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# Dynamic curricular concepts for research orientated programs in optics and photonics

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## ABSTRACT

Teaching and learning concepts that are adapted to the constantly evolving requirements due to rapid technological progress are essential for teaching in media photonics technology. After the development of a concept for research-oriented education in optics and photonics, the next step will be a conceptual restructuring and redesign of the entire curriculum for education in media photonics technology. By including typical research activities as essential components of the learning process, a broad platform for practical projects and applied research can be created, offering a variety of new development opportunities.

**Keywords:** Curricular concepts, research-oriented education, learning scenarios, media technology, optics and photonics

## 1. INTRODUCTION

Teaching and learning concepts that are adapted to the constantly evolving requirements due to rapid technological progress are essential for teaching in media technology. A suitable learning environment also plays an important role here. Teaching and studying should be characterized by a student-oriented teaching and learning culture.

The last years were characterized by the implementation of different hands-on concepts in the laboratories and the realization of blended learning scenarios.<sup>1-8</sup> Similarly, the implementation of optical experiments in AR and VR was advanced.<sup>9-12</sup> Following the recent development of a concept for research-oriented teaching in optics and photonics, which includes the integration of a concrete doctoral project within the framework of a seminar, the next step will now be a conceptual restructuring and redesign of the entire curriculum for teaching in media technology.<sup>13-15</sup> The areas of research and teaching are to be specifically linked within the framework of research-oriented education. A defined strategy is pursued in order to convey all necessary topics and competencies in a vivid and intensive manner. By including typical research activities as essential components in the learning process, research is to be made visible and tangible for students. At the same time, a broader platform for practical projects and applied research can be created, opening up a multitude of new development opportunities for learners and teachers.

## 2. EDUCATION AT THE FACULTY OF MEDIA AT OFFENBURG UNIVERSITY

Offenburg University is a university of applied sciences with the independent profiles of technology, business and media. The mission as an educational institution is to enable students to independently apply and develop scientific knowledge and methods through qualified teaching and education. The goal of teaching is to provide students with the best possible qualifications based on a strong scientific and research-oriented education. The development of interdisciplinary competencies is also an important component in promoting the personal development of students. This applies in particular to independent scientific, artistic and creative thinking and working as well as social responsibility.<sup>13-15</sup>

The Faculty of Media focuses on interdisciplinarity. Students are offered a comprehensive range of courses in the fields of media informatics, media technology, media design and media economics. These are specifically combined in courses, lectures, projects and applications. Important for the success of this approach are teaching and learning concepts that are adapted to the constantly evolving requirements, as well as a suitable learning environment. Teaching and studying should be characterized by a student-oriented teaching and learning culture. Therefore, a concept for research-oriented teaching was developed as a further development of existing approaches. The areas of research and teaching are to be linked in a targeted manner. The best possible qualification of the students is to be achieved on the basis of a strong scientific and research-oriented education, which also includes the acquisition of important interdisciplinary competences.<sup>13-19</sup>

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Offenburg University has established the format of research-oriented education as a central principle of teaching in its mission statement. The concept developed at the Faculty of Media aims to familiarize students with current research topics and processes already in their first semesters. Typical research activities are integrated as essential elements in the learning process. Students are supported in developing from a comprehensible understanding of research topics, research processes, research methods and research results to conducting research as independently as possible. A research-oriented education combines the theoretical and practical aspects of the scientific cognition process and promotes the development of interdisciplinary competencies.<sup>13-15</sup>

### 3. REORGANIZATION OF THE CURRICULUM

Students in the media faculty at Offenburg University gain a comprehensive overarching insight into the world of media. The existing curriculum of the study program "Media and Information Engineering" is based on the four defined main fields of technology, informatics, design and economics, which are handled as independent pillars, but are interconnected in terms of content in an interdisciplinary manner. The program is designed for a standard period of study of seven semesters and enables students to obtain a Bachelor of Science (BA Sc.) degree. While in the first study section (semesters 1-3) these four fields are covered with fixed mandatory course content and lectures, in the second study section (semesters 4-7) students can specialize. They can choose a field as a focus of study according to their inclinations and the desired professional perspective. In principle, however, all fields can also be freely combined. The fourth semester is intended as an internship semester and is absolved in a company.

Due to this interdisciplinary approach, we have always noticed a high level of heterogeneity within the student body. The level of qualification can vary greatly, not least due to the German education system. The broad content of the study program also ensures that different inclinations, e.g. toward economics or design, can be identified. This has always been a challenge for the design of teaching. The Covid 19 pandemic has exacerbated these challenges. We are increasingly noticing that expected and required prior knowledge is missing and that soft skills such as the ability to concentrate or to work independently have also decreased among students. In order to be able to meet these challenges, a new concept for the curriculum of the study program is being developed, which is currently in the final planning phase and is then to be implemented in the summer semester of 2023. It has already been decided to rename the study program in "Media and Communication". The basis for this redesign is a set of goals that are aligned with one another and respond to the changed situation of first-year students.

- Goal 1: Teaching in the first study section should pick up the first-year students and get them excited about the courses.
- Goal 2: The contents of the first study section are intended to provide the necessary knowledge and give sufficient insight into the possible specializations in the further course of study. This is intended to provide the students the opportunity for orientation at an early stage.
- Goal 3: The scope of the first study section should be adjusted so that it is not overloaded and fragmented into what feels like too many different subsections.
- Goal 4: The fundamentally desired interdisciplinarity should once again be placed more strongly at the center of the study program and also be anchored in concrete lectures in the curriculum.

In order to implement these goals, the basic structure of the study program and the structure of the study sections were changed. The first study section has been shortened to two semesters, giving the second study section a higher weighting for the possible specialization of certain study focuses. The internship semester is moved from the fourth to the fifth semester, which means that students already have broader and deeper specialist knowledge here when they complete it in a company.

The interdisciplinary approach with the four main fields of technology, design, informatics and economics has been retained. Newly created is an additional area for social and scientific skills. This means that events such as "Scientific work", "Ethics", "Creativity" or "Rhetoric and presentation techniques" are deliberately given more prominence and are already offered in the first study section. These courses are already anchored in the curriculum, but have always been part of the second study section. Experience and insights from the implementation of a concept for research-oriented education in the field of media technology demonstrate that this is the right approach to support students here at an early stage.<sup>13-15</sup>

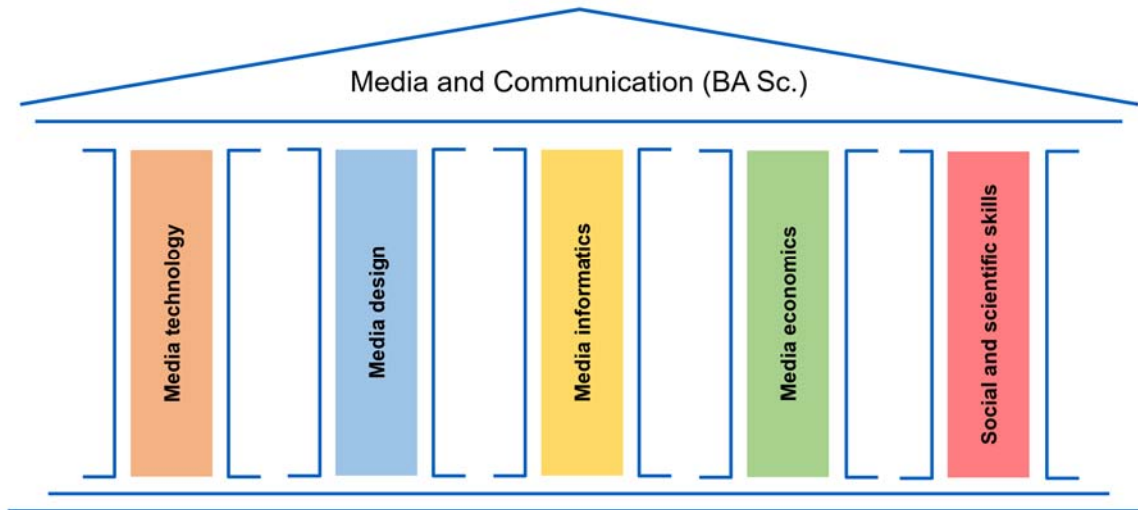


Figure 1. The new organization of the study program “Media and Communication” is based on an interdisciplinary approach with five main fields of study (pillars).

The importance of this content for the students but also for the design of the content of the study program became clear. This new structure naturally makes it necessary that an adjustment of the teaching must also take place. In order to emphasize the equivalence of all fields, one module per semester with 6 credit points (European Credit Transfer and Accumulation System ECTS) is offered in the first study section. This results in a volume of 25 credit points to be achieved by the students in semester 1 as well as in semester 2.

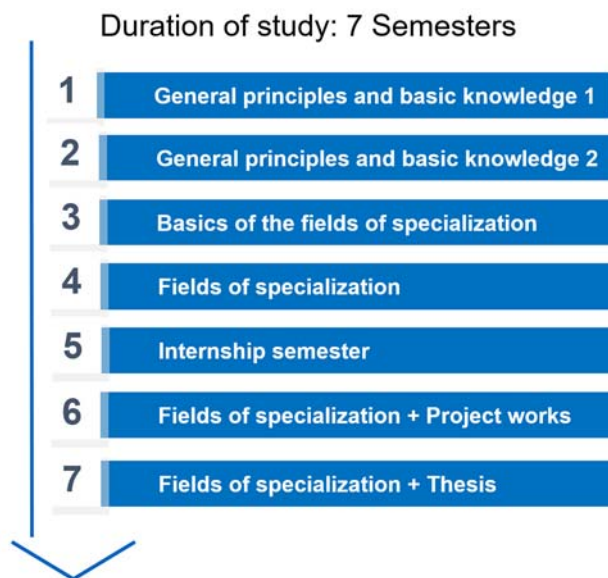


Figure 2. Organization of the planned study program over 7 semesters.

The third semester represents the most significant structural and organizational change. After a broad basic study with contents of all main fields, this semester should serve the students to specialize according to their inclination. For each of the four main fields, 2 modules with 5 credit points (ECTS) are offered. In addition, another module is planned to sharpen social and scientific skills. The students have the possibility to choose six of these nine modules. These provide the necessary advanced fundamentals for the lectures offered for specialization in the second study section and are a prerequisite for the respective further following courses. The interdisciplinary basic idea of the study program is therefore also maintained here, because initially only one main field can be completely deselected. The experiences of the last years indicate that an initial orientation of the students takes place relatively quickly, and early in the studies certain main fields

are excluded for the later specialization. The concrete specialization usually develops after attending the lectures in the second study section. And this experience is considered in the organizational form chosen for the third semester.

### New organization of Semester 3

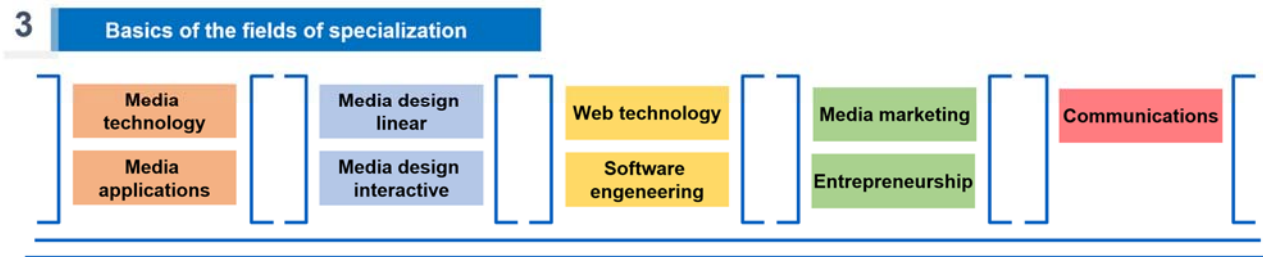


Figure 3. The redesigned modules in the various main fields (pillars) include the necessary advanced fundamentals for the specialization lectures offered in the second section of the study program.

Semesters 4 - 7 of the second study section include mandatory modules that must be completed by all students. These mandatory modules comprise a workload of 65 credit points (ECTS). In semester 5, the professional business internship is to be carried out. In addition, the completion of a project work (duration 1 semester) as well as the attendance of the module “Ethics and Media Criticism” and two further so-called cross-sectional competencies is mandatory. To complete the program, the final thesis must then be carried out to obtain the Bachelor of Science degree.

The so-called elective courses, which enable specialization within the main fields of media technology, design, informatics and economics, can be freely selected from the curriculum. There are 11 modules to be completed with a workload of 55 credit points (ECTS). In principle, the content of the individual courses here is based on the existing curriculum. A clear pillar assignment remains in place. At the same time, however, a great deal of emphasis is placed on interdisciplinarity through new courses. For example, existing laboratories are merged and synergies are exploited to enable cross-field collaboration. The world of media in particular offers an unbelievable amount of potential and opportunities, which will also be combined in teaching within the framework of a wide variety of projects. Technology, design, informatics and economics are not mutually exclusive, but are inseparably linked. These potentials must be exploited in order to offer the best possible teaching.

## 4. REORGANIZATION OF TEACHING IN MEDIA TECHNOLOGY

The realization of the new curriculum for the study program “Media and Communication” is both an opportunity and a challenge. The main challenge is to reduce the workload for students in the first part of the program. This is due to the new weighting and intended equality of all main fields (pillars). Therefore, a detailed adjustment of the lecture contents has to be made. The high opportunity for teaching is that it is no longer necessary to take all students regardless of their preferences. The possibility of specialization from the third semester onwards promises to work with a smaller group of students who have consciously chosen media technology and also have the corresponding motivation and enthusiasm. This makes it possible to raise the teaching to a higher level and also to place current research topics. The second study section must be expanded in a specific manner and include a high practical component in the form of projects. Interdisciplinarity will be given high priority, as this is the great strength of media technology. There are no media projects and media installations without media technology.

To further develop the teaching of media technology, we continue to rely on the existing hands-on concepts, blended learning and research-oriented education.<sup>1, 4-6, 13-15</sup> Not least, because of the challenges caused by the Covid 19 pandemic, we are working towards even more digitization and virtualization of teaching.<sup>9-11</sup> By further developing the existing teaching and learning concepts and creating an open and modern learning environment, a broad platform for practical projects as well as applied research is to be created. A student-oriented teaching and learning culture creates new opportunities for development and advancement for both learners and teachers.

The first challenge for the realigned teaching is therefore the design of the first study section. Because the new structure involves a significantly reduced workload for students compared to the existing curriculum, the course content can no longer be taught to the same extent as before. This means that a minimum requirement had to be defined, which level of knowledge should be achieved for all students, regardless of their inclinations. At the same time, this level is also the basis

for the following specializations. Various topics and contents have to be shifted to the second study section. This makes it possible to consciously set new focal points and at the same time increase the level of requirements. The aim is to design the lectures in the first study section (semesters 1 and 2) in such a way that as many interested students as possible can be inspired and attracted to the field of media technology.

In order to meet this challenge and achieve the goals we have set for ourselves, the number of hands-on courses will be increased in the first section of the study program and the content of the traditional lectures will be changed. The separation into mathematics, physics, electrical engineering and digital media that existed in the previous curriculum will be abolished; all courses will now be taught under the title “Media technology”. The focus of teaching will be on the various media technologies and the underlying physics, mathematics and electrical engineering will be taught in the direct context of the respective technical subject area. This creates a much higher level of acceptance for these topics and clarifies why exactly these fundamentals are so important. In recent years, it was unfortunately evident that, also due to the observed high heterogeneity within the student body, these subjects met with a low level of acceptance and the usefulness of these lectures within the curriculum was questioned. In parallel to the lectures, various hands-on workshops are offered in the media technology lab. At the end of the first study section, there is a final event with a defined practical part. This is also used to present current projects and research work in order to demonstrate the perspectives of the courses offered in the field of media technology in the further stages of the studies.

The second section of the study program begins with the third semester, in which the fundamentals for the desired specialization are established. Two modules with 5 credit points (ECTS) each are offered to deepen the basic knowledge, which must be completed as a prerequisite for the further courses in the field of media technology. The module “Media Technology” contains advanced physical and electrotechnical basics as well as basics of sensor and microcontroller technology. The contents of the module “Media applications” are more specific. Here, on the one hand, basics of audio-video (AV) studio technology and broadcast technology are offered, as well as basics of print production. These modules must be completed as a prerequisite by all students in order to be able to attend the advanced courses offered in the following semesters in the area of media technology. Starting in the fourth semester, the range of courses is broad and includes many hands-on activities. The modules offered here are "Broadcast technology," "Audio-Video (AV) studio technology," and "Printing technologies and print production. In addition, participation in current research projects is also made possible as part of the "Research and projects" module.

### New organization of teaching in media technology

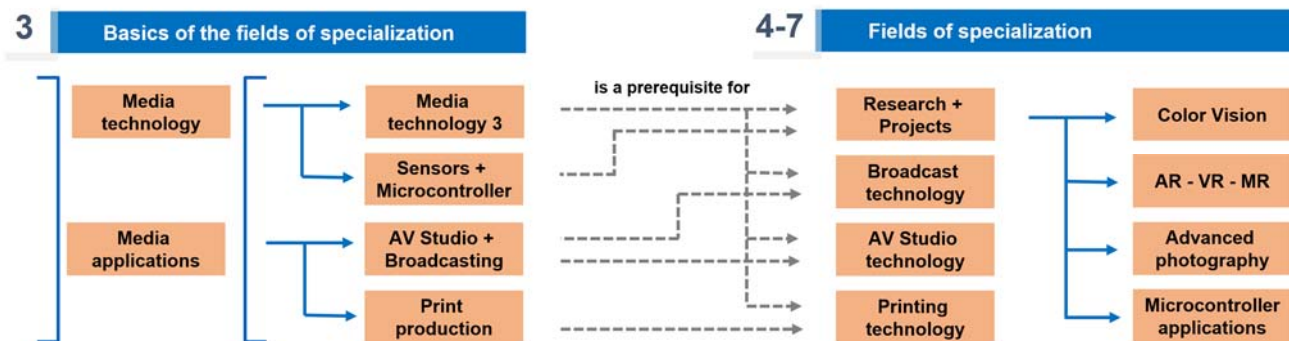


Figure 4. Overview of the new organization of teaching in media technology with all advanced courses offered.

In the course "AV studio technology", the structure and function of a digital audio-video studio are conveyed in detail by a series of different laboratory exercises and practically developed by the participants. The main focus is on live broadcasts of events, especially via the Internet in the form of streaming. A fully functional TV studio is available, which is completely IP-based and state of the art, to enable the students to work with an IP infrastructure and fiber optic technology. A variety of university live events and live studio productions are realized and produced as part of this course.<sup>8</sup>

The course "Broadcast technology" focuses on the development of competencies through the independent acquisition of comprehensive knowledge in the fields of TV and radio technology, transmission and high-frequency technology in the digital broadcast sector. Production, distribution and in particular the transmission of audio and video signals by electromagnetic waves or by cable from the transmitting station to the receiver form the knowledge basis. Mathematical

and modulation backgrounds of the most important digital video standards and their possible fields of application are also essential.

The aim of the course "Printing technology and print production" is to create a basic understanding of the development and production of print products among students. In addition to the current market situation of the entire printing industry, they will learn above all about the interrelationships between specific product configurations and the latest printing processes. They also gain detailed knowledge of the technical processes and thus the differences between the many available printing technologies. Another focus here is also on the constantly detectable innovation through new technological developments.

Under the title "Research and projects", students are offered participation in current research projects, thus realizing research-oriented education on real projects. Here, all the fundamentals of scientific work and research taught during the course of studies are brought together and applied in practice. Students are thus given the opportunity to systematically familiarize themselves with an entire research process. Students should not only understand this, but also be able to construct, apply and reflect on it themselves. The implementation of the research, the evaluation and presentation of the results up to the reflection of the entire research process is completely in the hands of the students. This gives them the opportunity to experience all the different aspects of research.<sup>13-15</sup>

The title of the first research project is "Characterization of color vision by spectrometry and nanotechnology: application for media photonics". This research will examine specific properties of display technologies in relation to typical features of human visual perception. The research focuses on how quantum dots (QDs) modify the color representation capabilities of liquid crystal displays (LCDs). The focus is on the visual perception of the spectrum produced by these nanoparticles in interaction with the backlight of the display.<sup>20</sup>

The research project "AR, VR, MR: a new challenge in digital teaching of optics and photonics" focuses on the realization of virtual experiments and laboratory environments. The goal is not to replace real experiments, but to extend them digitally. Complex topics shall be supported in an informative and innovative way. The research aims to gain new insights in the field of e-learning in conjunction with augmented reality (AR) virtual reality (VR) and mixed reality (MR) technology. Among other things, the core question of the compatibility of the individual media components will be explored.<sup>9-12</sup>

Various projects are brought together under the title "Advanced photography". These are interdisciplinary projects in which optics and photonics are specifically applied in art, which should lead to concrete art installations.<sup>7, 21</sup> Currently, the focus is on the variety and artistic possibilities in photography through polarization. A mathematical modeling of polarization by Jones matrices will be done and will be visualized by practical photographic examples. Another focus is the photography of astronomical events and their media accompaniment, e.g. via live streaming.<sup>22, 23</sup> There is also the opportunity to work with a scanning electron microscope (SEM), which enables images of object surfaces with a high depth of field to be produced. These are then colorized by the students to produce a creative artistic reference.<sup>24</sup>

A final project focus is set with "Microcontrollers with media technology applications". In this interdisciplinary course, microcontrollers are used in a variety of ways to convey content from the fields of optics and photonics. They can be used to control LEDs, light detectors, and infrared sensors, allowing the construction of measurement devices such as a photometer, a light barrier, or an optical range finder. But also media technology applications such as the programming and control of displays, cameras or the control of mixing consoles are possible.<sup>1, 4</sup>

## 5. PERSPECTIVE

The reorganization of the curriculum of the study program allows us to bring together all the previous advancements of our teaching concept towards research-oriented education. At the same time, we also get the chance to set new focal points in order to meet the challenge of inspiring students for media technology. We believe it is very important to familiarize students with research and scientific work by integrating real research projects. The areas of research and teaching must be very consciously linked. Become. For this purpose, typical research activities must be integrated as essential components in the learning process, in order to make research visible and tangible for the students. Through this expansion to research-oriented education, we hope for an even higher motivation to deepen knowledge and to work independently within the framework of the offered teaching. We want to achieve the best possible qualification of our students, which is only possible through a strong scientific and research-oriented education.

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