Broadening personal competence profiles through transdisciplinary project modules

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ABSTRACT

Engineering education today is often organised in discipline-specific modules. Although it is essential to build up basic knowledge, cross-disciplinary knowledge is fundamental for solving complex problems. Transdisciplinary approaches can provide the necessary hard and soft skills, improve self-determination in education and broaden personal competence profiles.

The experience gained is conveyed using the example of project-based modules on the topics of a) AI applications to minimise racial biasing in medical technology and b) construction of microfluidic systems to avoid animal testing. These were developed over several semesters by interdisciplinary student groups involving industry and research partners. The concept was initially carried out online in an interdisciplinary project module focusing on individual learning objectives, composed of the disciplines "Mechanical Engineering", "Computational Engineering Science", "Physical Engineering Sciences" as well as "Biomedical Engineering" and is being expanded in a hybrid-transdisciplinary manner through gradual additions including systems engineering, philosophy and sustainability in technology, ergonomics and human-machine systems.

Through active participation in researching and solving real challenges, collaboration of transdisciplinary teams over several group generations and setting individual learning goals, profound knowledge and new methodological competences can be acquired beyond engineering disciplines. The integration of non-technical methods and approaches allows students to recognise complex problems and identify the necessary competences in order to realise a successful project. To further expand this approach, a new module concept for interdisciplinary cooperation in production engineering was developed. It takes up the aspects of individual, project-based learning and brings together all the competences of the institute in transdisciplinary exchange.

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1 INTRODUCTION

1.1 Current situation

Constant technological change, the increasing acceleration of innovation, and changing work environments are changing the context in which science and teaching take place. However, adaptation to changes can be achieved through tailored teaching and dynamic teamwork. Higher education institutions should prepare students for lifelong learning and social interaction, involving those complex, rapidly changing social and socio-economic team structures. To meet these challenges, appropriate teaching concepts are needed that offer choice and flexibility, promote multi- and interdisciplinary learning, but also teach responsibility, methodological skills and ethical foundations. In an increasingly interconnected world, there is a need to provide the basis for taking global perspectives and experiences that go beyond the learning of engineering disciplines. Being prepared for career and the mixtures of disciplines that come along with it means having the capability of holistic thinking, initiative, self-confidence, creativity, lifelong learning, agility and corresponding methodological competences which should be taught as key components [1].

Transdisciplinary teaching formats represent one approach to this. The greatest challenge at present is to break down the prevailing, discipline-bound specialisation and, thus, fragmentation of thought and action. However, there is still a large gap between the advocacy of cross-disciplinary teaching and reality. Disciplines composed of specialist areas, disconnected modules and methods, each with its own concept of research and learning, have become the fundamental structures of modern universities giving only little space to different formats [2].

In the following, two examples demonstrate how interdisciplinary and transdisciplinary teaching approaches in small project groups of students that have been developed across different generations can look like. The work includes socially relevant problems, with focus on industry involvement.

1.2 Inter- and transdiciplinar teaching approaches: A way to strengthen individual learning goals?

In the 1970s, models have been postulated to promote measures to integrate research across different disciplines and sectors, with intensive collaboration between all participants. Transdisciplinarity has emerged as an approach best suited to enable the integration and implementation of research across disciplines and societal sectors, linking it to intensive participatory processes. Transdisciplinary work in teams is characterised by highly participatory, mixed methods involving science and industry from different disciplines and sectors of society, including those who are expected to benefit from the interventions. These stakeholders are brought into focus from the outset and on an ongoing basis. Although some interdisciplinary and transdisciplinary models overlap, transdisciplinary approaches typically go beyond an interdisciplinary contribution: they involve a transcendent approach, where students create a shared definition of a problem that goes beyond their own disciplines and even create new paradigms and methods for solving real-world problems [3]. For optimal collaboration, a synergistic combination of values, attitudes, skills, knowledge and behaviours must be communicated and taught to students. In particular, values are guiding principles that make team members want to participate, collaborate with others, and become comfortable with unfamiliar theories and methods. Attitudes include a willingness to invest time in learning as well as to adapt individual disciplinary thinking patterns to the demands of teamwork. Behaviours, in turn, include learning activities such as participation in team projects [4].

Further studies reveal what individuals need in order to work together successfully. Research on learning in psychology and education shows three main categories of competencies for successful outcomes: 1. Team knowledge (e.g. task understanding, shared mental models, role knowledge), 2. team skills (e.g. communication, assertiveness, situational awareness), 3. team attitudes (e.g. team orientation, trust, cohesion) [5]. These competences should be aligned with a cross-curricular approach. Furthermore, the approach of solving industry-related, real-life problems in joint teamwork has proven its effectiveness. It offers students the opportunity to experience how interdisciplinary knowledge can be integrated into practice, as well as the ability to challenge themselves to conduct industry-oriented research, giving them access to further postgraduate research.

2 METHODOLOGY: MULTI-GENERATIONAL PROJECTS FOSTERING CROSS-DISCIPLINARY METHODOLOGICAL COMPETENCES

2.1 Project organization procedure

A prerequisite for the interdisciplinary and hence self-determined tracking of individual learning goals is a high level of motivation to participate. For this reason, a broad spectrum of topics is offered, connectivity to current research projects or topics by industrial partners is given, and student co-determination in the setting of tasks is encouraged.

Below the procedure within the project modules is illustrated, adapted on the basis of experience. The currently preferred procedure is shown in Fig.1.

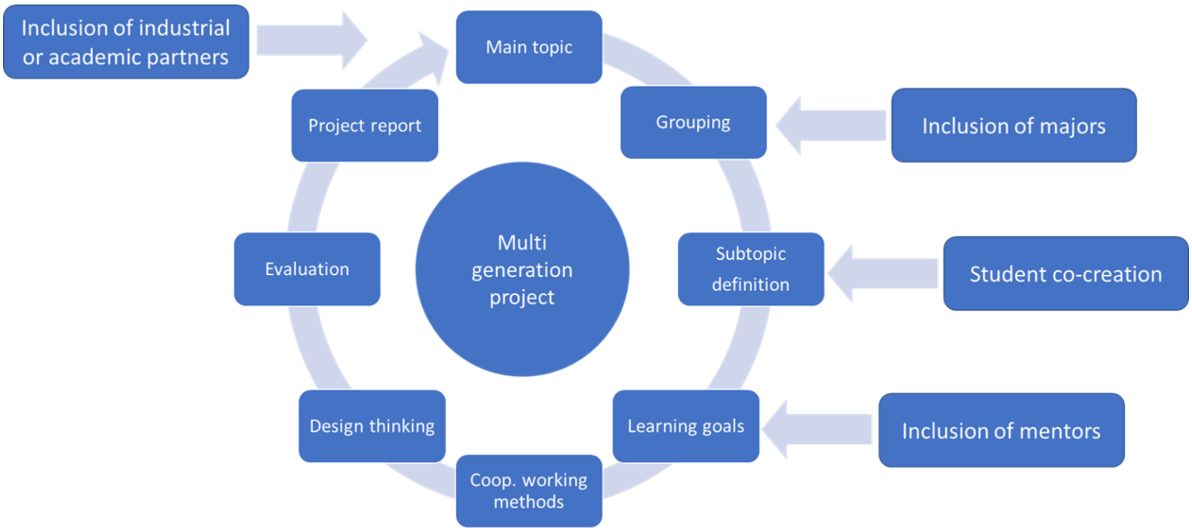

Fig. 1: Currently preferred procedure of the cross-disciplinary project module.

Students are recruited via the ISIS online portal of the TU Berlin. For each main theme, one-minute pitch videos are made available. The topics range from precision engineering, measurement technology, medical technology, micro-assembly, precision machining, micro fluidics, micro-optics, artificial intelligence to teaching topics by and for students. In individual cases, it is also possible for student groups to contribute their own topics. The fundamental requirement is that the task provides socially relevant and practical results that can be further worked on by other groups in subsequent semesters and that the solution requires different subject matter expertise to fulfil a transdisciplinary approach.

Within the limits of possibility, the project is offered to a variance of majors as wide as possible. Involved majors in the past were “Mechanical Engineering”, “Computational Engineering Science”, “Production Engineering”, “Physical Engineering Science”, “Transportation Engineering”, “Biomedical Engineering” and “Patent Engineering”. In the module under way, as well as in a planned expansion, there is involvement of the human factors science, technology assessment, and systems engineering.

On the online portal, students can assign themselves to the respective topic until a predefined group size is reached. The respective group supervisor defines the task in detail in cooperation with the students depending on their abilities, interests and individual learning goals. On this basis the students derive a working plan for the semester.

The following project work is done in regular consultation with the supervisor and progress is evaluated twice during the semester while the evaluation is based on interim presentations. The results of each group will be presented in the presence of the other groups and all supervisors. It is aimed that students actively and critically question their co-students and give hints on possible solutions that can be implemented in the further course. After the second evaluation, the final result is submitted in the form of a project report. This report forms the basis for further developments by subsequent generations of students. Depending on the project being theoretical or practical, the project team additionally presents and explains its results to students from lower semesters taking on a co-teaching part.

2.2 Examples of inter- and transciplinary project modules

The first exemplary student project was originally based on the development of a microfluidic set-up to demonstrate fluidic principles. The system was developed by an interdisciplinary group of students from the fields of biomedical science, production and mechanical engineering being intended to be used by students of lower semesters. The background was to encourage more experienced students to actively participate in preparing and imparting knowledge to other students. Since specific technical subcomponents were necessary for the realisation, industrial contacts to corresponding companies were established through the students' individual contributions. Based on these contacts, further socially relevant research ideas were derived.

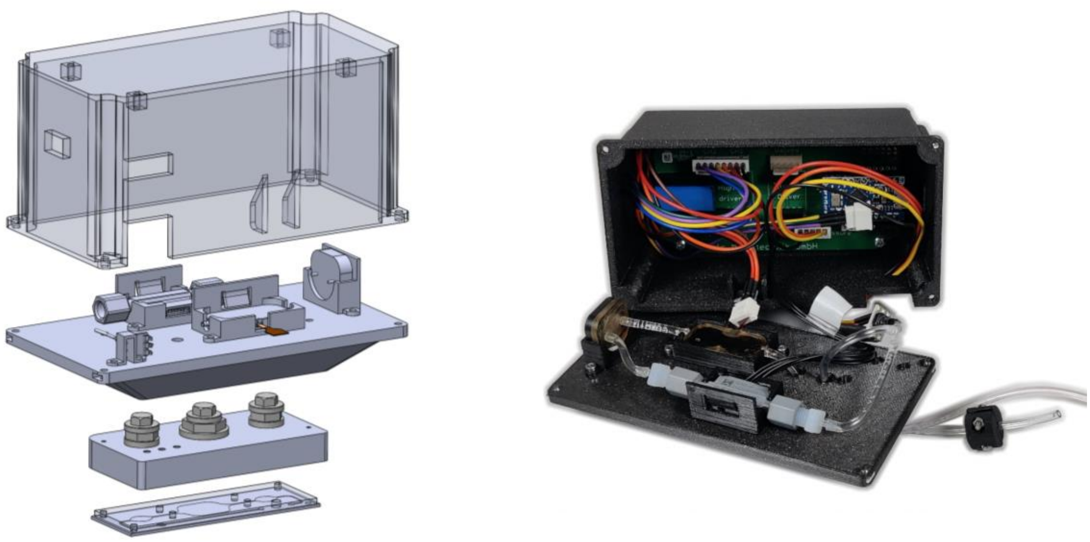

Fig. 2: CAD model of the micro fluidic setup (left) and physical model (right).

The project gave rise to the topic of a multi-organ chip with an integrated heartbeat. Background was to simulate the human body as close to nature as possible with the multi-organ chip, e.g. to determine the influence of drugs or other substances on the body. As part of the transdisciplinary approach, the ethical discussion of the avoidance of animal experiments was a driving motivation for the students. The properties of blood are difficult to reproduce using conventional reference fluids. Thus, experiments with fluids based on a newly developed 2-phase blood by medical and biomedical students of the Charité Berlin in the laboratory for Biofluid Mechanics were conducted. The blood model will further be improved by additional cross-universal investigations of multi-disciplinary groups with similar fluidic systems in the future.

The second project being presented was also developed over several generations of students. In the first iteration, an intelligent spectral measurement system based on low-cost filter sensors was to be built. Students from the fields of computer science and engineering initially collaborated. The students applied basic AI methods to the self-developed electronic system to analyse spectra. On this basis, the possibility of analysing skin pigmentation and vital data analysis was derived by other students' own initiative. The idea was raised to use spectral measurement to actively counteract racial biasing effects in the measurement of vital parameters which still poses a problem in applied systems as well as in consumer products like smart watches.

In addition, to the melanin content as an independent medical parameter, this also acts as a decisive influencing factor for other spectroscopically determined parameters, such as the oxygen content of the blood determined by pulse oximetry. Pulse oximeters are, however, very susceptible to error in heavily pigmented people. This example is frightening when the vital analysis decides on the medical necessity of inpatient or outpatient treatment. These are dramatic examples of racial bias in medicine - the fact that white patients are proportionally more represented in medical studies than people of colour, which leads to a structural disadvantage right from the development phase. This transdisciplinary project idea, thus, should contribute to being able to make statements regarding the melanin content of the skin on the basis of measured values from a non-invasive spectroscopic set-up.

Fig. 3: Measurements of melanin content (left) and comparison with colour charts for the analysis of skin pigmentation (right).

3 RESULTS: LESSONS LEARNED FROM FIRST ITERATIONS

In general, it was observed that the intended motivation for interdisciplinary cooperation, self-determined learning and thematic co-determination could be achieved through the procedure. High-quality results could be derived from this, as well as further final theses, which deepened the students' own learning goal, initiated a self-motivated acquisition of students for subsequent generations by the students themselves and enabled matchmaking with the industry partners.

In the future, however, methodological adjustments will be necessary to promote the achievement of the learning objectives. It was recognized that basic skills for interdisciplinary cooperation are often still lacking and must be taught as part of the project. This is done in the new generation by integrating system engineering approaches. In particular, the continuation of the work over several generations is positively received by the students, as the work carried out forms a basis for future students. In addition, the connection to actual research projects and industry partners leads to an increased appreciation of the results achieved, which is perceived as motivating by students. In the survey mentioned below, students indicated that the interactive and interdisciplinary collaboration increased their motivation and personal and subject-specific development.

The findings formed the basis for several already funded research projects in collaboration with industry, medicine and engineering to address the problem of racial bias and questionable animal testing. The trans-industry and trans-university cooperation, thus, not only offered students the opportunity to gain new knowledge from other, related disciplines, but also enabled the departments to develop long-term research interests. Since its introduction, the module has seen a steady growth in the number of participants. A quantifiable evaluation of the development of the content and the achievement of the learning objectives of the students on the basis of a survey has already being conducted. In an anonymous survey, it became apparent that the students' motivation to learn has decreased due to the pandemic. 50% of the students reported being more demotivated, while 37.5% experienced no change. For the future, the larger proportion of students (61%) would prefer hybrid teaching models to classroom or online teaching. There is a desire to participate more actively with regard to the design of teaching, particularly with a stronger focus on interdisciplinary and socially relevant content. 75% of the participants wish to participate more individually in teaching according to their own learning goals, but currently do not see the capacity to do so in existing teaching concepts (28%). 39% report that they lack the time to pursue their own learning goals in current teaching models. The realisation of these needs through a transdisciplinary, hybrid platform that promotes interaction and individualism corresponds strongly with the initial survey results.

4 DISCUSSION AND FUTURE DIRECTIONS

Implementing transdisciplinary group work requires opening the modules to a range of curricula as wide as possible. In principle, this can be easily implemented with the procedure described. Supervision by several departments to support the individual learning objectives would be useful, but requires adaptation and synchronisation of the curricula as well as improved communication between the departments.

The combination of several disciplines requires a high level of self-motivation, as the high supervision ratio leads to a lower creditable individual teaching performance. The added value arises first and foremost for the students and only secondarily for the departments through better trained students. In addition, the respective disciplines must acquire a good knowledge of the contents of the other disciplines in order to synchronize the offered teaching contents, from which the students can derive their individual teaching paths. Experience shows that this can only be achieved through an intensive exchange of motivated and leading protagonists from the disciplines who actively involve other disciplines and convince them of the added value. In order to promote interdisciplinary and transdisciplinary teaching, administrative conditions must be created that adequately value this teaching performance - the current practice of only partial credit, i.e. proportional distribution between lecturers, sometimes restricts such projects.

The experiences of the ongoing project module will be implemented in a collaborative module of all departments of the Institute for Machine Tools and Factory Management-TU Berlin. The methodology for interdisciplinary collaboration is taught at the beginning of the seminar. In addition to the established evaluation, consultations are held with mentors from all disciplines providing subject-specific tips that are implemented by the respective responsible students according to their own learning goals. Part of the seminar is an initial and a final discussion on technology assessment and sustainability approaches, as well as an initial professionally guided design thinking seminar. In recent semesters, the students have worked together in a mixture of online and face-to-face sessions, which will continue to be used in the future. The creative process and the exchange with mentors and supervisors as well as the evaluation with all students took place online. On site labs, production capacities and a budget were made available for the realization of the project.

As described, the extended transdisciplinary expansion of the project module is an ongoing process. It is planned to expand the spectrum of disciplines in collaboration with other disciplines, also across universities. This will be implemented, in particular, on the basis of the transdisciplinary consortium of the Berlin University Alliance project GlobalRestist. In addition, the human factors science is to be integrated.

Particularly considering the resulting complexity of the disciplines, it is essential that the methodology for collaboration continues to be part of the module in the future. Cross-university collaboration also requires a platform on which transdisciplinary content can be made available and interactive collaboration of different disciplines is made possible online. The materials and technical competencies developed during the pandemic provide an excellent basis for this kind of implementation. The aim here is to create a virtual space that expands the students' individual learning goals to transdisciplinary subject areas by having various disciplines like ethics, gender studies or medicine offer their courses there as basic and in-depth courses.

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