Realization of a concept for research-oriented photonics education

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ABSTRACT

This paper explains the realization of a concept for research-oriented photonics education. Using the example of the integration of an actual PhD project, it is shown how students are familiarized with the topic of research and scientific work in the first semesters. Typical research activities are included as essential parts of the learning process. Research should be made visible and tangible for the students. The authors will present all aspects of the learning environment, their impressions and experiences with the implemented scenario, as well as first evaluation results of the students.

Keywords: education and research, research-oriented education, learning scenario, optics and photonics.

1. INTRODUCTION

It is the responsibility of the universities to enable their students to independently apply and further develop scientific knowledge and methods through qualified teaching. The aim of teaching is to provide students with the best possible qualification on the basis of a strong scientific and research-oriented education, which also includes the development of important interdisciplinary skills. In accordance with the mission statement of Offenburg University, all students should be supported in their personal development. This applies in particular to independent scientific, artistic and creative thinking and working as well as social responsibility. [1]

The Faculty of Media and Information Engineering focuses on interdisciplinarity. Students are offered an extensive range of courses in the fields of media informatics, media technology, media design and media economics. These are specifically brought together in courses, lectures, projects and applications. Important for the success of this approach are teaching and learning concepts adapted to the constantly developing 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 education was developed as a further development of the existing approaches. The fields of research and teaching should be specifically linked within the framework of research-oriented education. A defined strategy will be pursued in order to convey all necessary topics and competences in a clear and intensive way. 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. [19] [20]

2. A CONCEPT FOR RESEARCH-ORIENTED EDUCATION

Offenburg University has established the format of research-oriented education as the central guiding principle of teaching in its mission statement. The concept of research-oriented education is to be integrated into all degree programs and modules and increasingly practiced at the university. The term "research-oriented education" provides the framework for a wide range of possibilities to combine the two principal activity fields of the university, research and teaching. [1]

The term "research-oriented education" describes a variety of courses that link the areas of research and teaching. The concept developed at the Faculty of Media and Information Engineering intends to familiarize students with current research topics and processes in their subject area already in the first semesters. Typical research activities are integrated as essential elements of the learning process. Students are supported in moving from a comprehensible understanding of research topics, research processes, research methods and research results to the most autonomous research possible. Research should be visible and tangible. Research-oriented education combines the theoretical and practical aspects of the scientific knowledge process and encourages the development of interdisciplinary competences. [2] [3] [4] [8] [10] [19] [20]

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2.1 Theoretical basis

In the literature, different theoretical models for the systematic classification of the combination of research and teaching and learning are presented. The internationally most popular model for systematizing research-related education was developed by Healey and Jenkins. Two focal points, the content focus and the degree of student activity, are used to divide the different forms of implementation. The combination of these two dimensions results in four different types of research reference in university teaching, which are presented in the so-called Research Teaching Nexus. Huber pursues a similar, also strongly receptive systematization approach. First, the common references of the different approaches are established and then their distinguishing features are described. This results in a classification of research-related education into three types, whereby he emphasizes the similarities with the Research Teaching Nexus of Healey and Jenkins. Rueß, Gess and Deicke take a less theoretical approach. Their systematization of research-related education is based on an analysis of the curricula of various universities. Here, too, the starting point is the differentiation between the focus of teaching and the level of activity of the students. The combination of these two comparative categories is used to create a classification matrix with three subcategories each. This can be used empirically to distinguish twelve groups of research-related education. It is general and applicable to all disciplines. [2] [3] [4] [5] [6] [7] [8] [9] [19] [20]

2.2 Objectives

At the center of the concept is the general demand that research should be made visible and tangible for students. The students are offered a concrete research context in courses in order to gain an insight into scientific work. The primary objective is the best possible qualification of the students on the basis of strong scientific and research-oriented education, which also includes the acquisition of important interdisciplinary skills. By combining theoretical knowledge with practical research work during the studies, it should be ensured that students not only develop a deeper understanding of science, but also a positive attitude towards research. For this reason, they need methodological research skills, but above all the ability to critically reflect on research activities and results. Students should gain experience in scientific cooperation with educational researchers and be systematically prepared for possible future activities in research or development. [2] [3] [4] [8] [10] [19] [20]

2.3 Teaching formats and digital tools

Students should be able to experience research, they should experience research in practice. Based on the Research Teaching Nexus, different teaching formats have been implemented to realize different aspects of research-oriented education (see Fig. 1). For this purpose, a framework of courses was created, which includes the acquisition of necessary theoretical knowledge and the independent processing of genuine, current, real or realistic problem situations. The students are supported by the teachers. The mutual exchange between teachers and students as well as among students is an important element in this concept. [2] [3] [4] [8] [9] [10] [19] [20]

The concept of the Faculty of Media and Information Engineering implements the research-oriented education with the selected teaching formats lecture, exercise, laboratory, seminar and study project. A closer look at the implementation shows that, in the sense of the underlying Research Teaching Nexus, not only research-oriented education is offered, but that there are overlaps with all forms of research-related education. This is done consciously, the different aspects of research-related education should be used in the different teaching formats. Lectures provide the necessary basic knowledge to prepare students for independent research-oriented learning. With the working format exercise, students should gain a deeper understanding of a topic by applying it themselves. It is important that students work on solutions as independently as possible. Laboratory courses are a particularly important part of teaching in engineering and natural sciences. Here students have the opportunity to apply the methods they have learned in practice and to conduct research. Seminars are used on the one hand to teach various interdisciplinary skills. On the other hand, they are also used specifically to give students the opportunity to systematically familiarize themselves with the entire research process. Study projects with a research-oriented design and a complex, open problem-solving approach enable students to apply the acquired knowledge and thus prepare themselves for research tasks that may come, e.g. in a thesis. [2] [3] [4] [8] [9] [11] [12] [19] [20]

For the success of the concept the development of a suitable teaching and learning environment is necessary and crucial. The use of digital tools is essential for research and teaching today, but gains even more importance through the use of blended learning scenarios. Many different digital applications and tools are available in the relevant functional areas of teaching and research: Collaboration, communication, research, documentation, visualization and presentation. It is important to plan the use of digital tools in advance in order to be able to use them effectively throughout the entire

teaching and research process. The choice depends on the teaching format and the level of activity of students and teachers. [13] [14] [19] [20]

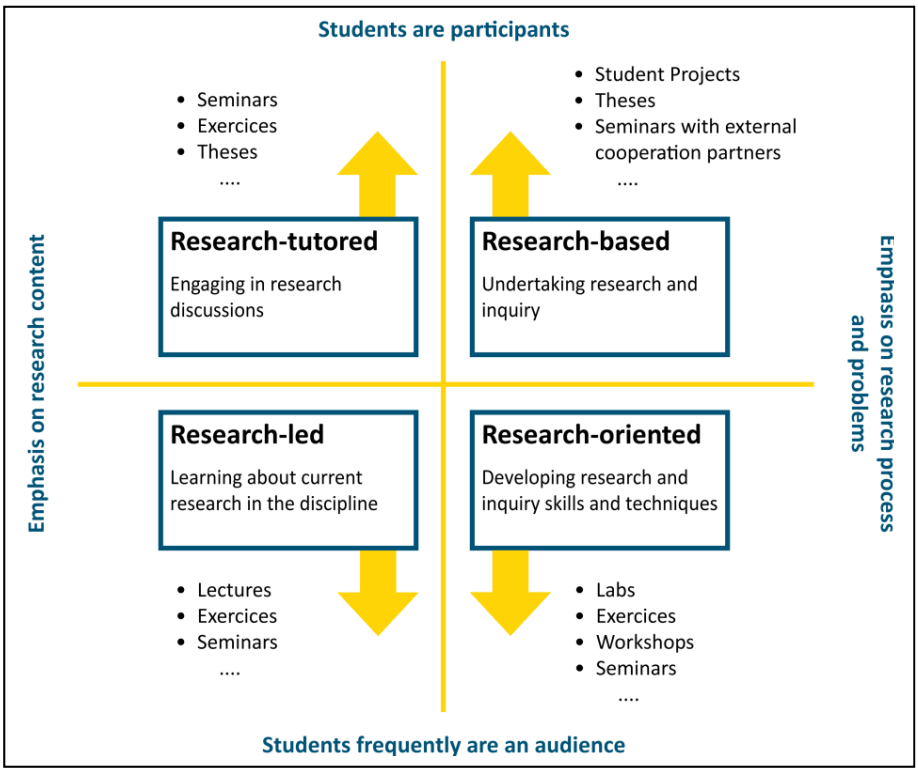

Figure 1. The planned teaching formats used in the concept, presented in the Research-Teaching Nexus. [3] [4] [9]

2.4 The existing blended learning scenario

Blended Learning describes a teaching and learning scenario that provides a didactically meaningful correlation of attendance and online periods. The aim is to improve the intended knowledge transfer and to consciously make individual learning easier. In theory, different models for the implementation of blended learning are described. The blended learning scenario used at the Faculty of Media and Information Engineering is a combination of several of these models, which are used to better structure the comprehensive concept of blended learning. There is a fixed schedule for regular lectures, the planned workshops and self-directed online learning. The e-learning platform moodle used by Offenburg University has a central role in this process. [14] [19] [20]

For the first time, the developed concept was implemented for the Blended Learning Course "Media Technology: Color representation and Display Devices". This course is offered in four consecutive segments in semesters 2 and 3 of the basic study period. As already mentioned, a fixed schedule defines the attendance and online periods (see Fig. 2). Each segment is assigned to a defined content focus. In order to impart the necessary theoretical knowledge, three regular lectures are used per segment (participation is optional). For the online-learning phase, the e-learning platform moodle provides the entire content of the lectures, additional teaching materials and exercises. The online learning phase also helps to enable students to work independently. In order to successfully complete a segment, the respective integrated practical workshop in the media lab must be completed (compulsory attendance). As a prerequisite for participation, an online test must be passed to check the level of knowledge. The results obtained in the practical workshops are published in a lab report and then presented to all participants with a poster. [14] [19] [20]

3. IMPLEMENTATION OF THE CONCEPT

The existing educational concept was further developed in the direction of research-oriented education in order to activate previously unused potentials. As a consistent continuation of the development process that the Blended Learning Course "Media Technology: Color representation and Display Devices" has undergone in recent years, the research

project "Characterization of Color Vision using Spectrometry and Nanotechnology: Application to Media Photonics" has now been integrated into segments 3 and 4. In this way, students are involved in real research activities as part of the teaching and learning process, providing a deeper insight into the topic of research and the key elements of scientific work. This makes it easier for the students to recognize the importance of the acquired theoretical knowledge and to derive new own insights from it. In the scientific knowledge process a combination of theory and practice takes place, which strongly supports the development of specialist knowledge and interdisciplinary skills. [2] [3] [8] [14] [18] [19] [20]

3.1 Extension of the existing blended learning course in the context of research-oriented education

In order to implement the planned concept for research-oriented education, the original structure of the engineering course was redesigned and supplemented with additional teaching formats. This expanded offer provides students with the opportunity to systematically familiarize themselve with the entire research process. A deepening of the content of the main topics as well as the individual steps of the research process is thus made possible. Students should not only be able to understand, but also to construct, apply and reflect themselves. [14] [19] [20]

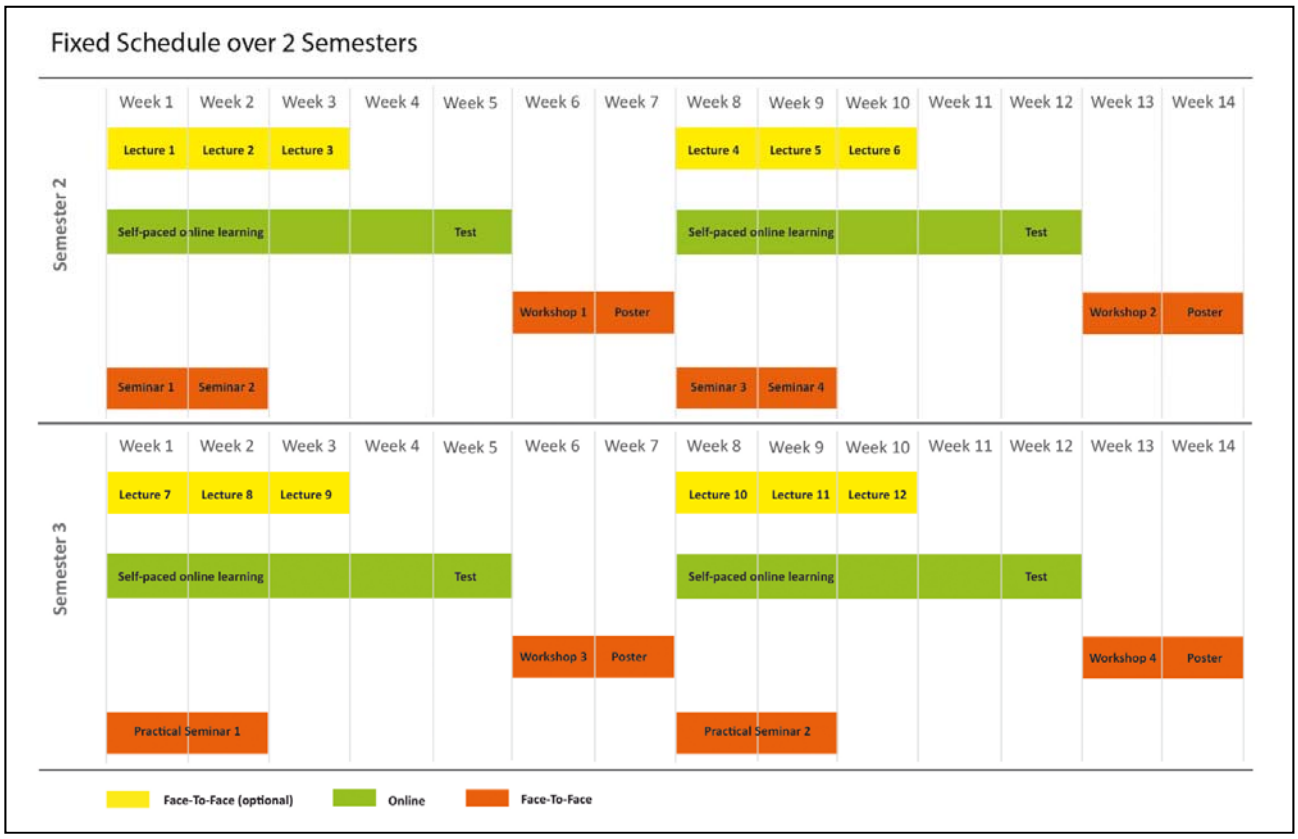

Figure 2. The extended schedule of the blended learning course „Media Technology: Color Representation and Display Devices". [14] [19] [20]

Figure 2 shows the current schedule of the Blended Learning Course "Media Technology: Color representation and Display Devices". This engineering course is an integral part of semesters 2 and 3 of the studies. It is divided into four main topics, which are offered in four segments. The specific theoretical basics are taught in three lectures per segment. At the end of the online-learning phase there is a test which has to be passed in order to be admitted to the practical workshops in the laboratory. In the sense of research-oriented education, this schedule has now been significantly expanded. In segments 1 and 2 four additional seminars are offered to develop and improve interdisciplinary skills. The research project will be integrated into segments 3 and 4 in the format of seminars in the associated laboratory. [14] [19] [20]

3.2 Organization and teaching formats

Segment 1 is under the headline "From light to color". The focus is on the scientific theories and findings of Newton, Maxwell, Hertz, Young, Brewster, Helmholtz and Hering. Segment 2 "Development of the color representation" focuses on colorimetry. It shows how human color perception is physically quantified and described. Segment 3 "From CIE Lab color space to color management" is clearly more application-oriented. The topic is ICC color management with all aspects such as ICC profiles, gamut mapping and rendering intents. And finally, Segment 4 "Color representation on display devices" is an intensive discussion of various display technologies and their applications. The focus is on LCD technology and OLED technology [1] [2] [3] [14] [20]

3.2.1 Lectures on theory

Three regular lectures per segment are used to impart the necessary theoretical knowledge in a fundamental way. The participation is optional. The entire content of the lectures, additional teaching materials and exercises are made available via the central online platform moodle. The classroom sessions can be used by students for personal communication with the lecturer. The online learning phase is designed to encourage students to work independently. Support by the teacher is also provided online. Here it became apparent that for some students personal contact was very important. For this reason, direct on-site support was provided in the form of small group sessions. At the end of this phase an online test is available, which must be passed in order to participate in the practical workshops in the Media Technology Lab. [14] [19] [20]

3.2.2 Practical workshops in the laboratory

To successfully complete segments 1 and 2, the respective integrated practical workshop in the media laboratory must be completed. Active participation is mandatory for all students. Various experiments on the subject of light and color, based on the imparted theoretical knowledge, must be carried out. Experimental tasks should be solved as independently as possible with a given experimental setup. The use of different measuring instruments will be explained. Personal communication with the teacher is very important, as most students have little or no experience with such tasks. The results of the workshop will be published in a laboratory report and then presented to all participants with a poster. [14] [19] [20]

3.2.3 Interdisciplinary seminars

The range of courses in Semester 2 will be expanded by four additional seminars (two per segment). These have the aim to develop and promote interdisciplinary competences. Seminar 1 has the title "Scientific Writing". Theoretical basics as well as the application of the imparted contents are taught using selected and own examples. Furthermore, the research and management of literature with the help of the software Citavi is presented. This program is provided by the University of Offenburg to all students free of charge via a campus license. The aim of the seminar is to prepare and support the preparation of scientific papers. Seminar 2 "Presentation Techniques and Rhetoric" focuses on the specific preparation for upcoming presentations and talks. It is taught how projects and ideas are presented professionally and convincingly. Aspects such as oral pronunciation are also taken into account, as well as the confident appearance and natural charisma of the presenter. In this seminar, all important principles of presentation creation are imparted, combined with a variety of practical tips and tools. Seminar 3, entitled "Intuition and Creativity", aims to identify and promote creativity and intuition potentials. For the students it is not only important to understand creativity and intuition, but also to experience and explore them. For this purpose, a creativity-promoting environment is designed. Only in this way can creative results be assessed and used. The fourth seminar "Rational Decision Making" concludes the accompanying interdisciplinary seminar series. Here basic techniques are presented, with the help of which decision situations can be modelled and resolved in such a way that a decision made can be formally justified. The focus is on behavioral and decision theory. In this way, students should learn to question their own decision-making behaviour. [19] [20]

3.2.4 Seminars for the integration of the research project

In the third semester, the research orientation is now being established. For this purpose, various seminars are offered in the media technology laboratory. The basis will be concrete tasks of the PhD project "Characterization of Color Vision by Spectrometry and Nanotechnology": Application for Media Photonics". This is an international cooperation between the ICube Institute of the University of Strasbourg (France) and the Faculty of Media and Information Engineering of Offenburg University (Germany). Within this research, specific characteristics of display technologies are studied in relation to typical features of human visual perception. The research focuses on the question of how quantum dots (QDs)

change the possibilities of color rendering of LCDs. The focus here is on the visual perception of the spectrum that these nanoparticles produce in interaction with the backlight. Various aspects of the research project are integrated into the offered seminars. The research project can be viewed and reflected upon as a whole, even if it does not cover the entire research cycle. These seminars offer the students the opportunity to experience different aspects of research. On the other hand, the lecturer has the opportunity to report on a personal level about his own work as a researcher. For the seminars, the research environment specially designed for the research project is used. The technical setup consists of four available test displays, a spectrometer, four different display calibration devices, as well as the necessary computers and software applications to control the devices. [18] [19] [20]

"ICC Color Management" is the title of the first research-oriented seminar in Segment 3. Color management has the goal of achieving the best possible color consistency between the various input and output devices in a production workflow. Color reproduction should be predictable and reproducible at any time. In order to impart the importance of a standardized workflow especially in media production, the students are given various tasks. These are based on the colorimetric studies that are conducted within the research project. The first step is a performance benchmarking of the used test displays. The obtained results are compared with the results of the research and can be used for their evaluation. They also enable a long-term study of the performance of the displays. This is followed by a color calibration of the displays, for which four different display calibration devices are available. In addition, a study is discussed which examines the influence of the used displays and color calibration devices on the quality of the color rendering and evaluates it objectively. The obtained data can also be used to evaluate the study. [18] [19] [20]

The final seminar in segment 4 is entitled "Color Matching Experiments". Here the identical color matching experiments of the research project will be conducted. The test person has the basic task of mixing a target color shown on the display in an inserted mask with the help of the three primary colors red, green and blue until the visual match is as accurate as possible. The target colors were selected based on the x-rite ColorChecker Classic Target. The experiments are conducted with two different test geometries, i.e. in two steps. For step 1, 10 target colors were selected. These are shown one after the other in a defined order on the display. This means that only one color field is shown at a time, a change will only take place when the task is completed. The displayed color patch has the size of 10 x 10 cm. In the center there is a circular mask with a diameter of 5 cm. In step 2, the complete x-rite ColorChecker Classic Target is shown on the display. This has a total size of 29 x 19 cm. Included are 24 color patches with a size of 4 x 4 cm. Each of these color patches is provided with a circular mask with a diameter of 2.2 cm. The task here is also the mixing up to the visual congruence. The processing sequence is not specified here, however, it can be freely selected. Subsequently, all spectral values of the processed color fields are measured with a spectrometer. These are then compared with the stored digital color values in a standardized reference system and possible color differences are determined. The exact evaluation of the expected intrapersonal and interpersonal variations allows conclusions to be drawn which contribute to a better understanding of individual observers and their color perception. By continuing the experiments outside the research project, the amount of data obtained will be significantly increased. A continuous evaluation and updating of the data obtained in the research process is made possible. [18] [19] [20]

3.2.5 Digital tools

The central application is the e-learning platform moodle. It offers the students easy access to all provided online learning materials with many interaction possibilities. All content such as lecture notes, additional literature, scientific papers and documents are made available here. Animations, videos and podcasts to visualize the content are integrated as well as preparatory exercises, tasks and tests to check the level of knowledge. Video tutorials and detailed technical instructions are available to prepare for the workshops in the Media Technology Lab. Further different software applications are used for presentation and visualization (MS PowerPoint, Affinity Designer, Prezi), research (Citavi, EvaSys, LimeSurvey, Wisemapping), collaboration and communication (Zoom, Trello) and documentation (Trello). These are provided by the university via campus licenses or can be used as license-free online applications. Tutorials on the required software applications are provided by postgraduates throughout the studies. These tutorials are deliberately designed to meet the needs of the students and are therefore not integrated into the intended organizational structure. [18] [19] [20]

4. EVALUATION

In its new concept, the blended learning course has now been conducted for the first time in the winter semester 2020/2021 and summer semester 2021. Twelve students took part and were divided into four teams of three students each for all practical tasks. At the end of the course, the participants were asked to fill out an evaluation form and to

critically review the course in order to identify potential for improvement from the students' point of view. The standard short questionnaire of the Offenburg University for the evaluation of lectures was used. It is divided into five segments with corresponding questions. Segments 2 and 3 were to be answered specifically only in relation to the research-oriented seminars in semester 3. In segment 5 AOB, questions 5.2 and 5.3 may be commented with texts (see figure 3).

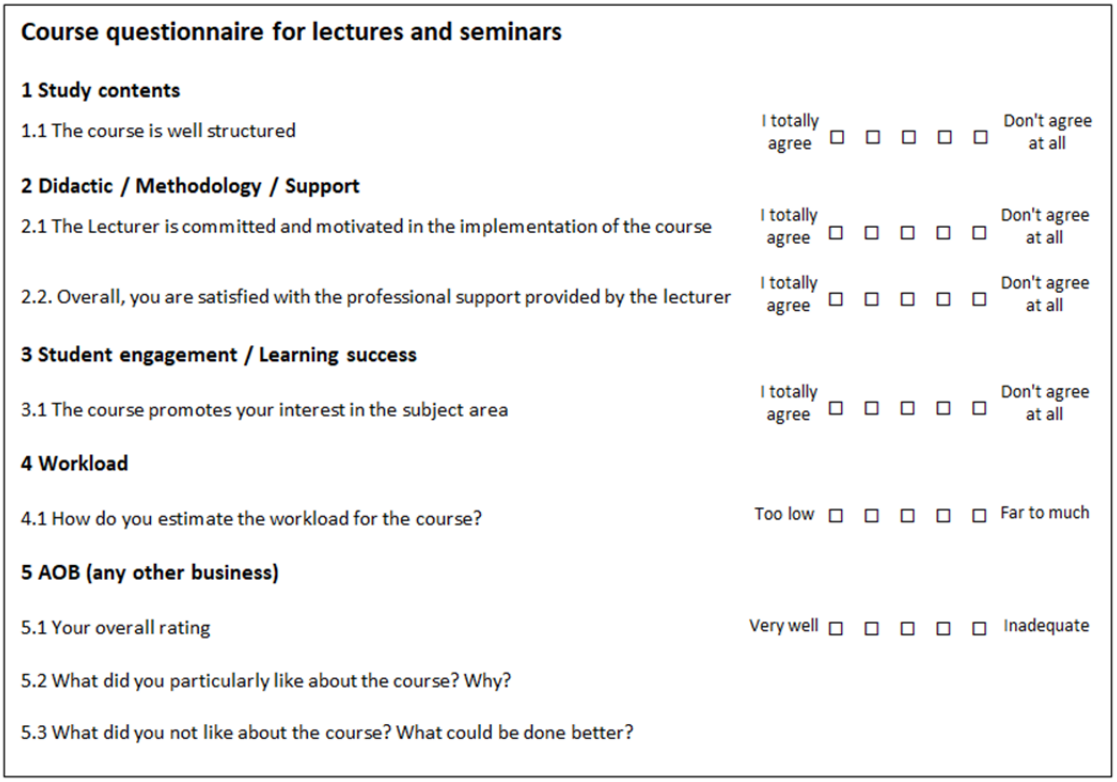

Figure 3. Content summary of the standard short questionnaire of Offenburg University for the evaluation of lectures.

The results of the evaluation are very encouraging and validate the implemented concept of research-oriented education. The structure, the organization of the blended learning course was assessed as good to very good. The comments on question 5.2 show that especially the mix of classroom teaching and the self-determined online phase was very well accepted. The communication and interaction with the lecturer was also evaluated very positively. This is very important for the students. The research-oriented seminars in Semester 3 were also highlighted as successful. Above all, the change of perspective to conduct experiments in the context of a research project and to be able to exchange ideas with the lecturer about the entire research process has changed the students' view of their studies.

Didactics, methodology and support in the research-oriented seminars in semester 3 were predominantly rated as very good. The work with the students in small groups of 3 persons has proven to be very successful. This makes communication and interaction easier and encourages the ability to work in a team. It has also been shown that strengths and weaknesses of the individual participants in the group usually balance each other out. This enables the lecturer to deal with them more individually, which is seen as very positive by the students. The support by the lecturer is evaluated as predominantly very good. When evaluating the workload, the picture is somewhat more mixed. Here, the time spent on the course, especially preparation and follow-up work, should be assessed. The majority of participants consider the workload to be well adapted, but three participants also say that more time than usual had to be invested. This reflects a continuous observation of the last few years that the knowledge level of first-year students often varies considerably, which of course makes it difficult to estimate the amount of time required for the individual student.

The evaluation should conclude with an overall assessment of the blended learning course "Media Technology: Color Representation and Display Devices". 10 times the evaluation very good with 12 participants is an extremely pleasing result. At the end of the evaluation there was the possibility to comment on what was particularly good or what was negative. Here the positive comments clearly predominate. The statements on structure, organization and communication

were already mentioned. But also the stringent combination of necessary theory with practical workshops, in which the imparted theory must be applied, has convinced the students. The interdisciplinary seminars offered in Semester 1 are also considered important. Here in particular, the students have recognized that important competences are developed and encouraged here, which they also need in their professional life beyond their studies. However, a slight criticism of the didactics of one of the teachers engaged in this area was also expressed here. A further point of criticism was that the university no longer has a campus license for Adobe software and therefore software from alternative providers is used in the course. The results of this evaluation also show how important good communication between students and lecturers is. Many uncertainties and problems could be solved directly in this way. Suggestions and alternatives were discussed, which led to a very open and positive atmosphere.

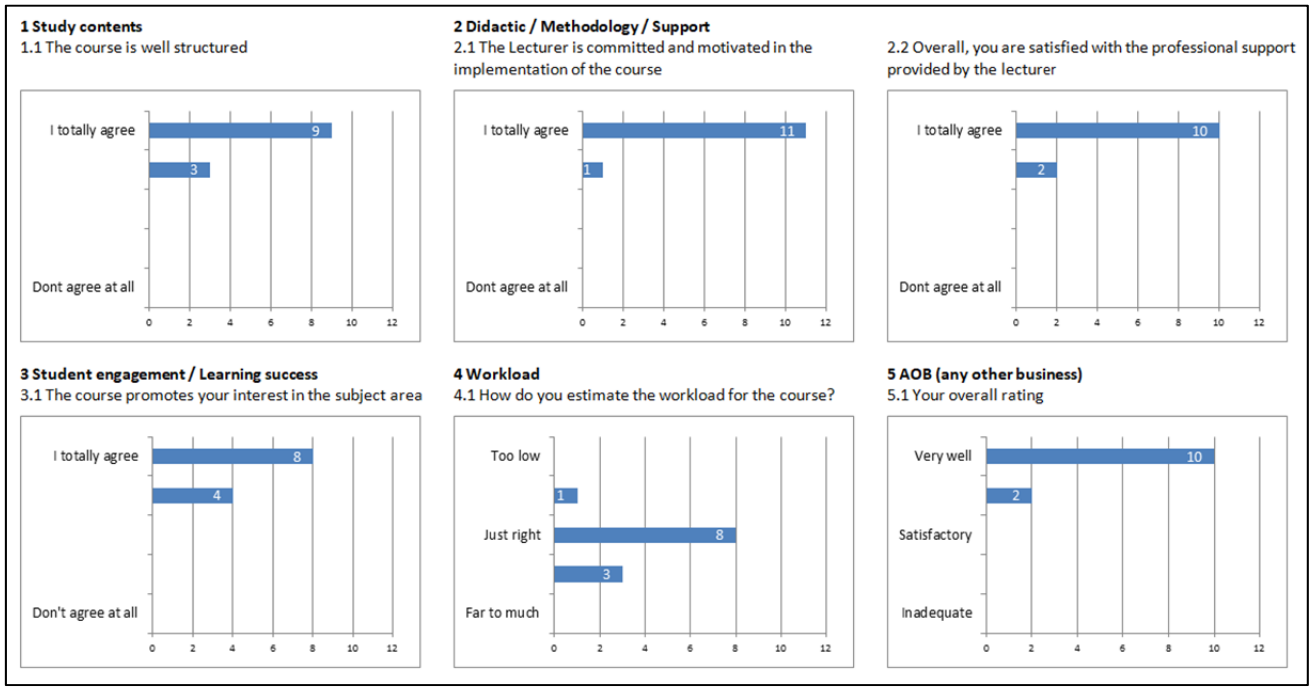

Figure 4. Overview of the results of the questions of the evaluation form, which were to be evaluated by ticking them.

5. PERSPECTIVE

The evaluation shows that the existing educational concept has been successfully expanded towards research-oriented education by combining the areas of teaching and research. By integrating the research project "Characterization of Color Vision by Spectrometry and Nanotechnology: Application to Media Photonics", students are familiarized with the topics of scientific work and research in the first semesters. Typical research activities are integrated as essential parts of the learning process. The expected higher motivation to deepen knowledge and to work independently within the framework of the offered courses can be observed. This is the best prerequisite for achieving the best possible qualification of the students on the basis of a strong scientific and research-oriented education.

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