Team research project - the evolution from a faculty activity to a university-wide study standard

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ABSTRACT: In this article, the authors describe the idea of a university-wide team student project as a tool of modern academic teaching in the era of widespread use of artificial intelligence tools. The emerging tools for automatic content generation, including didactic and scientific content create some issues in contemporary teaching including the question of how to verify students' qualifications and learning outcomes. A possible solution may be students' group work on an interdisciplinary problem and a comprehensive approach to solving it. The authors present the current experience of the Faculty of Electronics, Telecommunications and Informatics at Gdańsk University of Technology (Gdańsk Tech), Poland, where the combination of several fields of study enabled the implementation of interdisciplinary projects that go beyond one specialisation. The implementation of this idea in other faculties at Gdańsk Tech, and eventually in inter-faculty settings, marks the emergence of a new university-wide standard during Master's studies.

Keywords: Project-based learning PBL, pilot study, industry cooperation, study programme

INTRODUCTION

Today's students and skilled workers must learn to function in a climate of constant technological change, innovation and social transformation. In order to keep up with the changes and challenges of Industry 4.0/5.0 and prepare graduates for their future professional careers, universities must implement new, attractive and creative forms of education and training, also taking into account the predispositions of Generation Z and subsequent generations. The aim of the article is to present the assumptions and content of the subject Team Research Project (TRP) implemented at second-cycle studies, and to assess the effectiveness of the method used in the development of technical and social competencies, including co-operation in a project team. The objectives of the subject and its specificity were indicated on the example of projects implemented in 2022-2024. Good practices and conclusions for programme improvement were proposed, which can be implemented in engineering education.

Project-based learning (PBL) is an active method of learning through the exploration of real problems: it requires planning, implementation and evaluation of solutions that are applicable in specific conditions [1]. A common approach when formulating assumptions for PBL classes is the design thinking approach [2]. The most important advantage of PBL is the combination of three areas: cognitive, interdisciplinary and social. The implementation of the project involves co-operation with specialists from various fields, and the project itself is complex, achieving educational outcomes requires support from an academic teacher (lecturer, project supervisor). Advice and feedback should concern both the substantive side of the project and teamwork processes [3]. In project-based education, the lecturer plays the role of an active facilitator (i.e. a person who coordinates the team's work but leaves the decision-making to the group, supervises co-operation, but does not impose its forms, on the one hand supports group processes, and on the other hand discreetly advises without imposing his/her own solutions), whose task is to influence the work of the group and who helps achieve the best results at the optimal time, using the potential of team members [4].

Over the last few years, many articles have been published devoted to the implementation of the practical concept of project- or challenge-based learning. Most of these articles/reports come from technical universities and concern the education of future engineers in various fields. These are future engineers in the field of ICT, IoT, machine learning [5][6], but there are also specialities, such as energy, civil engineering, environmental engineering and chemical technologies [7]. However, these are often projects narrowed to one issue/field. There is a lack of an interdisciplinary approach that requires the project to last longer than one semester. The duration of PBL projects can vary widely

depending on factors, such as grade level, curriculum requirements, learning objectives and the complexity of the project. While some PBL projects may span a few days or weeks, others could last an entire semester or even an academic year. The challenge of recent years, accelerated by the Covid-19 pandemic, is the implementation of PBL classes in the form of on-line classes and in mixed teams [8]. This is also important due to the decreasing interest in second-cycle studies. To encourage working people to improve their qualifications, they can be offered on-line or blended learning classes.

METHODS

The idea of a team research project arose from the desire to reproduce the processes implemented in the company - from the recruitment of employees for the project, through the creation of a project group, project implementation, to its acceptance. Educating engineers who are responsible for providing ICT solutions for the 4.0 economy requires the use of methods that develop not only technical competencies, but also competencies related to co-operation in project teams and building relationships with the client. For example, it can be assumed that IT and electronics specialists will provide services to other technological and social fields, as well as health care. This approach opens the door to other needs. Additionally, specialists observe the encapsulation of industry language, which is often incomprehensible to other participants of production and social processes. The implementation of interdisciplinary projects necessitates the development of universal forms of communication, unification of concepts and mutual sharing of knowledge.

The idea of a team student project for the academic year 2022/2023 was implemented at the Faculty of Electronics, Telecommunications and Informatics (ETI) at Gdańsk University of Technology (Gdańsk Tech), Poland, in the second cycle of studies (Master's studies). It is a relatively large faculty, composed of 16 departments, 200 teaching and research staff and 3,143 students of first- and second-cycle studies. The Faculty offers five fields of study: automation, cybernetics and robotics; electronics and telecommunications; computer science; space and satellite technologies; and biomedical engineering. This combination of fields enabled the implementation of interdisciplinary projects that went beyond one specialisation.

For almost 20 years, in the years 2004-2019, the ETI Faculty conducted a subject called *Group Project* for all fields of study. It was a team student project, obligatory for all students of the 1st and 2nd semester of MSc studies. The project group of students could consist of three to five people, who selected a leader/manager from among the members of the group to supervise the implementation of the project. From 2020, the subject changed its form into a team research project, and from 2024, it was extended to another three faculties of Gdańsk Tech. Ultimately, from the academic year 2025/2026, this student project is to be implemented at all the faculties and in all fields of study. Gdańsk Tech educates students in the faculties of: Architecture; Applied Physics and Mathematics; Chemistry; Civil and Environmental Engineering; Electrical and Control Engineering; Mechanical Engineering and Ship Technology; Electronics, Telecommunications and Informatics; and Management and Economics, in over 30 fields of study. This provides the opportunity to implement interdisciplinary projects combining scientific disciplines and fields represented by the above-mentioned faculties. The assumption is that a project group can consist of three to eight students and, ideally, it should be a mixed group of students from different fields of study. This will allow for a comprehensive approach to the research or application issue to be solved.

The organisational structure created for the implementation of the university-wide team research project is presented in Figure 1 (shown on page 3). The University Coordinator has the overall supervision, and is responsible for the implementation of the concept to the Vice-Rector for Education. Faculty Coordinators (eight faculties) who are responsible for implementing assumptions, monitoring progress and settling the implementation of projects at a given faculty report to the University Coordinator. They are assisted by Department Coordinators who manage implementation at the level of fields of study and in individual departments. The last rung in the hierarchy are Project Supervisors, who have direct contact with the project client (it may be an external company customers) and at the same time act as mentors for the project group.

In order to synchronise the implementation of the assumptions of Team Research Project, Faculty Coordinators meet at regular meetings with the University Coordinator.

Project topics may be submitted by external institutions, including companies and public sector organisations. However, most topics are reported by research and teaching staff, i.e. academic staff. A group of students can also propose a topic. In Figure 1, this process is marked in green. Both external clients and students who submitted project topics must find a substantive project supervisor from Gdańsk Tech, most often from the faculty conducting research or teaching classes on the proposed research project topic. This process is illustrated in red.

The initial process ends with the selection of the preferred topic by interested students - dark brown in the diagram. From this moment, the process of negotiating the formation of a student group and selecting a group leader from among the students begins - this is illustrated in Figure 2 (shown on page 4). In the general scheme of the process of implementing a group project for a company, it is assumed that the company is responsible for providing conditions for the implementation of the project by students (production environment), defining the project goals and accepting the plans and work results. The company may acquire rights to the resulting product or a licence to use it by including

a separate agreement clause with detailed rules for the acquisition and use of these rights. The result of the design team's work is transferred to the company on the basis of the Acceptance Protocol. If the contract is not signed, the students remain the owner of the property rights to the project results. The Vice-Dean for co-operation and promotion, and the appropriate project supervisor, in consultation with the head of the department, are responsible for negotiating the project implementation agreement. Students, therefore, have the support of the faculty authorities and, if necessary, the University's legal department. Efficient management of the entire project is supported by, among others, a specialised group project system (SPG) conducted in Polish and English.

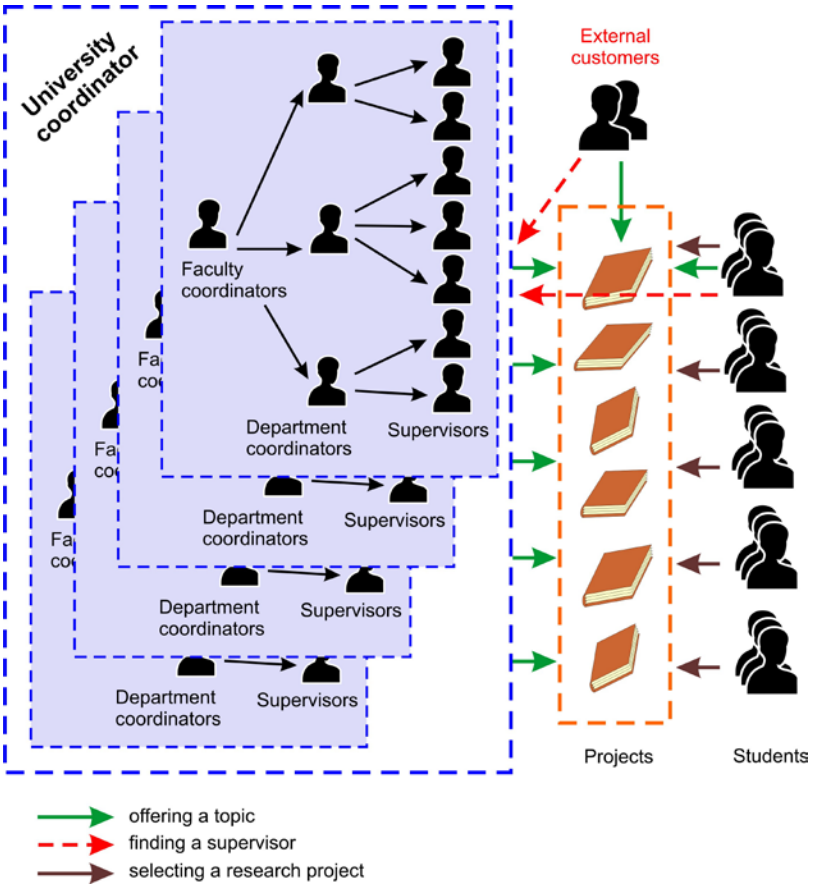

Figure 1: Organisational model of Team Research Project at Gdańsk Tech.

The stages of implementing a team research project (TRP) are shown in Figure 2 on page 4. The first stage is collecting offers from project customers (clients) and publishing them in the TRP electronic management system (TRP_EMS) [9] (a student in TRP_EMS finds several hundred proposals for design topics - this corresponds to hundreds of job offers for engineers). A student may declare his/her willingness to participate in one or more projects (this corresponds to reporting his/her willingness to work for many employers). At TRP_EMS, a student obtains volunteer status. The project supervisor organises individual meetings with people applying for the project and interviews them (this corresponds to the interview stage). Often, a joint meeting of all volunteers interested in a given project is organised. This allows both parties - the supervisor and the students - to get to know each other. The supervisor can learn about the skills and knowledge of potential project participants and their aspirations, e.g. regarding team leadership. The scope of work that individual people are to perform, as well as the grading rules, are also established. At this stage, property rights (not only intellectual property rights) are also determined.

The group formation process is a one-iteration process and ends with assigning students to the group and selecting the project leader (manager). It is often proposed by students, although the final word belongs to the supervisor, who acts as the principal. Then, for the first time, co-operation of the entire team is visible in decision-making and co-operation allowing the group to self-organise (this corresponds to the organisation of the project team). During the implementation of the project, such team co-operation, also in technical matters, will occur many times, e.g. when determining the details of the schedule. Establishing a schedule involves adding to the generally imposed deadlines (end of semesters) the exact dates of completion of individual tasks, people responsible for them and methods of documenting them (in companies it is also known by then when the project should be completed, and depending on the management method - subsequent plans are prepared in more or less detail considering the stages of its implementation). In certain circumstances the schedule may be changed. However, after discussion with the group, it is always decided by the supervisor.

The decision on the choice of project management methodology (e.g. agile or classic) is made by team members after consultation with the supervisor. In order to encourage students to implement innovative projects and devote an appropriate amount of time to them, competitions are organised: the Dean's competition for the best project and the competition

sponsored by one of the IT companies involved - for the best project in the field of artificial intelligence. The awarded student ideas are presented during the inauguration of the first year of second-cycle studies at the Faculty (400 people in the room). In parallel to the implementation of projects in teams, in order to reduce the gap between the knowledge acquired during studies, students' imaginations and the actual work of an engineer [10], a series of meetings (workshops) with representatives of enterprises were organised as part of the Team Research Project subject. They presented from various angles the problems related to the implementation of projects in companies, the expectations they have towards students and young employees coming to work, the required soft skills, etc.

Examples of meeting topics:

- Where to get money to implement your own ideas and how to use it well.
- The role of documentation at INTEL.
- Project seen from the management's perspective.
- Ways to prepare a presentation.
- How to plan a career in IT, including how to pass a job interview.
- Design challenges based on the examples of failures and successes of development projects.
- The difference between a research project and a non-research project.
- Analyst as an interface between the client and the ICT project team.
- Innovative, international R&D projects in the military area - issues of the manufacturing process and its documentation with examples.
- Working in an open-source project.
- From student to developer, a painful journey, but is it for sure?

Thanks to the diversity of implemented projects and two-level support for students by project supervisors and through a package of knowledge provided in the form of workshops, the Team Research Projects subject meets the requirements of project-based learning and team learning. During the semester, the project implementation processes may be repeated many times, such as the process of updating project documentation, because the documentation must be approved by the project supervisor and often also by the external client. Therefore, the process of uploading files to the system (TRP_EMS) may have to be repeated many times, which is illustrated in Figure 2 with a blue loop.

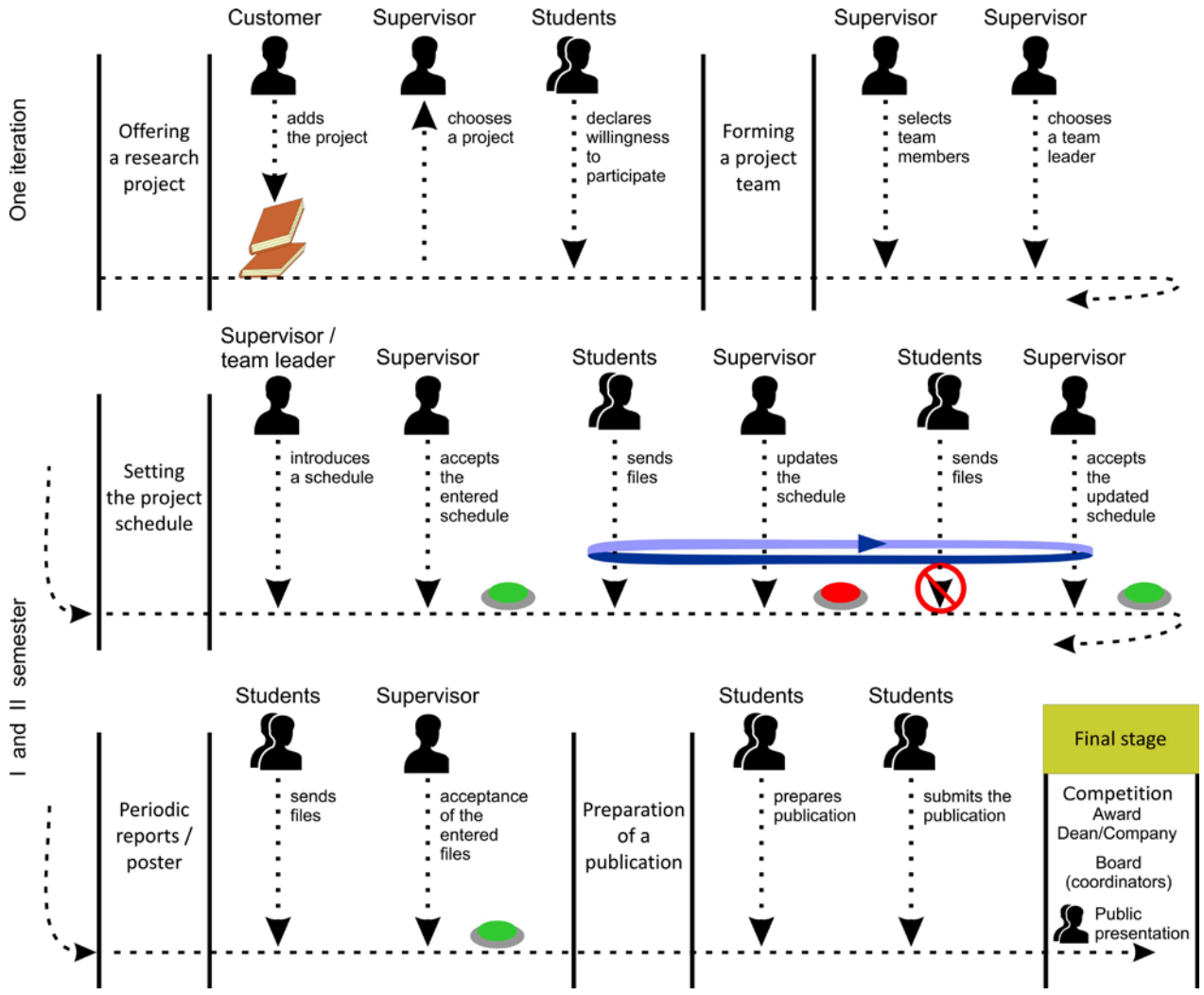

Figure 2: Research projects service - project life cycle – 2nd semester activity.

The first and second semester of the project must end with the development of a promotional poster, and the entire project, apart from the classic project documentation, ends with the development of a report in the form of a publication for a scientific journal or conference materials according to a specific template, e.g. IEEE [11].

RESULTS

At the moment, one can summarise two full editions of Team Research Project carried out at the ETI Faculty and the last (current) pilot edition of the Project with the participation of three additional faculties. The results are summarised in Table 1. The measure of success is the interest of external companies in submitting and implementing research project topics. Such activity requires the company to delegate an employee to look after the project group, but also to decide to what extent it wants to share the company's know-how. Company secrecy is often a problem, especially when preparing a report in the form of a publication and submission for publication in a journal or for a conference. It happens that reviewers demand more detail, but the company does not agree to it and as a result the article has to be withdrawn.

The average number of students in the first semester of second-cycle studies at the ETI Faculty amounts to approximately 400 people. In the pilot edition of 2024/2025 (four faculties), the number of students increased to approximately 520. The reported number of research project topics is at a similar level, on average 250 projects ± 12. The number of projects seems excessive if one assumes that the project group is to consist of three to eight students for whom the number of projects ranging from 65 to 173 (assuming groups of eight or three people) would be sufficient. The redundancy of topics allows students to choose topics that interest them. In the next three editions, however, a decrease in the number of topics submitted by external companies could be observed - a drop from 51 to 24 (a decrease of 53%) with a larger number of faculties. However, the authors are pleased that the number of external projects carried out by student groups remains at the same level.

The first two editions have been completed and summarised earlier [12], while the third 2024/2025 started in February 2024 and will end in January 2025, so for this edition there is no data available yet on manuscripts published in journals or conferences. Each project from the first two editions ended with a report in the form of a publication or a report in the form of a patent application. Fifteen manuscripts from the first edition and three from the second edition were successful in publication. For the 2023/2024 edition, 13 articles are still in the review phase - the project ended in January 2024 and due to the long publication cycle, they are still being processed, and conference applications often concern conferences that will take place in the second half of the year.

Table 1: Summary of three editions of Team Research Project.

Research Project						
Faculty	Academic period	Number of submitted project topic from FETI/other faculty/ industry	Status		Published research papers	Under review research papers
			Submitted/taken by students	Number of teams cooperating with industry		
FETI	2022/23	250/0/51	301/92	11	15	1
	2023/24	243/0/39	282/84	13	3	13
FETI, FAPM, FCEE, FMEST	2024/25	262/73/24	359/87	12	-	-

*Note: FETI - Faculty of Electronics, Telecommunications and Informatics; FAPM - Faculty of Applied Physics and Mathematics; FCEE - Faculty of Civil and Environmental Engineering; FMEST - Faculty of Mechanical Engineering and Ship Technology

Selected/awarded completed team research projects are presented below. These are projects implemented in the fields of study conducted at the Faculty of Electronics, Telecommunications and Informatics [12]:

- *Investigation of machine learning algorithms for speech recognition in the context of medical personnel*; The aim of the project was to develop a methodology for retraining and testing available speech-to-text transcription algorithms for Polish medical expressions used in describing diseases, referring patients for tests by specialists, and issuing prescriptions. Results were published [13].
- *Cleaning Robot - cleaning the world with the support of a mobile artificial intelligence platform*; Created as part of the project Cleaning Robot is an autonomous vehicle programmed with Nvidia Jetson Nano for its precise arm movement, which picks the waste/garbage when detected by the camera with its computer vision capability for object detection.
- *Parameter analysis and optimisation of phase interpolators of different architectures in low-scalable CMOS technology*; The aim of the project was to compare two different architectures of phase interpolators (PI) that are used in clock and data recovery systems. Both PI blocks have been implemented in 16 nm technology using same 0.9V power supply.
- *Implementation of a genetic algorithm on multiple GPUs and performance-energy exploration using power capping*; Within the project, the goal was to design and implement three selected applications, which utilise the genetic algorithm in an environment with eight GPUs. Furthermore, within the project, it was necessary to

evaluate the performance-energy results for the aforementioned implementations with various power capping settings for the GPUs and determine preferred configurations for selected performance-energy metrics.

- *Driver's condition detection system using multimodal imaging and machine learning algorithms*; The project's aim was to create, test and improve a driver condition detection system using multimodal imaging and machine learning algorithms. The driver's condition is classified as tired or untired. Results were published [14].

CONCLUSIONS

The main goal of teaching PBL (in the outlined case the Team Research Project subject - TRP) is to enable students to interact and communicate with peers while working on projects, and to engage in reflective and critical thinking about what they are learning and doing. Therefore, project-based learning is considered an important approach to learning that can also support the improvement of students' communication skills during the project and the acquisition of the so-called soft skills, increasingly required from job candidates by employers and preparing them for a life of long education. Ultimately, the goal of TRP is to provide students with authentic learning experiences that promote critical thinking, problem-solving, collaboration and communication skills, regardless of the duration of the project. Students from different faculties may work together on a project that integrates various disciplines, such as science, technology, engineering, arts and mathematics (STEAM).

Industries benefit from employees who can think critically, generate creative ideas, and innovate to improve processes, products and services. It helps students understand the expectations and demands of the industry by simulating real-world scenarios. The implemented TRP topics are closely related to the specificity of the region (Pomerania) and fit into the development assumptions of the Pomeranian Voivodship region. The authors notice that TRP is suitable for students who do not like theory and do not like didactics carried out in the form of traditional lectures and, possibly, laboratory classes consisting in reproducing tasks from the laboratory manual. The added value is also sometimes proving that the research hypothesis is false. This is specific to scientific research, but also to industrial projects - not every hypothesis is true, not every product idea will be a sales hit.

The competition for the best completed team research project proves that the best projects are interdisciplinary projects in which specialised knowledge is only a tool to solve a more complex problem, often related to the optimisation of a process or a problem related to broadly understood health care. This is also confirmed in the work of student scientific clubs. Scientific clubs conducting interdisciplinary work enjoy great interest from students, and the results of their activities are often awarded in various scientific competitions. Unfortunately, the first pilot edition of 2024/2025 did not result in inter-faculty research projects. Projects are implemented within individual faculty or even departments. In the next academic year, all Gdańsk Tech faculties will join the programme and then the authors hope there will be more inter-faculty and really interdisciplinary projects. Hopefully, more companies from the Pomerania region will also co-operate and submit research project topics for implementation.

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BIOGRAPHIES

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Krzysztof Nowicki is an ICT specialist, and a professor in the Faculty of Electronics, Telecommunications and Informatics at Gdańsk University of Technology (Gdańsk Tech), Poland. His scientific interests and passion are in computer networks. He is the author and co-author of over 250 scientific papers and six books, including two monographs honored with awards from the Minister of National Education in Poland. He has been very well rated by students and awarded several times as the best lecturer. He conducts research and development grant-based work, such as Future Internet Engineering, Internet in the Baltic Sea, National Laboratory of 5G Networks and Services with its Surroundings, to name a few. He is the Deputy Head of the Department of Teleinformatics at Gdańsk Tech. For many years, he has been the representative of the Dean of WETI PG for group/research projects. He is the representative of the Rector of Gdańsk Tech for the Team Research Project.