Interdisciplinary Teaching at RWTH Aachen University - Project "Leonardo"

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Abstract
For coping with global challenges based on best available knowledge, the interdisciplinary training of scientists is seen as a key feature of academic education. Scientists educated this way – t-shaped scientists – are seen as being better prepared to facilitate problem-solving processes by combining different disciplinary views on the strong fundament of one discipline. In order to promote these competencies and to enable students to participate in shaping society in the sense of shaping competence, the interdisciplinary teaching project "Leonardo" was launched at RWTH Aachen University. A central characteristic of "Leonardo" is that lecturers from different disciplines offer joined courses focusing on global challenges, which are directed at students from all faculties. The goal is to discuss a guiding theme in an interdisciplinary perspective and to bring together both students and lecturers from different disciplines. Three selected courses, namely "Sustainable Development Goals", "Technology and Society" and "Resource Policy", offered since 2019, serve as case studies to show, whether this approach succeeds in reaching the goal of t-shaping scientists while the following research question is in focus: What are opportunities and challenges of interdisciplinary teaching, especially regarding the t-shaping focus? Results of analysing the evaluation outcomes and reflection papers of the students show that the main challenge is on both producing depth and breadth of knowledge in thinking. Besides, students appreciate interdisciplinary teaching and – independent of their disciplinary background – they reflect this as common knowledge in the context of social responsibility.

Keywords: Interdisciplinary Teaching, T-shaped Scientists, Sustainability, Responsibility

1. Introduction

Interdisciplinary teaching and research are increasingly important, especially at universities with a strong technical and engineering focus (Neeley & Steffensen, 2018). With regard to addressing global challenges in the face of sustainable development, the interdisciplinary training of scientists is seen as a key feature of academic education (UNESCO, 2014). By definition, interdisciplinary research "is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice." (National Academies of Sciences, 2005, p. 2). Accordingly, there is a need for creative and innovative problem-solving which goes beyond disciplinary boundaries, as "interdisciplinarity is supposed to integrate knowledge and solve problems that individual disciplines cannot solve alone" (Jacobs & Frickel, 2009, p. 47).

Especially with regard to global challenges, as formulated by the UN's 17 Sustainable Development Goals (SDGs) within the framework of the 2030 Agenda, interdisciplinary approaches and methods are needed to meet the central challenges of the 21st century (OECD, 2019; UN, 2015; UNESCO, 2014). One key aspect in this context is the concept of Education for Sustainable Development (ESD), which is internationally framed by UNESCO (Tilbury, 2011; UNESCO, 2005, 2014) and should empower "everyone to make informed decisions for environmental integrity, economic viability and a just society for present and future generations, while respecting cultural diversity" (UNESCO, 2014, p. 20). For this purpose, various relevant competencies are discussed in the context of ESD, including interdisciplinary thinking and working (Annan-Diab & Molinari, 2017; Barth, Adomssent, Godemann, Rieckmann, & Stoltenberg, 2007; de Haan, 2006; Lozano, Barreiro-Gen, Lozano, & Sammalisto, 2019; Lozano, Merrill, Sammalisto, Ceulemans, & Lozano, 2017; Parker & Fadeeva, 2010; Svanström, Lozano-García, & Rowe, 2008; UNESCO, 2005, 2014; Wiek, Withycombe, & Redman, 2011). And as UNESCO states: "No one discipline can claim ESD for its own, but all disciplines can contribute to ESD" (UNESCO, 2005, p. 31). Furthermore, interdisciplinary learning is identified as a relevant learning type for ESD alongside discovery learning, critical-thinking-based learning, problem-based learning and collaborative learning (UNESCO, 2014).

Higher Education Institutions (HEIs), such as Universities, are jointly responsible for educating these competencies for sustainable development. One approach for educating this way is described by "t-shaped" scientists or professionals, who combine depth and breadth of knowledge and expertise (Babatope A, Samuel, Ajewole, & Anyanwu, 2020; Conley, Foley, Gorman, Denham, & Coleman, 2017; Demirkan & Spohrer, 2015; Neeley & Steffensen, 2018). This concept is based on Leonardo da Vinci, known as universal genius of the Renaissance (Gadol, 1973). There are many different graphical illustrations of the t-shaped ideal, however, on the main idea and knowledge and competencies associated with it, a widespread agreement exists (Neeley & Steffensen, 2018). Scientists educated this way are seen as able to facilitate problem-solving processes by combining different disciplinary views on the strong fundament of one discipline (Conley et al., 2017; Neeley & Steffensen, 2018).

In order to promote these specific knowledge competencies and to enable students to participate in shaping the society in the sense of shaping competence and ESD (de Haan, 2006), the interdisciplinary teaching project "Leonardo" was launched at RWTH Aachen University. The goal of the project is to discuss a global guiding theme from an

interdisciplinary perspective and to bring together both students and lecturers from different disciplines. Teaching this way aims at showing the construction of interdisciplinary knowledge from different disciplinary sources in a real-time mode, meaning that the teachers from different disciplinary backgrounds are in the best case showing the process of co-constructing interdisciplinary knowledge directly and vividly while teaching.

However, the question arises whether this approach succeeds in reaching the goal of t-shaping scientists. Against this background, three selected courses, namely "Sustainable Development Goals", "Resource Policy" and "Interdisciplinary Perspectives on Technology and Society", will be analysed while the following research question is in focus: What are opportunities and challenges of interdisciplinary teaching, especially regarding the t-shaping focus? This question is answered by re-analysing the evaluations of the courses as well as the critical reflection papers of the students.

2. Project "Leonardo"

In the following, the project, its goals and development are described. Based on this, the three courses are presented and discussed as case studies.

2.1. Project Goals

Project "Leonardo" was launched in 2008 at RWTH Aachen University. It is part of the university's interdisciplinary Human Technology Centre "HumTec". Referring to Leonardo da Vinci as the "universal genius" of the Renaissance, the project aims to empower students to use their subject-specific knowledge in a broader context to tackle global and societal challenges. Students who take part in Project "Leonardo" should not only get to know different ways of thinking but also learn approaches of disciplines through joint, interdisciplinary work. In addition, they should also get into conversation with fellow students from other departments and fields of study. To this end, for the project three underlying principles apply:

Interdisciplinarity is fundamental to solving future challenges: In order to ensure interdisciplinarity, people from different departments at the university take joint responsibility for courses. It is particularly important that the different subject contents and cultures not only coexist but rather are constructively integrated into the conversation. Interdisciplinarity refers not only to the type of content students are confronted with, but also to the students' experience in the exchange with other students and lecturers from other disciplines.

Integrating responsibility for science, research and teaching into the university discourse: The responsibility of science is reflected in all courses. To this end, the work is always oriented towards a holistic as well as impartial consideration of relevant topics. Students are deliberately required to form well-founded opinions: fact-oriented and differentiated, based on the knowledge and competencies they learn during their studies.

Participation and co-creation of all students in order to solve global challenges: The idea of participation concerning the content of the project means that there is a conscious decision not to presuppose specialist knowledge and prior knowledge. Courses should have as few barriers as possible. Where specialist knowledge or background is necessary to a certain

extent to understand more complex contexts, this will be provided within the framework of the courses.

These principles are framed by the aforementioned SDGs, which address the relevance of a more sustainable future and formulate numerous global challenges (UN, 2015). Within this framework, global challenges are highlighted in "Leonardo" courses and all topics are aligned with the problems that are distinguished by the SDGs as relevant and in particular need of a solution.

A central characteristic of "Leonardo" courses is that – usually two – lecturers from different scientific disciplines offer a course that focuses on global challenges aims to reach students of all faculties. The aim is to discuss a central topic in an interdisciplinary manner under academic supervision and to bring together both students and lecturers from different disciplines. Sometimes, the project proposes topics, at other times, members of the faculty propose lectures to the project, which was the case with all three courses in question. Moreover, student initiatives can also offer "Leonardo" courses in cooperation with a lecturer. So far, courses have been offered on topics such as energy, climate change, world population and health, flight and migration, culture, medical technology, Sustainable Development Goals, human-animal studies and fake news.

It is important to mention that the "Leonardo" courses are voluntary for most students and are currently anchored in only a few study programs. Nonetheless, nowadays more than 1000 students per semester participate in "Leonardo" lectures, which is twice the number of participants five years ago. This correlates with an increasing course offer in the last years, the development of a public relations concept and the offer of larger courses that address global challenges. But, as RWTH Aachen University has about 45,000 students enrolled, only between ten to twenty percent of the students ever partake in a "Leonardo" lecture during their study. Each of the lecture series featured in this work regularly attracts between 150 and 200 students, including freshmen, graduate and post-graduate participants.

2.2. Course Descriptions

Three courses are presented below as examples, each of which regularly attracts between 150 and 200 students, including freshmen, graduate and post-graduate participants from all faculties. Each course took place twice in the time period we are analyzing, which is from 2018 to 2020, as the courses were introduced in 2018 and 2019. All three courses address sustainability and responsibility as global challenges in different interdisciplinary ways. The courses generally consist of a series of expert talks, anchored with an introductory and a closing session by the organizing lecturer. Each lecture consists of roughly 45 minutes of prepared talk and another 45 minutes of discussion with the students, who are frequently given preparatory reading assignments.

2.2.1. Course I – Sustainable Development Goals

Due to the variety of globally discussed topics, such as climate change, energy transition and gender equality, the SDGs are particularly well suited for conveying and understanding interdisciplinary perspectives, which also goes along with the concept of ESD. Thus, two colleagues within "Leonardo" launched a course named "Sustainable Development Goals – A scientific approach to 17 Goals for the 21st Century" which took first place in winter 2019 and since then is regularly offered in the winter semester.

In both years, seven SDGs were presented and discussed by experts. Since it is not possible to discuss all 17 SDGs in one semester, different SDGs were selected in each case. This addresses a breadth of topics that students should learn about from interdisciplinary perspectives. The following learning goals were intended: Students should be familiar with the SDGs and understand their role as political objectives and models for a worldwide development process. They should be able to differentiate between the Millennium Development Goals and the SDGs and understand the relevance of the SDGs, especially for Western nations. The students should be able to evaluate issues from their respective studies under the paradigm of sustainability. They should identify how the work in their subject areas contributes to solving the problems identified in the SDGs. In addition, students should learn to evaluate different career paths in terms of global sustainability.

2.2.2. Course II – Technology and Society

As in the winter semester course, the SGDs form a conceptual framework for the summer semester course on "Technology and Society – Progress: Between Responsibility and Growth". However, in this course, the focus is more closely set towards promoting sustainable, innovative and future-oriented research and development. Learning goals include getting to know possible points of intersection between academic research and social issues and learning to identify potentially questionable avenues of research. Reoccurring topics include technology (impact) assessment, research ethics and responsibility, and gender and diversity integration. The course was first offered in 2019 and is since offered yearly in the summer semester.

It is important to note that the course mostly takes place on a meta-level. It is assumed that the students themselves use their own disciplinary knowledge and learn to contextualize it with humanities and economics frameworks. For this reason, assignments are geared towards getting students to apply interdisciplinary perspectives to their own expert knowledge.

2.2.3. Course III – Resource Policy

Contrary to the other two courses, "Resource Policy" represents a concrete and practical approach to address the SDGs. Within the framework of the lecture series in both years, firstly, central concepts for understanding this complex of problems were presented in an interdisciplinary manner, secondly, the various forms of raw material extraction were examined. Big foci were also the comprehension of the interdependencies of different factors (economic, ecological, social) and their application to concrete examples as well as the complex issues of resource dependency of transformation processes regarding the energy transition.

In summer 2019, raw materials policy problems were analysed based on concrete fields, thereby demonstrating their complexity. These examples were energy, mobility, construction and perspectives for a sustainable raw materials policy. In summer 2020, challenges of a sustainable raw material strategy were dealt with based on energy transition. The following learning goals were intended: Students should be able to describe different types of raw material extraction and distinguish them from each other based on their respective requirements and framework conditions. In addition, they should be able to describe the importance of sustainable raw material extraction and explain the role of domestic mining against the background of a secure supply of raw materials. Apart from that they should be

able to discuss the background and elements of a raw materials strategy and put the raw materials strategy of the Federal Government into context.

Due to the global Corona pandemic, the lecture series of 2020 was offered via Zoom and pre-recorded video presentations. The digital realisation of the lecture series enabled a thorough insight into and exchange about the lecture topics, as the pre-recorded video presentations (of 45–75 minutes) were followed by the students at home, so that the 90-minute lecture duration via Zoom offered room for questions and discussions.

3. Empirical Results

The empirical analysis is based on two sorts of documents, which were generated during the courses: *evaluations* and *reflection papers*. These documents offer insights into opportunities and challenges of interdisciplinary teaching. Each was analysed as specified below with specific questions being: How do students reflect on interdisciplinary teaching? How can global challenges be taught in an interdisciplinary way and do students contextualize these challenges in their exams? Which role does the t-shaping play? After describing these two forms of empirical documents, the following sections compare the three courses by using the difference between the two forms of documentation as lens for describing specific insights about interdisciplinarity and its teaching in "Leonardo" courses.

At the end of each course, students do an *evaluation*. It is explicitly tailored to the interdisciplinary teaching format of the "Leonardo" project. Within free-text fields, students can provide information on the interdisciplinarity of the respective event ("Did the course enrich your (inter)disciplinary horizon? Were the lectures comprehensible to all of you? If not, to what extent did you see this as a limitation?"), on the respective contents of the lectures ("Which contents did you like particularly well, which less? Do individual dates stand out? How do you rate the level of the content?"), on their expectations and satisfaction with the event ("What expectations did you have of the course you chose and to what extent are/were these fulfilled?") as well as on organisational and technical aspects.

As graded work, students can hand in a *reflection paper* on a lecture of their choosing. These are up to ten pages and consist of a reproductive part and a critical analysis. Beyond the prescribed structure, the content can be chosen by the students themselves, as long as it contains some link to the lecture topics. The aim of the reflection papers is to relate the knowledge acquired in the lecture to existing knowledge and to reflect on the respective topics. In doing so it is possible, for example, to go into greater depth on an aspect of the lecture that was either not considered in sufficient detail or to place technical or professional findings in a broader social context and analyse their significance. We aimed at categorising those with regard to content and examined them with consideration on the following questions: Do the students introduce new points or do they address lecture topics? Do the students reflect on the course or the lecture in general?

3.1. Course I – Sustainable Development Goals

With regard to the *evaluation outcomes*, the students were generally satisfied with the course, its content and the interdisciplinary approach. The only criticism that can be found in both semesters relates to the level of detail of individual lectures. In some cases, students would have liked more in-depth discussion and more concrete approaches to solutions. Other students, however, emphasized the breadth of the content and the resulting general

knowledge as a major positive point. This discrepancy is a central challenge of interdisciplinary teaching, and a reoccurring theme when discussing the t-shaped approach (Jacobs & Frickel, 2009; Neeley & Steffensen, 2018; Vasilyeva, Samigullina, & Danilova, 2020). Since students from all disciplines participate in the "Leonardo" courses, for some many new aspects are addressed, while for others hardly any new content is taught. This is particularly relevant in the SDG course, as global challenges from different very large areas, such as climate change, water supply or sustainable urban planning are addressed. Accordingly, in a single lecture on climate change, the topic can only be covered in-depth to a limited extent.

For this reason, and also to address the criticism of the students, for the coming semesters it is planned to focus on individual SDGs with similar emphases, such as the topic complex "Reduced Inequalities", "Gender Equality" and "Quality Education". Through this focus, the individual SDGs can be studied in greater depth and interdependencies can also be analysed and discussed.

In view of the *reflection papers*, most students made use of the opportunity to introduce new aspects, which largely address concrete and also often local implementation measures, e.g, with regard to SDG11 ("Sustainable Cities and Communities"). The question "What does it all mean now and what can I do?" was often in the foreground. This aspect and accordingly approaches for practical solutions were missed by some students in the presentations, which often presented the respective SDG in general. This point was also formulated in the evaluations, as explained earlier.

Furthermore, it was found that global topics, such as climate change (SDG13), were frequently addressed by the students. Here, the contents of the presentation were usually further deepened, reflected upon and questioned. In particular, the question of climate justice and international cooperation with regard to climate change occupied the students. One person – exemplarily – concluded in her critical reflection on SDG 13 "Climate Action" that there needs to be an 18th Goal: "a common change in values that anchors compassion, connectedness, responsibility, solidarity in society and thus supports all other SDGs. In order to work towards this Goal 18, the training of engineers, for example, should also be addressed, so that they are strengthened in communication. Only together can we create a present and future worth living." (translated by the authors)

Notably and furthermore, the winter 2020 release papers frequently addressed the respective implications of the SDGs for the Corona crisis and vice versa.

3.2. Course II – Technology and Society

With regard to *evaluations*, students frequently report the course to be a valued contribution to "democratic participation" and citizenship skills, with many students highlighting the applicability of the content to a wide range of interdisciplinary topics. Students value the interactive nature of the course and the approachability of the staff, both during and outside the lectures. As one student put it: "What I valued most were the direct interaction and the flat hierarchies, which give room to a safe space for respectful and appreciative debate." (translated by the authors). Moreover, the fact that discussion sessions regularly exceed the time limits set by the lecture periods is something that the students frequently describe as "conductive to the discussion".

However, each year there is a small number of students who criticize a lack of practical examples in the lectures of this course, too. Similarly to the SDG course, this has been grounds for frequent, inconclusive discussion. Due to the extremely heterogeneous nature of the participants from engineering, sciences, math, humanities and medicine, in-depth analysis of practical examples tends to quickly overwhelm non-experts while at the same time providing little to no new input for participants from the relevant subject areas.

Already in the summer semester of 2020, the Corona crisis was a topic frequently dominating discussions. While it was not deemed expedient to change the course outline during the semester, keeping in mind the reoccurring evaluation results regarding practical examples, for the summer semester of 2021 it was decided to put a special emphasis on local university research projects aimed at tackling the Corona crisis. However, a formal evaluation is currently outstanding and initial feedback is mixed. A few students positively remark on the relevance of the topic, yet many also miss the more generalist debates.

With regard to the overall topic of the lecture, a reoccurring theme is students' assessing or discussing technical innovations in their *reflection papers*. General issues such as digitalization and transformative change are common topics in the reflection papers, as are more specific subjects such as medical engineering (e.g. diagnostics, gene editing) and artificial intelligence (e.g. autonomous driving, big data). For the latter, a close link between the students' area of study and the topics of the analysis can be observed, whereas, for the former, the distinction is less pronounced.

Furthermore, each year a number of students hand in reflection papers that focus on discussing the nature of interdisciplinary teaching at RWTH Aachen University, both with respect to this course and in general, with the gist being that the course "[…] enables me to look at technology development from a different perspective, […]. I hope I have gained some measure of ability to identify possibilities and risks and their respective relevance to society.", as a student put it (translated by the authors).

3.3. Course III – Resource Policy

Overall, the *evaluations* in the last two years were once again very positive and the interdisciplinarity was highly emphasized by the students. The tandem lecture by two professors was particularly well received. The pre-recorded videos in summer 2020 allowed a good introduction and were perceived as a very helpful low-threshold introduction. The wide range of questions due to the very different backgrounds of the students but also of the lecturers was also highlighted. Thus, the debates were never monotonous and the interdisciplinarity was highly emphasised. However, some students remarked that as the individual external lecturers represent specific perspectives, it would have been helpful if, in between, the focus was put again on an overarching analytical level, again illustrating the tension between generality and specialist knowledge.

Furthermore, the students wished for a political speaker or someone who stands for disruptive change in resource policy. For the future, the students asked to invite role models, who would also give them inspiration for their future professional activities. Both points are at least somewhat controversial, as in either case an invitation of speakers always implies implicit support and, at RWTH Aachen University, the political neutrality of the university remains a major principle. Some efforts have been made to address this tension through close cooperation with student initiatives and the student unions.

In addition, the students wished to specifically engage with global futures approaches such as post-growth theories and circular economy.

In their *reflection papers*, many students dealt with the lecture contents such as international raw materials policy, followed by energy production and mobility, in greater depth, new aspects were introduced only in isolated cases. Notably, issues such as the nationwide coal phase-out and its local dimension concerning the structural changes were considered. In particular, the social and environmental responsibility of large corporations, the challenges posed by the recultivation and rehabilitation of the opencast mines, but also the job losses caused by the coal phase-out were discussed. Regarding the latter, topics around climate change and sustainability were chosen, but also, in light of the Corona pandemic in summer 2020, the students addressed the dependence of states on the international market and more issues of equal access to goods and resources.

Finally, issues such as the nationwide coal phase-out and its local dimension with regard to the structural changes in the *Rheinisches Revier* were considered. In particular, the social and environmental responsibility of large corporations, the challenges posed by the recultivation and rehabilitation of the opencast mines, but also the job losses caused by the coal phase-out were discussed.

One student concluded: "Ultimately, it is the responsibility of national and European policies to create effective, market-based incentives that flank the energy transition in order to ensure a timely transformation to a cheap, secure and environmentally friendly energy supply. The need becomes clear in light of irreversible disruptive forces that humanity's activities threaten to unleash, […]. It is an interdisciplinary task of the century that deserves no simple answer and is rightly called the *Great Transformation*." (translated by the authors)

4. Conclusions

The three selected and presented courses all address sustainable approaches in the context of the SDGs and social as well as individual areas of responsibility in different interdisciplinary ways. Nevertheless, they differ in their didactic approach and in the depth and breadth of the topics. Setting the goal of t-shaped scientists, the main challenge is bridging the gap between broad and deep knowledge. This is a recurring element in all three courses, which also became apparent in the students' reflection papers, most of which address practice-based and concrete solution strategies.

The SDG course, which can also be seen as an overarching course to convey the relevance of these topics, is characterised by a recurring discourse on depth vs. breadth of topics, which is reflected in the idea of the t-shaped approach. At the same time, the challenge of interdisciplinary teaching and learning becomes clear here, both in terms of producing both broad and deep knowledge and thinking (Vasilyeva et al., 2020). The same applies to the course "Technology and Society", where the evaluations diverge between the statement that general knowledge was gained through the course and, at the same time, the partial lack of showing concrete solution possibilities is criticised by the students. This is also reflected in the critical reflection topics, as most of them delve further into a concrete aspect and focus on practical implications. In contrast, the course "Resource Policy", which per se has a concrete delimited thematic area, has other implications. Here, some students wish for a stronger overarching analytical focus, i.e. wish for more breadth than depth.

We did not go into detail with regard to the didactic mediation (as mentioned before, the resource policy course is nowadays thought in a flipped classroom model), as this also gives rise to other perspectives, which in turn need to be examined scientifically.

In all courses, having some practical examples was useful and frequently students performed very well if they were given a general framework and the opportunity to employ this by discussing a practical example. Furthermore, if students are given more practical examples, as in the case of the "Resource Policy" course, they frequently, wish to lead more action-oriented discussions, which in some cases stress the mandate of a (German state) teaching institution. While no specific measures to that effect were taken in either of the analysed courses, in other courses this feedback was subsequently included. Cooperation with student initiatives has shown to generate positive feedback as those who wish further lecture topics towards a "call to action" can do so via the associated initiatives or student unions. There is no patent solution for this either, but what we have learned from the project perspective is that the involvement of student initiatives could be a solution to generate more practice and application-related content. This has been highlighted very positively by the students so far.

Another challenge is that students who take part on "Leonardo" courses mostly have different levels of knowledge and are from different fields of study. As the majority of students take the courses voluntarily, we observe a high intrinsic motivation. And, with regard to evaluation, "Leonardo" courses are highly appreciated by students. But how can we close the gap between "too much depth" and "too much breadth" for these students?

The above-mentioned intrinsic motivation may also be a reason why in general student feedback is excellent and why the debates tend to be very lively. However, this also points towards further challenges and implications for research: How can we motivate more students to participate and engage in lectures, the content of which does not immediately correspond to their regular disciplinary knowledge? And, as we consider large courses here, how can participation-based and interdisciplinary formats effectively be scaled up to address larger numbers of students?

In order to teach and learn about global challenges in the context of ESD in an interdisciplinary way, a clearly structured and competence-oriented curriculum design is required. It is necessary to raise awareness of the relevance of interdisciplinary thinking, especially with regard to ESD, as well as to integrate it meaningfully into study programs with different disciplines (National Academies of Sciences, 2005; Vasilyeva et al., 2020)

The "Leonardo" courses presented can serve as an example of teaching global challenges in an interdisciplinary way. While the courses being voluntary limits the number of participants, it also seems to be a main aspect for success. Beyond that, there is a need for further research. A next step is to establish correlations between the individual courses of study and the topics addressed in the reflection papers to identify possible differences between the individual disciplines and study programs. The courses examined here all have a high heterogeneity of students, but we would also have to look at courses that are more homogeneous in terms of study programs. We observed that this is especially the case in technical courses, such as energy or medical technology. Furthermore, it cannot be ruled out that the respective expert presentations in their different forms have an influence on the acquisition of interdisciplinary competences. A combination of different learning approaches, as formulated by UNESCO (2014), such as problem-based learning or collaborative learning, in addition to interdisciplinary learning, could further improve the acquisition of competencies (see also de

Graaff & Kolmos, 2003). Through the integration of student initiatives, attempts have been made to achieve this goal and to increase learning success.

Overall, the "Leonardo" project represents an interdisciplinary teaching and learning approach that is to be further developed and consolidated in the future for mainstreaming t-shaping activities at a Technical University – and beyond.

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References

Annan-Diab, F., & Molinari, C. (2017). Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *The International Journal of Management Education, 15(2, Part B), 73–83*. doi:https://doi.org/10.1016/j.ijme.2017.03.006

Babatope A, A., Samuel, T. M., Ajewole, P. I., & Anyanwu, O. M. (2020). Competence-driven engineering education: A case for T-shaped engineers and teachers. *International Journal of Evaluation and Research in Education (IJERE), 9(1)*. doi:10.11591/ijere.v9i1.20274

Barth, M., Adomssent, M., Godemann, J., Rieckmann, M., & Stoltenberg, U. (2007). Developing key competencies for sustainable development in higher education. *International Journal of Sustainability in Higher Education, 8(4), 416–430*. doi:10.1108/14676370710823582

Conley, S. N., Foley, R. W., Gorman, M. E., Denham, J., & Coleman, K. (2017). Acquisition of T-shaped expertise: an exploratory study. *Social Epistemology, 31(2), 165-183*. doi:10.1080/02691728.2016.1249435

de Graaff, E., & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education, 19(5), 657–662*.

de Haan, G. (2006). The BLK '21' programme in Germany: a 'Gestaltungskompetenz'-based model for Education for Sustainable Development. *Environmental Education Research, 12(1), 19–32*. doi:10.1080/13504620500526362

Demirkan, H., & Spohrer, J. (2015). T-Shaped Innovators: Identifying the Right Talent to Support Service Innovation. *Research-Technology Management, 58(5), 12–15*. doi:10.5437/08956308X5805007

Gadol, J. K. (1973). Universal man. In P. F. Wiener (Ed.), *Dictionary of the history of ideas: Studies of pivota ideas* (Vol. 4, pp. 437–443).

Jacobs, J. A., & Frickel, S. (2009). Interdisciplinarity: A Critical Assessment. *35(1), 43–65*. doi:10.1146/annurev-soc-070308-115954

Lozano, R., Barreiro-Gen, M., Lozano, F., & Sammalisto, K. (2019). Teaching Sustainability in European Higher Education Institutions: Assessing the Connections between Competences and Pedagogical Approaches. *Sustainability, 11(6)*. doi:10.3390/su11061602

Lozano, R., Merrill, M., Sammalisto, K., Ceulemans, K., & Lozano, F. (2017). Connecting Competences and Pedagogical Approaches for Sustainable Development in Higher Education: A Literature Review and Framework Proposal. *Sustainability, 9(10)*. doi:10.3390/su9101889

National Academies of Sciences. (2005). *Facilitating Interdisciplinary Research*. Washington, DC: The National Academies Press.

Neeley, K. A., & Steffensen, B. (2018). *The T-Shaped Engineer as an Ideal in Technology Entrepreneurship: Its Origins, History, and Significance for Engineering Education*. Paper presented at the 2018 ASEE Annual Conference & Exposition.

OECD. (2019). *OECD Future of Education and Skills 2030: OECD Learning Compass 2030*. Retrieved from https://www.oecd.org/education/2030-project/contact/OECD_Learning_Compass_2030_Concept_Note_Series.pdf

Parker, J., & Fadeeva, Z. (2010). Competencies for interdisciplinarity in higher education. *International Journal of Sustainability in Higher Education, 11(4), 325–338*. doi:10.1108/14676371011077559

Svanström, M., Lozano-García, F. J., & Rowe, D. (2008). Learning outcomes for sustainable development in higher education. *International Journal of Sustainability in Higher Education, 9(3), 339–351*. doi:10.1108/14676370810885925

Tilbury, D. (2011). *Education for sustainable development: An expert review of processes and learning*. Paris: UNESCO.

UN. (2015). Sustainable Development Goals: Quality Education. Retrieved from https://www.un.org/sustainabledevelopment/education/

UNESCO. (2005). *United Nations Decade of Education for Sustainable Development (2005–2014): International Implementation Scheme* Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000148654

UNESCO. (2014). *Shaping the Future We Want. UN Decade of Education for Sustainable Development (2005–2014). Final Report*. Paris: United Nations Educational, Scientific and Cultural Organization.

Vasilyeva, E. R., Samigullina, L. Z., & Danilova, O. V. (2020, 2020/07/23). *Interdisciplinarity as a Key Component Contributing to Sustainable Development of Modern Engineering Education.* Paper presented at the Proceedings of the International Scientific Conference on Philosophy of Education, Law and Science in the Era of Globalization (PELSEG 2020).

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability Science, 6(2), 203–218*. doi:10.1007/s11625-011-0132-6

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