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Sustainability And Innovation: Exploring The Relationship Between Sustainability And Companies' Engagement In Innovation Ecosystems In The German Engineering Industry

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Sustainability and Innovation: Exploring the Relationship between Sustainability and Companies' Engagement in Innovation Ecosystems in German Engineering Industry

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ABSTRACT

This study identifies sustainable companies in the engineering industry in Germany and investigates their engagement in innovation ecosystems based on varying collaborative formats and transfer pathways. To this end, 200 medium and large companies were interviewed. For the analysis of the data, the study operationalised sustainability and identified sustainable companies based on responses concerning their environmental, social, and economic performance. These results were then cross-referenced with activities within innovation ecosystems.

Results are consistent with the state of research and indicate that sustainable companies are more engaged in innovation ecosystems than non-sustainable companies. This suggests that companies considered sustainable are more likely to contribute to solving grand societal challenges through innovations. For engineering educators, it highlights the relevance to promote sustainability and innovation as part of engineering education and prepare students for cooperative and collaborative activities in their careers.

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1 INTRODUCTION

The concept of sustainability entered the political discourse with the Brundtland Report in 1987 and took its place alongside the concepts of transformation and innovation (D. Maier et al. 2020; United Nations 1987). At the very latest since the publication of the UN's Sustainable Development Goals, major societal challenges have been viewed through this lens. This is also evident in research on sustainable business models. In the 2010s, there has been an exponential increase in studies on the topics of innovation and sustainability (D. Maier et al. 2020). They point to a correlation between sustainability orientation and innovative strength. In this study, sustainability is understood as economic, ecological and social sustainability following the triple bottom line model (Elkington 1998, 1997). The engagement of companies in innovation ecosystems could be identified in other countries as a factor for innovative strength and thus as an important variable for the emergence of transformative products and services (Kuhl et al. 2016). Innovation ecosystems are a structured set of multilateral partners that interact on the basis of an aligned interest (Adner 2017; Jütting 2020). Interactions rely on various formats of engagement, collaboration, and transfer pathways so that, conversely, the level innovation activity can be inferred from formats used. This is in line with the work of Gibbons et al. (1994) on knowledge production and Carayannis and Campbell (2009) on innovation ecosystems who state that socially robust, knowledge-based solutions for complex societal challenges need to involve multiple stakeholders from different backgrounds. Sustainability is a driver. Therefore, it is important to have a clear understanding of the type of sustainability orientation as well as innovation-oriented activities in industry.

In order to provide an empirical basis for these theoretical considerations, a quantitative interview study was conducted with 200 medium-sized and large companies from engineering industries in Germany. To this end, it investigates the relation between sustainability orientation as well as the level of success in cooperations respectively and innovation ecosystem activity based on the relevance of various literature based, surveyed formats. The main research interest may be summarised as follows:

> *This study surveys what type of sustainability companies from the engineering sector in Germany practice and investigates whether there are differences regarding collaborative formats and transfer channels used depending on the sustainability orientation and success in cooperations.*

Results complement our understanding of sustainability in innovative engineering practice and are relevant for curriculum development in engineering education. Based on the results engineering educators can align their teaching with industry practice with regard to collaboration formats. In this way, engineering education becomes more relevant in terms of deliverables as well es more interesting for learners.

2 METHODOLOGY

This study was designed as a quantitative survey of industry practices. The survey was conducted in the form of structured computer-assisted telephone interviews

(Weitkunat and Crispin 2000). In November and December of 2021, 200 managing directors or heads of R&D departments of medium-sized and large companies from the automotive engineering, electrical engineering, chemical engineering and mechanical engineering sectors were surveyed. These sectors were selected because they are the four largest industries in Germany. It is assumed that the results are thus as generalisable as possible and have greater relevance. In total, the following cases were realised:

Table 1. Sample by Industry Sector and Size of the Company

Industry Sector	**Staff Headcount 50-249**	**Staff Headcount ≥250**
Automotive Engineering	31	16
Chemical Engineering	31	16
Electrical Engineering	34	22
Mechanical Engineering	30	20

In order to assess the sustainability of a company, 9 questions were analysed based on the assessment of interviewees of their own company's activity with regard to the three pillars of sustainability (ecological, social, and economic sustainability). For the purposes of this study, only those companies that indicate no negative effects in all three dimensions and a positive effect in at least one dimension are considered to be sustainable. Satisfaction with collaborations, the achievement of goals in networks and the importance of different activities were surveyed directly. For this study, companies are considered successful if they achieve a mean value of ≥8 on a 10-point interval scale based on satisfaction and goal achievement.

To determine whether and in what way sustainability orientation (based on self-assessment of interviewees) of the companies relates to cooperative engagement and transfer activities used by them, a sustainability index was developed based on items that survey profit orientation, desirable social effects and reductions in the use of resources. This index is based on the triple bottom line approach.

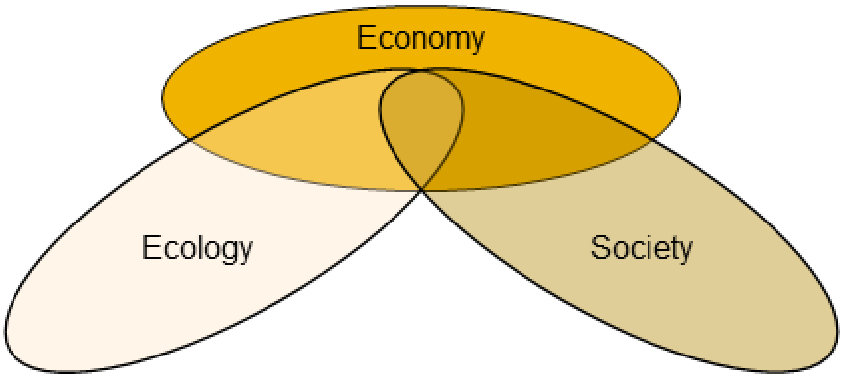

Fig. 1. Triple Bottom Line Approach (Own Presentation Based on Schulz 2012)

The triple bottom line approach is based on the beforementioned Brundtland Report and expands the understanding of sustainability to include the three dimensions of economy, ecology and society. All three dimensions need to be integrated because of their complex interconnectedness (Alhaddi 2015; Elkington 1997). It follows that there is sustainability only if optimisation can be achieved in at least one dimension without deterioration in any of the other dimensions. These conditions may be referred to as pareto-sustainability or pareto-sustainable. Sustainability orientation of companies was operationalised accordingly. Companies are considered sustainable if in their self-assessment they achieve no mean value <3 in any of the three sustainability dimensions, and a mean value of >3 in at least one of the dimensions, with the value 3 being neutral on the scale of the conducted survey ("neither agree nor disagree").

Table 2. Survey Items of Sustainability Index for Classifying the Sustainability Orientation of Companies (Operationalisation in Relation to the Triple Bottom Line based on 5-Point Interval Scale: 1 – 'fully disagree', 2 – 'tend to disagree', 3 – 'neither agree nor disagree', 4 – 'end to agree', 5 – 'fully agree')

Dimension	Item	Mean Value
(a) Economy	(1) Our innovations ensure the economic success of the company (e.g. profit, turnover or market share). (2) Our innovations contribute to overall economic growth and strengthen Germany as a business location. (3) Our innovations are oriented towards a concrete market or customer need.	≥3
(b) Society	(4) Our innovations improve people's living conditions and quality of life. (5) Our innovations have a positive social impact beyond the individual customers. (6) Our innovations are designed with their potential social and societal impact in mind.	≥3
(c) Ecology	(7) Our innovations contribute to climate and environmental protection. (8) Our innovations replace resource-intensive products or processes. (9) Our innovations are created in resource-saving and environmentally friendly manufacturing processes.	≥3

If, to illustrate with an example, a representative of a company answers the three questions (cf. Table 2 items 1-3) of the economic sustainability dimension (with "tend to agree", "neither agree nor disagree" and "tend to disagree", the answers on a 5-point interval scale correspond with the values 4 ("tend to agree"), 3 ("neither agree nor disagree") and 2 ("tend to disagree"). It follows that the mean value for the economic dimension is 3 and, thus, the result neutral (neither economically sustainable nor unsustainable). Assuming identical answers and values for the questions assigned to the social sustainability dimension (cf. Table 2 items 4-6) and thus also a mean value of 3, the classification whether the company in question is considered sustainable or unsustainable depends on the answers to the questions of the ecological dimension (cf. Table 2 items 7-9). If these answers result in a mean value of >3, in the context of this study, the company is classified as sustainable. If, on the other hand, the answers result in a mean value <3, the company is not classified as sustainable but instead considered unsustainable because there is no desirable impact in the respective dimension.

As an additional condition, the sustainability orientation must not be negative in any dimension. If the value in one of the dimensions as depicted in Table 2 is <3, a company is not considered sustainable even if the sum of the mean values of the three dimensions is >9, because it is then assumed that an optimisation in one dimension can only be achieved at the expense of a deterioration in another dimension.

$$S = \{a, b, c \mid a \geq 3, b \geq 3, c \geq 3 \ \wedge a + b + c > 9\}$$

Sustainable companies (S) are those that achieve a mean value from the associated questions (items 1-3 (a), 4-6 (b), 7-9 (c)) in each of the economic (a), ecological (b), and social (c) dimensions on a 5-point interval scale of greater than or equal to three and whose sum of a, b and c is greater than nine. The operationalisation, then, results in different sustainability categories. Each company is assigned to one category, depending on the focus of its activities. Results are listed in Fig. 2 and Table 3.

A further distinction can be made between companies that indicate a sustainable orientation in only one dimension in which the mean values is >3, companies that consider themselves to be sustainably oriented in two dimensions in which each mean value is >3, and companies that are sustainably oriented in all three dimensions with mean values >3 in a, b, and c. In addition, there are companies that give neutral answers to all three dimensions (mean values for a, b, and c = 3), as well as companies that are classified as non-sustainable because the answers in at least one of the dimensions result in a mean value <3.

In order to investigate a relation between sustainability and innovation ecosystem engagement of the companies, all interviewees were asked about general satisfaction of their cooperation and achievement of set goals. Deviating from the 5-point interval scale used for the other items (1-9 as shown in Table 2), here a 10-point interval scale was used to generate a more precise and meaningful data set. Values 8-10 correspond to "(very) good" satisfaction or achievement of set goals and are considered as successful. All answers in the range 1-7 are clustered and are interpreted as non-successful cooperation in innovation ecosystems.

If questions were answered with "don't know" or "no information", data is not included in the analysis.

Finally, the relevance of formats and activities derived from literature in R&D activities of companies was surveyed. Formats and activities were identified as part of a joint research project with Fraunhofer IAO Center for Responsible Research and Innovation (CeRRI) and Berlin Social Science Center (WZB) (Jütting 2020). For this purpose, sixteen formats and activities were evaluated on a 5-point interval scale. Considered are activities if it ranks "relevant" or "very relevant" for a company, because then it can be assumed that companies use this format at least several times ranging to a regular pursuit of the activity. The data collected allows for a comparison of the respective importance between sustainable and non-sustainable as well as successful and less successful cooperating companies.

3 RESULTS

3.1 Transfer Activities and Collaboration Formats

In order to answer the question of whether and how sustainable companies differ with regard to the transfer activities and collaboration formats they use, first the orientation of companies was operationalised and analysed in regard to the triple bottom line approach (ecological, social, economic). This results in seven possible sustainability profiles, one neutral profile and a non-sustainable profile. The sustainability profiles have an ecological, social or economic focus, or a combination of two sustainability dimensions, or all three respectively. The analysis yields the following results:

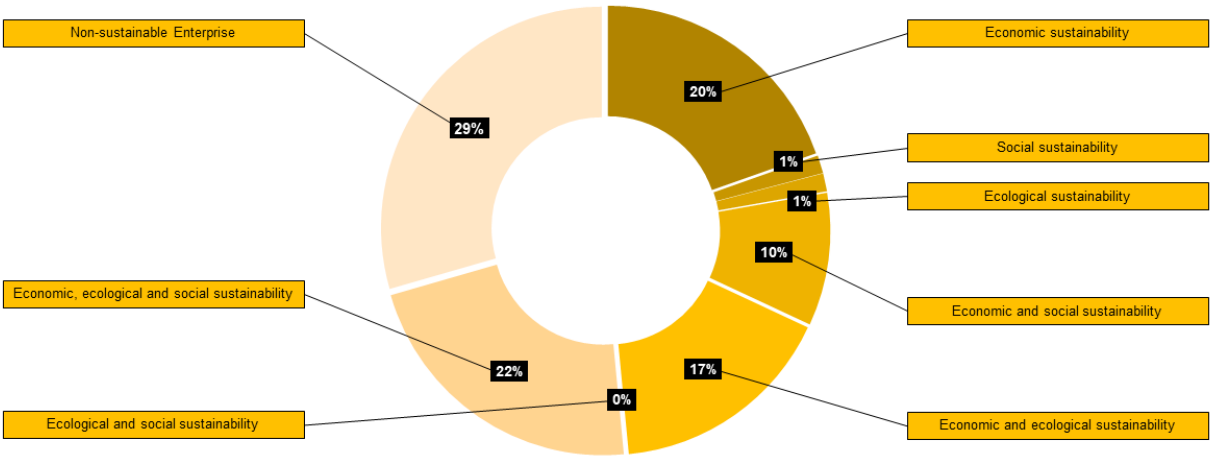

Fig. 2. Sustainability Categories of Companies in the Sample in Percentage

This illustration shows that the majority of companies, namely about 70%, are sustainably oriented. The results thus confirm a shift in mentality among industry. It is striking that only about 20% of the companies have a purely economic sustainability orientation. Conversely, this means that about half of the sample practice social or ecological sustainability. The absolute figures are documented in the following table.

Table 3. Sustainability Categories of Companies in the Sample in Absolute Numbers

Category	Number
Economic Sustainability	31
Social Sustainability	1
Ecological Sustainability	1
Economic and Ecological Sustainability	34
Economic and Social Sustainability	21
Ecological and Social Sustainability	0
Economic, Ecological and Social Sustainability	49
Neutral Results	2
No Sustainability	55

For the following analysis, all sustainable companies were subsumed under the category of sustainability. Inconsistent and incomplete data sets were not considered. Thus, 137 companies with a sustainable profile and 57 companies with a non-sustainable profile (including neutral orientations) were considered. Figure 4 shows the percentage of sustainable and non-sustainable companies (on the y-axis) for which the respective activity is either relevant or very relevant in their research and innovation practice (on the x-axis). Non-sustainable companies are cited as a control group to measure whether sustainability orientation has an impact on engagement and activities in innovation ecosystems.

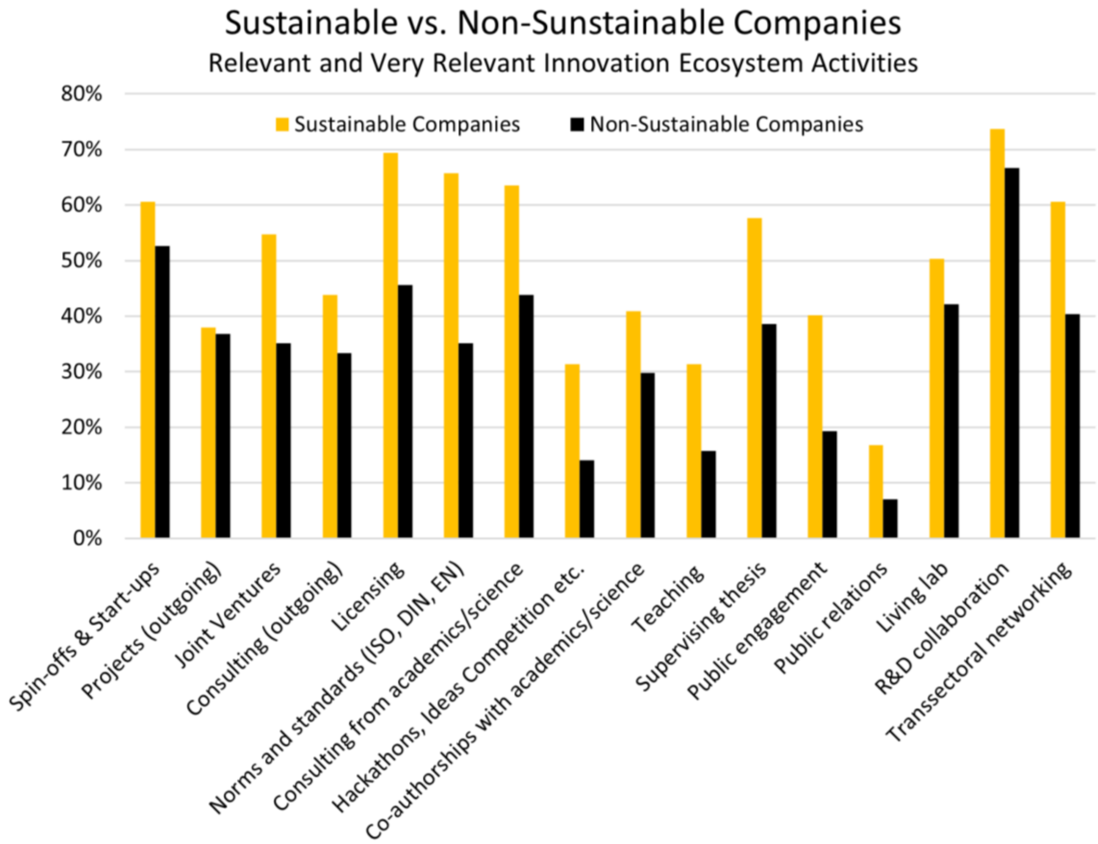

Fig. 3. Activities of Sustainable and Non-Sustainable Companies

Results show that those companies whose interviewees report a sustainable orientation of their organization are more likely to engage in innovation ecosystem engagement and collaborations than non-sustainable companies. Two findings deserve special consideration at this point. First, it may be unexpected that involvement in setting *norms and standards* is significantly more common among sustainable companies, as this is a decidedly traditional activity. However, on closer scrutiny, this alleged incongruity dissipates because sustainable (as well as innovative) companies in particular have a keen interest in normalising and standardising new processes, developments, and products (Thumfart 2022). What is particularly curious, however, and for which it is challenging to find an adequate explanation, is the widespread participation in *living labs* (Parodi and Steglich 2021). At this point, it may merely be pointed out that the format now seems to be established in companies and that from it derives potential for curriculum development in engineering education because it can bring together academic training and practice (Coones, Johannsen, and Philipp 2023). This development is reflected in an ongoing legislative debate introducing a Living Lab Act (Süssenguth and Jagdhuber 2023).

Finally, activities of those companies were analysed that are satisfied with their research and innovation collaborations and report that they are achieving their set goals. These companies were classified *successful* and were then compared with those companies that are less successful in their collaborations. The analysis included 74 companies that collaborate successfully and 113 companies that do not report high success and satisfaction scores. 13 data sets were incomplete.

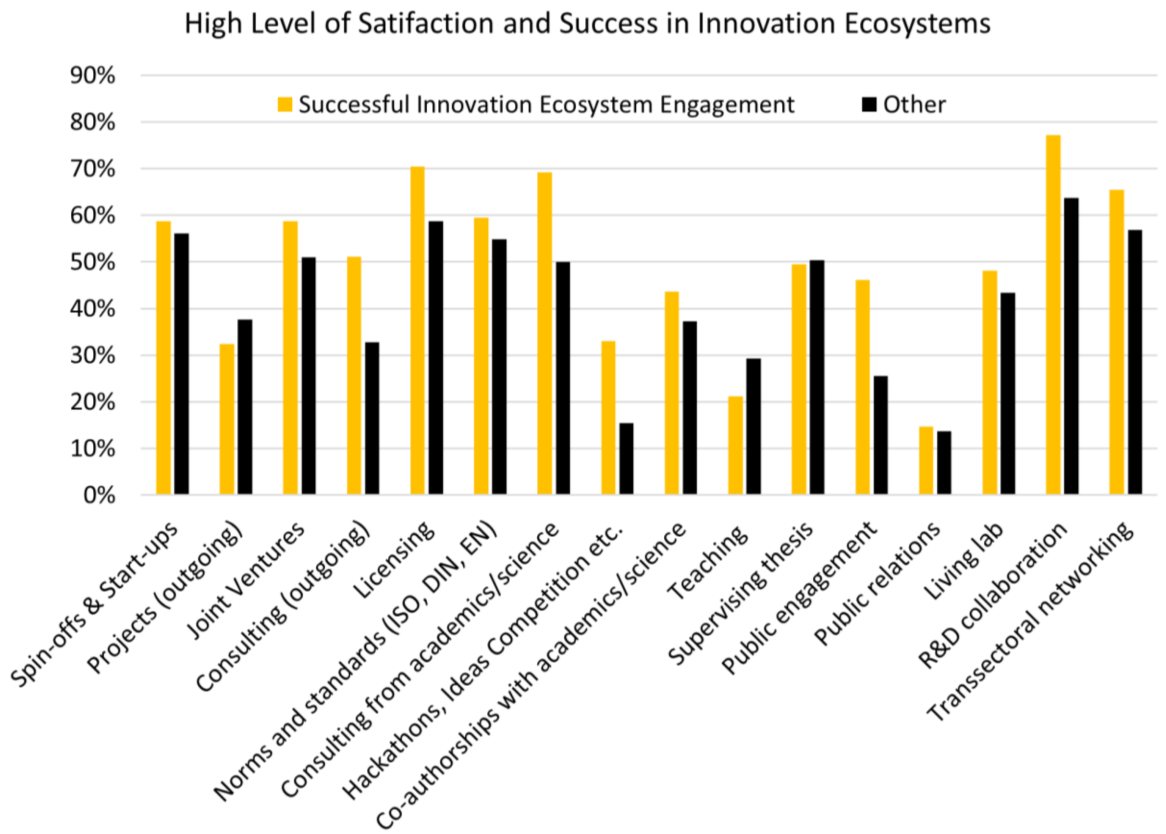

Fig. 4. Activities of Companies with a High Level of Satisfaction and Success in Collaboration

Overall, results show that successful collaborators are more likely to engage in innovation ecosystem activities. However, there is a shift compared to Figure 4 insofar as less successful collaborating companies are more engaged in *teaching* and are more inclined to enter into *joint ventures*. This is also the case for *public relations*, even if the difference is negligibly marginal for the latter.

The fact that collaborative innovation ecosystem activities are widespread is surprising insofar as an even higher prevalence could have been expected based on their relevance in funding policies. Remarkable, however, is that successful collaborative companies use innovative, interdisciplinary, or transdisciplinary formats such as *hackathons* much more frequently and tend to involve the *public* more readily. This practice contributes to a systemic understanding of complex problems and thus helps to find adequate solutions. These results are in line with the state of research in science, technology, and innovations studies as these formats build on the theoretical framework of the quadruple helix which advocates a systematic interaction of the academic, economic, political, and societal spheres (Schütz, Heidingsfelder, and Schraudner 2019). Results of this study may hence be interpreted as empirical support for the approach.

3.2 Limits

The results of the study should be acknowledged considering its limitations. On one hand, only four industry sectors were surveyed. While the comparison of results across sectors suggests generalisability, it cannot demonstrate it conclusively. In addition, sampling errors can occur in random selections (M. Häder and S. Häder 2019). On the other hand, despite the sample size of 200 enterprises, it cannot be ruled out that there is a common method bias (P. M. Podsakoff et al. 2003).

Furthermore, it may be argued that data collection by means of telephone interviews can lead to a reduction in the reliability and validity of the data due to self-reporting of the interviewees (Möhring and Schlütz 2013). It must be considered that answers are (socially) desirable for multiple reasons such as a (subconscious) identification with the employing company. Yet, others argue that self-reporting is limited to assess conscious contents, lacks temporal resolution, and is subject to response sets and memory biases (Pekrun 2020).

3.3 Implications for Engineering Education

Engineering education can benefit from the findings because they highlight the relevance of collaborative activities in professional settings in engineering. With an increasing importance of sustainability and intersectoral approaches to solving complex problems and societal challenges, academic training and higher education also needs to prepare students for these activities. One approach to preparing students for these tasks is to shift the paradigm of curriculum development away from 'first teach the fundamentals' and towards 'start by engaging with the engineering problems' (Hadgraft 2017).

For curriculum development, this means that appropriate formats are integrated into university teaching in the sense of the 'shift from teaching to learning' (Biggs and Tang

2011). The formats, as listed in Fig. 4 and Fig. 5, can be subject to teaching in terms of content or implemented as a proactive teaching format in such a way that students gain experience in the respective formats themselves. However, not all formats are equally suitable. Teaching and learning objectives must remain decisive here. Nonetheless, the list may serve as inspiration for educators.

4 SUMMARY AND ACKNOWLEDGMENTS

The study presented here has shown that about 70% of the companies surveyed in the German engineering sector are sustainably oriented. This is accompanied by an increased engagement in innovation ecosystems of which this study provides an overview. If integrating sustainability into academic training is indeed a declared objective in higher education, then these results provide a strong argument in favour of a more interdisciplinary and transdisciplinary approach in engineering education, in which problem-oriented learning approaches and application-oriented teaching are used to develop transversal competencies that prepare students for the needs of practice, considering sustainable and ethical issues.

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