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COMMENTARY

Research–Practice–Collaborations in Engineering

Commentary on "Research–Practice–Collaborations in International Sustainable Development and Knowledge Production—Reflections from a Political-Economic Perspective"

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Abstract

In her recent article, Bender discusses several aspects of research–practice–collaborations (RPCs). In this commentary, we apply Bender's arguments to experiences in engineering research and development (R&D). We investigate the influence of interaction with practice partners on relevance, credibility, and legitimacy in the special engineering field of product development and analyze which methodological approaches are already being pursued for dealing with diverging interests and asymmetries and which steps will be necessary to include interests of civil society beyond traditional customer relations.

Résumé

Dans son article récent, Bender traite plusieurs aspects des collaborations entre recherche et pratique (CRP, autrement connues comme « recherche collaborative» ou « recherche-action»). Dans ce commentaire, nous appliquons les arguments de Bender aux expériences dans le milieu de la recherche et développement (R&D) en ingénierie. Nous investiguons l'influence des interactions avec les partenaires de recherche sur la relevance, la crédibilité, et la légitimité dans le développement de produits, qui est un des domaines spécifiques de l'ingénierie. Nous analysons quels approches méthodologiques ont déjà été poursuivis afin de gérer des intérêts divergents et des asymétries; et quels pas seront nécessaires afin d'y inclure les intérêts de la société civile, au-delà des relations clients traditionnels.

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Introduction

The concept of transdisciplinary research has become increasingly important in recent years. As early as 1992, the role of science in sustainable development was addressed in Agenda 21 of the UN Conference on Environment and Development in Rio. There, it is demanded to intensify the cooperation between science and the public against the background of the upcoming decisions and transformation processes.[1] Accordingly, this commentary takes an interdisciplinary perspective on RPC. Starting from an engineering perspective, in particular from the perspective of product development as an engineering sub-discipline, we apply arguments developed from a political economy perspective to engineering research and development (R&D) as presented by Bender (2022).

In her article, Bender (2022) addresses the opportunities and challenges that arise from the joint research process of actors from the academic and non-academic sectors. In her article, Bender (2022) discusses three reasons why and in what ways research outcomes from Research–Practice–Cooperations (RPCs) can improve the quality of research: *Relevance, Credibility, and Ligimitacy.* In addition to the benefits of RPCs in terms of research quality, it also addresses the difficulties of implementing RPCs: *multiple and divergent interests* among those involved in the research process, and *asymmetries* in terms of information and resources.

In the commentary presented here, the opportunities and challenges described by Bender are examined against the background of engineering development processes. The focus is placed on the area of product development. Product development is the process of converting needs into a technical and commercial solution (Whitney 1990). In this field, there is a long tradition of collaboration between engineering research in exchange and practice partners. The latter are usually involved in the product development process as customers and users. Research is part of the development process if non-existing solutions have to be developed to meet the requirements expressed by existing or potential customers. Systematized methods have been developed over the past decades with the aim of optimally structuring the process of interaction. In the following, this very specific form of RPC will be examined against the background of Bender's analysis.

Chapter 2 examines how the interaction between research and practice partners affects the relevance, credibility, and legitimacy of product develop. Chapter 3 analyzes which methodological approaches already exist to deal with diverging interests and asymmetries in product development and which steps are necessary to include interests of civil society beyond traditional customer

[1] "…The cooperative relationship existing between the scientific and technological community and the general public should be extended and deepened into a full partnership. Improved communication and cooperation between the scientific and technological community and decision makers will facilitate greater use of scientific and technical information and knowledge in policies and programme implementation. […] Existing multidisciplinary approaches will have to be strengthened and more interdisciplinary studies developed between the scientific and technological community and policy makers and with the general public to provide leadership and practical know-how to the concept of sustainable development…" (Agenda 21 1992, Chapter 31.1).

relationships. Chapter 4 summarizes the findings once again and draws conclusions for the scientific framework.

Assuring Research Quality: Relevance, Legitimacy, and Credibility

Following Cash et al. (2003) and Belcher et al. (2016), Bender defines three dimensions in which the quality of research increases due to collaboration between researchers and practice partners. She claims that the *relevance* of the research will increase by involving the perspective of practitioners. This will help formulate relevant research questions, according to the practice partners involved. This makes sure that the solutions developed by researchers really solve real-world problems. However, different practice partners will define different research questions. Depending on who is involved, the definition of relevance might differ. It matters, who will be involved as practice partners. In product development, the practice partner usually is an existing or presumed customer. As much of engineering R&D takes place in an industrial context and in the context of customer relationships, often the research question is formulated by existing or potential customers while the engineer points out different solution pathways. User requirements engineering is a discipline that systemizes the collection of requirements that have to be addressed by R&D projects. Innovation, however, also happens, if researchers propose solutions for problems not yet formulated by the practice partner. This might result in innovative products or in new patents. However, even then, the results will be soon confronted by real-world needs. Innovation in product development is not a self-sufficient process, but products are functional in the sense that they are made to satisfy a specific need.

Despite some differences between the various engineering disciplines, a common idea exists about how the process of research with practice partners is organized in the context of product development. Most often a six-step process is proposed in which the relevance of the content of the engineering research activity is ensured (Butt et al. 2018): The research process starts with the *recognition of needs and requirements* (terminology according to Ertas et al. 2003). In general, there are different approaches to capture the needs of users when designing a product. These include the use of statistical data and standards, the use of procedural standards, the use of user models and simulations, emphatic elements, and user integration. User-centered methods of product development (e.g., Üreten et al. 2020) include observations of user behavior in a given context, contextual inquiry or usability tests, or even visualization, always focusing on the benefit for the user. The needs of the practice partners (e.g., a customer) are systematically recorded in the context of *requirements engineering*. Only when a common understanding of the research needs has been agreed upon does the R&D of the engineering solution begin. R&D is or on the part of academia or of industry. It takes place in several stages, which repeatedly allow a dialog about the practicality of the proposed solutions developed. After an initial *conceptual design*, the feasibility of the developed concept is examined. This is followed by different *design stages* resulting in a *prototyping* with a *test phase*. By this multiphase research process involving practice partners, *relevance* of research is well assured.

However, not everybody will be able to encounter this type of partnership, in which economic and financially powerful practice partners dominate. This raises the question about the *legitimacy* of such research but also about the *credibility* of the achieved results. The individual practice partners define their own individual needs and accept the solution if it fits them. Accordingly, the question arises as to who has the power to define the relevance and quality of research in the process described above and how actors can be involved who are not directly related to engineering R&D processes. This could be marginalized groups or generations not yet even born. Such groups are especially addressed in the Brundtland definition of sustainable development, where the needs of existing and future generations are equally addressed with an emphasis onto the needs of the poor (WCED 1987). R&D for sustainable technologies should try to include these needs in the requirements engineering process.

An example how to address the needs of social groups who are often neglected in requirements engineering is given by Glende (2010), who searched for methods to take account of the needs of older people in the context of product development. He confirms that especially in the product definition phase and during technical development, the affected groups should be actively involved. This finding is in line with the results of Schmidt and Pröpper (2017) who show for large RPC projects in an international development research context. They found as well that already during the phase of project definition asymmetries between researchers and practice partners can arise, which have a negative impact on the research results.

Besides the direct involvement of stakeholders, additional user-centered methods have been developed in the context of product development processes. They involve adapted user models, or context-specific statistical data. These methods can be applied in almost all phases of the product development process (problem identification, requirements analysis, testing and evaluation of concepts, mockups, prototypes, product improvement after market entry). Bhattacharyyaa and Timilsinab (2010) give an example for such context-specific data based applied in the context of product development in the energy sector, considering the specific needs of energy systems in developing countries.

Independent of the exact method used: By involving a wide variety of perspectives including sustainability criteria rather than only requirements based on customer relations and by involving multi-stakeholder settings in requirements engineering and prototype testing, transdisciplinary engineering will improve the *legitimacy and credibility* and, thus, the quality of R&D.

Conflicts of Interest, Power Asymmetries and Multi-criteria Optimization: Challenges for Transdisciplinary Engineering Projects

Besides the traditional way of including user requirements in product development, there is a growing need to develop methods to include multi-stakeholder perspectives. Especially in the context of *research for sustainable development*, the collaboration of research and practice in the context of transdisciplinary research is repeatedly called for. Transdisciplinary research, as transformative research, has the mission to align *relevance* with the needs of society as a whole (Schneidewind and Augenstein 2012). This shift towards a new agenda setting process can be achieved by means of participatory research or co-production of knowledge. It means that research needs are not defined by traditional customers and business partners but are formulated in close exchange with actors from politics and society. Here, we use the term *transdisciplinary engineering*, to describe the new approach to involve multi stakeholders and to tackle complexity in design problems due to resulting multidimensional requirements.

Transdisciplinary RPC projects are usually performed in large, long-lasting projects involving multi-disciplinary teams, including engineers from different disciplines, practitioners, and multiple stakeholders. As Bender points out, this requires *collective action of actors with multiple partly conflicting interests.* Her analysis mentions various reasons for conflicts, including differences in time horizons or different expectations regarding the theoretical level and practical use of the outcome. Cundill et al. (2019) strengthens the importance of both*, relational features* such as interpersonal trust, mutual respect, leadership styles, as well as *systemic features* such as legal partnership agreements or power asymmetries between partners and institutions as well as differences in culture. Both features also play a role in complex transdisciplinary product or system design projects, e.g., in the energy sector, where decisions on grid extension, energy storage technologies, or renewable energy production require multi-stakeholder involvement. In such settings, relational and systemic features should more explicitly be integrated in the engineering design process. They should be subject to all phases of project management. And they should be subject to the design process itself, which has to be adapted in such a way that it is able to handle conflicting user requirements in all phases of the design process.

What about requirements that are not addressed in the above-mentioned process? What about requirements of stakeholders, who are not affected as potential users of the R&D results, but due to unintended negative environmental or social side effects? During the recent years, methods have been developed to systematically take account of sustainability criteria in product development. The aim here is to minimize negative effects in terms of environmental impact and social conditions caused by production, use, and waste while, at the same time, minimizing overall costs for all stakeholders involved. The life-cycle analysis (LCA) method allows to take account for environmental impacts during the entire design process (EN ISO 14040:2006). Similarly, the social impacts in the immediate environment of production, use, and waste can be dealt with. Through the method of social LCA (S-LCA), the requirement of minimizing negative social impacts can also be systematically integrated into the product development process (e.g., Benoit and Benoit 2009). This systematic recording of extrinsic effects during product development contributes to requirements beyond user needs.

Ertas (2018) offers a methodology for transdisciplinary societal problem-solving processes including multidimensional user requirements. Methods using multi-criteria optimization algorithms to reduce complexity in decision-making processes can be used. However, engineering solutions to complex problems require not only the development of complex systems with multiple components and subsystems that interact with each other, but also a process of design and redesign that involves key stakeholders from society, politics, industry, and commerce, and other disciplines of knowledge. The primary goal is to solve multidimensional, complex problems. In addition to mathematical-technical problem-solving skills, this requires social and conflict solving management skills. In this way, it should be made possible to systematically capture different requirements and mathematically incorporate them into the solution-finding process.

The increasing complexity allows to recognize interdependences between partial solutions at an early stage when developing an overall solution. The multi-perspective formulation of requirements in transdisciplinary, socially oriented RPC places new demands on engineering and requirements engineering processes. Many of the problems are complex and require interdisciplinary teams both for the definition of user requirements and for developing solutions. Accordingly, engineering education should increasingly prepare students to handle complexity by teaching how to tackle complex real-world problems instead of using simplified textbook problems (Van den Beemt et al. 2020). This includes new IT-based tools to find optimal solutions for complex problems, e.g., multi-criterial optimization. It also includes new participatory methods. Interestingly, user participation in the product development process buffers the effect of uncertainties (Enam et al. 1996).

However, it remains a challenge for design engineering to include stakeholders from diverse cultural backgrounds - including marginalized groups - in the design process. Defining and including societal needs automatically lead to a multi-perspective formulation of the problems and product requirements to be tackled. As a consequence, the research object gains in complexity, but it also reflects conflicting interests.

Bender's reference to the effect of role and power constellations in transdisciplinary R&D projects on research results seems quite helpful here: When it, e.g., comes to the question of financing transdisciplinary R&D projects, there is always the danger to foster resource asymmetries. In traditional R&D design projects, companies place orders with research institutes or researchers seek companies as R&D partners in third-party funded projects. In both cases, collaboration is possible in a contractually regulated semi-symmetrical relationship. In many situations, such traditional research formats are appropriate. However, when it comes to the design of widely used products with strong impact on society as a whole, e.g., energy system components, transdisciplinary R&D formats including a wide variety of social stakeholders might be more appropriate.[2] For such projects, the challenge due to power asymmetries and conflicts of interests is far greater: For example, professional researchers and companies involved might get financed more often than representatives of the targeted stakeholder groups and they might also be more involved in research agenda setting processes. As Bender suggests, it might be helpful in such settings, if

[2] In the context of German energy research, the format of the "Reallabore der Energiewende" (Real Labs of the Energy Transition) was introduced for this purpose, in which project partners take a holistic approach to testing new technologies and business models under real conditions: "Research questions that cannot be investigated in the artificial conditions of a laboratory environment are examined in particular. The goal of real laboratories is primarily to accelerate the transfer of innovations into practice." (7th EFP, 2018, p. 92).

all actors involved in the development process are aware that their involvement differs depending on their role within the project (*different working realities*).

Increasing complexity and additional conflict potential require additional time and space to carry out transdisciplinary R&D projects. Especially when applying user-centered methods, the additional time and effort should already be accounted for when planning such projects. In traditional design projects, customers often order research support and set the research agenda. In case of joint projects based on third-party funding, already agenda setting should be done jointly, which poses a challenge. Here additional research on adequate methodologies for RPC in transdisciplinary product and system design is still needed.

Concluding remarks Research–Practice–Collaboration is quite common in engineering and ensures the *relevance* of research, while in product development, *relevance* is automatically ensured by requirements engineering. User requirements are usually not oriented to the needs of society as a whole, but to customers who pay for the requested R&D service. This raises the question about the *legitimacy* of such research, but also of the *credibility* of the results obtained. Bender's reference to the impact of role and power constellations on research results in RPC projects seems quite relevant in this context. *Transdisciplinary Engineering* as a research approach that involves multiple stakeholders and multidimensional user requirements enhances both the legitimacy and the credibility of research. Methods that consider life-cycle-based sustainability criteria and use multi-criteria optimization algorithms help support decision-making processes with societal relevance. *Transdisciplinary Engineering* requires not only mathematical and technical problem-solving skills but also social and conflict-resolving management skills. This should be taken into account both in engineering education and in estimating the resource requirements for transdisciplinary research.

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