

Global Journal of Engineering Education

Extra-curricular project-oriented education in optoelectronics in the Faculty of Electronics, Telecommunications and Informatics at Gdańsk University of Technology, Poland

Adam Mazikowski & Paweł Wierzba

Gdańsk University of Technology
Gdańsk, Poland

ABSTRACT: Project-oriented education constitutes a key part of the curriculum in the Faculty of Electronics, Telecommunications and Informatics of Gdańsk University of Technology (Gdańsk Tech), Poland. Students on the engineer and Master of Science level studies take part in several projects, both individually and in teams. In addition to compulsory activities, students have the opportunity to take part in the activities of student scientific chapters of international professional societies, such as SPIE or Optica, as well as in scientific research projects, in particular financed by Gdańsk Tech in the framework of its Technetium and Plutonium programmes. In this article, the authors present the framework and implementation of these projects. Opportunities, limitations and threats in the projects in optoelectronics are discussed, based on selected cases. Results of example projects are outlined, and modifications to the process are formulated.

Keywords: Extra-curricular education, student scientific chapter, popularisation of science, student research supporting programmes

INTRODUCTION

Education in the Faculty of Electronics, Telecommunications and Informatics (ETI) at Gdańsk University of Technology (Gdańsk Tech), Poland, is provided at three levels: engineer (Bachelor), Master of Science (MSc) and doctoral, and is consistent with the European Union education framework. Studies at the first two levels last seven and three semesters, respectively. After six semesters students at the engineer level start their education in the specialisation they have selected. In particular, students studying electronics can select one out of four specialisations offered to them. One of them is optoelectronics that will be the object of further discussion. Optoelectronics is also offered at the MSc studies of electronics.

Project activities constitute an important part of the curriculum on both engineer and MSc levels of study. Apart from projects that are a part of courses, where students work individually designing circuits or systems relevant to the scope of the course, more modern types of projects have been introduced.

At the engineer level, a two-semester compulsory Team Project subject was introduced. Students from the ETI Faculty select project proposals from the list provided by all departments, form project teams (typically from three to eight students) and conduct necessary research, design, implementation, testing and verification as per requirements set by the person responsible for the particular project proposal. Within this subject, students acquire soft skills needed in the industry, in particular teamwork, external and internal communication in the team, setting and following project timelines, planning and assigning tasks, creating documents relevant to the project. Moreover, students practice a multidisciplinary approach to problems, as most of project proposals require development of various hardware and software modules, as well as the application of mathematical methods. A series of accompanying lectures provides a necessary background on the soft skills and design thinking.

At the Master's level, a two-semester compulsory Team Research Project subject was introduced. While its form is similar to that of Team Project, it provides a gentle introduction to scientific research, writing manuscripts and reports, as well as reinforces previously acquired soft skills.

Apart from compulsory and elective courses, students are also encouraged to participate in student research clubs and in student chapters of international professional societies, such as the Society of Photo-Optical Instrumentation Engineers

(SPIE) or Optica (formerly the Optical Society of America (OSA)). Moreover, students can also submit proposals for student research projects. This framework offers the students opportunities to engage in a range of activities, from which they can select the most interesting ones. These activities can be divided into four groups, discussed in more detail in the following section.

METHODS

The scope of extra-curricular education in optoelectronics at the Department of Metrology and Optoelectronics is shaped by four factors: research conducted by the Department's employees, scientific profiles of societies whose chapters are active at the Department, popular demand coming from outside of the University, and, last but not least, interests of individual students belonging to student research groups. Activities resulting from the aforementioned factors can be divided into four groups: taking part in research grant programmes, participation in, and organisation of, scientific conferences, popularisation of science and technology, as well as conducting engineering projects.

Research Grant Programmes

Since 2020, Gdańsk Tech has ranked second in Poland in terms of scientific research, therefore it belongs to the elite group of the so-called research universities in Poland, often referred to by the Polish acronym IDUB (IDUB - Excellence Initiative - Research University). For this reason, a number of university grant programmes have been launched for which students can apply, both individually and in groups [1]. The most relevant ones are the Plutonium and Technetium programmes, supporting the transition of MSc and doctoral students from education to scientific research, in particular in the fields and scientific disciplines related to the University's priority research areas.

The Plutonium supporting the Team Research Project programme at Gdańsk Tech is aimed at supporting the research of student groups, most often consisting of MSc and/or doctoral students, supervised by a faculty staff member. Projects are implemented on a rather limited budget, often using equipment available at the Department, in the last 12-24 months and should result in the publication of a scientific paper.

The Technetium Talent Management Grants programme at Gdańsk Tech is aimed at supporting especially gifted students in their research activities and at facilitating the mentoring of such students by selected academic teachers. Finally, students at all levels of education can take part in research projects funded by external agencies, both national and European. In some research projects, provisions are made to promote the inclusion of students into the research teams. In externally-funded projects, the students are most often responsible for making custom electronics, writing software, performing measurements or data processing and visualisation.

Participation and Organisation of Scientific Conferences

Outstanding students belonging to student chapters of international professional societies, such as SPIE and Optica can apply for a special type of financing (travel grant) to participate in an international scientific conference and present a paper. Recipients of such grants often take part in student chapter networking events or events promoting co-operation with industry.

Student chapters of these two societies can organise scientific conferences under their patronage. These conferences are targeted mostly at students and early-career researchers from Poland and abroad, and often feature a section of invited lectures (school) delivered by renowned scientists from academia and industry.

Popularisation Activities

Scientific clubs are also active in the field of popularising science. Popularising activities are mostly carried out as part of larger programmes or projects run by the ETI Faculty (ETI Academy), University (University of Talents) or universities of the region (Baltic Festival of Science). Some of these activities are aimed at a particular group of people, such as secondary school pupils, while others have a wider focus including general public.

Outreach activities for primary and secondary school pupils are organised by the scientific clubs in the form of workshops and demonstrations, taking place either at schools or at the ETI Faculty. In some cases short workshops and training are organised for other groups of students to provide them with some additional skills or give them a preview of studying electronics or optoelectronics.

Engineering Projects

Student scientific clubs or individual students undertake also a number of engineering projects, mainly related to the interests of the club members or the needs of the club (e.g. equipping the club's room). Funds for such activities may be obtained through a chapter of an international organisation or through financing from the Students Union of Gdańsk University of Technology (based on a prepared preliminary).

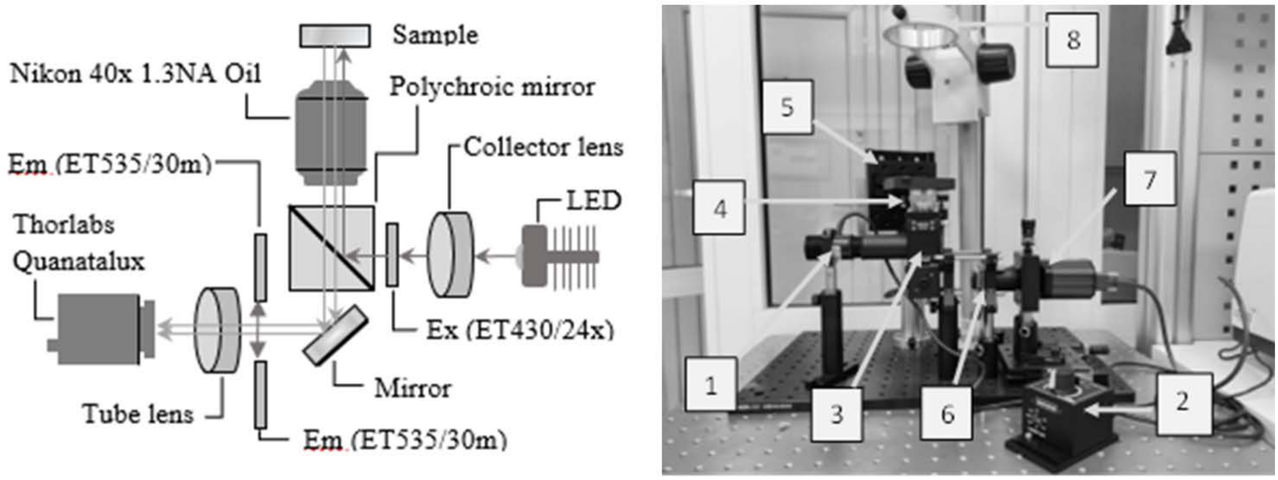
RESULTS

At present there are two scientific clubs related to optoelectronics at the Department of Metrology and Optoelectronics: Soliton and Biophoton. Additionally, there are student chapters of SPIE and Optica [2][3]. Students of these chapters and clubs have participated in all four groups of activities described in the previous section. Selected activities from each group are presented in the reminder of this section.

Research Grant Programmes

Since 2020, when IDUB university grant programmes have become available, the students have been awarded two Plutonium and one Technetium programmes. The example, the Plutonium project presented below was aimed at the development and implementation of a budget modular system for imaging fluorescent materials. Such systems are important in many diagnostic and sensing application areas where the widespread adoption of fluorescence microscopy techniques is taking place. The developed system was designed in particular for biosensing [4][5] of proteins and bacterial spores, as well as for detection of fluorescent materials [6], including synthetic fluorophores. The system was also designed as a tool for research on sensor structures using synthesised diamond layers with color centres [7][8] that are produced in the Department.

The fluorescence imaging system was designed to be built mostly from stock opto-mechanical and optical components, available from companies, such as Thorlabs, Edmund Optics or Chroma. A good-quality Nikon microscope objective and a Thorlabs USB camera were used in the system, and an Ocean Optics spectrometer could be attached to it. A schematic diagram of this system, with optical beam paths marked, is shown in Figure 1a, and the assembled system is presented in Figure 1b.



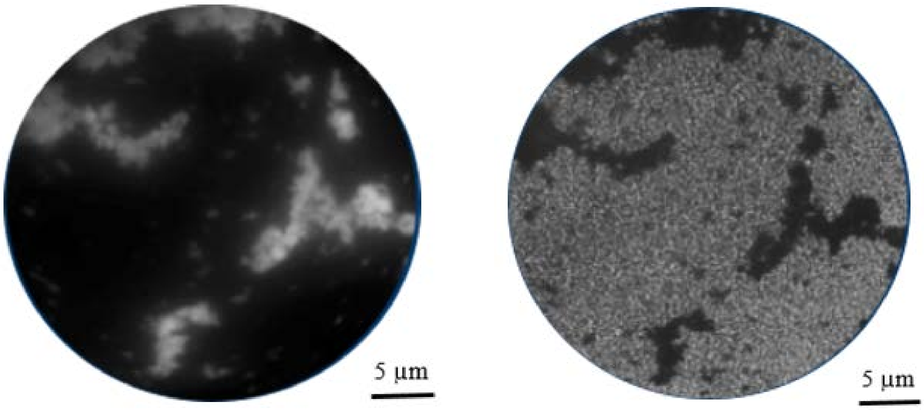
a) b)

Figure 1: Schematic diagram of the designed system layout, a) assembled system side view (Ex, Em - interference filters) [9]; b) the assembled system: 1 - light source with collimating lens and filter; 2 - power supply for the light source; 3 - beam splitter and plane mirror; 4 - lens, table with holder sample, vertically adjustable; 6 - color filter module; 7 - camera with an additional positioning system (or alternatively a spectrometer); 8 - holder for an additional light source.

One of the advantages of the system is its modular structure, which allows for easy adapting of the system, for example to other wavelengths of excitation and fluorescence response. The system allows for observation of the sample in several modes. The basic mode is the observation of a fluorescent image. The use of an additional white light source (on an additional handle) with the fluorescent excitation source turned off allows the traditional microscopic image of the sample to be obtained. Importantly, switching between these imaging modalities can be accomplished without the need to change the position of the tested sample, making it possible to superimpose areas of fluorescence on a classic microscopic image. Turning on both sources (fluorescence excitation and white light) results in an image that is a composite of the fluorescent and traditional images.

In order to check the system and assess the quality of imaging, a number of tests were carried out. In the test presented below nanodiamond powder containing nitrogen-vacancy (NV) color centres, resulting from the substitution of nitrogen atoms in the diamond crystal lattice. These centres fluoresce, i.e. they absorb and then emit electromagnetic waves of appropriate lengths, i.e. around 530 nm and over 550 nm, respectively.

The recorded images are shown in Figure 2. In Figure 2a, the fluorescent response of the diamond powder with NV color centres is presented. In the traditional microscopic image shown in Figure 2b, dark areas corresponding to the diamond powder obscuring and scattering the illumination are clearly visible. The tests also made it possible to assess the resolution of the imaging system (c.f. scale in Figure 2).



a) b)

Figure 2: Observed images: a) fluorescent; and b) classic in white light.

The designed and developed system is characterised by considerable flexibility in configuration (reconfiguration), and can be relatively easily improved in the future (e.g. adding a second, independent excitation and response channel). Satisfactory imaging quality was obtained, both of the fluorescence response and in white light.

Conferences

The OPTO-Meeting is a cyclical conference in the field of optoelectronics and photonics, organised by different student chapters in Poland since 2006. Students of the Department’s scientific clubs organised it several times in Gdańsk, in 2014, 2016, 2018, 2020 (on-line, due to Covid-19) and in 2023 [10]. Approximately a hundred participants (students or doctoral students) took part in each of them, including several participants from abroad. Invited guests from all over the world (e.g. from India, Germany, USA and Spain) also participated in each conference, including President of the SPIE in 2016 and Optica Europe Director in 2023. A photo from the 2023 OPTO-Meeting opening ceremony is shown in Figure 3.

Figure 3: Opening ceremony of the student scientific conference OPTO-Meeting 2023 (photograph by A. Mazikowski).

Moreover, students took part in various scientific conferences both in Poland, e.g. *Integrated Optics - Sensors, Structures and Methods* (IOS 2023) in Szczyrk [11], cyclical conference on optics and photonics in Wilga [12], and abroad, e.g. the SPIE conference in San Diego [13] or the Optica’s Student Leadership Conference in 2022 [14].

Popularisation Activities

Since the formation of the first scientific club in 2008, students have taken part in and organised several popular science events (Figure 4). Most of them was organised within the framework of the Baltic Festival of Science (BFS), which is a multi-day series of popular science events intended for everyone, regardless of age and education, organised by universities, institutions of the Polish Academy of Sciences, research and development units and non-university institutions related to science from the Pomeranian region since 2003.

Two BFS events have been usually organised with the participation of students: *Optoelectronic Shooting Competition* and *The Exciting World of Optoelectronics*. The former is designed as a competition in which shooting takes place with a pulse of light, while the subject of the latter is broadly related to optoelectronics and is adapted to the level of the group of participants, from simple color mixing demonstrations to a workshop on splicing of optical fibres (Figure 4a).

a) b)

Figure 4: Student chapter's popularisation activity: a) Baltic Festival of Science - splicing of optical fibres workshop; and b) workshop on logic devices (photographs by A. Mazikowski).

Another series of more focused popular science activities is the ETI Academy, which includes short courses on the topics from within the scope of activity of the ETI Faculty. These topics include digital logic, 3D printing and colorimetry. These courses are intended for students of secondary schools in the vicinity of Gdańsk (Pomerania region), and are conducted by academic teachers with support provided by students from student chapters and scientific clubs.

Finally, outreach activities conducted independently by the student chapters and the scientific clubs take the form of demonstrations and workshops. Demonstrations, covering selected areas of optics, optoelectronics and optical sensing, are organised for primary school pupils to stimulate their interest in STEM subjects and for secondary school pupils to encourage them to study engineering or science at university. Workshops and training are organised on topics ranging from fundamentals of electronics and optoelectronics to programming of microcontrollers (MCUs) and splicing of optical fibres. They are offered to undergraduate students (third-fifth semester) who want to learn new skills or need a hands-on experience in the selection of their field of study.

Engineering Projects

A good example of an engineering project developed by a member of a student chapter is a microcontroller board containing a Texas Instruments (TI) MSP430I2011 MCU. It is inexpensive, offering small size and low power consumption. It can be used with programming/debugging circuits on TI low-cost MSP430 boards and with the TI free Code Composer Studio development environment. The board was developed mainly to facilitate the development of systems that need one or two 24-bit sigma-delta A/D converters of the 'I2020 MCU. The board was successfully built and tested and can be used in systems like multimeters, optical power meters or simple lock-in amplifiers.

DISCUSSION

Undertaking extra-curricular activities by students is associated with a number of benefits. First, these activities can serve as an introduction to more serious scientific or engineering projects in the future. Valuable solutions are often created that can be used for educational purposes or in research. Participation in multi-person projects also reinforces and expands the soft skills acquired during their study, especially leadership, project planning and execution, and responsibility for co-workers.

Participating in conferences allows students to gain experience in presenting results of their scientific research or engineering work, often in a more receptive environment, free from harsh (and often unwarranted) criticism, offering instead a constructive feedback and suggestions for improvement. An important aspect of student activity is also gaining experience in organising scientific and popularisation events. Moreover, transferring knowledge to other students or pupils allows for better knowledge consolidation and organisation.

Unfortunately, this form of student engagement encounters some substantial problems. First, students must divide their time between regular studies and additional activities, with the former often suffering due to excessive cumulative workload. Second, some students also undertake part-time work, either because of economical constrains or because of perceived expectations of employers who are often reported to expect over a year of professional experience at the graduation date. Third, some students are also discouraged from several activities by the extensive bureaucracy, including public procurement procedures for supplies, components and devices. Finally, there are also no clear rules allowing the students to be exempted from selected subjects (or some of their parts) or be awarded European Credit Transfer and Accumulation System (ECTS) points on the basis of above-standard activities, especially for students at the engineer level.

CONCLUSIONS

Students have the opportunity to educate themselves through activities that interest them most. The activities they undertake also may allow them to acquire knowledge that goes far beyond the standard knowledge taught during the regular education process. Extra-curricular activities of students allow for natural selection of leaders of research groups and organisations. They can be also a factor encouraging students to enrol in the MSc studies or take up doctoral studies. However, students taking part in them can face challenges that often discourage engagement.

REFERENCES

1. Gdańsk University of Technology: IDUB Programs, 18 April 2024, https://pg.edu.pl/en/research-university/idub-programs/research-centers
2. Babińska M., Suplewski, M. and Mazikowski, A., Fluorescent microscope for observation of nanodiamonds with color centers. *XVII International SPIE and OPTICA Student Chapter Meeting OPTO 2022*, *Poster Session*, Warsaw (2022).
3. SPIE student chapters, 18 April 2024, https://spie.org/membership/student-resources/student-chapters #_=_?filter Country=Poland
4. OPTICA, 10 April 2024, https://www.optica.org/events/global_calendar/events/2016/optomeeting_for _young_ researchers_spie _osa_student _chapter_meeting_2016/
5. Stockert, J.C. and Blázquez-Castro, A., *Fluorescence Microscopy in Life Sciences*. Bentham Science Publishers (2017),
6. Zhang, T., Pramanik, G., Zhang, K., Gulka, M., Wang, L., Jing, J., Xu, F., Li, Z., Wei, Q., Cigler, P. and Chu, Z., Toward quantitative bio-sensing with nitrogen–vacancy center in diamond. *ACS sensors*, 6, **6**, 2077-2107 (2021).
7. Wolfbeis, S., Materials for fluorescence-based optical chemical sensors, *J. of Materials Chemistry* 15, **27-28**, 2657-2669 (2005).
8. Nunn, N., Torelli, M., McGuire, G. and Shenderova, O., Nanodiamond: a high impact nanomaterial. *Current Opinion in Solid State and Materials Science*, 21, **1**, 1-9 (2017).
9. Yu, S.J., Kang, M.W., Chang, H.C., Chen, K.M. and Yu, Y.C., Bright fluorescent nanodiamonds: no photobleaching and low cytotoxicity, *J. of the American Chemical Society*, 127, **50**, 17604-17605 (2005).
10. OPTO Conferences, 10 April 2024, https://www.opto2024.cz/opto-history
11. The 18th Integrated Optics - Sensors, Sensing Structures and Methods (2024), 10 April 2024, https://ios-conference.pl/index.php/ios-2023-pl
12. Szymaniak, M., Mazikowski, A. and Meironke, M., Investigation of tracking systems properties in CAVE-type virtual reality systems. *Proc. Photonics Applications in Astronomy, Communications, Industry, and High Energy Physics Experiments*, SPIE, 10445, 558-563 (2017).
13. Szreder, A. and Mazikowski, A., Light box for investigation of characteristics of optoelectronics detectors. *Proc. Sixteenth Inter. Conf. on Solid State Lighting and LED-Based Illumination Systems*, SPIE, 10378 (2017).
14. OPTICA Conference (2022), 13 April 2024, https://www.optica.org/optica_blog/2022/november/student_ reflections_at_frontiers_in_optics_laser_s

BIOGRAPHIES

Adam Mazikowski received his Master’s degree in electronic equipment design in 1995 from Gdańsk University of Technology (Gdańsk Tech), Poland. In 2003, he received his PhD degree in optoelectronics from the same University. From 1995 to 2003, he was a research assistant in the Department of Optoelectronics at Gdańsk Tech, where since 2003, has been an assistant professor in the Department of Metrology and Optoelectronics. His previous and current research interests include: non-contact emissivity, temperature measurement, optoelectronic sensors, optoelectronic displays, photometry and colorimetry, and virtual reality systems. He is one of the designers of the Immersive 3D Visualisation Laboratory that was opened at Gdańsk Tech in December 2014. Dr Mazikowski is a member of the SPIE and the Photonic Society of Poland.

Paweł Wierzba received his MSc, PhD, and DSc degrees in electronics from Gdańsk University of Technology (Gdańsk Tech), Poland, in 1994, 2001 and 2018, respectively. He is presently an associate professor in the Department of Metrology and Optoelectronics at this University. He conducted scientific research at the VTT Technical Research Centre of Finland in short-term positions from 1997 to 2000. From 2002 to 2003, he was the recipient of a Finnish Academy scholarship, also at the VTT Technical Research Centre of Finland. His research interests include optical and fiberoptic sensing, thermal detectors and low-noise preamplifiers. Dr Wierzba is a member of the SPIE, Optica (formerly OSA) and the Photonic Society of Poland.