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Facing the future: trends in development environments that enable engineers to thrive

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ABSTRACT: The evolving landscape of engineering is shaped by trends such as digitalization, sustainability, and globalization. While these trends impact product development, their direct effects on engineers remain underexplored. This study investigates how current trends shape engineering work environments and identifies key factors that enable engineers to thrive. Using a mixed-method approach, we conducted qualitative interviews and a quantitative survey with 122 engineers across industries. Our findings reveal that trends influence collaboration, autonomy, stakeholder involvement, and digital tool integration. The results emphasize the need for human-centered approaches, such as New Work, to balance flexibility and structure. The insights contribute to designing adaptive engineering environments that foster resilience, well-being, and innovation.

KEYWORDS: new work, workspaces for design, design management, trends in engineering, human behaviour in design

1. Introduction

The rapid development of generative AI systems, which gained widespread recognition with the advent of voice assistants and the significant advancements by OpenAI, is presenting companies with new opportunities (Floridi & Chiriatti, 2020; Moriuchi, 2019). A prime example is Bosch's announcement that by 2025, all of its products will either be equipped with AI or developed and manufactured with the help of AI (Ebberg, 2020). The current transformation of the workplace goes beyond the adoption of AI and encompasses a variety of other trends that are profoundly affecting the role of engineers (Dumitrescu et al., 2021). In addition to the increasing use of AI and digitalization, the demands for sustainability, global connectivity or the focus on more meaningful work are reshaping how products are developed. These changes create opportunities to optimize product development and support engineers in their work by the help of a well aligned work environment but also pose challenges in engaging with the trends (Krause & Gebhardt, 2023). In this context, the concept of "New Work" has gained prominence (Teichert et al., 2023). It promises to design work environments that cater to the individual needs of engineers and foster the realization of their potential to eventually enable them to thrive. In this study, we define 'thriving' as engineers being able to work productively, feel secure in their roles, and engage in meaningful and innovative work (cf. Spreitzer et al., 2005). But are human-centered concepts like New Work truly the solution to the challenges posed by current and future trends in product development? This paper thoroughly examines the impact of current trends including the resulting challenges and potentials by taking a snapshot of the actual impact of trends on engineers that need to be considered when designing an environment where engineers can thrive.

2. State of the art

2.1. Developing advanced systems: ASE - Advanced Systems Engineering

In addition to the evolution of mechanical products into cyber-physical systems, modular product architectures and lightweight design developments (Krause & Gebhardt, 2023), the trend radar by Dumitrescu et al. (2021) demonstrates that a multitude of disparate trends, predominantly classified as megatrends encompassing digitalization, globalization and sustainability, exert a profound influence on engineering. In response to the ongoing changes in engineering, the guiding principle of Advanced Systems Engineering (ASE) was formulated (Dumitrescu et al., 2021). This principle is constituted by a triad comprising Advanced Systems (AS), Systems Engineering (SE), and Advanced Engineering (AE), thereby providing a comprehensive framework for modern product development. ASE integrates systematic methods, digitalization, and interdisciplinary collaboration to enable engineers to develop advanced systems efficiently. ASE recognizes that engineers face increasing complexity in cyber-physical systems and must continuously adapt. However, existing research within ASE primarily focuses on technical solutions rather than the work environments engineers need to thrive in (Dumitrescu et al., 2021).

2.2. The engineer at the center of product development

Recent literature has increasingly focused on the role of engineers as central figures in product development. This shift is exemplified by the system triple of product engineering, which positions engineers at the core of the process, emphasizing their crucial role in transforming goals into tangible outcomes through their unique contributions (Albers et al., 2019). The system triple of product engineering, comprising the system of objectives, the system of objects, and the operation system, offers a socio-technical perspective on product development, highlighting the critical influence of individual engineers in the success of the operation system (Albers & Lohmeyer, 2012). The significance of placing people at the heart of product development has been long recognized. Allen (1966) noted that understanding product development inherently requires an examination of human behavior, while Hales and Gooch (2004) underscored the essential role of human responsibility in ensuring successful development processes. Creativity, a key driver of innovation, is deeply rooted in human cognitive processes, which involve memory, knowledge, and both intuitive and analytical thinking (Bender & Gericke, 2021). Effective problem solvers rely on intelligence, creativity, decision-making, and flexibility, attributes that are uniquely human and essential to navigating the complexities of product development (Dörner, 1984). Prior research has also identified several interdependent factors that influence engineers, which can be grouped into macroeconomic, microeconomic, organizational, project-related, and personnel categories (Albers et al., 2019; Gericke et al., 2013). These factors present both opportunities and challenges throughout the product development lifecycle, impacting engineers in various ways. Successfully integrating these human factors into the development process is crucial for fostering innovation and overcoming obstacles, ultimately leading to more adaptive and innovative outcomes. Recognizing the importance of the engineer's role sets the stage for exploring how human-centered approaches can further enhance the environment in which engineers operate, to eventually ensure a successful development of Advanced Systems (Reich & Subrahmanian, 2020).
This results in our understanding that an engineering environment is a socio-technical system in which engineering teams perform analysis and synthesis activities to develop innovative solutions. It includes all contextual factors that an organization can influence, structured within the dimensions of people, organization, and technology. These dimensions provide the foundation for enabling engineers to thrive:

- People: e.g. competencies, collaboration structures, decision-making autonomy, and motivation.
- Organization: e.g. project management approaches, leadership styles, corporate strategies, and stakeholder engagement.
- Technology: e.g. digital tools, software systems, physical workspace design, and automation systems.

Understanding how these dimensions interact is critical for developing work environments that foster creativity, problem-solving, and productivity while addressing challenges such as growing product complexity, interdisciplinary collaboration, and increased external demands.

2.3. New Work in engineering

A key factor in designing enabling development environments is the consideration of human-centered approaches that address both professional and personal requirements. By aligning the workplace with engineers' needs, organizations can create conditions that promote innovation and productivity (Zoltowski et al., 2012). A concept called New Work, rooted in the ideas of Frithjof Bergmann from the 1980s, has gained significant relevance in modern engineering as it aligns with the evolving demands for human-centered approaches. New Work emphasizes autonomy, flexibility, and meaningful work, offering a framework that addresses the changing expectations of engineers and the complexities of modern product development (Hofmann et al., 2019). In the context of Advanced Systems Engineering (ASE), where interdisciplinary collaboration and continuous adaptation are crucial, New Work provides a human-centered approach that empowers engineers to thrive. The principles of New Work directly respond to the challenges engineers face in today's rapidly evolving technological landscape. By promoting flexible work environments, decentralized decision-making, and personal development, New Work enhances engineers' engagement and creativity. This approach could support in ASE, where the integration of digital tools and agile methods requires engineers to be adaptive and innovative (Grote et al., 2020). The flexibility promoted by New Work practices, such as remote working and self-organized teams, not only improves job satisfaction but also increases productivity by allowing engineers to work in ways that best suit their individual needs and project demands (Savic, 2020).

The essence of concepts like New Work lies in creating environments where engineers can excel by aligning work structures with individual strengths and motivations. New Work suggests that these environments must be flexible, supportive of continuous learning, and focused on human-centric values, emphasizing work-life balance and fostering a culture of innovation (Teichert et al., 2023). This ensures that engineers can adapt to and lead within the dynamic context of ASE (Impertro et al., 2023). While New Work offers significant benefits, its successful implementation in development environments requires overcoming cultural resistance and ensuring that the necessary digital infrastructure is in place. Leaders must adopt management styles that support autonomy and flexibility while maintaining productivity and innovation (Impertro et al., 2023; Von Au, 2020). New Work provides a framework that directly addresses the essential characteristics of development environments needed for engineers to thrive. By aligning work practices with the evolving demands of ASE and the individual needs of engineers, New Work represents a critical pathway to creating more adaptive, innovative, and human-centered development environments.

3. Research objective and research methodology

The overarching objective of this study is to identify the essential characteristics of a development environment that enables engineers to thrive. Considering the evolving trends in the engineering sector, this research aims to determine what specific demands such environments must meet to place engineers at the center of product development, ensuring their well-being and productivity. Therefore, the goal of this paper is to thoroughly examine the current trends in engineering, including the challenges and potentials these trends introduce. By taking a snapshot of the evolving work environment, this paper seeks to understand how the trends impact engineers and their individual needs in a work environment that enables engineers to thrive.

The main research question guiding this investigation is:

- What are the essential impacts of trends on engineers that need to be considered when designing an environment where engineers can thrive?

To address this research question, a mixed-method approach is employed following Tashakkori and Creswell (2007). Our approach is divided into four stages, each linked to specific methods and objectives (cf. Figure 1).

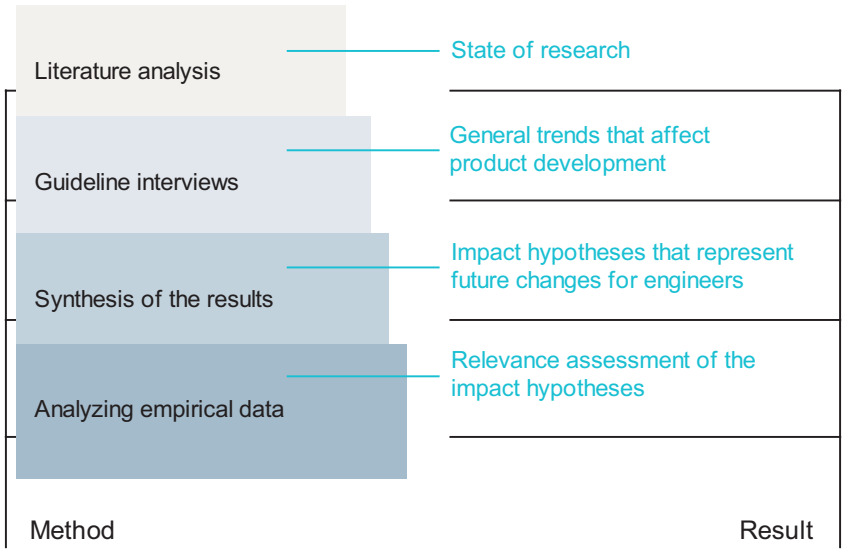

Figure 1. Mixed method research approach

The first stage involves clarifying the research context by establishing a general understanding of the study's focus. This is achieved through an extensive literature review, which helps to clarify the study's objectives.

The second stage includes an exploratory data collection process. This stage is based on semi-structured interviews with eight industry professionals to gather qualitative insights. This includes various job profiles and hierarchy levels. For example, a Principal Scientist from the glass industry or a Solution Manager from the automotive industry. Semi-structured interviews, widely used in qualitative research (Kallio et al., 2016), allow for structured questioning while exploring unknown areas, thereby uncovering new aspects within partially known research fields (Wilson, 2014). These interviews are conducted following the methodology suggested by Buber and Holzmüller (2007). Following the interviews, a systematic text analysis of the transcribed interview data using MAXQDA software is conducted. The analysis is based on inductive and deductive coding (Kuckartz, 2010; Mayring, 2015), offering insights into the qualitative and quantitative content of the engineers' statements.

The third stage involves the formulation of impact hypotheses based on the previous findings again using MAXQDA software. To this end, a new coding guide was created based on the general trends and their challenges and potential. This made it possible to derive thematic impacts. These impact hypotheses represent the current and future impacts of trends on engineers in the context of product development. The hypotheses are ultimately evaluated in a fourth stage through a quantitative, cross-industry survey. To recruit participants for the study, engineers were contacted via several digital platforms, including LinkedIn, internet forums, Prolific, SurveyCircle and email, over a period of 50 days. The survey data of 122 engineers, analyzed using SPSS software, assesses the relevance of the impact hypotheses, giving answers about the impacts of trends that need to be considered when designing development environments that enable engineers to thrive. For each hypothesis of impact, agreement was gauged using two items: one for the general agreement with the described hypothesis (occurrence) and the estimated positive and/or negative impact strength of the impact hypothesis (impact), each representing a dimension of relevance. The respondents were asked to rate each of the aforementioned items on a five-point Likert-like scale (ranging from 1 - strongly disagree to 5 - strongly agree), or alternatively, they could choose to refrain from answering (Likert, 1932; Sullivan & Artino, 2013). Furthermore, data pertaining to the respondents' demographic characteristics were collected for subsequent analysis to identify potential differences between age groups and company sizes. To ensure the representativeness of the sample, respondents were also asked to provide information regarding their occupation and industry. Additionally, an attention check question was integrated into the questionnaire to assess the respondents' engagement with the material. Trends on engineering from the perspective of engineers

Based on the inductive and deductive approach, a total of 25 trends were identified in the semi-structured interviews, which were deemed to exert an influence on the work of engineers. An overview of the frequency and distribution of mentions per interview (column) and trend (row) is shown in Figure 2. The

size of the squares is indicative of the quantity of mentions, thereby elucidating the comparative disparities in mentions. In addition to identifying the trends themselves, the analysis also identified challenges and potential opportunities associated with each trend. For instance, the agility trend was found to present several challenges, as well as offering several opportunities. Similarly, some trends could be assigned to a higher-level trend if this was evident from the context. To illustrate, the observed trend towards the utilization of patents (Patents) was found to align with the trend towards overarching competition (Market competition). The trends of artificial intelligence (AI), agile working methods, sustainability and open innovation were highlighted particularly frequently in the interviews. However, the number of overall mentions varied between the interviews.

Figure 2. Overview matrix of the naming distribution of all codes identified in the interviews by interview (column) and code (row), in relation to all cells

4. Impacts of trends on engineers in product development

Based on the interview data, impact hypotheses were formulated to examine the influence of trends and their associated challenges and potentials for engineers (cf. Table 1). The objective of this analysis is to illustrate the impact of the trends on the individuals at the center of product development and to establish a causal relationship between them. For a more detailed understanding, the 14 impact hypotheses were divided into 24 individual, distinct items that represent the separated main contents of each hypothesis.

Table 1. Impacts of trends on engineers in product development

No.	Impact hypothesis	Item
H1	Engineers are increasingly working in more diverse and larger teams with less continuity of collaboration.	H1.1: I am increasingly working in diverse teams. H1.2: I am increasingly working in larger teams. H1.3: I am experiencing increasing fluctuation in my working environment.
H2	People working in product development are increasingly confronted with a growing number of stakeholders. As a result, engineers are devoting a higher percentage of their work to stakeholder communication and involvement.	H2: I am increasingly working with more stakeholders in my day-to-day work.
H3	Engineers are experiencing an increasing number of meetings in their day-to-day work, which can be time-consuming and not goal-orientated. As a result, the usefulness of meetings is increasingly being questioned.	H3.1: I am spending an increasing amount of my working hours in meetings. H3.2: I find meetings increasingly unproductive.
H4	Engineers are increasingly experiencing a discrepancy between what trends could make possible and what is realized in day-to-day product development.	H4.1: I increasingly notice a gap between what trends promise and what is actually implemented in product development.
H5	Engineers have an increasing feeling of anxiety and uncertainty regarding their working environment and the economic situation of the company.	H5.1: I am increasingly worried about losing my job at the company. H5.2: I am increasingly worried about the economic situation of my company.
H6	In future, engineers will increasingly focus on employers who take current trends into account at an early stage in the product development process.	H6.1: I think it is increasingly important that my working environment takes trends into account early in the product development process or already implements them.
H7	Engineers are using a growing number of tools in their day-to-day development work. However, some of these are difficult to integrate into established structures. There is also an increasing lack of compatibility between tools.	H7.1: I am using more and more tools in my working environment, but they are difficult to integrate.
H8	Engineers are increasingly experiencing a change in the focus of their activities and thus a change in their usual work situation.	H8.1: I realize that the focus of my work is increasingly shifting, and I won't be working the way I used to.
H9	Engineers will increasingly integrate training and further education into their day-to-day work.	H9.1: I plan to increasingly take part in training and further education.
H10	Product development is increasingly focused on the needs and capabilities of engineers, while at the same time the demand for autonomy is growing.	H10.1: My autonomy within the company is becoming increasingly important to me H10.2: My working environment increasingly takes my needs and abilities into account.
H11	Engineers experience an increasing number of product requirements in their work, which cause conflicts of objectives.	H11.1: I have to take more and more product requirements into account. H11.2: I have to reconcile increasingly conflicting product requirement.

(*Continued*)

Table 1. Continued.

No.	Impact hypothesis	Item
H12	Engineers complete a larger part of their work in a checkbox approach. At the same time, they are confronted with a growing demand for responsibility and depth of integration. This represents a conflict of objectives for managers when it comes to determining the appropriate depth of tasks for engineers.	H12.1: I increasingly organize my work according to checklists. H12.2: I am increasingly given more responsibility for the results of my work.
H13	For engineers, the conflict of objectives is growing both between generations and in comparison, to historically grown structures, especially regarding new working methods and intrinsic goals.	H13: I am increasingly experiencing conflicts between representatives of established ways of working and those advocating for modern approaches.
H14	Engineers are increasingly experiencing a conflict between software and mechatronic development regarding methods that have not been adapted as required and different development speeds.	H14.1: I am increasingly experiencing a conflict between different development departments due to different development speeds H14.2: I am increasingly noticing the use of inappropriate methods and processes from other departments.

5. Evaluation of impact hypotheses

Eventually, the impact hypotheses were evaluated through a quantitative, cross-industry survey with 122 participants. The three most common age groups were 25-29 (22 %), 30-34 (25 %), 35-39 (13 %) and 50-64 (14 %). In terms of company size, the majority of respondents were from organizations with more than 250 employees (70 %). However, organizations with fewer than 10 (4 %), 10 to 50 (11 %) and 51 to 250 (13 %) employees were also included in the survey. It should be noted that a small proportion of respondents did not provide any information about the organizations (2 %). The impact hypotheses were allocated to the adapted trend portfolio by Fink and Siebe (2011) based on the mean values by item (cf. Figure 3). The trends in area 1 of the trend portfolio (*tackle immediately*) are of particular significance due to the high rating of both dimensions (occurrence and impact) within the portfolio.

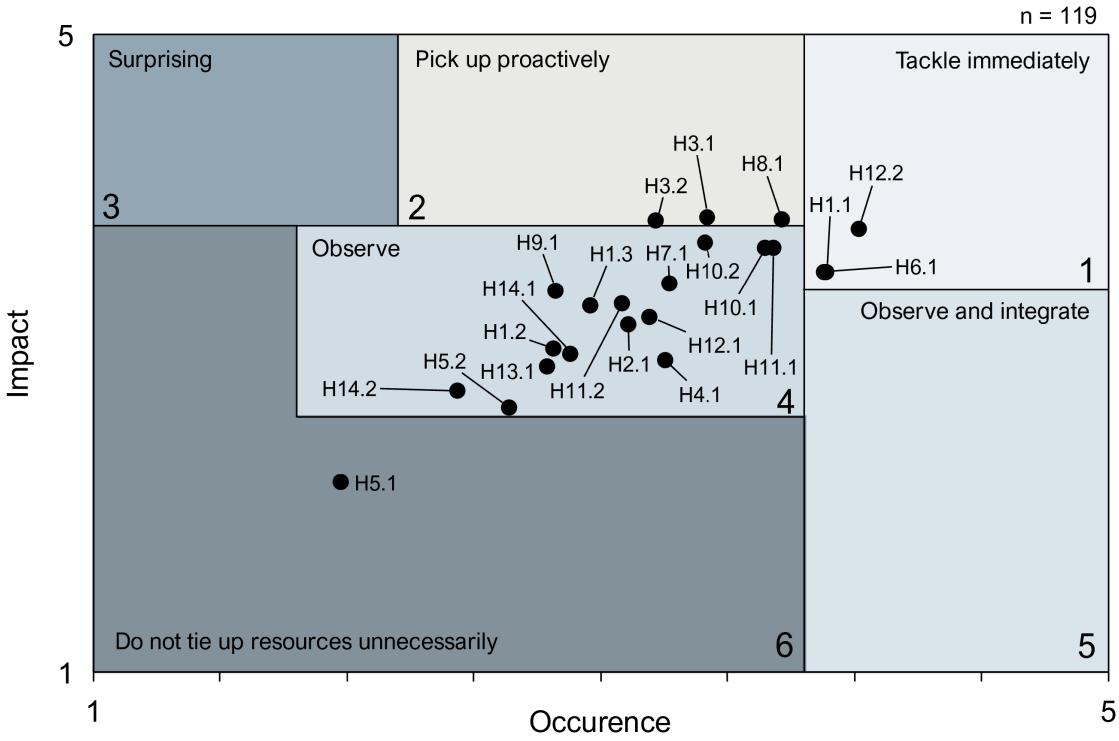

Figure 3. Adapted trend portfolio according to Fink & Siebe (2011) for the relevance assessment of the evaluated impact hypotheses with a scale of 1 (do not agree at all) to 5 (completely agree)

It is therefore evident that there is a significant degree of relevance in the increase in responsibility for work results (H12.2), working in diverse teams (H1.1) and taking account of trends in the workplace (H6.1). In contrast, trends in area 2 (*pick up proactively*) as the growing importance of autonomy (H8.1) as well as the high number of meetings (H3.1) and their inefficiency (H3.2) need to be considered to foster environments where engineers can thrive. The majority of trends are situated in the midfield of the portfolio (observe), and thus should be considered in the context of future working environments, using resources and capacity. (cf. Figure 3). Moreover, the results indicate that engineers are apprehensive about the prospect of losing their employment (H5.1) as displayed in are 6 (*do not tie up resources unnecessarily*). However, the respondents stated that the potential impact on their work was minimal. It is therefore not essential to address this trend.

6. Discussion and outlook

This study investigated how current trends in engineering impact engineers in the center of product development. While prior research has identified general trends and their implications for product requirements or societal shifts, it often fails to consider their specific effects on the individuals driving innovation - engineers. Additionally, these studies tend to focus on isolated trends without examining their combined effects or the mechanisms underlying their impact. On the one hand, the results of the study demonstrate that trends such as digitalization, sustainability, and global collaboration persist in their significance, as would be anticipated. On the other hand, these trends influence not only product requirements but also the working conditions and demands placed on engineers. For instance, sustainability efforts necessitate balancing resource constraints with the pressure to innovate (e.g.: "[...] however, this also means that if sustainable solutions cannot at least be reconciled with the cost requirements." Interview F). These findings extend existing knowledge by emphasizing how trends collectively shape the experiences, expectations, and challenges faced by engineers, an aspect previously underexplored in literature. However, it does not aim to redefine or reinterpret these trends but rather to provide empirical evidence of their multifaceted impact, particularly regarding challenges like maintaining creativity under increasing time and resource pressures.

The insights gained from this study contribute to the overarching goal of designing development environments that enable engineers to thrive by aligning their work conditions with their individual needs. One limitation is the subjectivity of the results, for example in the categorisation of the hypotheses in the portfolio, which is why further studies based on structured design methods are being carried out. Future work will focus on developing methods, processes, and tools that support engineers based on their individual needs, aligning with the principles of New Work. For example, the identified need for structured collaboration despite increasing flexibility (H3, H10) highlights the importance of balancing autonomy with organizational structure, a core element of New Work (Teichert et al., 2023). Additionally, findings such as the challenge of increased stakeholder involvement (H2) emphasize the need for transparent decision-making structures, another key aspect of New Work. One other direction is the development of a modular organization system tailored for engineering teams based on applying structured design methodologies (e.g. Kolberg et al., 2014). In our approach, we will draw from the principles of modular product development to combine standardized structures with flexible options to accommodate diverse needs. For example, modules could include tailored collaboration frameworks, flexible scheduling models, or tools for remote work, allowing teams to adapt their workflows while maintaining consistency. This approach aims to balance efficiency with individuality, fostering collaboration and reducing internal complexity. Beyond organizational improvements, the overarching goal of this research is to enhance the resilience of both engineers and organizations. By fostering environments that prioritize engineers' well-being, creativity, and productivity, the research aims to strengthen their capacity to navigate emerging trends and challenges, ultimately driving sustainable innovation in product development.

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