results important and original?
- Should they be published in the specific journal?

After analysis conducted with regard to many published articles researchers have identified common patterns they follow. The stages identified are the following (see Figure 4.52):

1. Context, field of research and importance of the investigated problem.
2. More specific information of what has been done by others.
3. Research gap that the paper should fill in.
4. Main objectives of the research.
5. Motivations or justification of the study.

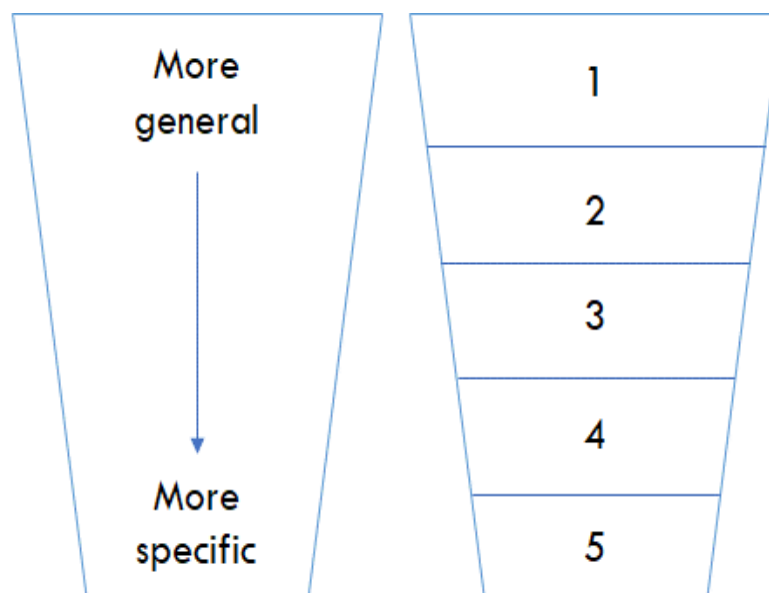


Figure 4.52. The structure of the Introduction section

In the first place you should develop the setting for your paper. It means more general sentences commonly accepted by the members of audience. They are usually expressed in present tense as it describes information perceived as always true. Sometimes present perfect tense is used to present what has already been done in the area from past to present. These introductory statements may or may not include references, depending on the field and the topic addressed.

Activity 6

Look at the Introduction section of your selected papers from your domain of research and answer the following questions:

- Can you say that introductory statements express common knowledge and facts generally accepted in your domain of the research?
- Are some sentences written in the present tense? How many?
- Are some sentences written in the present perfect tense? How many?
- Which tense is used more? Why do you think this is the case?
- How many sentences contain references?
- Are there any references in the sentences? Which ones do not have any references?

After general introduction author of the article move the readers towards more specific area and then to the paper's topic subdomain.

The stages 2 and 3 of the Introduction authors usually use references to already published papers (research articles, review articles, books) and try to show the state-of-the art as well as set the stage which is the niche (gap) that is important and should be filled in by their own work results and new knowledge developed. References also known as citations may be used in all stages of the Introduction. Before you will be doing so, read carefully Instructions for Contributors of the journal explaining the referencing style. Citations are playing important role in proving that you really know what has already been done in your area of research in general and in particular the one addressed by the article. This also helps with constructing an argument that will be used to justify your study and its importance for the area of the research.

It is commonly accepted that citation should refer only to the publications an author has read. However sometimes, what the original source is not available or cannot be accessed you can cite the "second level" paper in which original article has been cited. In that case only secondary citation paper will appear in References section. Paying careful attention to referencing has several significant benefits:

- avoid plagiarizing other researchers' work unintentionally. It is important as plagiarism is considered as a form of cheating in academic contexts,
- present yourself as a knowledgeable member of research community,
- make an impression on referees evaluating your article,

- allow other researchers to benefit from the sources of information you have used,
- clarify which ideas described in article statements are your own and which come from the work of other people.

The stage 3 main aim is to set the gap or niche that should be filled in with your research. It is usually done by using so-called signal words/phrases like *remains a major challenge*, *not well understood*, *presently unclear*. In all cases these words signalized that something requires further work and research to be done.

In the stage 4 the statement of purpose/aim should be elaborated. This will drive readers expectations with regard to what they can expect when reading the article and what they could learn from it. This should help to make them a decision if it is worth to read the whole article. The wording in this part is quite flexible. One hint may be to carefully read and analyze how this has been done in papers of other authors you have read. It is good idea to collect the sentences/wordings with aim research aim descriptions from most cited papers in your area.

The process of drafting Introduction may be carried out through the following stages:

1. Write an *aim statement* for your paper (Stage 4). As it is considerably easy part and will drive other stages write it as soon as possible. In the final version of the Introduction it will be one of the last (but not least) paragraphs.
2. Describe the gap you have identified (Stage 3). Use proper signal words to emphasize the need for further research in the area you have focused in the article.
3. Elaborate the setting with regard to interests of your intended audience, background knowledge and ideas included in the article's title. Think how to catch the audience attention from the first words of the introduction.
4. Organize the information that is drawn from literature and you have analyzed to form the content for Stage 2. Focus on the most important and most recent publications from your domain. This may require some more searching, ranking and analyzing the importance of literature items.
5. Put it all together and develop coherent Introduction. Add sentences providing background if needed and reorganize and elicit the content to get best possible logical flow of the Introduction.

There are several strategies supporting logical flow of the Introduction section. The most important are listed below.

Introduce interesting ideas. Titles, subheadings should be informative enough to set up the expectations of readers. In the paragraphs use topic sentences that enable readers to understand the main point of the paragraphs and to link the currently read content with the upcoming one.

Use top-down approach. It is good idea to move from general to more specific information. This will smoothly introduce the readers from general information presented first to details what will enable to better understand the context and more specific description.

Stick to the time frame and present given information before the new one. This approach will make the content easier to understand and follow.

Create the link between sentences within 7-9 words. The basic question in here is about the number of word the readers have to go through before the conceptual link between what they are reading and is already known can be found.

Activity 7

Look at the *Introduction* section of your selected papers (and maybe your own ones) and revise them with regard to the hints and strategies presented in this section.

Discussion Section

As a Discussion section should emphasize the importance of research you have done there are some important issues that have to be taken into consideration.

The first important issue is the structure. When building the Discussion section structure it may be useful to determine what it should include and what are the relationships with other parts of the article. In order to clarify these the Guidelines related to journal your would like to publish in should be taken into consideration. The guidelines will enable to answer the structure related questions with regard to the following aspects:

- Is it possible to combine Results and Discussion sections and finally add Conclusion as a separate section. If yes, does it suit your story the paper conveys.
- Would it be beneficial for the article to add Conclusion even if the Discussion section is quite long?
- Can the Discussion section be divided with subheadings? Will this division enable you to emphasize the main messages you would like the audience will receive after reading your article?

The next important hint is to closely relate the Discussion section to the article's title. After you have emphasized the most important elements of your paper's story in the Discussion look at the article's title again and redraft it if needed. This should better reflect the story from the beginning – directly in the paper's title.

Besides the Title, the Introduction should also be closely related to Discussion section. As the Discussion should have clear connection with the issues you have raised in Introduction, such as research niche or statement of purpose, try to keep close fit. It means that after you have Discussion section draft ready, make sure the you have clear connection with Introduction content. If the connection has been lost, redraft the Introduction to re-establish the connection properly. However there is no need to repeat unnecessarily information and all referred literature in both sections.

There is a checklist for Discussion section validation you can go through to make sure that you have taken into consideration all the most important issues. The checklist items are presented below.

1. Remember about reference to the aim/hypothesis of the study.
2. Review the most important findings starting with the highest significance. Do the findings support the hypothesis or enable to achieve the aim of the research? Are the findings comply with those from other researchers or they are totally different?\
3. Explain carefully the findings in the context information collected from referred literature.
4. Present the limitations of the study with regard to possible generalizations made beyond the study conditions.
5. Provide and explain the possible implications based on the research results. What the results mean in the broader context in your field of research?
6. State the further work recommendations and practical applications if you can see any.

Some of the items, especially 2-5 may be repeated for each group of results.

Activity 8

Look at the *Discussion* section of your selected papers (and maybe your own ones), analyze it and finally:

- Revise it with regard to the information elements presented in the list above.
- Try to find the strategies authors have used to clarify the key messages Discussion section should provide.
- Try to find clear connection between key “take-home” messages conveyed by Discussion section and the article’s title. Is everything coherent closely related?

It can be useful for readers to emphasize the main points they should understand well from Discussion section by introducing subheadings that will highlight the main threads discussion focuses on.

The Title

The title should attract the attention of target readers effectively. It is an important part of communication with an article’s audience. At first place the title should clearly indicate the content of the paper. This section includes guidelines how to achieve as a short description of different strategies.

First strategy says: *provide as much relevant information as possible but be very specific and concise*. It is about the judgement your target audience makes with regard to how relevant your paper is to their interests. The sample article’s title hints drawn from the Author Guidelines provided by prominent journals: “a concise and informative title (as short as possible)” or “concise and informative title (for research papers, ideally stating the key finding or framing a question”.

Capturing attention of the readers and effective indexing of the paper by literature-scanning services may be improved by using proper keywords in the title content. Therefore the best place for most important word(s) is the beginning of the title. The first keyword-containing part of the paper can be separated from the second, explanatory part by colon (:) or dash (-).

It could be also useful to choose strategically between such forms of the title as *a noun phrase*, *statement* or *question*. In a noun phrase there are a number of words clustered around one important “head” noun. An example would be “*Most effective design patterns for e-business systems development*”. This kind formulation of title may be very effective because it is brief, informative and containing important keywords. However it may not be the best choice for all situations. Sometimes better approach is to use statement, the sentence with a subject and a verb, that enables to give more specific information about the study results. This kind of title is suitable for papers that address specific questions and present non-complex answers. When the paper presents more complex answers, better option is to write a title as a question, e.g. “*Which design patterns are the best for scalable e-business systems’ data layer?*”. When taking into consideration the options presented above it is worth to check if the journal has specific conventions or recommendations with regard to form of the titles.

Whenever noun phrases are used it should be clear that the title is unambiguous. Ambiguity may be caused by nouns used as adjectives, i.e. placed in front of the head word of the noun phrase. There is general guideline which says restrict these noun phrases to a maximum of three words, and this many only if there is no risk of misunderstanding. If they grow longer, rewrite them by inserting the prepositions that clarify the meaning (e.g. of, by, for).

Activity 9

Look at the *Titles* of your selected papers (and maybe your own ones), analyze them and finally:

- find the strategies authors have used to develop a good title for the publication,
- assess if the titles have been properly developed with regard to their role in the paper. Do you have any suggestions how these titles may be improved?

The Abstract

As in case of title, an abstract also plays very important role in the paper for the following reasons:

- Some readers are quite busy and sometimes this is only part of the paper they can read. After they will have the abstract read they should be motivated to find the time to read the whole paper.
- In developing countries potential readers may have the problems with an access to the literature with an abstract as only part of your paper they can read.
- Services that collect and index papers’ abstracts usually use the title and abstract part of the article.

All these reasons make an abstract crucial part of every article that has to be properly developed. The first step you can undertake, to make an abstract better, is to add extra keywords into its content. In order to do that you can use relevant indexing services and select additional keyword from the results lists. Good idea is to look at the keywords used in papers that the topic and problem's category correspond to your article. Think also carefully about your target audience and their interests in terms of keywords they can use when searching for the information about published papers.

Writing an abstract can be driven by the typical information elements it should contain. Many journals, provide the list of questions authors may use as a starting point. In all cases the information about the length of an abstract (maximum number of words that can be written) is available. Analysis that has been done by many researchers revealed the pattern including typical abstract elements. In most cases abstracts contain the statements that explain the following issues:

1. Background information
2. Aim and scope of the research
3. Methods that have been used
4. Concise and description of the research results
5. Few sentences related to most important conclusions and recommendations

Sometimes the list is cut down and points from 1 to 3 are merged into one section of an abstract with 4 and 5 written as self-contained paragraphs.

The final advice is to read carefully an Author Guidelines of your target journal and stick to the requirements that have been set for a paper's abstract.

Activity 10

Read the Abstracts of your selected papers and identify the basic building blocks presented above. Are all of them present in the Abstract part? Are the listed abstract's information elements merged somehow? What about the description size of every element? What is your impression with regard to interests stickiness? Are the abstracts self-contained, which means that you have a clear picture about what the paper contains? Could you suggest any improvements?

Activity 11

Write an abstracts for 1-2 of your papers. You can start with writing few sentences for every abstract's information elements presented above. After you will have few paragraphs with statements describing your paper combine them into the first draft of your paper's abstract. Count the number of words you have used. If the abstract is too long for your target journal make it more compact by merging the sentences, deleting less important words etc.

Editorial procedures for preparing the manuscript

Usually it is very difficult to correct our own texts because we write them with the confidence that they are correct. When the first draft is ready, you should distance yourself from your article for a while. It is necessary to distance yourself from your own study and gain a fresh perspective. When you come back after two or three days, you will read what is actually written in the article, not what you wanted to write. You should then read the entire document, from the beginning to the last paragraph, to determine where the content needs to be revised. While reading the article, make any changes you deem necessary. Also mark all the fragments that raise doubts and on which you will still have to work on.

After reading the entire manuscript, go back to the beginning. Work on correcting each identified problem, engage co-authors if necessary. After the amendments have been introduced, the revised text should not raise any doubts as to its correctness and clarity.

After you've finished proofreading the entire article, take another break, and then edit the article again as you did before. In the case of articles written by a team of authors, each author should proofread the entire content, because everyone may notice other errors. Of course, in the case of team work, it is important to exchange information and discuss the best solution. Usually, text editors that allow you to track changes and support authors' discussions with comments are very helpful in this process. The correction of the article should be repeated until the full satisfaction with the substantive, linguistic and visual content of the article is achieved.

During the linguistic revision (style, punctuation and grammar), special attention should be paid to common mistakes. Pay attention to the correct numbering of chapters and subsections as well as the numbering of tables and figures. You may find it helpful to use spell-checking tools, but be aware of the limitations of such systems. For example, a word may be spelled correctly, but is in the wrong form or in the wrong context.

When revising an article, check the style of the bibliography and the correctness and consistency of the references to the bibliography. Each reference in the text must lead to an appropriate item from the bibliography, and each item listed in the bibliography must have at least one reference in the text of the article. To ensure the correctness of the style of the bibliography as well as the consistency of references, it is worth using an electronic bibliography management system. The most popular bibliography managers include Mendeley, EndNote, Zotero, RefWorks and Citavi. By using the bibliography manager, we can be sure of the correct formatting of the bibliography in the style required by the journal and automatic checks of the consistency of the list of items and their citations in the article content.

Once you've finished proofreading your article, it's worth doing one more "final" reading to catch any "minor" errors that may have gone through. This can be done by reading aloud in a team of authors. It is also a good idea to ask a colleague in the research field to do an additional reading, because, as already mentioned, it is difficult to check your own studies.

Checking the manuscript before the review

You already have in your hand the manuscript you intend to send to the journal. All co-authors agree that the article meets the journal's requirements - after all, all detected errors have been corrected. On the other hand, you know that reviewers of your article will judge whether the article meets the acceptance criteria listed in the review sheet. Since in many cases journals provide lists of questions that reviewers answer, you can ask an experienced researcher from outside the author's team for a critical opinion on your article. Such an opinion may be developed on the basis of questions to which the reviewer will be answered. Examples of questions in such a checklist might include the following:

1. Does the title reflect the content of the article?
2. Have the research methods used been presented sufficiently accurately?
3. Is it possible to reproduce the results of research based on the description?
4. Does the article ends with conclusions, which highlight the key achievement and its significance?
5. Are the conclusions justified (confirmed by the obtained results)?

After obtaining and analyzing such a critical opinion, it may turn out that your article requires additional correction or supplementation. As you can see, the process of creating an article is quite complex, however, after final proofreading and checking, you can finally submit your manuscript to a journal.

Manuscript evaluation process

It is obvious that you need to prepare a manuscript first in order to submit it to the journal, however, on the other hand, knowledge of the process of reviewing a manuscript is very useful for preparing an article. For this reason, before presenting the process of creating a scientific article, we will familiarize ourselves with the review process and the criteria for evaluating the article. This knowledge will definitely help you create articles with a high chance of publication.

The first recipient of your manuscript is usually the journal's chief or associate editor. The Editor checks whether the article you submit falls within the journal's area of interest and meets the journal's quality and editorial requirements. From the above, it can be concluded that the choice of the journal cannot be accidental, but based on the scope of the journal's interests and the rank of scientific achievement. For more guidance on selecting a journal, see the Manuscript Preparation section. If the editor decides to reject the manuscript, you will receive in response the justification for this decision and in many cases proposals of journals which, in the editor's opinion, may be interested in publishing your article.

Rejection of an article by an editor does not mean that the article is not good, it may turn out to be enthusiastically received in a journal with a slightly lower prestige or more relevant subject matter. If, in the reviewer's opinion, the manuscript meets the journal's requirements, the editor sends it to the reviewers for review.

Review is the process by which scientists (peers) evaluate the quality of work of other scientists. In doing so, they try to ensure that the work is rigorous, consistent, builds on previous research, and enriches what we already knew. Reviewers are selected by the editor on the basis of their experience, publishing achievements and expert knowledge. Often, after the publication of a valuable article, the authors receive a proposal from the editor to review articles submitted for publication. The condition for receiving an invitation to review is the lack of professional ties with the authors. The reviewer should not collaborate with the authors, e.g. by working in the same research team or creating joint publications. The peer-review process usually involves two or three reviewers, but there are also publishing houses that publish on the basis of one review (low-prestige journals), there are also publications that require four or more reviews (e.g. high-rank journals or publications that are the basis for awarding the degree or academic title). The more prestigious the journal, the more demanding the peer-review process will be and the more likely it is to be rejected.

On the other hand, thanks to the high prestige of the journal, articles published in it are read more often and cited more often. The peer-review process is "blind", which means that the authors of the manuscript do not know who is reviewing their work (the reviewer remains anonymous). In many journals, in order to ensure full objectivity, the peer-review process is "double-blind", so the reviewers also do not know who the author of the assessed work is. Thanks to this, the work of a professor who is an outstanding authority in a given area of research is assessed as scrupulously as the first article by a novice scientist. After accepting the article for review, the reviewer has a designated time to read the manuscript and write a review. Typically journals require two weeks to be reviewed. The review can end with one of four conclusions:

- paper accepted – does not require any action from the authors,
- paper accepted with minor changes – the authors introduce minor changes to the work and submit it for publication,
- paper accepted with major changes – the authors introduce corrections and additions and answer the questions and comments of reviewers, after which the work is reviewed again by the same reviewer,
- paper rejected – authors can take advantage of reviewers' comments, improve the article and consider publishing the article in another journal.

Since reviewers are primarily researchers who publish their own scientific papers, it can be said that reviewing papers is an additional obligation for them, which takes time and does not directly contribute to increasing their scientific output. Most reviewers are very conscientious in assessing the manuscripts entrusted to them, but there are also those who read the manuscripts in a hurry, without delving into the story told by the article and immediately

expressing the opinion that the manuscript is okay and can be published. Before you complain about the multitude of serious and meticulous comments from one reviewer while the other reviewer accepts the work as it stands, think about which reviewer really wants to help you. Each journal provides the reviewers with its own set of questions and instructions for evaluating the work. Assessment forms are usually available on the journal's website, so authors who submit an article for publication know exactly what to pay attention to.

The judges must answer the questions on the evaluation forms. Frequently used questions are [4.34]:

1. Is the achievement new? Reviewers must verify that the work is original and new.
2. Is the contribution significant? The contribution should significantly increase the scope of knowledge in the research area. The authors should emphasize the importance of the scientific achievement.
3. Is the manuscript suitable for publication in a journal? According to the third criterion, the article should be relevant to the journal's area of interest and rank high enough to be published in the journal.
4. Is the structure of the manuscript acceptable? The structure of the manuscript should follow the journal standard.
5. Do the research methods and interpretation of results conform to acceptable scientific standards? Regarding this question, the research methodology should be appropriately selected and described so that other researchers can replicate this achievement.
6. Are all conclusions firmly based on the data provided? Conclusions should be reliable, meaningful and supported by research. There should be no conclusions based on guesses or assumptions.
7. Is the number of manuscript pages appropriate? Typically journals have a limited maximum number of pages for published scientific articles
8. Are all pictures and tables necessary? Reviewers must check whether all the figures and tables provided are needed to illustrate the research carried out.
9. Are the numbering and format of figure captions and table titles appropriate? The article should conform to the journal's editorial standards such as style, formatting. Authors should use the manuscript templates provided by the journal.
10. Do the title and abstract clearly indicate the content of the article? "Title" and "abstract" are the showcase of the article, therefore they must be edited very carefully to reflect the content of the article and be able to encourage the reader to study the entire work.
11. Are the references up-to-date and complete? Scientific work should be based on the current state of knowledge in a given area. Authors should demonstrate knowledge of the research area and achievements that underpin their work.

12. Is the article perfect, good or weak? Reviewers must attempt an overall evaluation of the manuscript. Due to the increasing number of manuscripts submitted to journals, reviewers may be asked to provide some quantitative assessment of the relevance of the article. An example question might be: Is this manuscript in the top 10% of manuscripts you've read in the last year?

Some journals use an extensive quantitative part of the evaluation questionnaire, allowing questions to be assessed on a multi-point scale. Table 4.7 contains sample questions rated on a five-point scale. At the left end of the scale there is an adjective describing the most negative rating, while the right end of the scale contains the adjective describing the most positive rating.

Table 4.7. Quantitative evaluation questionnaire

			1	2	3	4	5	
1	Consistency of the title with the content of the article	Inconsistent						Consistent
2	Scientific achievement rank	Irrelevant						Significant
3	Selection and description of research methods	Poor						Excellent
4	Structure of the article	Poor						Excellent
5	Conclusions	Unauthorized						Fully justified
6	Selection and use of literature	Poor						Excellent
7	Language	Poor						Excellent
8	Quality and relevance of tables and figures	Poor						Excellent

In addition to selecting the appropriate rating, reviewers are often asked to comment on each issue and make comments about improvements or additions to the article that authors should introduce prior to publication.

How to respond to editors and reviewers: practical tips

1. You should not assume that you are always right, it can cause problems. It is rare that the author is completely right and the reviewer is completely wrong, or vice versa.
2. Start your answer by thanking the editor and reviewers for the time they took to rate and improve your article.

3. Respond to any comments from reviewers and justify any changes to the document. You can only comment on the linguistic remarks collectively by saying that all errors have been corrected. You should address each substantive comment separately.
4. Your answer should satisfy the reviewer without detriment to the article. If a reviewer requested change doesn't affect the submission of the article, try to make that change. However, if you feel that a proposed change will negatively affect the article, boldly and respectfully disagree.
5. Underline at every opportunity that you are doing everything you can to improve the manuscript.

Criticism and rejection do not automatically mean that your research is not valuable or that the article is not well written: consider other journals, also consider supplementing, developing the article, or rewriting part or all of the article. If your manuscript gets rejected, it's important to identify the reasons. Reasons for rejection will help you decide what to do next. Almost every experienced researcher has faced rejection of the article, so it is worth discussing this experience with an older colleague. Criticism and rejection are a natural and necessary part of scientific work (Einstein's scientific theories are criticized by some scientists to this day). Almost any experienced scientist will also tell you that many of the results from their rejected papers were eventually published. Successful authors should deal with rejection of articles as well. Figure 4.52a presents an example of the response to the reviewer's comments.

Answers to the Reviewer comments

We wish to thank the editor and the reviewers for constructive comments in this review. Your comments provided valuable insights to refine contents and analysis. In this document, we try to address the issues raised as best as possible.

Reviewer #1

English language and style ☐ Extensive editing of English language and style required
☐ Moderate English changes required
☒ English language and style are fine/minor spell check required
☐ I don't feel qualified to judge about the English language and style

	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant references?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Is the research design appropriate?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are the methods adequately described?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are the results clearly presented?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are the conclusions supported by the results?	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Answers to Reviewer #1 comments:

In the following, we provide detailed answers to the reviewers' comments. To facilitate following the comments and the answers in this document, we use black font for the reviewers' comments and blue font for our answers. In the paper revised version, all modifications are highlighted in purple.

The comments are as follows:

Does the compression task assume a priori knowledge about k ? Is this parameter coded separately? Yes, we need to know k , or at least the k/n ratio. Appropriate explanations have been included in the article. [Line 214]

It is not clear how Theorem 2 is applied to the developed compression. Is it crucial? The relationship between Theorem 2 and the proposed compression algorithm is described (perhaps too general) in section 2. To emphasize the use of Theorem 2 in the developed compression algorithm, the ending was added to the reasoning:

"The proving of Theorem 2 was crucial to making this observation."

The Algorithm 1 accept w as a codeword length. It is not clear how this input is obtained. Is it obtained from Inequation (2)? This inequation has the range the entropy belongs to. Besides, a rounding would be necessary.

We do not currently have exact theoretical results as to the magnitude of w . This is currently the subject of further research. We have included information in the article that we can share at the moment. We think they will be helpful. [Line 214]

We hope that the reviewer will find our updates and clarifications satisfactory, and our revised version suitable for publication.

Figure 4.52a. Example answers to the reviewers comments

Manuscript Submission: Five Successful Authors' Practices [4.35]-[4.38]

Sending a manuscript to a journal can be compared to participating in a competition, in which the success is determined by reviewers using specific evaluation criteria.

Authors can use five practices to increase the chances of their articles being published:

- Review scientific papers. These could be the work of your colleagues or articles that the journal editor will ask you for a review. The first practice can be difficult for beginners - they should at least read research articles and discuss critically about the research they describe.
- Edit your research and scientific papers to meet the quality criteria required by the editor and reviewers.
- Select carefully the journal to which you will submit your article. Refer to articles previously published in the journal, adjust the structure and style of your manuscript.
- Use the questions that reviewers are answering and ask colleagues for reviews to improve the article before submitting it for publication.
- Improve the article using feedback from reviewers and present the improvements to the editor of the journal.

4.3.2. Intellectual property rights

4.3.2.1. Some aspects in the universities

The problem of respect for copyright exists and has a different scale.

We can define issues that require improvement in education and research:

- knowledge of copyright and related rights,
- awareness of the importance of respecting someone else's intellectual property - no acceptance of plagiarism,
- possibilities of use of own and other people's works – CC licenses,
- ability to write the references correctly,
- taking care of correctly prepared material for classes.

In universities, students are provided with knowledge of copyright in different subjects. These are, for example, "Protection of intellectual property", "Diploma Seminar". Universities in Poland use Uniform Anti-Plagiarism System. Users, promoters of the diploma thesis for example, have to log in or use the access from the Archive of Diploma Thesis website. This system is a tool to develop of the thesis to facilitate text analysis for copyright infringement.

After the checking process the supervisor receives the report. First information is about the percentage of similarities found. This information should be verified using the detailed report. In the extended version of the report we can see, which the borrowings come from where: from legal acts, from Internet from Polish Repository of Diploma Thesis or from Institution base. We know and decide about the plagiarism. Plagiarism will be in the situation, when

author of the thesis did not sign the references. Sometimes, when the percentage is high, but in the thesis there are the references, supervisor can only have doubts as to the preparation of the thesis on student's own. Many universities are checking by the antiplagiarism systems all student studies.

The organizers of the conferences, publishers also point to the plagiarism and ethical behavior of the each authors. They may use different types of software for this purpose.

It is therefore very important to create a culture of respect for copyright also among students. Next point is being an author of article. When we publish our research results, we also transfer the property rights to the publisher. Then the publisher can sell the paper or monograph and define the allowed field of use.

But the author and publisher can define directly these fields by Creative Commons License use. The CC licenses are known since 2001. At present we can use four types of licenses. CC BY – recognition of authorship/attribution – then we may copy, distribute, present and perform a work covered by copyright and derivative works based on it, provided that the name of the original author is mentioned. CC NC – non-commercial – we may copy, distribute, present and perform a work covered by copyright and derivative works based on it only for non-commercial purposes. CC SA – Share Alike – we may distribute derivative works only under a license identical to that under which the original work was made available. CC ND – No Derivative works - we are allowed to copy, distribute, present and perform the work only in its original form – as a quote (creating derivative works is not allowed). The special kind of licenses is CC0 (zero). CC0 – no rights reserved - enables scientists, educators, artists and other creators and owners of copyright - or database-protected content to waive those interests in their works and thereby place them as completely as possible in the public domain, so that others may freely build upon, enhance and reuse the works for any purposes without restriction under copyright or database law. CC0 is the broadest type of "re-rendering" of copyright. For this license, we do not need to provide the author, the source, link to the pages, give the type of license, we can also rework the photo. Sometimes the problems are caused by photos that we want to copy from the Internet. If the photo is not in a photo database that can be purchased or is not in a commercial photo database, it cannot be copied. Unless the author of the photo has consented by entering a certain type of CC license. However, always we should check that the CC0 license is still in effect.

Public Domain Mark 1.0 is a designation used to identify a work as belonging to the public domain. Such a work can be used, distributed and changed, even for commercial purposes, without the author's consent. The Public Domain Mark 1.0 is different from other Creative Commons tools.

It is not a license or any other legal instrument, it does not even have to be an act performed by the author of the work. It is not accompanied by any legal text or contract. Anyone can mark any work in the public domain as such to make it easier to identify its legal status. The person marking the work does not accept responsibility for the marking of the work in accordance with the legal status.

There are works that are free from known copyright restrictions around the world:

- very old works, when the author is dead and 70 years have passed,
- the works are not products of human labour, e.g. geological exhibits,
- works that have never been subject to copyright.

In order to reconcile the protection of the rights of authors and the freedom of social sharing of content - a license notice must accompany any material distributed under the terms of CC. Then the note must include:

- indication of the author (CC-BY is the basis),
- indication of the type of license with a link to its explanation,
- title indication (if any),
- link to song source (if any).

Creating educational materials based on the published works requires the obligation to provide the source. The training raised the issue of preparing a bibliographic census.

Many times there are situations that we use songs more than once. Then the so-called bibliography generators and bibliography managers are useful. It is additional software that facilitates the work and organizes biographical lists. This is so useful that publishers can ask the author to perform such an list according to a specific scheme. Therefore, information about citation styles is important information. Correct list of references should be prepared using the same citation style in the paper/monograph. Sometimes universities have these information on their websites.

We even had examples of examples of teachers who prepared the citation styles themselves for their students, quoted with many examples. It is not a common practice.

The final conclusions of the review and analytical work carried out are as follows:

4. It is necessary to train students and lecturers in respect of copyright. Such knowledge should be obligatorily passed on at all stages of education. In many cases, the lecturers at the diploma seminar draw attention to copyright problems. However, this practice is not common and the classes may be conducted in different ways in different groups of the same year.
5. Plagiarism is treated indulgently in many universities. Some carelessness in making decisions by promoters can be noticed in the context of verifying the anti-plagiarism check report. The interviews show that many lecturers are not properly trained and do not understand the provisions of the report. It is quite common practice to mechanically classify the percentage number into the "there is plagiarism" or "no plagiarism" range. Therefore, there is a need for frequent training on the ability to use the anti-plagiarism program and to interpret the report. In universities where anti-plagiarism procedures are unclear or lacking, such procedures should be implemented. In universities where the procedures treat the report result mechanically (e.g. 10% - no plagiarism, but 30% - conditionally there is or not, more than 50% is already plagiarism) - they should be corrected and combined with training of teachers and students.

6. There is a need to train students in the correctness of the bibliographic list. Some universities have comprehensively developed websites with examples of citation styles. Others limit themselves to developing guidelines for graduate students and provide only style names and a small number of examples. Students are not always good at finding the information they need about citation style.
7. Often the supervisors of diploma theses come from the group of employees who do not conduct any scientific research, and therefore do not publish any studies. They are then not exposed to changing requirements in the sphere of plagiarism and editorial requirements.
8. They are then unable to pass this knowledge on to students because they are not aware that there is such a need.
9. It is necessary to extend the requirements for respecting copyright to all works written by students. In many universities, severe penalties, up to and including dismissal, can be imposed for infringing copyright and for submitting another author's work (or with excerpts from another author's work) for evaluation. However, many universities are indulgent about plagiarism among students.
10. A significant problem is the lack of awareness of the rules of citation and the rush in the preparation of teaching materials by the lecturers. If the presentation at the lecture, the instruction for the exercises does not contain bibliographic annotations (although it should, because there are transcribed or paraphrased fragments from other works), then such bad practices translate into bad habits of students.
11. In addition to respecting the copyrights of other authors, the following principle should be adopted: „My publications should be treated in the same way as other works”. If we have transferred the property rights to another publisher, it should be remembered and respected. Personal copyrights always remain with the creator.

4.3.2.2. Scientific databases available on-line at the Rzeszow University of Technology

Rzeszow University of Technology has library with its own web page. This web site is in Polish, partially in English and websites of foreign publishers.

The access to electronic databases may be twofold, from top and left menu. Top menu gives access for students to Access Engineering and Access Science databases, and other information about how to sign up for the library, how to prepare references and gives access to library resources on-line. On this site there are information about the rules of use, license policy granted by the publisher. Access Engineering is a multimedia engineering database of McGrawHill Publisher.

This menu gives similar possibilities for teachers, additionally access to scientific achievements.

In part “e-sources” there are rules of the use from electronic resources including resources available temporarily.

Left menu enables use of ALEPH: on-line catalogue of printed books in library, IBUK and BIBLIO – external databases, and two web pages of well-known Web of Science and Scopus. In ALEPH students and teachers can find monograph, doctor thesis by author, keyword, title, ISSN, ISBN, publisher, language, other. IBUK-Libre enables access for books in different branches of sciences after log in. Similar is e-book point, where the multimedia digital library is.

From computers at the University or other after proper server setting all students and teachers can use Scopus, SciVal bases of research results from all over the world.

Additional possibility is on-line access to different servers like Taylor-Francis, Elsevier, Springer on the Polish licenses. The University library gives bibliometric tools, journals on consortium and national licenses, other resources like legal acts. The library warns users against unauthorized copying or reselling of works in whole or in part.

An electronic resources are sorted alphabetically. Information about the base is generally accessible of from proxy server, or that it is in Polish, access to references only or to full text.

Sometimes the collections are available temporarily and then the website provides information about the time and type of database. Usually, an invitation to test such access appears on the library news page.

4.3.2.3. CC licenses and access to educational and scientific content

In didactic work with students, attention should be paid to respect for personal and property copyrights, which was discussed earlier in the report (it will be discussed later in the report).

When making various studies, in which there is a need to use studies that have already been published, the excerpt is marked with quotation marks. But whether it is possible to develop someone else's text and what data should be presented in the bibliography, this knowledge may not be fully known to students. It can be said that in many cases the author himself shows the possibility of using his work.

Creative Commons licenses protect intellectual property and clear information.

It is not true that CC licensed material can be used without restriction. There are several indications on how to describe the material used and how it can be used. Oznaczenie wykorzystanej licencji CC rozpoczyna skrót CC – co oznacza, że dany materiał można dowolnie rozpowszechniać. Symbol BY, który jest obligatoryjny przy każdym oznaczeniu licencji, oznacza autora (BY – attribution – w domyśle by „who”).

Possible markings and guidelines are as follows:

- CC BY - the entry means that each use of the material used under this license requires the authorship (the author should be indicated in the signature, footer, bibliographic list). Material under the CC-BY license may be copied, presented and made as a quote, the content may be edited provided that the author of the original is given.

- CC BY-NC - the record means "Noncommercial" - you may copy, distribute, present and perform a work under this license and a study prepared on its basis only for non-commercial purposes.
- CC BY-SA - the entry means Share Alike - the material can be modified, but the end result must be distributed under a license identical to the original work.
- CC BY-ND - means No Derivative Works - the material may be copied, distributed, presented and made only as the original, no studies may be made.

A license notice must be included in the work to be developed and distributed, it protects the creator and at the same time allows others to use the work. The license note should contain information according to the template presented in Figure 4.53.

Author/s	Type of license	Link to the license terms	Title of work (article, book, etc.) if this exists	Link to the work (article, book, etc.) if this exists
----------	-----------------	---------------------------	--	---

Figure 4.53. Bibliographic data for works published on a CC license

The type of proprietary license is indicated by the publisher with a letter or picture abbreviation. Figure 4.54 shows the examples.

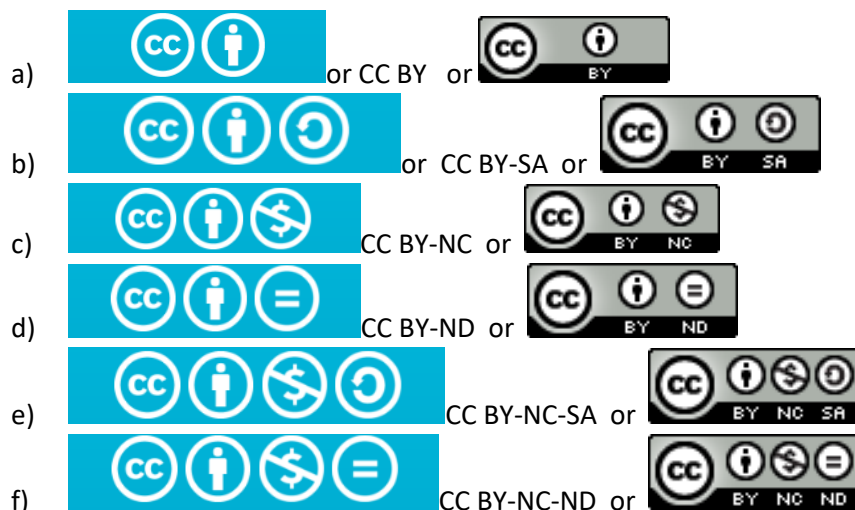



Figure 4.54. Ways of marking the license granted by authors [4.27]

If the teacher / student has found a publication that interests them, knows the author, title and publisher, and wants to use the article in their study, then they should check the information on the licenses granted. Examples of such a situation are shown in Figure 4.55.

Article

Characterization and Modeling of Surface Roughness and Burr Formation in Slot Milling of Polycarbonate

David Adeniji ^{1,2} , Julius Schoop ^{1,2,*}, Shehan Gunawardena ^{1,2}, Craig Hanson ³ and Muhammad Jahan ³

¹ Department of Mechanical Engineering, University of Kentucky, Lexington, KY 40506, USA; doad224@uky.edu (D.A.); shehan1998@uky.edu (S.G.)

² Institute for Sustainable Manufacturing, University of Kentucky, Lexington, KY 40506, USA

³ Department of Mechanical and Manufacturing Engineering, Miami University, Oxford, OH 45056, USA; hansonce@miamioh.edu (C.H.); jahanmp@miamioh.edu (M.J.)

* Correspondence: julius.schoop@uky.edu; Tel.: +1-859-323-8308; Fax: +1-859-257-1071

Received: 4 May 2020; Accepted: 19 June 2020; Published: 23 June 2020



Abstract: Thermoplastic materials hold great promise for next-generation engineered and sustainable plastics and composites. However, due to their thermoplastic nature and viscoplastic material response, it is difficult to predict the properties of surfaces generated by machining. This is especially problematic in micro-channel machining, where burr formation and excessive surface roughness lead to poor component-surface integrity. This study attempts to model the influence of size effects,

Figure 4.55. An example of an interesting article we found

J. Manuf. Mater. Process. **2020**, *4*, 59

22 of 22

38. Aramcharoen, A.; Mativenga, P. Size effect and tool geometry in micromilling of tool steel. *Precis. Eng.* **2009**, *33*, 402–407. [[CrossRef](#)]
39. Denkena, B.; Koehler, J.; Rehe, M. Influence of the Honed Cutting Edge on Tool Wear and Surface Integrity in Slot Milling of 42CrMo4 Steel. *Procedia CIRP* **2012**, *1*, 190–195. [[CrossRef](#)]



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).

Figure 4.56. Information at the end of an article about the licences on which others can use it

The CC BY license is given and a link to the website where you can find the guidelines for this license – presented in [Figure 4.57](#).

Attribution 4.0 International — CC BY 4.0 - Creative Commons ...

<https://creativecommons.org/licenses/by/4.0> ▾

Creative Commons **License** Deed. Attribution **4.0** International (**CC BY 4.0**) This is a human-readable summary of (and not a substitute for) the **license**. Disclaimer. You are free to: Share —...

Author: Michaela Škorupová **Publish Year:** 2020

Polski

Uznanie autorstwa 4.0 Międzynarodowe
(CC BY 4.0) This is a human-readable ...

Castellano

Reconocimiento 4.0 Internacional (CC BY
4.0) This is a human-readable summary ...

When We Share, Everyone Wi...

Creative Commons is turning 20! We're
celebrating with a special Better Sharing ...

License

Creative Commons Attribution 4.0
International Public License. By ...

See more ▾

Licenses/CC-BY-4.0 - Definition of Free Cultural Works

<https://freedomdefined.org/Licenses/CC-BY-4.0> ▾

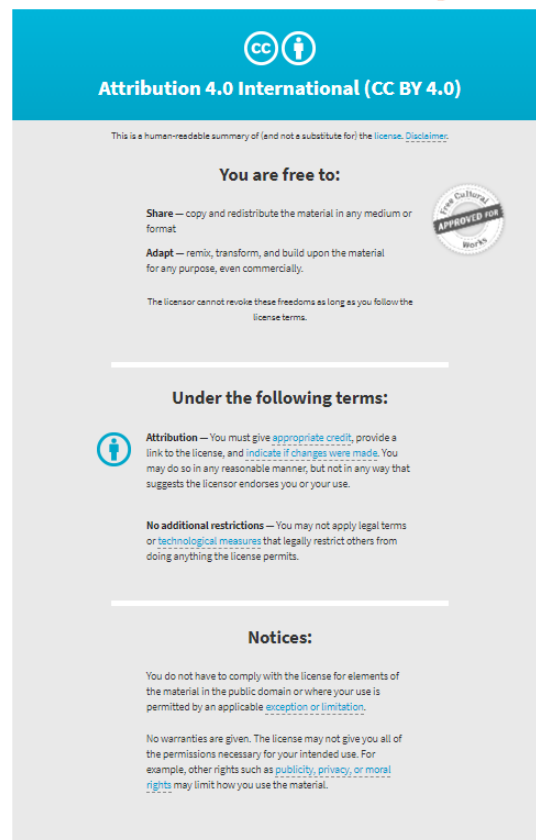
Licenses/CC-BY-4.0. The Creative Commons Attribution **License** is the most permissive of the six main **licenses** created by the Creative Commons project (**Licenses/CC-0** effectively releases a...

Attribution 4.0 International — CC BY 4.0 - Creative Commons ...

<https://creativecommons.org/licenses/by/4.0/legalcode> ▾

Creative Commons Attribution **4.0** International Public **License**. By exercising the **Licensed** Rights (defined below), You accept and agree to be bound by the terms and conditions of this Creative...

Figure 4.57. Webpage link with CC BY 4.0 license



Learn more about CC licensing, or use the license for your own material.

This page is available in the following languages:

Bahasa Indonesia Bahasa Melayu Castellano (Espanña) Cetelä Dansk Deutsch English Español Esperanto Euskara français Galego hrvatski
Italiano Latviāli Lietuvių Magyar Nederlands norsk polski Português Português (BR) română Slovenščina srpski (latinica) suomi
svenska Türkçe Íslenska čeština Ελληνικά Беларуская русокий українська العربية বাংলা 中文 日本語 ភាសាខ្មែរ (ខ្មែរ) 한국어



Figure 4.58. Attribution 4.0 International (CC BY 4.0)

In your work, when quoting a fragment from an article marked in this way, you should provide a bibliographic footnote in the text, and in the list of bibliographies according to the adopted style, information:

Authors, title, (<http://creativecommons.org/licenses/by/4.0/>) (a link to this article) as it was schematically shown in Figure 4.53.


Example 2 Book

The author of the book, the title, the publisher are known, the CC license is given on the publisher's website, the terms of which can be found on the website (example in a language other than English is showed in the Figure 4.59. and 4.60.).

As in example 1, the borrowed text fragment should be marked (with quotation marks if it is rewritten without changes) and a bibliographic footnote, and in the list of bibliographies, the authors, title, license name and link to it should be given, link to the book according to the previously provided template.

There are also collections on the Internet that share photos, for example, under the CC0 license. The CC zero license allows the omission of data about the author, but on such sites you can find an incentive to mention at least the author of the study [4.28].

Public Domain

Public Domain sign  [4.29] is a simple statement that informs you that there is no copyright restriction on the work in question. It is not a Creative Commons license, and anyone (not only its creator) can mark a work with such a mark. Works in museums, archives, galleries and libraries, including digital collections, are often marked with this sign, which:

- have never been subject to copyright due to the time in which they were created,
- economic copyrights have expired, because 70 years have passed since the death of the author, the last of the co-authors, the date of distribution or the date of establishing the work,
- they are not subject to copyright, e.g. official documents,
- are not the product of human labor, e.g. geological exhibits.

To find works in the Public Domain, the so-called calculator may be used.

In some countries, the term Public Domain is not legally defined, then authors can mark their work with the CC0 symbol, being aware of the fact that other users can access their work (e.g. in Poland).

Assets that are not licensed under the CC license - e.g. older books, printed articles, should be treated with due respect and copyright laws should be respected.

The rules for sharing collections are common and useful under Open Access. For over 30 years, there has been a movement of scientists and creators, which assumes the possibility of free, permanent and universal access to educational and scientific content. The authors do not waive their copyrights, but they allow people to see their works.

Creating a bibliography list – citation styles

There are known various ways of writing the works used in the text and of making a bibliographic list. These are called citation styles and their selection often depends on the discipline.

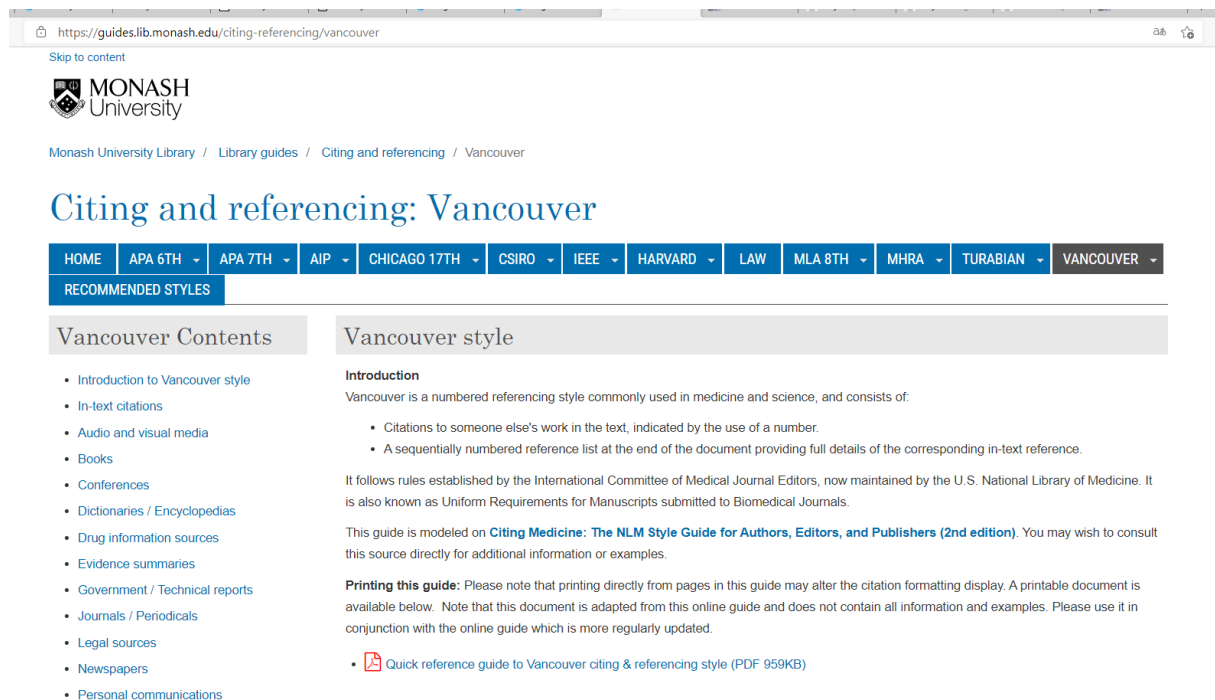
The following styles are distinguished:

- Harvard (also called Oxford),
- APA (American Psychology Association),
- Chicago (TCMOS CMOS/CMS),

- MLA (Modern Language Association),
- AMA (American Medical Association),
- SAGE Vancouver,
- IEEE,
- and many others.

Sometimes, the style guidelines also take into account, in addition to the format of the data provided, the editing method (e.g. alignment, text indentation, font size, margin width and even the place of the page number) as well as the place of footnotes and bibliographic list. There are also differences in names – some styles of the bibliographic list are called "Bibliography" and others "Reference List" or "References".

Some universities' websites provide information on citation styles but also separately (Figure 4.61–4.62).



The screenshot shows the Monash University Library website. The URL in the browser is <https://guides.lib.monash.edu/citing-referencing/vancouver>. The page title is "Citing and referencing: Vancouver". A navigation bar at the top lists various citation styles: HOME, APA 6TH, APA 7TH, AIP, CHICAGO 17TH, CSIRO, IEEE, HARVARD, LAW, MLA 8TH, MHRA, TURABIAN, and VANCOUVER. Below this is a "RECOMMENDED STYLES" section. The main content area is titled "Vancouver style" and includes an "Introduction" section. The introduction states that Vancouver is a numbered referencing style commonly used in medicine and science, and consists of:

- Citations to someone else's work in the text, indicated by the use of a number.
- A sequentially numbered reference list at the end of the document providing full details of the corresponding in-text reference.

 It also mentions that it follows rules established by the International Committee of Medical Journal Editors, now maintained by the U.S. National Library of Medicine. A sidebar on the left titled "Vancouver Contents" lists various topics: Introduction to Vancouver style, In-text citations, Audio and visual media, Books, Conferences, Dictionaries / Encyclopedias, Drug information sources, Evidence summaries, Government / Technical reports, Journals / Periodicals, Legal sources, Newspapers, and Personal communications.

Figure 4.61. An example of the Monash University website

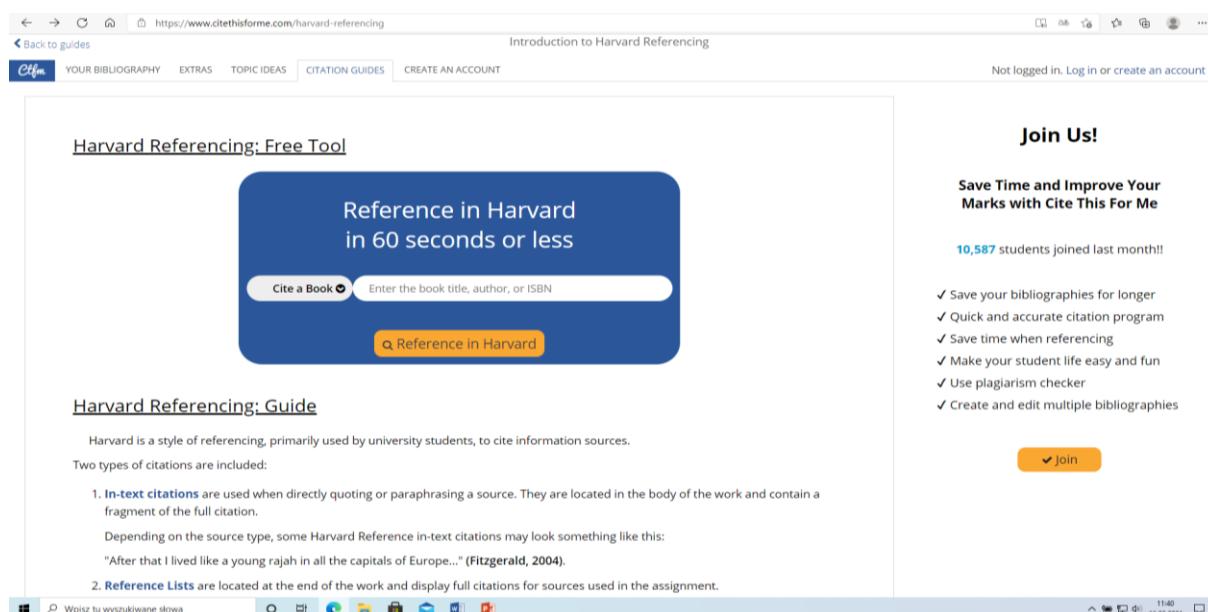


Figure 4.62. An example of the Harvard Referencing website

An example of differentiating the way of writing a bibliographic item according to different styles [4.30]:

- **according to APA**

Whitaker, K., Colavizza, G. (2019). *Alan-turning-institute/das-public: First release with minor updates* (Version v1.1) [Data set]. Zenodo. <http://doi.org/10.5281/zenodo.3268810>

- **according to IEEE**

Whitaker K., Colavizza G. (2019). *Alan-turning-institute/das-public: First release with minor updates*, Version v1.1 July. Distributed by Zenodo. <http://doi.org/10.5281/zenodo.3268810>

- **according to AMA**

Whitaker K., Colavizza G. *Alan-turning-institute/das-public: First release with minor updates*. July 2019. <http://doi.org/10.5281/zenodo.3268810>

Searching for published content for your teaching and student work

The easiest way to get to your published work is through internet resources. However, it is not always a satisfactory and relatively fast process, due to the enormity of data. There are several ways to search for works by different authors (articles, books, diploma theses) (Figure 4.63):

- Entering keywords in the search engine – it can be done by adding, for example, the expected file format, e.g. "laser use + pdf". From among many search results, we choose the one that satisfies us.
- Entering the title of the work in the search engine - provided that we know it - does not guarantee that the full text of the work will be found. Sometimes you can use the full-text databases of universities.

- Searching for articles in professional databases:
 - ✓ ResearchGate - includes articles, books - you can search by authors, keywords, titles
 - ✓ Open Access resource search engines, np.: citebase Search, E-Print Network, FreeFullPDF, Google Book Search, Google Scholar, iSeek, Infomine, OpenDOAR, ROAR.

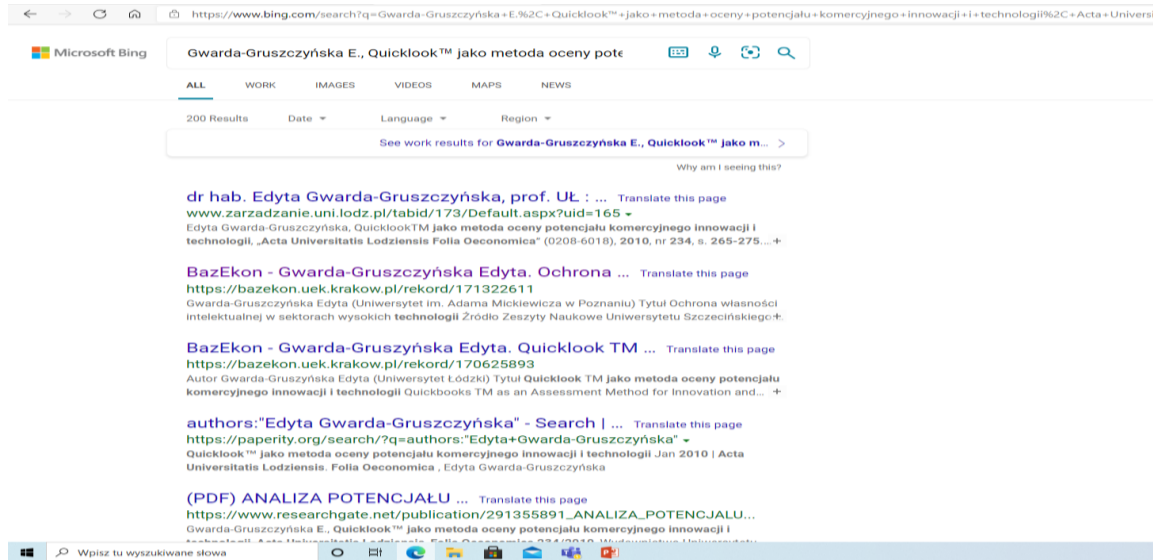


Figure 4.63. An example of a search by a known author and title

An example of access to the full text of an article in Figure 4.64 and 4.65.

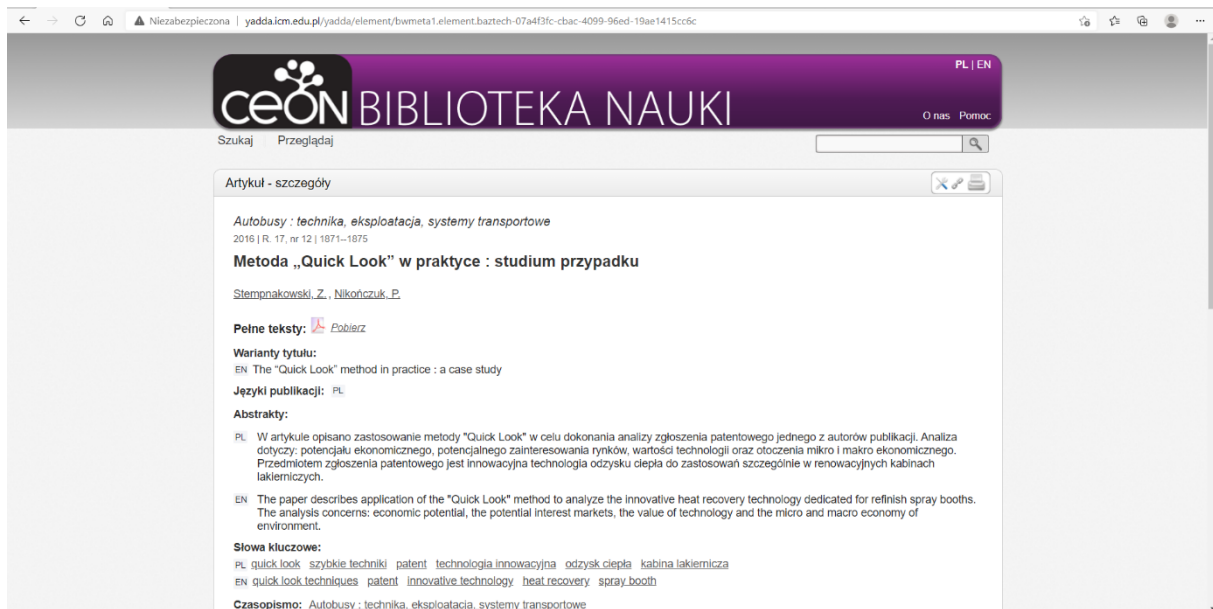


Figure 4.64. An example of searching in the CEON database

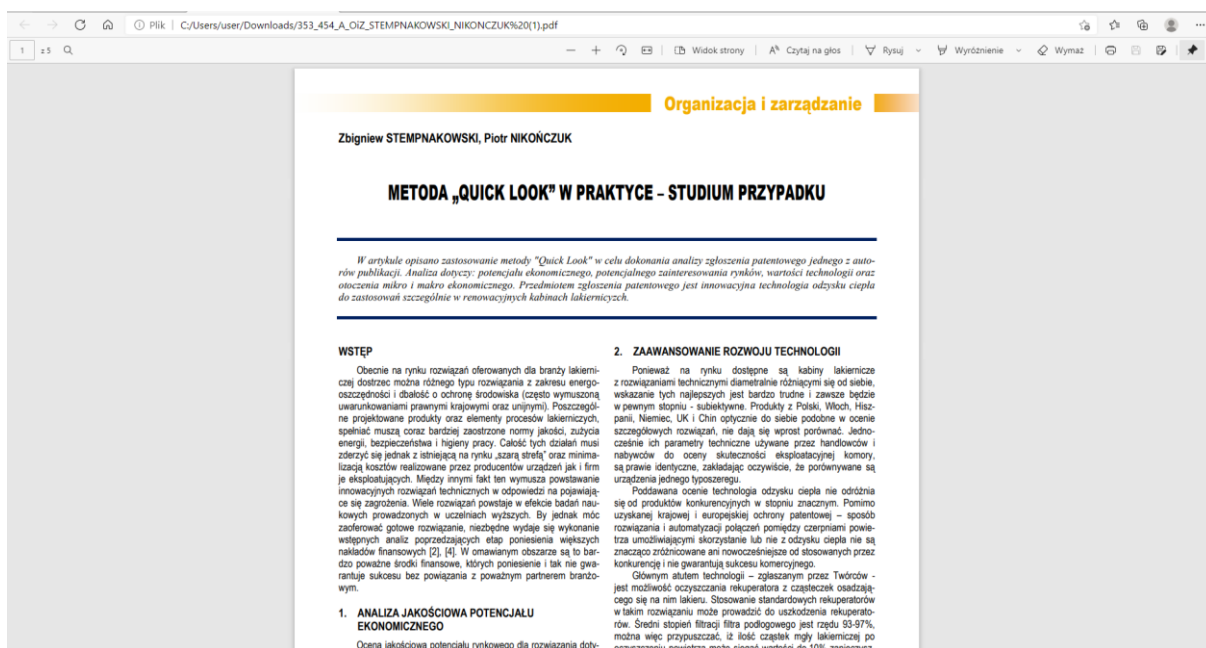


Figure 4.65. An example of access to the full text of an article found

In the Figure 4.66 – an example of searching of articles process in Research Gate.

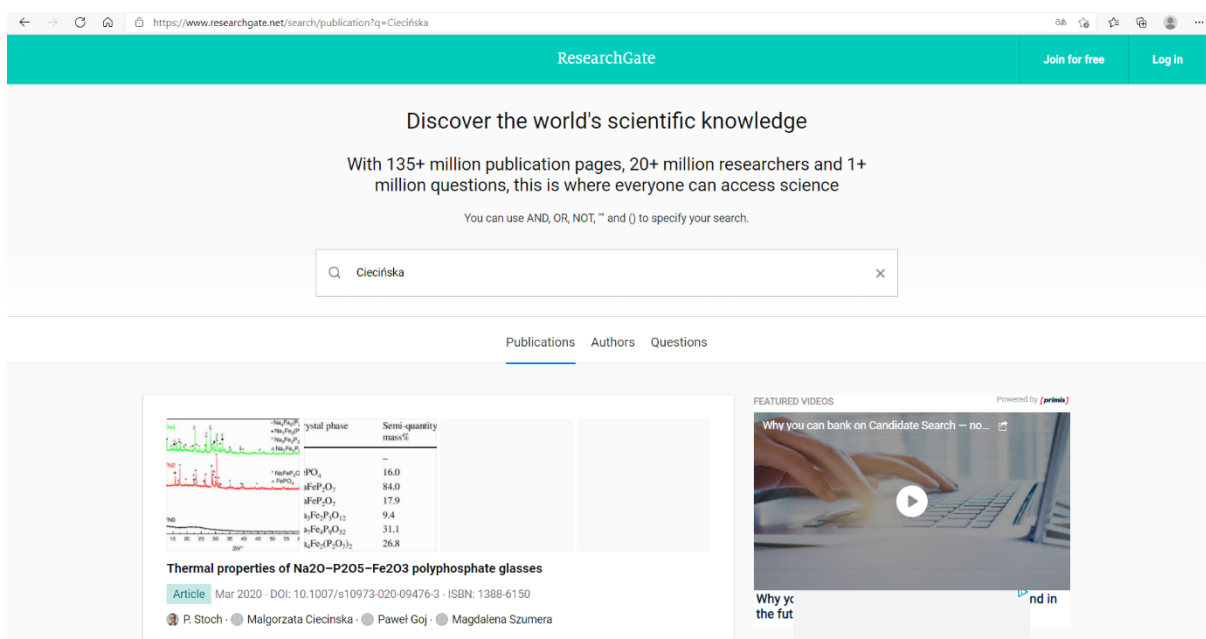


Figure 4.66. An example of searching in the ResearchGate database

Many resources are available through the Open Access movement. The Open Access movement has been developing since the 1990s and works to build a model of scientific communication based on the distribution of knowledge without restrictions. Knowledge is distributed through repositories, blogs, e-laboratories, and open journals. Repositories and journals are the two main models of the Open Access movement.

Repositories are the so-called the green way, consisting in archiving copies of works in publicly available archives. Currently, all repositories can be searched on the Open DOAR portal (Directory of Open Access Repositories). There are institutional repositories (e.g. at universities) that collect articles, dissertations, lectures and other materials archived by their employees; and domain repositories - in which knowledge from one field (e.g. ELIS) is collected.

Open journals – the so-called the golden road is publishing in peer-reviewed open access journals. The portal where you can find open journals is DOAJ (Directory of Open Access Journals).

For the so-called open sources also include open educational materials, digital libraries and more.

In any case, the authors do not waive their copyrights and publishing is subject to free Creative Commons licenses [4.31].

You can also use the various Open Access resource search engines, np.: BASE (Bielefeld, Academic Search Engine), citebase Search, DRIVER search portal, E-Print Network, FreeFullPDF, Google Book Search, Google Scholar, Infomine, iSEEK, OAster, OpenDOAR, ROAR, and others.

An example of searching in the FreeFullPDF database is presented in Figure 4.67:

Step 1 – define keywords.



Figure 4.67. An example of searching by keywords in the FreeFullPDF database

Step 2 – determining which articles are of interest to us.

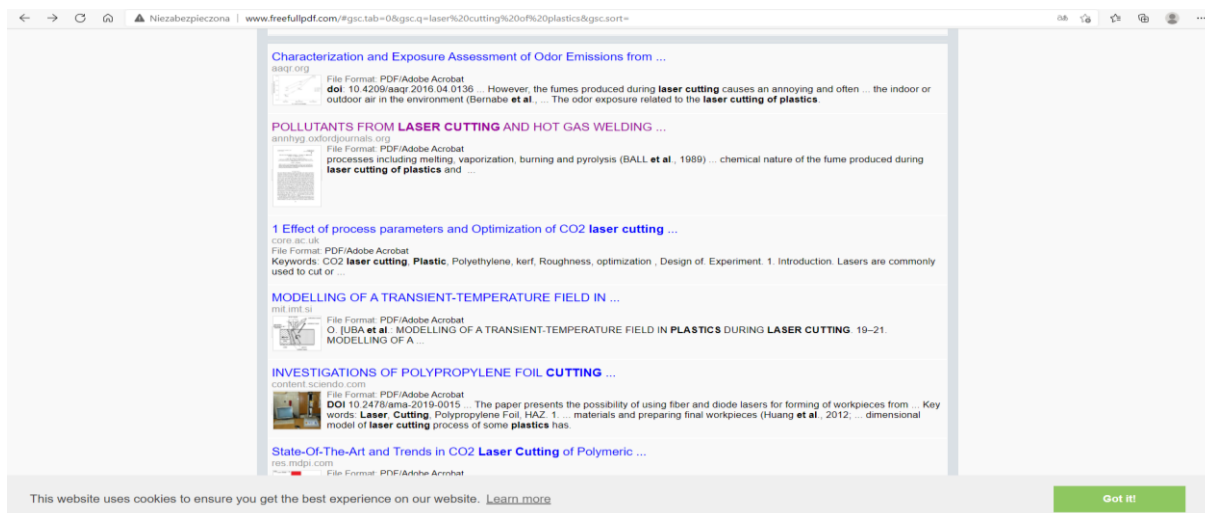


Figure 4.68. List of found publications

Step 3 – opening the file with the full text of the article.

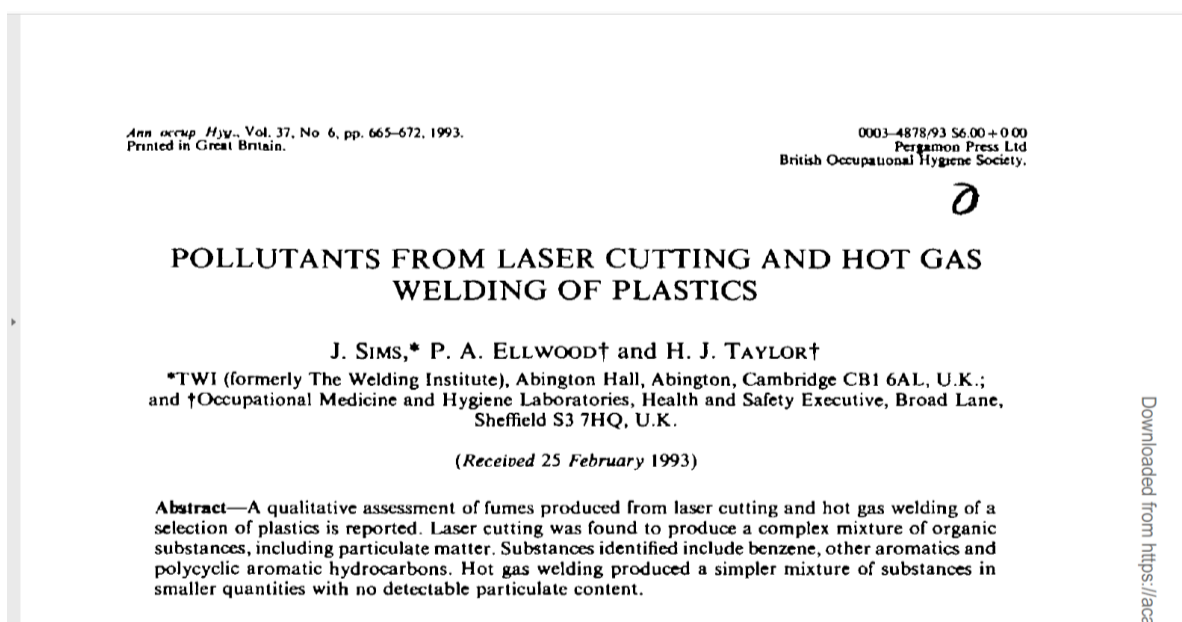


Figure 4.69. Full text access of interesting article in FreeFullPDF database

There are bibliography **managers** and **generators** to facilitate working with multiple references.

The bibliography manager is a tool that helps to collect and manage data about the materials used (articles, books, chapters, websites). The manager allows you to collect bibliographic records that can be downloaded from their databases, from the Internet, entered manually.

Data is entered into the manager once and can be used many times. Additional help is to make a bibliographic list in one style (APA, IEEE, Vancouver, etc.) and its automatic change. Many bibliography managers work with word processors. Known managers are: Citavi, Mendeley, EndNote, Zotero, RefWorks, Papers [4.32]

Bibliography generators are only used to create a valid bibliography. Examples of generators are: CiteThisForMe, Bibsonomy, EasyBib, Harvard Generator, Citation Machine, and others.

4.4. Scientific Reading Cookbook

4.4.1. Introduction to the Scientific Reading Cookbook

This is the main challenge of how to deal with scientific reading. Based on their experiences, many researchers and students have their methodology to conduct a scientific reading. Scientific reading based on only experiences cannot be a promising strategy to obtain the right goal. Therefore, the development of the structure that shows a roadmap would be considerably valuable. Accordingly, this chapter is allocated to the development of a systematic structure for the Scientific Reading Cookbook. Figure 4.70 provides a guideline on scientific reading that includes searching platforms, selection, and reading. In the following, each of these steps will be explained.

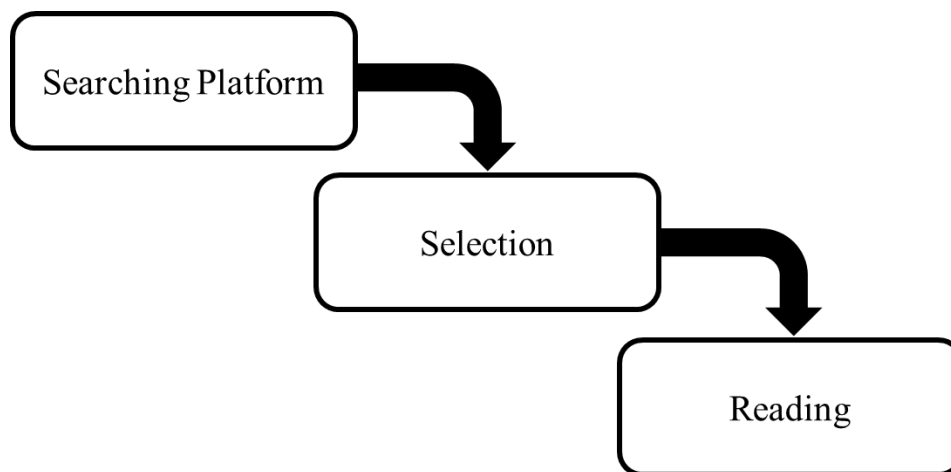


Figure 4.70. Structure of Scientific Reading Cookbook

4.4.2. Step1: Searching Platforms

The appropriate sources to study and read the books and papers is essential. A wide variety of sources are available on the internet that can be used. Among them, two well-known sources for doing the search are provided as below

- **ScienceDirect:** It is a website with access to a variety of scientific databases. In this platform, the journals are mainly categorized into four groups of Physical Sciences and

Engineering, Life Sciences, Health Sciences, and Social Sciences and Humanities. Access to the abstract is possible, but a subscription is required for full access to the journal.

- **Scholar. Google:** It is a website with free access to many peer-reviewed online academic journals, books, conference papers, dissertations and other literature.

In addition to the introduced sources, the provided link (https://en.wikipedia.org/wiki/List_of_academic_databases_and_search_engines) includes a list of several scientific sources with some information regarding their description and access. To have a comprehensive search, it is highly recommended to use several sources. Additionally, all scientific publications have a reference section, including several papers. This can also be considered as a good source for further reading in the relevant topic. In recommended links, some sources may not be available like Master and Doctoral thesis. Many universities have digital libraries that students and researchers can benefit a great deal from.

4.4.3. Step2: Selection

In the previous section, different sources for finding scientific papers and books are introduced. To collect the information, each searching platform can provide us with different papers and books. To have a good selection among different available papers, the appropriate keywords should be used to cover the area of study.



Find articles with these terms

In this journal or book title

Year(s)

Author(s)

Author affiliation

Volume(s)

Issue(s)

Page(s)

Title, abstract or author-specified keywords

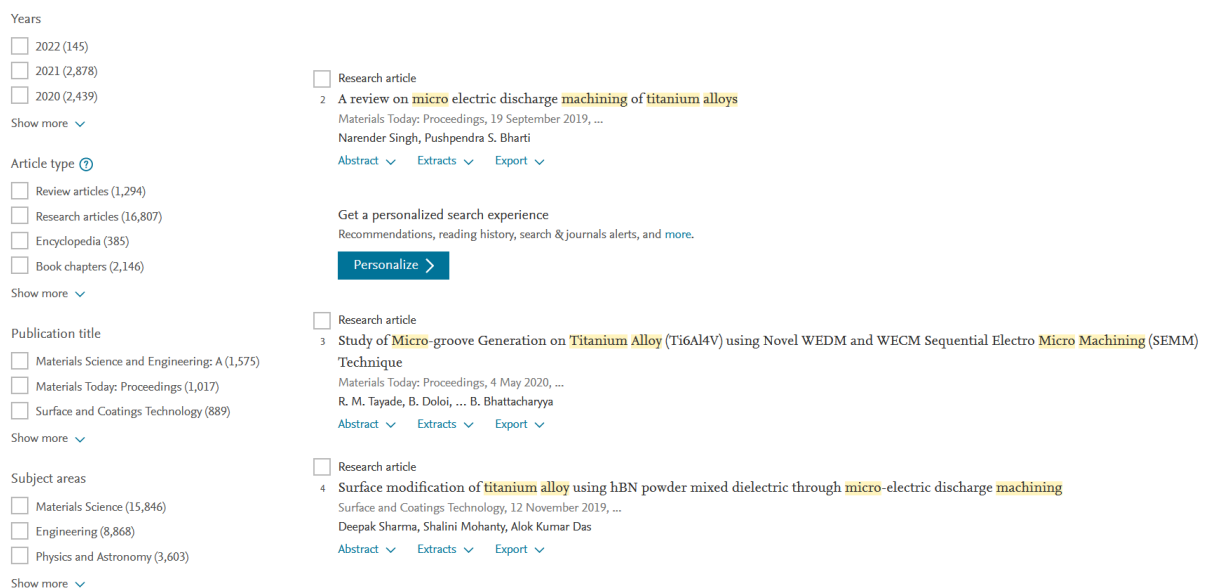
Title

References

Figure 4.71. Advanced search box in ScienceDirect

Figure 4.71 shows an advanced search box in ScienceDirect. This search box provides different options such as the article's name, name of the journal, the year of publish, name of authors,

Author affiliation and others. After entering the necessary information, the search results can be provided. The first step regarding the selection of appropriate sources is the name of the article. Although the words entered in the search box appear in the title of papers, this does not guarantee that the corresponding papers are suitable to read. Therefore, the title of each paper should be thoroughly read to find whether the paper is suitable for further reading or not. In addition, the date of published papers must be considered to obtain up-to-date information. In this regard, several filters are also provided for users in many platforms like ScienceDirect that can be used after the appearance of search results. Figure 4.72 indicates some of the search results concerning the micro-machining of titanium alloy. Accordingly, some online filters are listed on the left side regarding years, article type, publication title, and subject area. After selecting a paper based on its title and given filters, a quick review of a paper would be helpful to determine whether the paper is relevant to our search or not. Each paper has several sections that will be explained in the next step (**Step3: Reading**). Among different sections, the abstract and conclusion are enough to get appropriate information about the paper. In the selection process, the authors and their institutional affiliations are important. In detail, some institutes are well-respected, and their research results are trustable. Moreover, the reputation of the journal in which the paper is published is another factor that should be considered in the selection process.



The screenshot displays the ScienceDirect search interface. On the left, there are four filter categories: Years, Article type, Publication title, and Subject areas. Each category has a list of options with checkboxes and counts. For example, under 'Years', 2022 has 145 results, 2021 has 2,878, and 2020 has 2,439. Under 'Article type', 'Research articles' has 16,807 results. The main search results are listed on the right, showing three articles. The first article is 'A review on micro electric discharge machining of titanium alloys' by Narender Singh, Pushpendra S. Bharti, published in Materials Today: Proceedings, 19 September 2019. The second article is 'Study of Micro-groove Generation on Titanium Alloy (Ti6Al4V) using Novel WEDM and WECM Sequential Electro Micro Machining (SEMM) Technique' by R. M. Tayade, B. Doloi, and B. Bhattacharyya, published in Materials Today: Proceedings, 4 May 2020. The third article is 'Surface modification of titanium alloy using hBN powder mixed dielectric through micro-electric discharge machining' by Deepak Sharma, Shalini Mohanty, and Alok Kumar Das, published in Surface and Coatings Technology, 12 November 2019. Each article entry includes a title, authors, journal name, and links for Abstract, Extracts, and Export.

Figure 4.72. Available online filters for search results in ScienceDirect

4.4.4. Step3: Reading

Reading scientific papers is a completely different process compared to reading a newspaper or some scientific information on a website. In the case of reading scientific papers, taking a note and multiple readings are required to understand the context. Additionally, it may be necessary to look at other scientific papers while reading one paper. Obviously, reading papers

demands much more time and concentration. Generally, the scientific papers include abstract, introduction, methods, result and discussion and conclusion.

- **Abstract:** it provides a brief overview of the paper. The paper goals and some results are also mentioned in this section.
- **Introduction:** this section contains background about the previous works in the relevant field, and the introduction can be useful for finding other relevant works.
- **Methods:** the technical details about the experiments and simulation are provided in this section.
- **Result and discussion:** the experimental results, including the graphics, tables, and pictures, are presented here.
- **Conclusion:** this section summarized important results and includes the probable outlook for further research works.

Before reading the paper, we should keep in mind to consider what the authors exactly tried to answer with their research works. The reading of the papers can be started from the abstract. It is noted to say that the abstract contains a summary of the entire paper and taking time to read the abstract deeply is not recommended. In some cases, the abstract can be skipped. In the introduction, the authors try to provide an overview of previous works and define the problem addressed by their work. Therefore, reading the introduction is helpful to be prepared for the next steps. In the result and discussion sections, multiple time reading is recommended to understand the research outputs. Additionally, after reading several papers, much information would be forgotten and searching for what we read a long time ago is time taking. Therefore, summarizing important results through reading a paper is an excellent strategy to collect valuable data. Figure 4.73 provides an example of summarized paper. Accordingly, the summarized paper includes the paper's title, summarized info (containing the important results) and the reference number that corresponds to the name of the paper saved in the folder. In some papers, most of the results are summarized in tables and figures. Thus, figures and tables can be used instead of some description in the text format. Alternatively, the combination of figures and text can be prepared to have a comprehensive summary of research results.

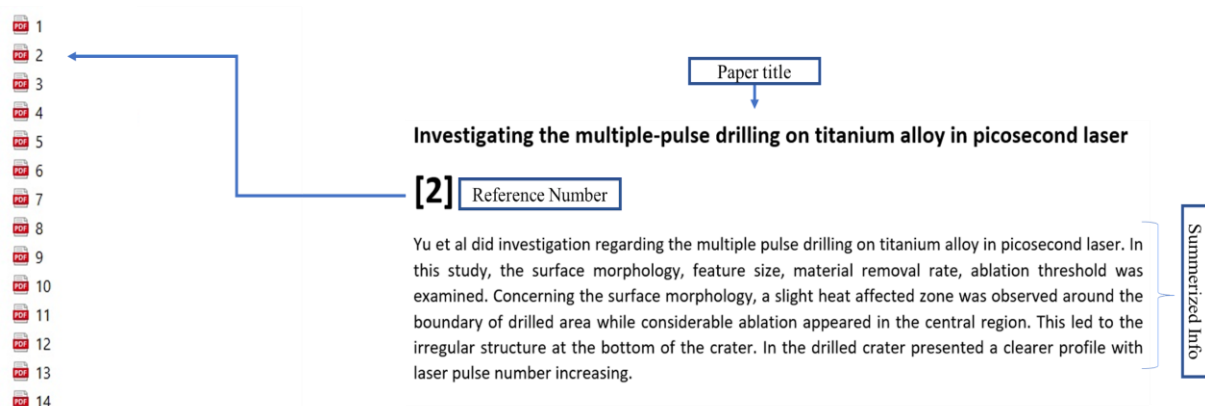


Figure 4.73. Summarizing the paper

In addition to summarizing, a database can be created from all collected scientific papers. This database can include the name of article, date of publishing, corresponding Author, input parameters and output parameters. This database can be helpful to give a quick overview from different research activities. Moreover, the database can also help those who are new in that field of study to accelerate their learning and expanding knowledge. Moreover, the database can be beneficial to save the time for writing the introduction of a scientific paper. Table 4.8. indicates a small example of a prepared database in the micro-machining of titanium alloys.

Table 4.8. Created database from literature review

No	Titel	Input	Output
1	G.M. Schueler 2010 Burr Formation and Surface Characteristics in Micro-End Milling of Titanium Alloys	Cutting speed/feed per tooth/axial depth of cut/radial depth of cut	Surface roughness-Burr Formation
2	Gael Le Coz 2017 Micro cutting of Ti-6Al-4V parts produced by SLM Process	Feed rate/ Cutting speed	Cutting force/Chip morphology/surface and subsurface microstructure
3	Tej Pratap 2015 Modeling Cutting Force in Micro-Milling of Ti-6Al-4V Titanium Alloy	Spindle speed/ Feed rate	Cutting force
4	Giuseppe Bonaiti 2017 Micro-milling machinability of DED additive titanium Ti-6Al-4V	depth per tooth/ depth of cut	Surface quality/cutting force/burr formation

4.5. Research Methodology

4.5.1. Research process methodology

4.5.1.1. Introduction

The methodology of the research process is composed of several stages. All of them are discussed in detail in [4.39]. They are also presented in Figure 4.74.

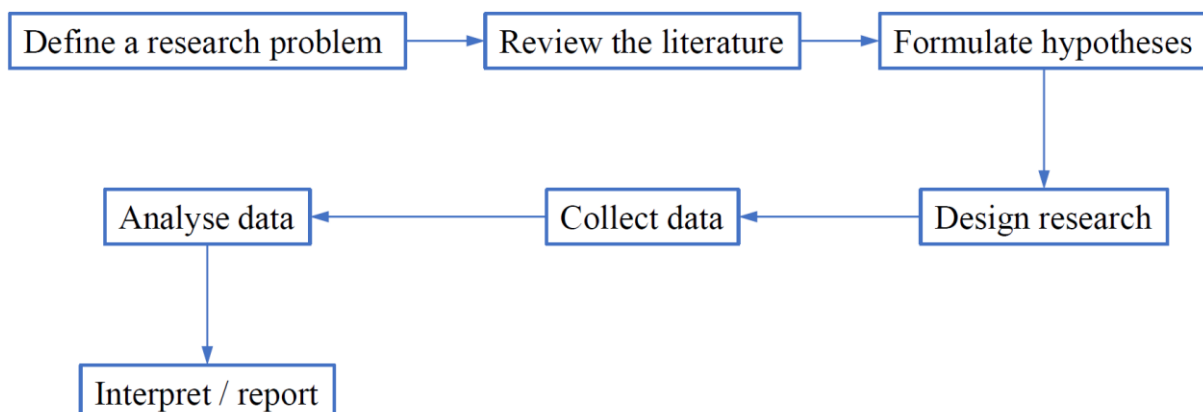


Figure 4.74. Flow chart of the research process [4.39]

In this document only selected stages of investigations, creating the research methodology, are presented. They were selected partly based on the analysis of scientific papers regarding

the field of manufacturing engineering. Therefore, the above-mentioned research methodology in the area of manufacturing engineering may consist of the six steps [4.39].

4.5.1.2. Identification of the research problem

At the beginning of the research process a researcher must understand the problem he / she wants to deal with and solve. Understanding the problem may be conducted based on the discussions with other researchers which are more experienced in the field of the research process or / and in the area which is close to the new research problem. The contact with very experienced researchers is relatively easy at universities. However, the mentioned exchange of experiences may be also possible in industrial conditions because a lot of companies, especially those from the aviation industry, have research and development departments responsible for research activities. Moreover, the identification of the research problem may be also performed based on the cooperation between universities and companies representing different branches of industry during the implementation of joint projects.

4.5.1.3. Survey of literature

After identifying a research problem, a researcher must study literature whose topics relate to the formulated research problem. Researchers must check e.g., if there are any available solutions of the problem identified in the previous stage and what are the achievements of other researchers in the field which is close to the chosen research area. The review of literature should mainly concern new scientific articles published in recent years by the very well-known publishers, the examples of which are Elsevier, Springer and MDPI. The example of an in-depth literature review is presented in the first two sections of the following paper, which was published by MDPI:

- Magdziak, M. A New Method of Distribution of Measurement Points on Curvilinear Surfaces of Products. *Sensors* 2019, 19, 2667.

as well as in the article (also published by the same publisher):

- Podulka P. Improved Procedures for Feature-Based Suppression of Surface Texture High-Frequency Measurement Errors in the Wear Analysis of Cylinder Liner Topographies. *Metals* 2021, 11, 143.

4.5.1.4. Preparation of research design

A researcher must define the plan of the research process. For example, he / she must determine:

- who will be the part of a research team,
- time needed to conduct research,
- costs of investigations,
- the plan of an experiment,
- how to collect the data,
- how to analyze the data.

The design of experiments (DoE) in production engineering, taking into account both the theory and actual data, is described in detail in the following book: *Davim J. P. Design of Experiments in Production Engineering. Springer, Cham, 2016*. DoE may be assisted by the specialized software packages. There are a lot of programs available in the market, helping their users to choose the plan of investigations. An example of such software is Design-Expert [4.40].

4.5.1.5. Collecting the data of investigations.

The selection of methods of collecting data during investigations depends on the type of research. In the case of mechanical engineering research generally may be divided into simulations and experimental investigations. When performing real experiments researchers may use e.g., various contact and non-contact coordinate measuring systems dedicated to measurements of both geometrical deviations and roughness parameters. The examples of coordinate measuring systems which may be applied for obtaining the results of research in the form of geometrical deviations are presented in the following papers:

- Magdziak, M. Selection of the Best Model of Distribution of Measurement Points in Contact Coordinate Measurements of Free-Form Surfaces of Products. *Sensors* 2019, 19, 5346.
- Magdziak M. Determining the strategy of contact measurements based on results of non-contact coordinate measurements. *Procedia Manufacturing* 2020, 51, 337-344.

Machines and measuring systems applied for obtaining results of investigations are sometimes presented in the section entitled *Materials and Methods* of scientific papers. The example of the mentioned section is in the article:

- Turek P., Budzik G. Estimating the Accuracy of Mandible Anatomical Models Manufactured Using Material Extrusion Methods. *Polymers* 2021, 13, 2271.

4.5.1.6. Results of research

Researchers should clearly present results gained during performing both numerical and experimental investigations. The presentation of the obtained results of research may be conducted by means of both figures and tables. However, figures are more preferred as they may present data of research in a more understandable way than tables. Moreover, they may include a lot of information and require less space compared to tables. The results of investigations, presented in the form of figures and tables, are shown e.g., in the papers:

- Kawalec A., Magdziak M. The selection of radius correction method in the case of coordinate measurements applicable for turbine blades. *Precision Engineering* 2017, 49, 243-252.
- Magdziak M. An Algorithm of Form Deviation Calculation in Coordinate Measurements of Free-Form Surfaces of Products. *Strojniški vestnik – Journal of Mechanical Engineering* 2018, 62, 51-59.

The following article presents gained results by using only figures showing the effects of roughness measurements.

- Podulka P. Improved Procedures for Feature-Based Suppression of Surface Texture High-Frequency Measurement Errors in the Wear Analysis of Cylinder Liner Topographies. *Metals* 2021, 11, 143.

4.5.1.7. Report / Discussion of results and conclusions

After gaining the results of research, investigators should discuss them and draw conclusions based on obtained findings. Conclusions should include the most important outcomes of research works. Moreover, researchers should always think about perspectives – an idea of what could be done in relation to the performed research [4.41] and how the research work can be improved. Some publishers suggest presenting discussion of results and conclusions in separate sections. The examples of such parts of articles are presented in the last two sections of the following scientific papers:

- Magdziak M. An Algorithm of Form Deviation Calculation in Coordinate Measurements of Free-Form Surfaces of Products. *Strojniški vestnik – Journal of Mechanical Engineering* 2018, 62, 51-59.
- Turek P., Budzik G. Estimating the Accuracy of Mandible Anatomical Models Manufactured Using Material Extrusion Methods. *Polymers* 2021, 13, 2271.

4.5.1.8. Example

The following section pertains to an example regarding the study of machining Titanium alloy Grade 5 with Electrical Discharge Machining (EDM). In the modern industrial and hence, research environment, EDM is widely utilized in machining difficult to cut materials, especially in cases where complex geometries and high dimensional accuracy have to be obtained. Thus, the study of machining this particular alloy with EDM has certainly practical value, and scientific interest as well.

First step: Literature review – building a robust theoretical background

At first, the researcher must have a minimum theoretical background regarding the process, which mainly is acquired during his studies. This general view will provide and allow the researcher to come up with the main idea of the study by considering its practical and scientific interest. So, after the main study concept is formed (i.e., the machining of Titanium alloy Grade 5 with EDM), the following step is to organize the study based on a solid theoretical background, and by adopting robust and appropriate scientific methods.

Taking into consideration the necessity of a theoretical background, almost every study begins with a review of the relevant literature. At first, the researcher has to fully and in depth understand and get familiar with the main physical phenomena and mechanisms that take place during the process that is going to be studied. Usually, books of relevant topics are the ideal solution since they include all the major and necessary information regarding the specific

subject. Books have to be as up-to-date as possible, and to cover all the main topics of interest. For the current example, the books of Jahan [4.42] and the Jameson [4.43] are adequately explanatory and illustrative regarding EDM, by discussing issues ranging from the basics of this process to more advanced topics.

The next step is the study of the relevant literature, but focusing this time on research articles. Usually, the researcher can start from a review paper, where the relevant literature has been brought together and summarized [4.44]. In our example, the researcher will soon understand that EDM is utilized in machining of a wide range of materials [4.45, 4.46, 4.47], while every material class has a significantly different behavior. Hence, his study must focus mainly on the material of his interest, emphasizing on the respective literature, conducted research. For example, the machining parameters which are employed in machining of steel alloys are different from those for Titanium alloys. By careful study of the literature, a researcher has to gradually shape his own research plan and idea, as an extension and addition to the current state of the art. At the end of the literature review step, the researcher must have a complete and spherical view of the subject, new ideas that will support the novelty of his work, along with a sense of the desired results.

Second step: Study methodology – Design Of Experiment

The next important step is the definition and design of the research methodology. In the current example, at first, it has to be decided if the study will be experimental [4.48], numerical [4.49], or a combination of those approaches [4.50]. Each approach has its own pros and cons, while, at the same time, it requires different resources and strategies in order to be successfully completed. Experimental studies usually require lab equipment, while numerical studies usually need sufficient computational power. Most often, and aiming in a more complete perspective, experimental and numerical studies are combined offering a better understanding and a more holistic approach.

The next step is the definition of specific study parameters, the Design Of Experiment (DOE), the expected results and how these results will be further analysed and discussed. Usually systems are extremely complicated, hence, a set of study parameters have to be carefully chosen, while others will be considered as constants. Another important aspect of the DOE is the selection of the range and the levels of each parameter. These parameters' levels must be realistic, have practical value, and must not be overlapped with the relevant literature. At the same time, the DOE must aim for tangible, accurate and not misleading results, in a realistic time and resources frame. Thus, often, DOE like Taguchi method [4.51, 4.52] or Response Surface Method [4.53] are employed in order to limit the number of the conducted experiments without negatively affecting the correctness, the accuracy and the precision of the deduced results. In our example, the main machining parameters are the pulse-on current, the pulse-on time, the applied voltage, the flushing pressure, the workpiece and electrode materials, along with a number of other machining parameters [4.54, 4.55]. Based on the relevant literature, the pulse-on current, the pulse-on time and the applied voltage are the machining parameters that mainly affect the process' results, and hence, they are most commonly being studied and employed as study parameters.

The expected study results is another issue of major importance, since there is a wide range of potential obtained results, and thus, the researcher has to choose those that are most correlated with the main concept of the study. In EDM for example, the Material Removal Rate (MRR), and the Tool Wear Rate (TWR) are related with the machining productivity, and process' economic feasibility, while the surface roughness and the surface quality are obviously related with process' quality issues. There are also different perspectives of EDM as a machining process that can be studied and investigated, like the environmental impact of EDM and/or the sustainability of the process. Considering the aforementioned the researcher has to choose which results are of his interest, along with how these results will be post processed and analyzed.

Third step: Results process and analysis

The main aim of the studies are to establish a correlation between the parameters and the results of the study, while, at the same time, based on the observation and/or simulations, to acquire a better understanding of the process' underlying mechanisms. Commonly, statistical tools like ANOVA and regression models are utilized, along with optimization methods. For example, in EDM, the optimization is focused on maximum MRR, with the minimum TWR and the minimum surface roughness [4.56, 4.57, 4.58].

The final step is the discussion section, where the researcher has to communicate and discuss in a critical way the study results and the deduced conclusions. For example, the resulted correlation between the pulse-on current and the pulse-on time with the MRR has to be discussed and evaluated, while an interpretation of the conclusions is also necessary. In this example, a comparison of the study's results with results from the relevant literature is necessary and interesting. Finally, conclusions have to be clearly stated, with novelty, and practical value.

Closing this brief example, we can assume that, as a rule of thumb, the main steps for a scientifically correct, complete and solid research study are the adequate and comprehensive study of the relevant literature, the robust DOE and adopted methodology, as well as a detailed and in-depth post-process and analysis of the obtained results.

4.5.2. Research based teaching activities

4.5.2.1. Improving quality of teaching activity

When we think about planning, conducting and publishing research results in the form of scientific articles and diploma theses, the methodology described in the previous chapter is also applicable in other fields of science, including civil engineering. However, the use of research results in the didactic process and their proper interpretation most often require both an appropriate theoretical foundation and a proper form of their presentation, adapted to the level of knowledge and experience of students. Therefore, every teacher, regardless of the education level, is responsible for adjusting the content, the form of classes and their continuous improvement. This also applies to his own teaching competences.

In the process of updating didactic content and adapting the forms of classes, we can use an approach called design thinking [4.22]. From this point of view, the teacher becomes the designer of the educational process. Therefore, when adapting the aforementioned approach to the needs of designing didactic classes, we can distinguish the following stages (Fig.4.75):

- **Goal** setting, which should answer the questions: who will be the recipient of the course and what entities will be involved in achieving the assumed goal?
- **Discovering** the recipient's point of view, in particular: what is important to him and what does he need?
- **Defining** and looking for all possible solutions in order to choose the most suitable one.
- **Building a prototype** that reflects the best solution and the best possible way to present it.
- **Testing** of the created prototype verifying what worked and what didn't work. Introducing the necessary corrections (each semester or year) is of key importance in the process of improving the education quality and maintaining its long term effects.

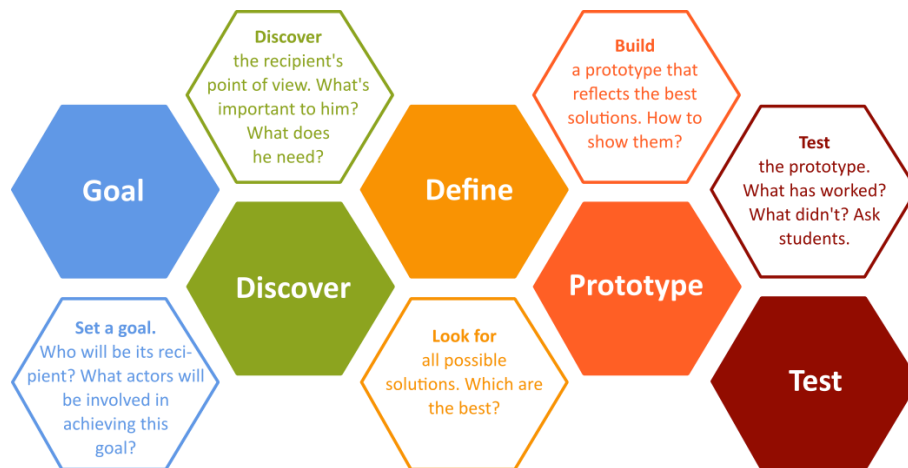


Figure 4.75. Design thinking applied to improve the quality of teaching activities

Using the presented approach in relation to a single subject or to entire training courses, their systematic improvement, taking into account the latest research results, is even a must if we want to educate competent graduates. Analyzing the current program of studies in the field of civil engineering at the Rzeszow University of Technology, we found two examples of introducing recent research results into the teaching process. The first one is the result of individual scientific work of two research and teaching staff related to the path of their professional development (e.g. obtaining a doctoral degree) in the field of road transport. In combination with other existing subjects, it resulted in the separation of a new speciality related to road engineering and traffic control. The second example is related to the results of research carried out in cooperation with partners from the economic environment and

financed from research funds awarded in the form of grants. This allowed for the inclusion of the most important results of these studies into the didactic process by creating a new subject related to modern solutions used in bridge construction.

4.5.2.2. Road traffic engineering

Course program

Road traffic engineering is a course whose existence is mainly **motivated by the research** conducted in the Rzeszow University of Technology. Its program is directly related to the research area of the authors and teachers of this course (including Szarata M., Bichajło L.), such as transport modelling and intelligent transport systems, with particular emphasis on the subject of the dynamic bus lane (DBL) concept. Mentioned lecturers have many publications in this area and are still conducting further research, also inviting students from the road-building science club.

Road traffic engineering is a compulsory subject for students of 'Construction and maintenance of roads' specialisation. It consists of lectures on which the following topics are discussed: measurement and analysis of road traffic, road traffic volume, rural and urban road capacity, crossroad capacity and designing of traffic lights programs. The learning outcome of this course is an **individual project** in which the student proves that he/she knows the method of calculating the capacity of roads and road junctions, traffic rules, human factor in traffic, rules of organization of cycling and public transport.

Research in education

During the course, not only the general knowledge of the subject is presented, but also that resulting from the scientific work of the teachers conducting this subject. Often the lecturer, in order to discuss certain issues, uses **his own research results**, referring to his own articles, to which students also have access.

Cases of roads that students use on a daily basis are discussed. Hence, the topic seems more interesting and engages students in a joint debate.

In project classes, the tools used by researchers, e.g. for measuring traffic, are presented. There are programs, such as PTV Vissim, which have a student version and students can work with them outside the classroom as well. **Possibility of self education** is essential, because the ability to work independently is the basis for developing problem-solving skills, including scientific ones.

Results of the used methodology

Student, that has widened the scope of knowledge related to the content of education within the subject and through self education can, of course, expect a higher grade, but also has experience in the independent review of articles, conducting discussions during classes, planning work, conducting measurements, collecting data, presenting and discussing them in front of the class, and solving problems in general.

Consultation with the tutor allows to dispel any doubts and help to guide the student. If the presented project stands out, it can be the basis for creating an article or master thesis with the tutor.

Summary

The presented example includes all the points of research methodology mentioned before: defining the research problem, literature review, research planning and organising, collecting data, presentation of the results and their interpretation, conclusion forming. Perspective thinking for future work or what can be done better is essential, in the context of an article, master's thesis or a possible doctorate [4.59-4.63].

4.5.2.3. Unconventional materials in bridge engineering

Unconventional materials in bridge engineering is subject conducting as part of Civil Engineering MSc course (specialization: construction and maintenance of bridges). The main aim is presenting basic information about non-conventional materials for bridge structures, such as aluminium or FRP (Fibre Reinforced Polymer) composites. The subject was implemented in 2018/2019 academic year and consist lecture (15 hours of lessons) and design lessons (15 hours of lessons). The following topics are presenting during lecture:

- aluminium alloys as a construction material,
- shaping/design aluminium elements and structures,
- review of aluminium structures in Civil Engineering,
- main principles of designing structures according to EN 1999 standard,
- FRP composites as a construction materials,
- shaping/design FRP elements and structures,
- review of FRP composite structures in Civil Engineering,
- main principles of designing FRP structures,
- aluminium and FRP composites structures as examples of sustainable development in Civil engineering.

The lectures are almost entirely (about 95%) based on the results of two research projects:

- “New aluminium alloys for construction in communication infrastructure”, grant financed by Polish Ministry of Science and Informatization, 2007-2009.
- “Com-bridge: Innovative road bridge made of FRP composites”, project has been carried out within the Demonstrator+ programme of Polish National Centre for Research and Development, 2013-2017.

The results of the current and recent projects will also be implemented in the lectures in the future, e.g.:

- “OptiDeck: Intelligent FRP deck system for construction and rehabilitation of road bridge structures, equipped with fiber optic sensors for structural health monitoring and bridge load controlling”, Polish National Centre for Research and Development, 2019-2021.
- “Innovative arch prefabricates with increased durability for transport infrastructure”, Polish Agency for Enterprise Development, 2018-2019.

- “An alternative to utilizing older generation wind turbines. The use of composite blades in the construction of bridge engineering structures”, Polish Agency for Enterprise Development, 2019-2021.
- “Innovative grid of GFRP composite bars for the reinforcement of concrete decking slabs of road bridge structures”, Polish Agency for Enterprise Development, 2021-2023.

During design lessons students prepare projects truss footbridge construction made of aluminium allows and FRP composites. In addition, information related to the production technology of FRP composite elements, their shaping and dimensioning is also provided. In case of design lessons the results of own research are implemented in about 20% of all (15) hours.

As a result of subject student knows the current materials and technologies for the construction of unconventional spans of bridge structures. Student knows the rules of performing a static analysis of complex bridge span structures and is able to dimension the cross-sections of aluminium and FRP composite elements [4.64-4.71].

References

- [4.1] Lewis, P.R., Reynolds, K., Gagg, C.: Forensic Materials Engineering: Case Studies. UK: CRC Press, 2003.
- [4.2] Rimnac, C.M. et al.: Failure analysis of a total hip femoral component: a fracture mechanics approach, in Case Histories Involving Fatigue and Fracture Mechanics, Special Technical Publication 918, ASTM, Philadelphia, 1986, pp. 377–388.
- [4.3] <https://yearbook.enerdata.net/>
- [4.4] <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf>
- [4.5] <https://ec.europa.eu/eurostat/statisticsexplained/> (16.03.2020)
- [4.6] <https://yearbook.enerdata.net/>
- [4.7] <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf>
- [4.8] <https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf>
- [4.9] <https://ec.europa.eu/eurostat/statisticsexplained/> (16.03.2020)

- [4.10] Kalpakjian, S.: Manufacturing Engineering & Technology, VitalSource Technologies, Inc. 2014.
- [4.11] Granado-Alcón, M.d.C., Gómez-Baya, D., Herrera-Gutiérrez, E., Vélez-Toral, M., Alonso-Martín P., Martínez-Frutos, M.T.: Project-Based Learning and the Acquisition of Competencies and Knowledge Transfer in Higher Education. *Sustainability* 2020, 12, 10062, <https://doi.org/10.3390/su122310062>.
- [4.12] Lalley, J.P., Miller, R.H.: The learning pyramid: Does it point teachers in the right direction? *Education*, 2007, 128(1), pp. 64-79.
- [4.13] Letrud, K.: A rebuttal of NTL Institute's learning pyramid, *Education*, 2012, (133), pp. 117–124.
- [4.14] Vogler, J.S., Thompson, P., Davis, D.W. et al: The hard work of soft skills: augmenting the project-based learning experience with interdisciplinary teamwork. *Instr Sci*, 2018, 46, pp. 457–488, <https://doi.org/10.1007/s11251-017-9438-9>.
- [4.15] Casner-Lotto, J., Barrington, L.: Are They Really Ready to Work? Employers' Perspectives on the Basic Knowledge and Applied Skills of New Entrants to the 21st Century U.S. Workforce. Washington DC: Partnership for 21st Century Skills, 2006.
- [4.16] Pengyue Guo, Nadira Saab, Lysanne S. Post, Wilfried Admiraal: A review of project-based learning in higher education: Student outcomes and measures, *International Journal of Educational Research*, 2020, vol. 102, 101586, ISSN 0883-0355, <https://doi.org/10.1016/j.ijer.2020.101586>.
- [4.17] Markham, T., Larmer, J., Ravitz, J.: Project based learning handbook: A guide to standards-focused project based learning (2nd ed.). Buck Institute for Education, Novato, CA, 2003.
- [4.18] Pan, G., Shankararaman, V., Koh, K., Gan, S.: Students' evaluation of teaching in the project-based learning programme: An instrument and a development process. *The International Journal of Management Education*, 2021, vol. 19, Issue 2, 100501, ISSN 1472-8117, <https://doi.org/10.1016/j.ijme.2021.100501>
- [4.19] Rodríguez, J., Laverón-Simavilla, A., del Cura, J.M., Ezquerro, J.M., Lapuerta, V., Cordero-Gracia, M.: Project Based Learning experiences in the space engineering education at Technical University of Madrid, *Advances in Space Research*, 2015, vol. 56, Issue 7, 2015, pp. 1319–1330, ISSN 0273-1177, <https://doi.org/10.1016/j.asr.2015.07.003>
- [4.20] Kolmos, A., de Graaff, E.: Problem-Based and Project-Based Learning in Engineering Education: Merging Models. In A. Johri, B.M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* 2014, pp. 141–161. Cambridge University Press. <https://doi.org/10.1017/CBO9781139013451.012>

- [4.21] Debnath, M., Pandey, M.: Impact of project based learning on recruitment of engineering students. Proceedings of the IETEC'11 Conference, Kuala Lumpur, Malaysia, Copyright © Debnath and Pandey, 2011.
- [4.22] Guaman-Quintanilla, S., Chiluita, K., Everaert, P., Valcke, M.: Mapping impact of design thinking in Teamwork, problem-solving and creativity, International Design Conference – DESIGN 2020, pp. 1715–1724,
<https://doi.org/10.1017/dsd.2020.125>
- [4.23] RR Nanik Setyowati, Maya Mustika Kartika Sari, Siti Maizul Habibah: Improving Critical Thinking Skills of Students through the Development of Teaching Materials, Proceedings of the 1st International Conference on Social Sciences, ICSS 2018. Series:Advances in Social Science, Education and Humanities Research, pp. 240–245.
- [4.24] Tarricone, P., Luca, J.: Successful teamwork: A case study, in Quality Conversations, Proceedings of the 25th HERDSA Annual Conference, Perth, Western Australia, 7-10 July 2002, pp. 640.
- [4.25] <https://www.thynk.com.au/critical-thinking.html> (09.09.2021)
- [4.26] <https://www.patnauniversity.ac.in/e-content/education/Med76.pdf> (09.09.2021)
- [4.27] <https://creativecommons.pl/poznaj-licencje-creative-commons/> (17.10.2021)
- [4.28] prakreacja.pl
- [4.29] https://pl.wikipedia.org/wiki/Domena_publiczna
- [4.30] <https://pg.edu.pl/openscience/cytowanie> (5.05.2021)
- [4.31] <https://biblioteka.uksw.edu.pl/pl/mode/83#overlay-context-pl/mode/467>
(May, 2021)
- [4.32] <https://biblioteka.uksw.edu.pl/pl/node/468>
- [4.33] Armani, A., 10 Simple Steps to Writing a Scientific Paper, 2020,
<https://spie.org/news/photonics-focus/janfeb-2020/how-to-write-a-scientific-paper?SSO=1>
- [4.34] Cargill, M., O'Connor, P.: Writing scientific research articles: Strategy and steps. John Wiley & Sons, 2021.
- [4.35] Alay The Craft of Scientific Writing. Springer, 2018.
- [4.36] Armani A.: 10 Simple Steps to Writing a Scientific Paper. 01.01.2020. <https://spie.org/>
- [4.37] Cargill, M., O'Connor, P.: Writing scientific research articles: Strategy and steps. John Wiley & Sons, 2021.
- [4.38] Körner, A.M.: Guide to Publishing a Scientific Paper. Routledge, Taylor and Francis Group, 2008.

- [4.39] Kothari, C.R.: Research Methodology. Methods and Techniques. New Age International (P) Ltd., Publishers, New Delhi, 2004.
- [4.40] statease.com/software/design-expert/
- [4.41] sv-jme.eu/guide-for-authors/
- [4.42] Jahan, M.P.: Electrical Discharge Machining (EDM): Types, Technologies and Applications, M.P. Jahan (ed.). Nova Science Publishers, 2015.
- [4.43] Jameson, E.C.: Electrical discharge machining. Society of Manufacturing Engineers, 2001.
- [4.44] Mohd Abbas, N., Solomon, D.G., Fuad Bahari, M.: A review on current research trends in electrical discharge machining (EDM). International Journal of Machine Tools and Manufacture, 2007, 47(7–8), 1214–1228, <https://doi.org/10.1016/j.ijmachtools.2006.08.026>
- [4.45] Manjaiah, M., Narendranath, S., Basavarajappa, S.: A review on machining of titanium based alloys using EDM and WEDM. Reviews on Advanced Materials Science, 2014, 36(2), pp. 89–111
- [4.46] Selvarajan, L., Rajavel, J., Prabakaran, V., Sivakumar, B., Jeeva, G.: A Review Paper on EDM Parameter of Composite material and Industrial Demand Material Machining. Materials Today: Proceedings, 2018, 5(2), pp. 5506–5513, <https://doi.org/10.1016/j.matpr.2017.12.140>
- [4.47] Ahmed, N., Ishfaq, K., Moiduddin, K., Ali, R., Al-Shammary, N.: Machinability of titanium alloy through electric discharge machining. Materials and Manufacturing Processes, 2019, 34(1), pp.93–102, <https://doi.org/10.1080/10426914.2018.1532092>
- [4.48] Nair, S., Dutta, A., Narayanan, R., Giridharan, A.: Investigation on EDM machining of Ti6Al4V with negative polarity brass electrode. Materials and Manufacturing Processes, 2019, 00(00), pp. 1–8, <https://doi.org/10.1080/10426914.2019.1675891>
- [4.49] Tlili, A., Ghanem, F., Salah, N. Ben.: A contribution in EDM simulation field. International Journal of Advanced Manufacturing Technology, 2015, 79(5–8), pp. 921–935, <https://doi.org/10.1007/s00170-015-6880-1>
- [4.50] Shabgard, M., Ahmadi, R., Seyedzavvar, M., Oliaei, S.N.B.: Mathematical and numerical modeling of the effect of input-parameters on the flushing efficiency of plasma channel in EDM process. International Journal of Machine Tools and Manufacture, 2013, 65, pp. 79–87, <https://doi.org/10.1016/j.ijmachtools.2012.10.004>
- [4.51] Gardiner, W.P., Gettinby, G.: Taguchi Methods. Experimental Design Techniques in Statistical Practice, 1998, pp. 289–321.
- [4.52] Roy, R.K.: Design of Experiments (DOE) Using the Taguchi Approach. Wiley, 2001.

- [4.53] Karkalos, N.E., Markopoulos, A.P.: Springer briefs in applied sciences and Computational Methods for Application in Industry 4.0.
- [4.54] Choudhary, S., Jadoun, R.: Current advanced research development of electric discharge machining (EDM): a review. *International Journal of Research in Advent Technology*, 2014, 2(3), pp. 273–297.
- [4.55] Ho, K.H., Newman, S.T.: State of the art electrical discharge machining (EDM). In *International Journal of Machine Tools and Manufacture*, 2003, vol. 43, Issue 13, pp. 1287–1300, [https://doi.org/10.1016/S0890-6955\(03\)00162-7](https://doi.org/10.1016/S0890-6955(03)00162-7)
- [4.56] Verma, V., Sahu, R.: Process parameter optimization of die-sinking EDM on Titanium grade-V alloy (Ti6Al4V) using full factorial design approach. *Materials Today: Proceedings*, 2017, 4(2), pp. 1893–1899, <https://doi.org/10.1016/j.matpr.2017.02.034>
- [4.57] Huu, P.N.: Multi-objective optimization in titanium powder mixed electrical discharge machining process parameters for die steels. *Alexandria Engineering Journal*, 2020, 59(6), pp. 4063–4079, <https://doi.org/10.1016/j.aej.2020.07.012>
- [4.58] Kumar, R., Roy, S., Gunjan, P., Sahoo, A., Sarkar, D.D., Das, R.K.: Analysis of MRR and Surface Roughness in Machining Ti-6Al-4V ELI Titanium Alloy Using EDM Process. *Procedia Manufacturing*, 20(2017), pp. 358–364, <https://doi.org/10.1016/j.promfg.2018.02.052>
- [4.59] Szarata M., Olszewski P., Bichajło L.: Simulation Study of Dynamic Bus Lane Concept, Sustainability, January 2021, 13(3):1302.
- [4.60] Szarata M., Olszewski P.: Traffic modelling with dynamic bus lane, conference paper of 2019 6th International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), published by IEEE in October 2019.
- [4.61] Szarata M., Nazarko P.: Analysis of the use of artificial neural networks to calibration of microsimulation traffic model. *JCEEA*, June 2017, t. XXXIV, z. 64 (2/II/17).
- [4.62] Szarata M.: Application microscopic simulation model for dynamic bus lane. *JCEEA*, March 2017, t. XXXIV, z. 64 (1/17).
- [4.63] Szarata M., Olszewski P.: Analysis of the effectiveness of bus lane with intermittent priority. *Budownictwo i Architektura*, December 2014, 13(4), pp. 275–284.
- [4.64] Kulpa M., Wiater A., Rajchel M., Siwowski T.: Comparison of Material Properties of Multilayered Laminates Determined by Testing and Micromechanics. *Materials* 2021, 14, 761.
- [4.65] Kulpa M., Siwowski T., Rajchel M., Wlasak L.: Design and experimental verification of a novel fibre-reinforced polymer sandwich decking system for bridge application. *Journal of Sandwich Structures & Materials*, 2021, 23(6), pp. 2326–2357.

- [4.66] Kulpa M., Howiacki T., Wiater A., Siwowski T., Sieńko R.: Strain and displacement measurement based on distributed fibre optic sensing (DFOS) system integrated with FRP composite sandwich panel. *Measurement* 2021, 175, 109099.
- [4.67] Siwowski T., Kulpa M., Rajchel M.: Advances in FRP composite vehicle bridges – the Polish experience. *Archives of Civil Engineering*, 2020, vol. LXVI, Issue 1, pp. 209–224.
- [4.68] Wiater, A., Siwowski, T.: Comparison of Tensile Properties of Glass Fibre Reinforced Polymer Rebars by Testing According to Various Standards. *Materials*, 2020, 13, 4110.
- [4.69] Wiater A., Siwowski T. Serviceability and ultimate behaviour of GFRP reinforced lightweight concrete slabs: Experimental test versus code prediction. *Composite Structures*, 2020, 239, 112020.
- [4.70] Siwowski T.: FRP composite bridges: shaping, design, research. PWN, 2018 (in Polish).
- [4.71] Siwowski T.: Aluminium road bridges – past, present and future. *Road and Bridges* 2005, 1, p. 39–74 (in Polish).

5. Conclusion and further tasks

The proposed content of the guide revealed the internal teaching environments and practices of the partners. Methodology of research results utilization into teaching has also been developed. The work is the basis for further tasks of the EDURES project. They enable developers to develop and implement proposed methodologies and also guarantee their sustainability.

The above mentioned further tasks are performed within the subsequent Intellectual Outputs which are as follows:

- Intellectual Output 2: Development of the digital platform methodologies for utilization of research results in technology education.
- Intellectual Output 3: Development of pilot lectures using EDURES methodologies.
- Intellectual Output 4: Digital platform with implemented EDURES teaching content.
- Intellectual Output 5: Report on the development of the set of tools and procedures for EDURES feedback and methods of continuous improvement.

The content of the guide has been discussed within the transnational project meetings and trainings organized by the partnership, also within frequent regular meetings, and is presented on the main webpage of the EDURES project: **edures.prz.edu.pl**.



This image shows a full page of primary-ruled notebook paper. It features multiple sets of horizontal lines designed to guide young learners' handwriting. Each set consists of three lines: a solid top line, a dashed middle line, and a solid bottom line. These sets are repeated down the entire page, providing ample space for practicing letter formation and writing. The paper is otherwise blank, with no margins, text, or illustrations.