Applied Research in a Higher Vocational Engineering Physics Education Environment

APPLIED RESEARCH IN A HIGHER VOCATIONAL ENGINEERING PHYSICS EDUCATION ENVIRONMENT

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Higher Vocational Education institutes are evolving from practical schools towards centers of expertise having a societal role for both teaching and research. At the Engineering Physics program of the Fontys University of Applied Sciences in Eindhoven, our research and teaching programs are integrated in a research theme with the name “Detection and Measurement”. In this theme, the staff invites companies to frame their physics problems as student projects. As a result, students meet real-life practical physics problems in their curriculum, and can learn to solve them under the supervision of the staff. The projects are an extra dimension of education besides the practicals, theory courses, pre-defined regular projects and internships.

Keywords: applied research, engineering physics, project-based learning

INTRODUCTION

Institutes for higher vocational education are subject of external influences. The developments in higher education are influenced by the European Higher Education Area (EHEA). This committee has introduced the international bachelor-master-doctoral construction in 1999 in a process that is called The Bologna Process [1]. If we want to see how technical education is shaped internationally and what lies ahead, we can follow the Bologna Follow-Up Group (BFUG). In the European BFUG agenda, three aspects are important to us:

- Support for the international mobility of students, staff and researchers as a way to develop their experience and skills
- Cooperation between higher education, research and business (circular careers)
- Ensure that higher education institutions contribute to innovation.

This clearly shows that the role of research, and in particular applied research ("Contributing to innovation") remains important in education and is even a focus of attention. In addition, the connection ("international mobility") is important.

Meanwhile, in the Netherlands, higher vocational institutes have had the statutory task of carrying out practical research since 1986. It was not until ten years later when the first research groups were created. Currently, the conventional stand-alone research groups are transformed into mature structural research organizations within the educational institutes.

The trends in education have led to the need of project-based learning, in which students gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge [2, 3]. Project-based learning is in fact a practical implementation of fundamental learning methods as referred to as Social Constructivism by Vygotsky [4].

The program of Engineering Physics at the Fontys University of Applied Sciences is operating under these external influences. The Engineering Physics track had its 50th anniversary in 2018. It was founded after the demand of local industry. Currently, it resides organization wise (but also with respect to housing) in an eco-system with the educational programs of Applied Science: microbiology, chemistry and chemical technology. What shares our programs is the research-nature of our education and company projects. We also share one research group Applied Natural Sciences [5]. Under the research group, there are six research themes. This paper is mainly about the research theme called “Detection and Measurement” which matches education and research within the Engineering Physics program.

Following the trend of project-based learning, the Engineering Physics program started student projects 20 years ago. Nowadays, it is embedded structurally in the curriculum to give the projects a central position for learning [6]. The research projects a student will encounter in the curriculum of the Engineering physics program are summarized in Table 1. The propaedeutic projects are fixed, meaning there is a project description that is repeated every year. Such projects have a directed outcome, and have learning objectives based on propaedeutic course contexts and topics. Students learn research-, design- and project management skills in a conditioned setting.

Table 1. Research projects in the Fontys Engineering Physics curriculum.

Year	Phase	Project	Duration	Research scope
1	Propaedeutic	4×3 group projects	4×8 weeks	Fixed research and design projects
2	Core	2 group projects	2×140 hours	Research theme
3		external internship (individual)	5 months	External definition
	Graduation	group project	280 hours	Research theme
4		Optional individual research project	280 hours	Research theme
		Final external bachelor graduation (individual)	5 months	External definition

The core-phase group-projects that are defined by the research theme originate from one of the themes under the research group. In that way, the projects are indirectly coupled to a company or societal context. Such projects are open ended because the challenge is defined from a real practical problem. The company defines the context, while the tutor frames the problem into a potentially solvable physics problem.

Because applied research in an education environment is inherently coupled to resources in the curricula, it is worth mentioning that the curriculum of the Engineering physics program is based on the European Domain of Applied Sciences [7-10]. This means that the skills-set addressed in the research projects should match the core skills as defined in the profile of the Engineering Physics program.

THE RESEARCH THEME FOR DETECTION AND MEASUREMENT

As explained in the introduction, the research theme “Detection and Measurement” defines the context and actual problems for the educational projects. This means that the topics addressed within the theme must satisfy certain boundary conditions. We have organized the topics within the theme in research lines. When selecting these lines, two criteria are important:

1. The lines under the theme must have a shared vision that connects the separate lines,
2. Each research line must be viable, meaning it has a reason it exists.

The chosen shared vision of criterion 1 will be discussed in the next section. The viability check of criterion 2 was done by ensuring that a research line under the theme can only be successful when we have:

- A national or regional relevance which can be checked with our internship contacts and the institutes' advisory board;
- Staff with personal expertise in the area;
- A laboratory;
- Relevant equipment;
- Collaboration projects;
- Courses or modules in the Engineering Physics curriculum;

This has resulted in the four research lines, and one common denominator, as indicated in Fig. 1.

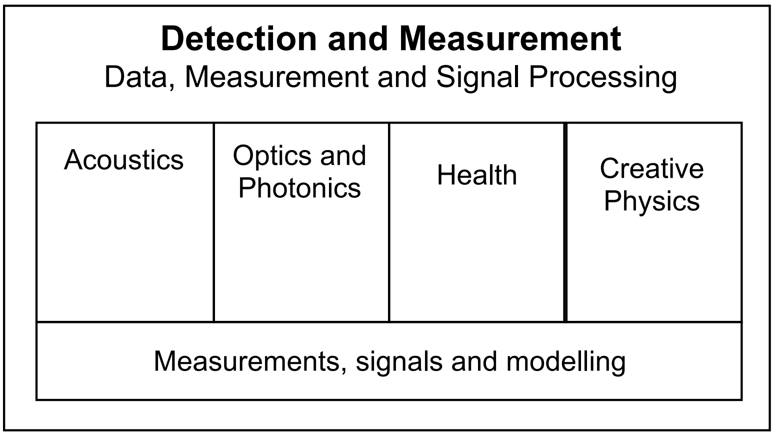

Fig.1. Organization of the research theme "Detection and Measurement".

We will now describe the four research lines and the shared common denominator of Measurements, Signals and Modelling based on some example projects.

MEASUREMENTS, SIGNALS AND MODELLING

What distinguishes an applied technical program from a fundamental program, is that the technology is deployed into products, measurement set-ups, verified advices and working concepts. This cannot be done without actually measuring in a multi-modal environment. In practice that means that the fundamental laws of physics (optics, mechanics, heat, waves, particles, etc.) are explored as real-live signals. To understand multi-modal interfaces and systems, the mathematics of signal processing and modelling is needed.

ACOUSTICS

The field of Acoustics is embedded in the program in the 2nd and 3rd grade. It starts with vibrations and is followed by the basis of the Acoustics. Here attention is paid to acoustic fields and to the influence that sound and vibrations have on the human body. In addition, there is a continuation of the discipline in the minor in Electro Acoustics. This covers the entire process from sound source, microphone, signal amplification, reproduction through a loudspeaker, to acoustic fields in a room.

In courses like Acoustics as well as in Electroacoustics, much attention is paid to the (correct) measurement of quantities. How do you measure sound pressure level, how do you determine the average noise load over a working day. Professional (Brüel & Kjær) measuring equipment is available for this purpose, so students become familiar with performing certified measurements and measuring methods as early as school time. Measurements can be carried out for ARBO noise and vibrations.

Fourier analysis is introduced in mathematics courses and in the same time in laboratory work and acoustic lectures. All students start immediately with a project in industry: Occupational Health measurement concerning sound exposure or human vibration by workers in industry. The students perform the measurements and write an advisory report (examples: metal industry, car workshop, kart instructor, kindergarten, dishwasher, timber workshop). In the practical laboratory work students work on: speed of sound in metal and air, measuring sound absorption, reverberation time, speech transmission index, sound insulation, etc. The lab is equipped with state-of the-art acoustical measurement systems. In a second project students worked on projects for industry as: brake noise squeal, roller coaster noise reduction, low frequency hearing threshold, cathedral acoustics, rehearsal room orchestra and room for hearing testing of seals. For the students this is the first time to interact with industry to solve a problem and face the difficulties it brings.

The department is involved in a development project with industrial partners for injection molding of record discs. Students work on the measuring of the sound quality of these discs, compared to former vinyl discs: measurement setups, distortion, frequency range etc. In the context of this vinyl project, measurements are made with regard to determining the audio quality. This concerns measurements of frequency range, SNR, harmonic and intermodulation distortion. These measurements can also be carried out with professional means. Measurements are also possible on loudspeakers, such as e.g. directivity, sensitivity, distortion and frequency response.

In the fourth year of the course students can choose for lectures in electro-acoustics, with laboratory work and a project. Projects done are: noise cancelling headphone, current and voltage driven amplifier and specifications of a column loudspeaker to use in a cathedral. Many subjects are combined in these projects and lectures: acoustics, electronics, measurement techniques as FFT, signal processing, waves, electrical networks and transformers and mechanics.

The acoustics research line makes students in a short time experts. They get known to the professional field resulting in many internships and final projects in acoustics. The department of Engineering Physics is known for these educated students [11], so many of them find an acoustical job after graduation.

OPTICS AND PHOTONICS

In the expertise area Optics for High-Tech Systems, we made the didactical decision to mainly buy instrumentation that helps students acquire an understanding of optical concepts, and with which they can develop skills like building a set-up, aligning, measuring, taking safety measures, etc. Therefore, our emphasis is on instrumentation that students can open, change, and align themselves.

In their first year, students follow two courses on the basics of refraction, lens systems and diffraction. Likewise, our second-year optics course also covers both subjects from geometrical optics and physical optics. The geometrical optics in the second year comprises concepts like aperture stops, principal planes, Seidel and chromatic aberrations, and analytical raytracing (matrix optics). The physical optics part covers polarization & retarders, thin films, interferometers, the resolving power of a grating, and intensity profiles caused by interference, by diffraction and by the combined effect.

During their projects, students work with instruments like spectrometers, integrating spheres, beam profilers, and other optical equipment.

Third- and fourth-year students can choose to follow the Photonics course, that broadens the knowledge of lightguides (backlighting, fibers), Machine Vision, Fourier optics, The Fabry-Perot interferometer, Fresnel diffraction (Cornu spiral) and Étendue.

This course comprises both a practical assignment and a simulation assignment, the latter using non-sequential raytracing software. For the practical assignment, we facilitate students to work four times during four hours on the same set-up, so that their alignment skills can substantially grow. They can choose to work on set-ups like: an open HeNe-laser (Fig. 2.), Fiber Bragg Gratings, Fabry-Perot interferometer, Fourier Optics, Optical Tweezers, and a system with which polarization-entangled photon pairs can be generated and analyzed.

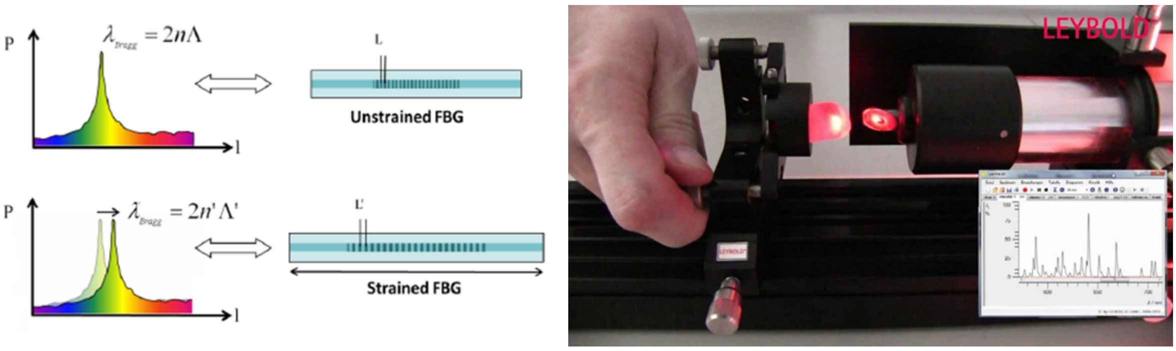

Fig. 2. Experiments with an open HeNe laser and a fiber Bragg grating

HEALTH

Quite some students are motivated when a project will eventually contribute to a healthier population. As the medical practice is becoming more and more dependent on technology, Engineering Physics alumni find interesting careers in hospitals and medical equipment manufacturers.

The 3rd year optional course Medical Technology shows the technology and physics behind the various applications. As the program Medical Imaging and Radiation Therapy is geographically close, our students can work with up to date x-ray and ultrasound equipment. Also radioactive sources and a SPECT camera are available.

The health research line consists of three focal areas: 1) working with sensors and data analysis to obtain information from the human body, 2) exploring the possibilities of medical imaging combined with 3D printing and 3) creating learning models to be used by doctors and paramedics during their training.

The body-area sensor projects give a very suitable context for the shared theme of data measurement and signal processing. The context of health stimulates the students to dive into exploratory open problems in signal processing.

Medical imaging shows practical applications of quite some phenomena the students have studied during their theory lessons, for example radiation physics [12], acoustics and electromagnetic waves. It even shows a practical application of quantum mechanics: the Zeeman effect is essential for creating MRI images.

Combining CT images with 3D printing has resulted in interesting project results, for example a 3D printed heart to be used for calibrating MRI software and a 3D printed left and right foot clearly showing the differences between a treated clubfoot and a healthy foot. Such tangible medical models were the basis of many more projects [6]. Learning models provide doctors and paramedics with a risk- and stress-free training environment. Other examples are a knee learning model to practice the drawer tests to check the cruciate ligaments (Fig. 3.), and an ultrasound phantom mimicking a gall bladder with stones or a vein on which the blood speed can be measured by Doppler. These projects are especially suitable to perform with a multidisciplinary team of students, both designers from electrical and mechanical engineering and researchers for engineering physics and chemistry are needed to create a useful product.

Fig. 3. Students working on a physiotherapeutic knee learning model

So, the health context creates an inspiring set of projects where the learning outcome is not restricted to health only: all generic phenomena like particle science, material science, signals, acoustics, radiation, and electromechanics can be encountered.

CREATIVE PHYSICS

In the Creative Physics projects, students learn creativity, project management and entrepreneurship related to physics projects. An annual application is the Eindhoven GLOW light festival. Students are asked to come up with creative concepts, and when verified and approved, scale it up for exhibiting it to the 750.000 people audience that visits the festival during the GLOW week each year. The students do not only have to come up with a creative installation: they must also acquire most of the budget and professionalize the installation for display. The 2018 contribution was an artistic 20m wide projection of the beauty of sound on the wall of a building as shown in Fig. 4. Other Creative Physics projects are scientific escape rooms and an annual multidisciplinary design case for industry.

Fig. 4. A huge laser projection mimicking interference of sound at the Eindhoven GLOW 2018 light festival

Creative thinking and design thinking is becoming more and more embedded in the Fontys Engineering Physics curriculum. In the first year, we give students workshops in which they learn skills with respect to the research and development process and the design methodology. An important part of these workshops is to learn how to analyze the problem, define project goals and set requirements for the outcome of the project. The students learn how to write a project plan in which they describe all the aspects of a project, such as the problem definition, goal of the project, project planning, risks, costs, etc.

In the core phase, the students get acquainted with a next level of project skills. By workshops the students learn about their responsibility they have regarding the outcome of the project. They learn to be aware that their project results have effect on society and our environment and that they have to take responsibility regarding their actions. In the curriculum of the core phase they also learn- more in depth- creative thinking techniques and how to be able to apply these techniques in practice.

CONCLUSION

When designing the research lines in the Detection and Measurement theme are chosen based on the experience of the staff, on the installed base of internship company contacts, and the core skills of the Domain of Applied Sciences. The current research topics are organized around the lines: Acoustics, Optics and Photonics, Health, and Creative Physics.

Table 2. The research lines address specific skills from the Engineering Physics program.

Research line	**Addressed skills**
Acoustics	Waves, mathematics, signals, control theory, electromechanics
Optics and Photonics	Optics, waves, radiation, particles, material science
Health	Nuclear phenomena, material science, signals, acoustics, radiation, electromechanics, multidisciplinary collaboration
Creative Physics	Entrepreneurship, project management, creativity, multidisciplinary collaboration

In Table 2, the educational skills and topics addressed in the four research lines are summarized. Although the skills and topics mentioned in this simplified table are not complete, it can be concluded that almost all basic courses are covered, together with the non-technical skills of project management and multidisciplinary teamwork. This is the first evidence that the current research organization is a suitable construction to link research to education.

Further evidence comes from our internship contacts and the institutes' advisory board. The internship and graduation companies do not only provide locations and contexts for the students, the whole internship and graduation process creates evidence for the effectiveness of our research program. In addition, the advisory board from industry is used to check market conformance of the content of the research program. The given research construction is not fixed: it is part of a process. Therefore, we are always open to projects outside the current scope to explore new fields.

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