When design meets material to transform public transport into a status symbol.

Experimental study on bus seat design

To create sustainable solutions, we should combine the expertise of different disciplines. In our experimental case study, a materials scientist and an industrial designer collaborated to design a bus seat contributing to transform public transport into a status symbol.

Kerstin Mayer, Jadwiga Slezak

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Abstract
To overcome the complex challenges of our time and prepare for a sustainable future, we must break new ground and find strategies for collaboration. In this experimental case study, we demonstrate how industrial design and materials science worked together on an equal footing to design a public status symbol. Since both disciplines are practice-oriented, the focus was on creating a specific object: a seat for a public bus as a *pars pro toto* for enhancing the value of public mobility. The design object was at the same time the object around which interdisciplinary collaboration evolved. In spite of differences in thinking between the two disciplines, the approaches finally enriched each other. The most important findings include the identification of mesh structures as a common denominator for the interdisciplinary co-design. The mesh structures' flexibility fulfilled ergonomic requirements and, at the same time, their aesthetic and haptic qualities inspired the development process. Working together between disciplines from the outset can help transform industrial design in a way that addresses the fundamental environmental challenges of our time.

Keywords
bus seat, case study, co-design, experimental approach, industrial design, interdisciplinarity, material design, mobility transformation, public transport, sustainable mobility

Dr. Kerstin Mayer (corresponding author) | Muthesius University of Fine Arts and Design | Kiel | DE | kerstin.mayer@muthesius.de

Jadwiga Slezak, MA | Muthesius University of Fine Arts and Design | Kiel | DE | slezak@muthesius.de

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Public mobility as public luxury

The shift from individual vehicular travel to public transport is an important step towards sustainable mobility. Mobility transformation research is part of the broader field of transformation research, which deals with the fundamental changes that are necessary to achieve sustainable and inclusive futures (Hölscher et al. 2021). Understanding mobility as a social practice (Reckwitz 2002) opens up possibilities for shaping this transformation. The social practice of using public mobility is composed of 1. materials, like buses and their interieur or railroad systems, 2. competences, for example understanding timetables and ticket systems, and 3. meanings, such as social status connected to (not) using public transport, or perceived reliability, safety and soundness. This interrelation means that infrastructure design is crucial for behavior. It is possible to act on each of these elements, by way of, for example, technological innovations, skills development, and changes in habits and social values (Shove et al. 2012, Reckwitz 2002).

The complex field of mobility design, therefore, relies on collaboration between different disciplines. It focuses on shaping the experience of mobility and emphasizing the quality of movement rather than just transportation modes (Vöckler and Eckart 2022, pp. 7–18). However, conventional *public* transport design often prioritizes efficiency and cost over user experience. Passengers usually do not identify with regional transport systems, leading to public mobility having little societal value (Coxon et al. 2007). Conversely, the success of the automobile as the flagship of individual transport would not have been possible without cities and infrastructure designed to favor cars (cf. Mattioli et al. 2020, Shove et al. 2012). In addition, there is a particular focus on aesthetic and sensory qualities in car design: surface feel, interior aesthetics, olfactory quality, and even the sound of car doors are meticulously designed, creating a perfect match of design and materiality (Schefer 2008). Design plays a central role in reinforcing values such as freedom, power, and independence, turning cars into status symbols (cf. Fitt 2023, Coxon et al. 2007).

The concept of *public luxury* (Monbiot 2020, Wilson 2023, p. 313) could help shift value perceptions and mobility habits by turning public mobility into a *public status symbol*. Luxury and the public sphere initially appear to be contradictory terms. Luxury is generally associated with something private that stands out from the general public, superfluous for survival, and yet *desirable* (Wiesing 2015, p. 132). Addressing mobility transformation through *creating desirable objects and experiences that embody public luxury* was central to the research cluster *Sustainable Mobility Transformation* funded by EKSH (Energie und Klimaschutz Schleswig-Holstein) in the Industrial Design Department at the Muthesius University of Fine Arts and Design in Kiel, Germany. Creating desirable qualities for public services should persuade others to choose the public option instead of the individual one. Additionally, it is valuable for a society to ensure that all citizens, especially those who cannot choose their mobility system, are granted access to comfortable experiences (Rhein and Slezak 2021–2022). A public status symbol can convey the experience and meaning of luxury. A strong focus on the high quality of shared goods is part of the idea of public luxury. Including aesthetic and sensory qualities is necessary to justify the term and truly transform the use of a product or service into a desirable experience – great opportunities for design to demonstrate its strengths in creating qualities. Just as language shapes our views and attitudes towards mobility (Caviola and Sedlaczek 2020), the influence of our visibly and tangibly designed environment should not be underestimated, although it is clear that public transport design cannot simply imitate the strategies and resource intensity of the individual status symbol car. Rather, public transport design is just one piece of the puzzle in sustainable mobility transformation (Schiefelbusch 2010, Van Lierop 2018).

There are already existing examples of what mobility as a public status symbol can look like. Copenhagen is considered one of the most livable cities due to its people-centered design of public spaces. The Cykelslangen bicycle bridge by Dissing + Weitling exemplifies aesthetic quality and outstanding mobility experience (Vöckler et al. 2023, pp. 86 ff.). A similar approach is found in Stockholm's metro system, often referred to as "the world's longest art gallery", featuring impressive artworks, efficient infrastructure, and accessibility for all users (Abramson 1994). The Wuppertal suspension railroad vehicles designed by Büro+Staubach are another example of desirable mobility design (Büro+Staubach 2024). The interior features high-quality materials, with lightweight molded wood seats and custom-made upholstery fabrics. Floor-to-ceiling windows transform the train ride into an attraction. As a landmark of Wuppertal, its design reflects the value that the train has in the society.

Case study[1]

The case study project described in this work was part of the above research cluster and involved an interdisciplinary team of an industrial designer and a chemist/materials scientist.

In the following subsections we describe the process, outcomes, and insights from our experimental approach. Figure 1 (p. 236) illustrates the research process schematically and highlights important steps.

1 Design task and research question

The goal was to design a joint object *(design task):* a bus seat as a *pars pro toto* for designing public luxury. We realized the mode of cooperation is crucial for developing sustainable solutions, leading us, beyond the design task, to ask the *research question:* how can different disciplines work together on an equal footing to define the characteristics that a public transport seat needs in order to allow the experience of mobility as a public status symbol?

The formulation of the research question resulted from a critical reflection process. Initially focused on designing a desirable, sustainable seat, it evolved into exploring how this object could facilitate good collaboration.

The designer and the materials scientist began with a comprehensive exploration phase, trying out many directions. In this phase, the seat's materiality was constantly redefined, from a solid hard shell to inflatable elements and free-hanging textile structures.

The designer's work was informed by qualitative user interviews and observations of people on their daily bus journeys ("fly on the wall" method). Based on this research, the designer identified problem areas that a new seat concept should solve: user interviews highlighted stress and discomfort due to lack of privacy, poor air quality, vandalism, inadequate maintenance, and a subjectively perceived lack of hygiene.

Visiting a local transport company and interviewing its employees revealed a key insight: "The higher the quality and better designed our interiors are, the less we have to contend with vandalism."[2] Consultations with an international manufacturer of public transport seats highlighted current challenges in sustainability issues of using and producing bus seats: current bus seats are typically made of plastic hard shells with cushions; durable and repairable but normally not recycled, mainly due to irreversible material bonding. Besides, there is room for improvement in material efficiency as seats are primarily made from full-surface plastic shells. A desired user experience for future public transport where people feel valued, safe, and relaxed, reducing stress factors to a minimum, was combined with the sustainability issues and translated into concrete design parameters: ergonomics, haptics, aesthetics, hygiene, repairability, recyclability, material efficiency, and vandalism resistance.

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1 The focus of this paper is on presenting the process and output of interdisciplinary work, further aspects regarding the design part of this project have been discussed in Mayer and Slezak (2022).

2 The "broken window theory" states that signs of disorderly and petty criminal behavior trigger further disorderly and petty criminal behavior (cf. Keizer 2010). The quote from the Kieler Verkehrsgesellschaft employee goes in a similar direction.

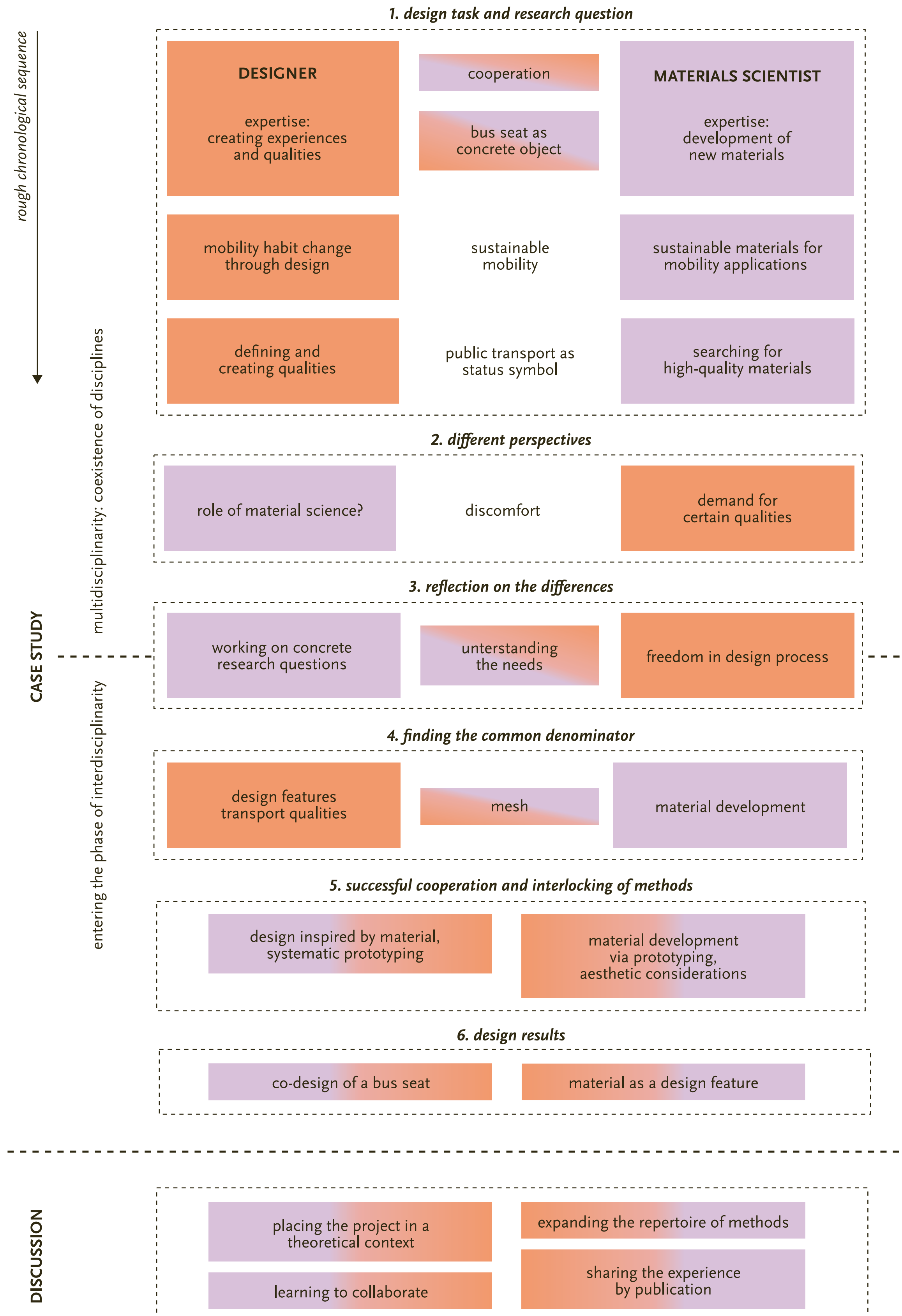

FIGURE 1: From multidisciplinarity to interdisciplinarity: scheme of the collaboration project between industrial design (orange) and materials science (purple) with important steps.

2 *Different perspectives*

At this point, questions arose regarding the materials scientist's role in the collaboration. After the initial exploratory phase, the materials scientist felt her research possibilities were limited due to the defined qualities. Insights from the design discipline were enriching but could not be reconciled with the typical working modes of materials sciences. Each of the required qualities would entail independent material research questions.

It turned out that from the beginning, in our different disciplinary perspectives, we framed sustainable mobility differently: the materials scientist focused on (new) materials with low ecological impact, the designer wanted to shape mobility habits through designing qualities and experiences.[3]

The materials scientist agreed with the designer that the underlying idea of mobility as a public status symbol cannot be achieved by optimizing single aspects or materials. To address this discrepancy, the project shifted temporarily to researching existing materials to deliver demanded qualities. This reduced the project for the materials scientist from a *research* to a *searching* project. As a chemist accustomed to synthetic work, she felt deprived of contributing her full potential and shaping the research object. This led to the need to shed light on how collaboration on equal footing can work without losing the focus on the experience of mobility as a public luxury.

3 *Reflection on the differences*

Industrial design relies on interdisciplinary collaboration, seemingly making it an ideal partner for materials science. However, our collaboration highlighted various tensions.

We reviewed comparable projects to gain perspective. From our view, in projects between materials sciences and industrial design, often one discipline dominates. Either design dictates the material choice by demanding certain qualities, or design develops from a pre-determined material (Wilkes et al. 2016, Van Bezooyen 2014, Karana et al. 2015). These strategies are valid and often effective, our project could also have worked in both of these ways. However, these extremes did not satisfy us, and we wondered what could happen if these hierarchies were abolished, convinced that the challenge of venturing into unfamiliar ways of working would even be a sort of "fun". We realized that this was maybe the starting point of working in a truly interdisciplinary way instead of a multidisciplinary approach (Nguyen and Mougenot 2022).

We first had to understand and adopt to a certain extent the principles and the professional jargon of the other discipline to work out a collaboration process. The first step was thus to recognize difficulties, admit, and analyze them. Many problems rooted in different ways of thinking and approaches of the disciplines: Industrial design differs significantly in mindset and working modes from materials science. Materials sciences rely on meticulous accuracy, repeatable tests, and systematic processes, while design thrives on disruptive thinking, creative experimentation, and abductive reasoning (Kretz 2020). Design constantly questions and rethinks without limitations, while materials science requires commitment, consistency, and a narrow research focus for in-depth exploration. This systematic approach is crucial for generating reliable findings.

Individual academic backgrounds also played a role, as both of us are not stereotypes for entire disciplines. The designer has a background in applied mobility design, aiming for feasible design solutions. The materials scientist, a chemist, had founded a material lab, thus it was natural for her to develop new materials. A more experimental-research-based designer and a more engineering-based materials scientist could have addressed totally different questions.

Despite differences, commonalities became apparent: design thinking is increasingly used and appreciated in fields outside design disciplines especially in inter- and transdisciplinary projects. Designing involves searching and researching for new knowledge (Kretz 2020, p. 9). The *Research through Design (RtD)* method aligns with scientific research by using the design process, including prototypes and iterations, to gain new insights. This practical engagement with materials and contexts, coupled with documentation of and reflection on the design process, constitutes research (Godin and Zahedi 2014).

Our aim was to show that both disciplines can complement and improve each other, especially when addressing wicked problems like sustainable mobility transformation. Without detailed work and data on material properties, design visions might lack persuasiveness and feasibility. However, data alone will not change behaviors; people need visions transformed into holistic, positive mobility experiences engaging all senses.

4 *Finding the common denominator*

Based on the identified needs our design object had to meet, we searched for a common denominator and found it in mesh structures. This material fulfilled the desire for new aesthetic and ergonomic possibilities for the designer: with the right seat geometry and mesh density, it should be possible to achieve ergonomic comfort with low material consumption. This addresses back-friendly sitting, ensures breathability, and makes the overall riding experience more pleasant compared to typical dusty and outdated seat cushions of bus interiors. Additionally, in terms of hygiene, liquids run through the upholstery instead of being absorbed, allowing for easy cleaning and minimal odors.

For the materials scientist, the meshes offered an interesting field to research on structure and function with the possibility to manufacture new materials and therefore have a relevant impact on the design. The research now specified on different degrees of flexibility, hapticity, and, of course, aesthetics of the generated network structures.

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3 We wanted to work according to the principles of design for sustainability or eco-design. Still, this makes it possible to address different levels: the very object-bound question of healthy, efficient, durable and less ecologically harmful materials for a specific product on one side is based more on the principles of eco-design, the focus on solutions that make social sense belongs more to design for sustainability (Tischner and Moser 2023).

5 *Successful cooperation and interlocking of methods*

Confronting methods of different disciplines initially exposes and unsettles the assumptions of each discipline but ultimately expands methodological repertoires and facilitates future collaborations (Woodward 2016).

At the beginning of the project, the materials scientist gained insights into the work of the design discipline. As the project progressed, she had to step out of her comfort zone more often. Her role was to research and develop mesh structures and to investigate different manufacturing methods. Therefore, material samples, or to say it in the words of design, prototypes, were produced. Those textiles cannot be directly produced on large scales but served to explore haptics, aesthetics and flexibility – and aided the decision-making for the final material design. While working with rough, makeshift prototypes is common in design, this seemingly imprecise way of working is an unfamiliar experience for a materials scientist: crocheting, laser cutting, 3D printing – is that still science? The unsettling effect of using unknown methods of creating material was evident.

The materials scientist started crocheting manually, exploring the appearance and characteristics of mesh materials. Manual crochet has a distinctive handmade look (figure 2a), while technical textiles can be finely fabricated so that the visible mesh structure is almost lost and turns into a diffuse transparency. At that moment, it was necessary to clarify concrete design issues: should the mesh fade into the background, or did we want to explicitly use the structure as a visual design element? This question was not answered at this point in the process.

A collective decision had been made to integrate certain functionalities into the textile via the mesh structure. Due to its "open" structure with few connections, the mesh remains elastic and can oscillate. This was primarily a research aspect for the materials scientist: changes in mesh size, pattern thickness, and type can achieve elasticity and oscillation (cf. Schumacher et al. 2018, Stoilkova 2021). We used laser cutting to investigate how precisely we could control the correlation between structure and rigidity (figure 2b).

Based on those first tests, we decided that the textile should convey transparency while making the pattern a prominent design feature and property carrier. Periodic patterns[4] were used for both aesthetic and process reasons. The structures modified on the basis of the periodic patterns retain the demanded qualities even with domains of different functions. Here we observed how the material could influence the design: the unsolved question – should the pattern be visible or not? – was driven by these test results. We decided to show how the material works and implemented it in the design to become a visible and even aesthetic element.

The next step was to map the structure design with available tools. The filament of a 3D printer is – similar to textile thread – a continuous material: this inspired the idea of using the 3D printer to create textiles. 3D printing proved ideal for the design concept (figure 2c), offering extensive material samples and insights into systematic material research for the designer. We printed filigree structures onto a transparent fabric, creating a two-layer textile combining transparency and structure visibility. By cleverly designing the (super)structure[5], printed on a carrier material, we could change seating properties such as ergonomics, air permeability and haptic-sensory qualities.

Especially in this phase of the project, we observed how the disciplinary boundaries were blurring, opening the way to a more intensive collaboration. Our project now clearly entered the interdisciplinary process of co-designing with two experts sharing their collective creativity (Coulter 2018).

The final design features a continuous "loop" of colorful mesh material for the seat and backrest, with a material gradient – compressed in the seat area and airy in the back – to accommodate weight distribution, ensuring ergonomic comfort, high transparency and material efficiency (figure 3a, p. 240).

Working with rough one-to-one models was crucial for advancing the design process. We tested joining principles using 3D-printed frame cross-sections. Here, the designer also supported working with systematic construction experiments, ultimately opting for the piping rail principle to attach the mesh to the frame. Avoiding adhesive connections and ensuring all materials can be recycled at the end of their service life enhances the seat's repairability, longevity, and hence sustainability.

6 *Design result: Identifying disciplinary contributions*

At the end of an intensive interdisciplinary work stands the seat concept *Loopx3,* which comprises three different options: 1. long-distance seats with face screens, allowing passengers to work, read or relax, 2. seats for short distances, optionally expandable with armrests for assistance, and 3. standing aids suitable for multifunctional areas. This variability is indispensable as travel times and the resulting comfort requirements in public transport vary greatly, and different target groups, such as commuters, are to be convinced of the benefits of public transport in the future (figure 3b to d).

Materials research directly influenced design decisions, providing the desired qualities and a distinctive aesthetic identity that showcased materials research as a design feature. Colorful patterns enhance the visibility of the produced structures. When reviewing the materiality and design concept of the bus seat, we were satisfied with the outcome and felt that both disciplines contributed equally. The bus seats use mesh in a way known from higher-end products. The luxury aspect is highlighted through the materiality and design of a qualitative experience across var-

4 The interest in periodic patterns and symmetry results from the chemist background of the materials scientist. A network basically consists of nodes and connections. The cavities (mesh) in between can either all have the same shape or be different. In the case of repetitive, constant structures, we speak of periodic patterns, which can always be broken down to the smallest unit. This makes it easy to build infinitely large networks by simply repeating the smallest unit as often as desired.

5 We borrow the term "superstructure" from crystallography, where it describes the need to enlarge a unit cell due to small structural differences. Here, it describes imposing a larger structure on a network.

FIGURE 2: Material samples:

A Examples of crocheted mesh structures, with an obvious "handmade" style.

B Examples of laser cut patterns; left: a gradient of the pattern thickness allows the adjustment of flexible zones in the network; right: depending on the pattern type different deformations of the network are possible.

C Process of 3D-printing structures on textile meshes and different examples of printed structures.

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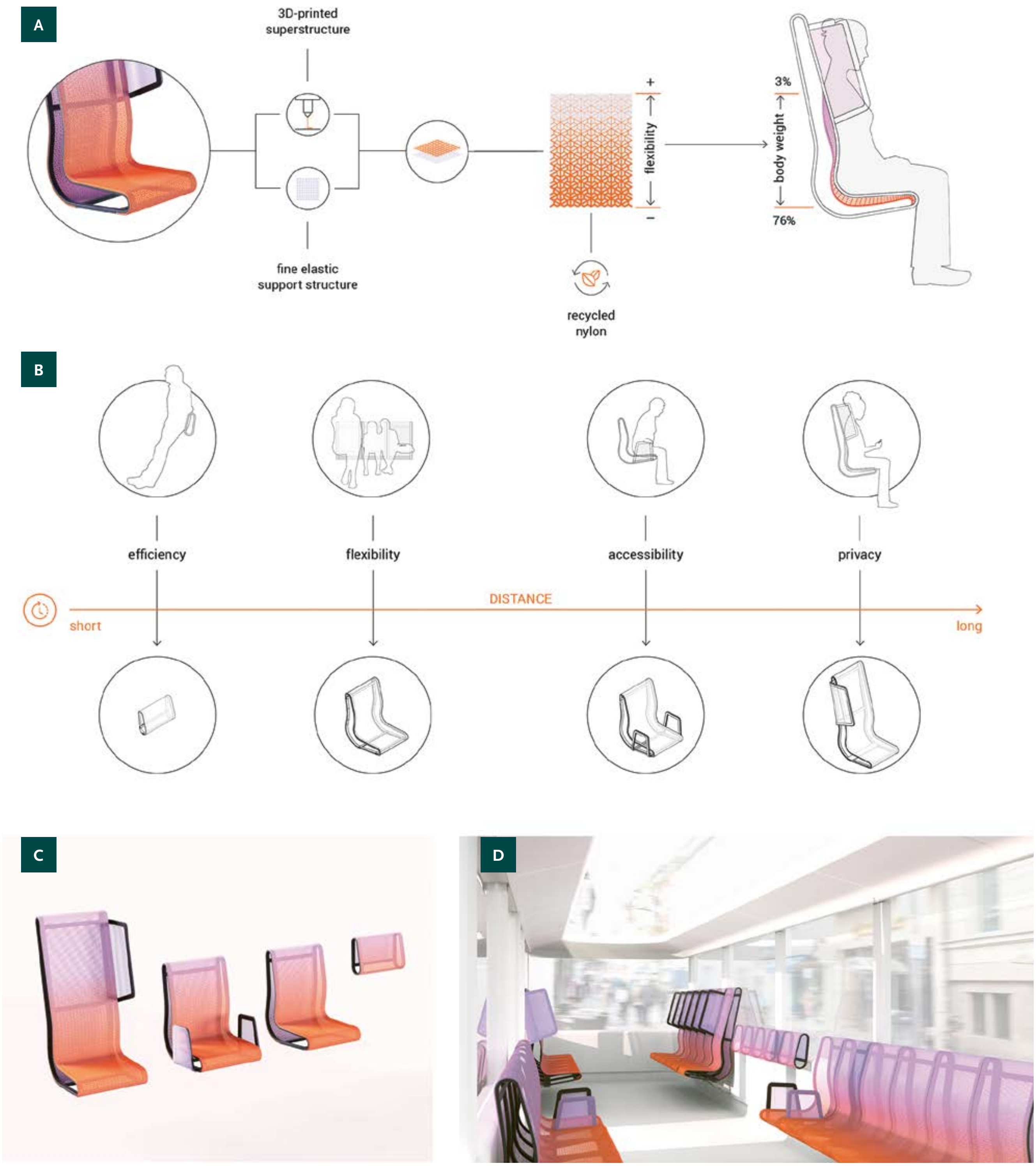

FIGURE 3:
A Mesh seat concept illustrating how the structure gradient adapts to weight distribution when seated.
B Illustration of different options for bus passengers regarding travel time, distance and comfort demands.
C Collection of the bus seat concept *Loopx3*.
D Rendering of a vehicle interior with *Loopx3*, illustrating the aesthetical atmosphere.

ious options, aiming to compete with the highly quality-focused automotive industry.

Discussion: Placement in an interdisciplinary context

This case study presents the process, outcomes, and insights from an experimental approach. We see our main focus on developing concrete objects and materials, with all its challenging aspects. Rather than focusing on theoretical discussions about interdisciplinary challenges, we developed a practical exchange during the project, expanding our repertoire of methods (Woodward 2016) and entering the realm of co-design by industrial design and materials science (Coulter 2018). However, the need for reflecting on the cooperation arose during the project and we wanted to position our project in the context of interdisciplinary research.

Industrial design seems to rely on interdisciplinary work all the time. However, this often involves only the use of the expertise and knowledge of other disciplines, but not the intensive exchange and acquisition of other methods. This could be interpreted as the difference between multidisciplinarity and interdisciplinarity (Nguyen and Mougenot 2022).

Interdisciplinary research teams face numerous challenges for which they may not be adequately prepared, as we personally observed. In order to improve interdisciplinary sustainability research, these challenges have to be taken seriously. There are various strategies to render such collaborations successful (cf. Boix Mansilla et al. 2016, Hall et al. 2019). Hall et al. (2018) underline that for tackling complex problems, it is helpful to not only integrate different disciplines, but to implement diverse perspectives and attitudes. Sustainability problems are inherently contentious and normative, involving researchers' beliefs, worldviews, and embodied life experiences (Freeth and Caniglia 2020). The feeling of discomfort (Freeth and Caniglia 2020) or "unsettling" (Woodward 2016) can be the starting point for deeper investigations and may both support or hinder the interdisciplinary teamwork. Fortunately, in our case, this discomfort was the beginning of understanding and "learning to collaborate while collaborating" (Freeth and Caniglia 2020).

Addressing these challenges requires time and effort at the outset. Having an unbiased accompanying researcher to observe and guide the process can significantly enhance the team's effectiveness. We had the luck to experience a fruitful process without support. As researchers with strong different positions, we wanted to shape the project from our two perspectives. We believe that, in addition to focusing on learning and teaching interdisciplinary skills, presenting accessible, experimental, and concrete projects like ours and highlighting the challenges and, more importantly, demonstrating the benefits of such projects can help convince other practice-based researchers to search for collaborations.

Conclusion

In this collaborative endeavor between industrial design and materials science, the aim was to elevate public mobility by designing a bus seat as a *pars pro toto* for public luxury. However, the project evolved into an experimental process, shedding light on the challenges and benefits of interdisciplinary collaboration, a necessary ability for successfully addressing sustainable solutions.

Unlike current design practices, where a designer creates a concept and hands it off to an engineer, or where the designer is only responsible for the final polish, this project integrated different disciplines from the start. Materials science took the design's message of creating new experiences seriously, transforming mobility into a desirable practice through material choices. At the same time, the designer appreciated the effort of inventing a new material especially for the seat.

The process began with shaping the research question, revealing differing perspectives. Collaborative work demands self-reflection and the willingness to leave one's disciplinary comfort zone.

Design's creative approach can sometimes free materials science from rigid methods and encourage unbiased experimentation. Materials can be both a solution and an inspiration for industrial design. The flexible mesh structures in our project solved ergonomic requirements, and their aesthetic and haptic properties inspired us as a team to make them the form-giving element of the seat.

However, the seat's suggested effectiveness depends on its integration within the broader bus interior. While a well-designed seat is crucial, it is just one piece of the puzzle in making public transport appealing and turning it into a public status symbol. Addressing issues like structural adjustments, accessibility, information dissemination, and design elements such as air circulation and handrails is key. Our extensive experience has equipped us to tackle challenges like these more effectively moving forward.

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Authors' contributions: *KM, JS:* ideas, authorship; *KM:* majority of experiments and approaches of the material part; *JS:* design, majority of renderings and mock-ups.

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Kerstin Mayer

PhD in chemistry, specialized on intermetalloid clusters. Since 2019 lecturer in Industrial Design at the Muthesius University of Fine Arts and Design, Kiel, DE; responsible for the domain *Material and Sustainability*. Founder of a material lab, focusing on eco-conscious material solutions. Research interests: regional and biobased materials, structures and patterns for material design, role of materials for sustainable design.

Jadwiga Slezak

Master's degree in Industrial Design. Work as a transportation designer, designing trains and street cars. Teaching and research in the field of sustainability transformation at the Muthesius University of Fine Arts and Design, Kiel, DE. Since 2023, designer at the studio Design for Human Nature. Leads seminars on design and design communication at various universities. Research interests: sustainable mobility, future mobility, common goods, public space design.