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CONNECTING SCIENCE COMMUNICATION RESEARCH AND PRACTICE: CHALLENGES AND WAYS FORWARD

Collaborative design to bridge theory and practice in science communication

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Abstract

The science communication field strives to connect theory and practice. This essay delves into the potential of collaborative design to bridge this gap. Collaborative design in science communication can involve scientists, science communication researchers, designers, and other stakeholders in developing new science communication solutions. By incorporating diverse perspectives and expertise, it can help create more effective and evidence-based communication strategies that cater to the needs of audiences. To integrate these demands, a structured approach is necessary. This paper discusses two established frameworks, Design-Based Research and Design Thinking, and applies practical insights to envision the impact of collaborative design on the future of science communication.

Keywords Science communication: theory and models; Bridging research, practice and teaching

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Introduction

The call for stronger connections between science communication research and practice remains powerful [Jensen & Gerber, 2020]. There are abundant theoretical frameworks, models, and studies offering valuable insights into effective science communication strategies. Yet, in practice, the application of these insights often falls short, with practical concerns typically overlooked in research. Collaborative design can be an interesting solution to this problem, emphasizing the involvement of diverse stakeholders throughout the design process of science communication products. When implemented effectively, this approach can help create evidence-based science communication products tailored to nuanced audience needs. However, successful implementation requires an intentional design process, one that effectively combines scientific information, evidence-based strategies, and the requirements and viewpoints of the target group during the design.

While the incorporation of design-based approaches in science communication is not novel [van der Sanden & Meijman, 2012; Bailey, Salmon & Horst, 2022; Kalmár

& Stenfert, 2020; Wehrmann & van der Sanden, 2017], the role of design often falls short in the meta-level discussions within the science communication literature, leading to a shortage of clear frameworks, documented cases, and research on how collaborative design plays out in science communication. At the Kiel Science Communication Network (KielSCN), a research center in Germany, we actively aim to consider, reflect on, and analyze design processes involving STEM (Science, Technology, Engineering, and Mathematics) research, science communication and education research, visual design, and practice partners.

When considering our design approach, we explored various design methodologies. In science education, the first author's root discipline, there is a long tradition of Design-Based Research (DBR) as a pivotal framework in bridging the gap between research and praxis. Fostering collaboration, embracing iterative design cycles, and considering contextual nuances are central features in developing, evaluating, and refining interventions — a process that typically unfolds over years. In our search for more agile and dynamic frameworks, we teamed up with an expert for Design Thinking and Innovation (second author), asking ourselves: Which agile frameworks and methodologies align with the context factors and quality standards inherent in science communication? How do we make sure our designs are solid but also find quick ways to test and get things out there? This essay encapsulates our insights and ideas, written after a joint product design sprint for creating one of our first science communication products.

Who collaborates and why?

Collaborative design comes in many shapes and forms. We see it as a structured process aimed at creating science communication products — be it tools, materials, or events — by involving diverse actors, each contributing their distinct perspectives and expertise to the design process. In our endeavors to characterize our design processes, we distinguish between two modes:

2.1 *Collaborative design among experts*

The first mode focuses on science communication product development through expert collaboration, utilizing the insights of specialists deeply immersed in their fields. Our team at KielSCN exemplifies this by forming a collaborative quartet involving science communication researchers, STEM scientists, designers, and practice partners. Together, we strive to create science communication products that not only meet academic standards but also resonate with real-world implementation, possess aesthetic appeal, and accurately convey the scientific content (see Figure 1).

Implementing this approach, as evidenced by our project, presents a unique set of challenges, starting with organizing an inter- or even transdisciplinary team [Chiu, 2002; Stempfle & Badke-Schaub, 2002]. Diversity may boost creativity, but at the same time potentially increases the risk of conflicts and project failure, an effect that is well documented in the literature on collaboration [Moirano, Sánchez & Štěpánek, 2020; Stokols, Misra, Moser, Hall & Taylor, 2008]. Synchronizing agents and activities and creating shared understanding during the design process has been pointed out as essential for success [Kleinsmann, 2006; Nguyen & Mougenot, 2022].

Our experiences with cultivating shared understanding strongly resonate with the concept of boundary work, particularly when integrating the exacting standards of research with the creative practices inherent in design and the arts [Owen, 2007; Rödder, 2017; Halpern, 2012]. Through workshops, design sprints, and intense dialogue, we actively engage in collaborative efforts to generate and assess visual science communication products, using artifacts such as sketches, prototypes, and mock-ups as boundary objects. These tangible items function as bridges between disciplines and between research and practice, aligning goals, bridging language and conceptual gaps, and supporting an iterative design process [Star & Griesemer, 1989; Mark, Lyytinen & Bergman, 2007; Rhinow, Koeppen & Meinel, 2012].

2.2 *Involving members of different publics*

The second mode we want to integrate into our work involves widening the composition of the design team to include members of diverse publics actively participating in the design process alongside experts. Over the past few decades, involving target groups, such as customers, citizens, and end users, has gained recognition across various fields, including architecture, the health sector, and information technology — often referred to as co-design, participatory design, or co-creation [Rock, McGuire & Rogers, 2018; Sánchez de la Guía, Puyuelo Cazorla & de-Miguel-Molina, 2017; Smith, Bossen & Kanstrup, 2017]. It not only aims to create artifacts that better meet the needs of the target group but also fosters a two-way exchange based on core ideals like democracy and empowerment [Lee, 2008; Sanders & Stappers, 2008]. It is worth noting, however, that the concrete evidence for its impact is somewhat limited, with research indicating positive outcomes in terms of product satisfaction, innovation, and the design process, albeit with potential challenges such as increased time and costs [Kujala, 2003; Steen, Manschot & De Koning, 2011; Trischler, Pervan, Kelly & Scott, 2018].

Importantly, the involvement of target groups spans a broad spectrum. In a well-known classification from product development, Kujala [2008] categorizes the involvement of users in the design process along a continuum from informative to participatory. In the informative involvement, users provide insights into their needs, preferences, and behaviors through techniques such as interviews, questionnaires, and focus groups. In consultative involvement, users give direct feedback, refining proposed solutions. The highest level is participatory involvement, where users actively shape design decisions, establishing them as integral partners in a co-design process to shape the product.

This is a parallelism to science communication, where we use a similar spectrum in how target groups engage with scientific information. Here, public involvement spans from simply receiving information in a one-way communication model, such as traditional lectures, to a dialogic and participatory approach. In the latter, members of different publics actively engage with scientific content, for instance through citizen science projects or public forums. Hence, while the underlying idea of participation aligns, the processes differ. The public's involvement in science communication usually focuses on engaging with scientific information rather than on participating in the design of science communication products.

Reflecting on our experiences in university-led science communication, target groups are usually not involved in the design of science communication products, or if they are, it often happens later in the process, mainly to gather information about impact. In our project, we aim to actively explore participatory design processes with the goal of involving users earlier in our design processes, aligning our strategies more closely with the principles of co-design and participatory involvement (see Figure 1).

Comparing these two modes, collaborative design processes involving experts alone and those incorporating members of different publics have distinct features in fostering the development of science communication products. Expert-driven processes infuse specialized knowledge and evidence-based strategies, establishing accuracy, credibility, and effectiveness for science communication products. The inclusion of target groups has the potential to enhance relevance, empowerment, and ownership in science communication products. Both modes come with challenges and levels of complexity, sometimes resulting in clashes, and need careful and strategic facilitation.

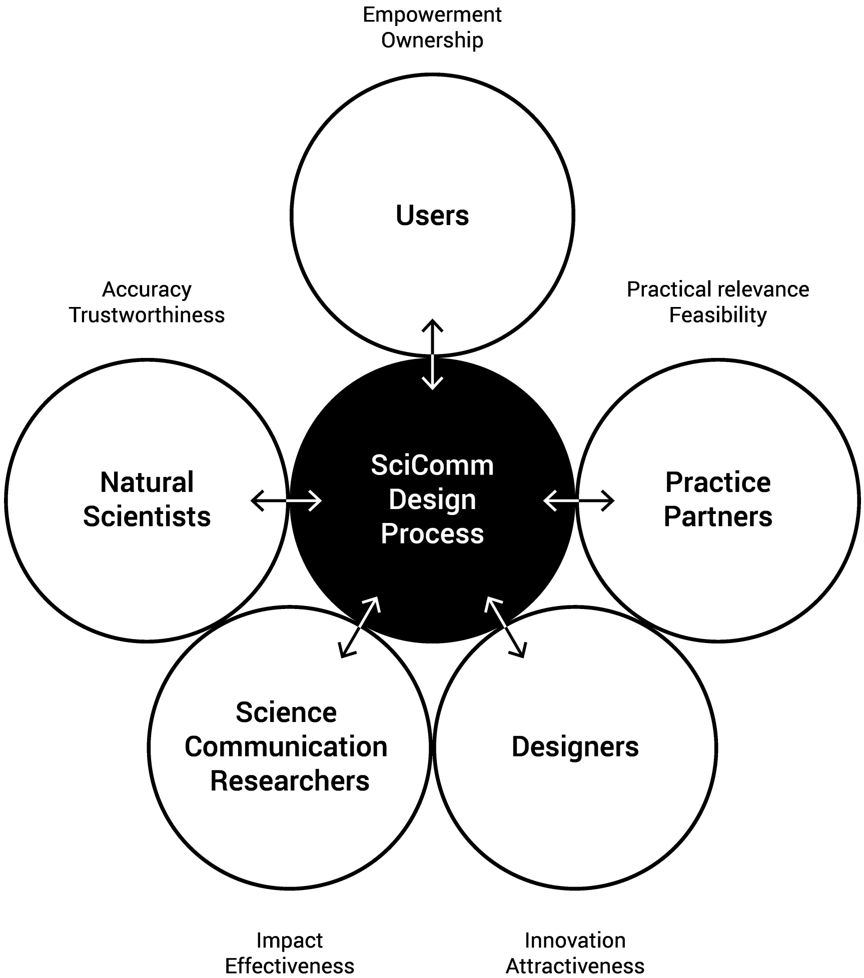

Figure 1. The framework for collaborative design teams in the Kiel Science Communication Network, a project where various stakeholders contribute to the design and evaluation of interactive scientific visualizations (illustrated by Björn Schmidt).

How to collaborate?

Effectively bridging disciplines and the theory-praxis gap in science communication through design demands intentional processes that not only acknowledge the diversity of stakeholders but also provide a structured pathway for collaborative design. Design frameworks can play a vital role in this context. Drawing from our diverse backgrounds, one in DBR and the other in Design Thinking, we share insights on these two approaches, each offering valuable angles for collaborative design in science communication.

3.1 Design-based research — Enhancing practices based on evidence

Educational research has a long history of exploring design processes [Bannan-Ritland, 2003; Cobb, Confrey, diSessa, Lehrer & Schauble, 2003]. A particularly well-known methodology in the domain is DBR, a systematic approach that iteratively improves educational practices through a collaborative synergy between researchers and practitioners [Barab & Squire, 2004; The Design-Based Research Collective, 2003; Wang & Hannafin, 2005]. DBR draws on a rich inventory of quantitative and qualitative research and evaluation methods that lead to context-sensitive design principles and theories. The DBR process typically involves iterative steps of analysis, design, implementation, and evaluation (see Figure 2).

In the context of science communication, the DBR process can unfold similarly to its application in education. In our case, in the analysis phase, science communication researchers, designers, and STEM subject experts collaborate with practitioners to understand the current state of a particular science communication problem or challenge. They identify theoretical frameworks, co-develop a design and research strategy, and practitioners provide context-specific information.

During the design phase, various team members collaborate to create a science communication product informed by insights from the analysis phase. In our team, designers play a crucial role in translating science communication theories, research questions, and subject-specific knowledge into visually appealing products. The designers' expertise intersects with the practical insights of practitioners, fostering the development of approaches that effectively address the identified challenges in science communication.

The implementation phase involves putting these products into practice. Researchers collect research data and practitioners monitor aspects such as usability and performance.

The evaluation phase assesses the impact of the science communication product, employing both research frameworks and practical considerations. Research metrics may include changes in audience perceptions or understanding, engagement levels, and effectiveness. Practitioners contribute by evaluating, for example, how well the product aligns with communication goals and fits into workflows.

3.2 Design Sprints in collaborative design projects for science communication: Mixing Agile Work and Design Thinking

After the dot-com bubble burst from 2000 to 2002, companies shifted away from technology-driven rationality. Influenced by thought leaders at the MIT Innovation

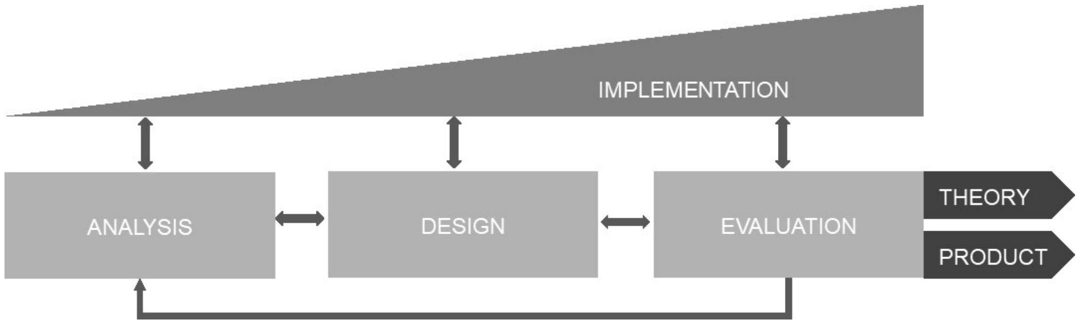

Figure 2. Design-Based Research culminating in both a product and enriched theoretical insights [based on Mckenney & Reeves, 2012].

Lab [von Hippel, 2005], there was a push for human-centered design and participatory methods in innovation. In response, IT startups, creatives, makers, and hackers adopted needs-driven exploratory practices, breaking away from number- and technology-centric approaches. Creative entrepreneurs and startup founders embraced 'post-rational innovation practices,' including Design Thinking, leveraging their nonlinear and multidisciplinary backgrounds [Marzavan, 2021].

Design Thinking, an approach grounded in designers' thought processes, underscores collaboration, iteration, experimentation, visualization, user-centeredness, and participation [Micheli, Wilner, Bhatti, Mura & Beverland, 2019; Brown, 2008]. It encompasses various phases that can vary in their implementation across different traditions and schools of thought. The model developed within the Stanford School of Design is one of the most common and well-established Design Thinking models, presenting five phases — empathize, define, ideate, prototype, and test [Plattner, 2015, see Figure 3]. But there are many other models, such as the widely respected Double Diamond framework [Design Council U.K., 2024], accentuating divergent and convergent thinking within the four phases discover, define, develop and deliver [Tschimmel, 2012]

Sarasvathy [2001] highlights that for startup entrepreneurs with limited finances but strong social capital, adopting effectuation over causation proved beneficial. This approach, emphasizing collaboration with end users in early stages and embracing uncertainty, contrasts with traditional top-down decision-making. The popularity of Design Thinking in corporate settings has given rise to agile practices like Design Sprints — four-day workshops that facilitate collaborative testing of assumptions and co-creation of features before launch. Exploratory agile activities paired with Design Thinking can foster innovation, for instance by multilayering collaborations with numerous stakeholders.

Therefore, Design Thinking as a "strategic collaborative innovation method" [Ind, Iglesias & Markovic, 2017] can connect user insights with collaborative design of science communication products — a perspective gaining ground in the science communication community [Kalmár & Stenfert, 2020; Magalhães et al., 2022], though not yet thoroughly substantiated through shared frameworks and systematic research. In the KielSCN, we explored an agile version of design thinking through the use of sprints. This approach quick-started the creation of our first science communication product but also helped us in aligning research and design goals.

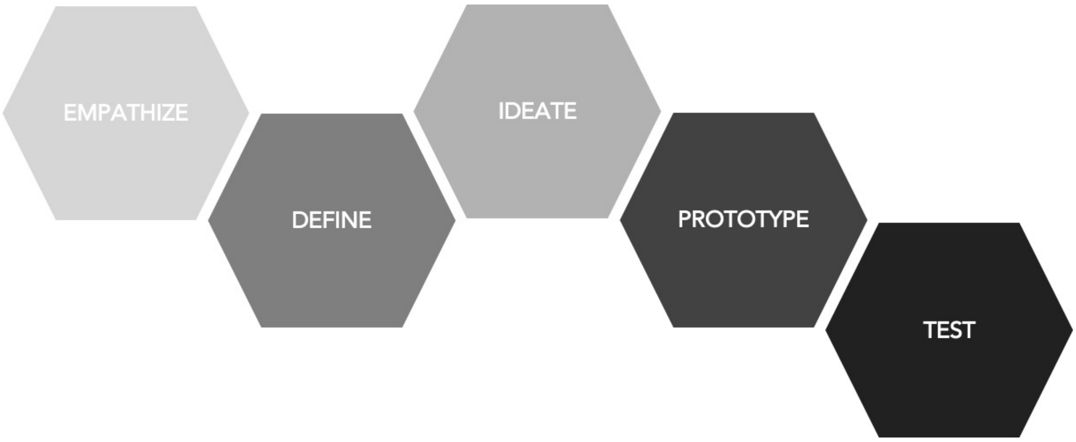

Figure 3. Design Thinking Process. d.school Stanford University Model, 2005.

Common ground and unique strengths

DBR and Design Thinking with agile applications such as design sprints both underscore collaboration and iteration as vital components for real-world designs. Yet, they each bring unique strengths to the table.

DBR excels in meticulous problem identification, analysis, and definition. This approach is strong at tackling core challenges in science communication practice, such as ill-defined goals or insufficient problem analysis and reflection [Sadler, Eilam, Bigger & Barry, 2016]. Principles such as identifying suitable theoretical frameworks, deriving hypotheses from these frameworks, and treating events and materials as targeted interventions that require rigorous and reflective evaluation can enhance collaborative design in science communication and help bridge the theory-practice gap. Nevertheless, DBR projects often span extended periods, leading to resource-intensive processes, potentially delaying innovation. There is also a risk of prioritizing research evidence rather than listening to target groups and practical considerations. This might potentially limit opportunities for disruptive innovation and novel solutions.

In contrast, Design Thinking as applied in our joint science communication product development sprint places particular emphasis on visualization and user-centeredness. Rapid prototyping drives innovation and facilitates effective cross-disciplinary communication. Early feedback and iterations help to get insights into different perspectives and needs early and build bridges between different groups — particularly useful for inter- or transdisciplinary ventures like science communication design. Agile applications of Design Thinking as Product Design Sprints can help infuse agile work routines into academia-led teams, which can challenge their pace and established decision-making norms. However, these approaches might initially be criticized for their lack of thorough in-depth research and opportunistic samples. Furthermore, the condensed timeframe of design sprints can result in a sense of urgency that may lead to oversights in certain design considerations. Careful timing, goal-setting, and aligning scope with the timeframe are crucial.

In Table 1, we synthesize some key characteristics discussed in Design Thinking and DBR that, form our perspectives, offer significant value for science communication design.

Table 1. Key characteristics from Design-Based Research and Design Thinking Sprints.

Design-Based Research		Design Thinking Sprints
	JOINT ATTRIBUTES	
Researchers, designers, and practitioners work together throughout the design processes to advance research and theory in line with advances in practice	*Collaboration*	Cross-functional, multidisciplinary teams ensure that different dimensions of a problem are represented and adequately addressed in the creative process
Process involves iterative cycles of analysis, design, implementation, evaluation, and redesign	*Iteration*	Iteration is used to clarify the problem being addressed and to trigger cycles of problem definition and creative solution finding
Strong sense of belonging due to a long and dedicated time span	*Empowering and inclusive*	Sense of empowerment due to quick prototyping of ideas and ad-hoc feedback loops
Addresses real-world problems and challenges, primarily used in educational settings	*Real-world context*	Focuses on solving real-world problems and creating user-centric solutions, primarily used in product design
	COMPLEMENTARY ATTRIBUTES	
Artifacts often in the form of pilot versions of instructional materials, teaching methods, or educational technologies that are tested at the end of a cycle	*Created artifacts*	Creating visual artifacts and prototypes as an essential part of the creative process, serving as tangible representations of ideas and concepts
In-depth, slow, thorough, engrained in institutional academic processes, hierarchies and timelines	*Work style & mindset*	Agile, like a startup, ad-hoc no hierarchy between stakeholders, fail early and cheap, no fear to fail, safe space
Understanding and addressing the prior knowledge, attitudes, and experiences of target groups, often through literature reviews or systematic study	*User insights*	Relies on direct engagement with users to gain insights and inform the design process, core value of empathy, ethnographic research, often guerilla-style
Strong emphasis on research methodologies and rigorous evaluation to test hypotheses, refine practical output, and contribute to educational theory to improve outcomes	*Role of research*	Research is used to empathize with users and validate design ideas, rapid experimentation to validate assumptions and learn from failures, usually no aims to contribute to theory

Advancing science communication through collaborative design — Looking ahead

With our two different perspectives on principles and practices, we aimed to provide entry points for delving into the dynamics of collaborative design within science communication. Our essay only touches the surface, for instance we only looked at the agile facet of Design Thinking, specifically through the lens of Design Sprints for science communication product development. We therefore conclude with recommendations and avenues for further research.

5.1 Recommendations

1. **Tailored design approaches:** DBR and Design Thinking are versatile frameworks, but their application needs tailoring to fit specific collaborative design projects. It is important to acknowledge that design perspectives encompass distinct theoretical and philosophical foundations tailored to specific domains. For instance, product design focuses on tangible objects, while social design is geared toward addressing societal issues and improving human experiences. In science communication, understanding the nuances of design perspectives is crucial for planning effective design processes that serve the respective intent. Especially when paired up with agile ways of working, the exposure to Design Thinking might impact management styles and the organizational structure of involved institutions, potentially triggering parallel organizational design processes [Schmiedgen, Rhinow, Köppen & Meinel, 2015].
2. **Reflective mindsets and social learning:** In the collaborative design process of science communication, fostering reflective mindsets is essential. This entails a thoughtful consideration of both the end results and the design process itself, aligning with the principles of facilitated social learning. Facilitated social learning encourages mutual awareness of expectations, knowledge co-creation, goal convergence, and coordinated action [Collins & Ison, 2009]. It should not only prompt surface-level adjustments but also systemic examinations and adaptive changes in strategy, known as triple-loop learning [Tosey, Visser & Saunders, 2012]. The exploration of how social learning frameworks can enhance collaborative design in science communication holds promise. Additionally, transdisciplinary learning frameworks may offer valuable insights into the interplay of various disciplines within both research and practice [McGregor, 2017].
3. **Transparent process documentation:** Based on our experiences, we recommend a clear documentation of the design process in science communication projects, including actors involved, methods used, insights gained, decisions made, and lessons learned. As this approach is relatively new in science communication, this documentation not only promotes transparency but also provides valuable insights for future projects and helps in refining chosen frameworks contributing to this hopefully growing body of research.

5.2 Future research

1. **Measurement and evaluation of impact:** While the principles of collaborative design in science communication are compelling, it is essential to quantitatively and qualitatively assess the impact of these approaches. Researchers could focus on developing unified metrics and evaluation frameworks that help measure and compare the effectiveness of collaborative design approaches. Research, implementation, and scaling of collaborative design approaches through real-world case studies and controlled experiments can illuminate the path forward. Long-term studies could explore how these collaboratively designed materials impact stakeholders and target groups.

2. **Digital technologies, boundary objects and artificial intelligence:** In light of the escalating impact of digital technologies, we should further explore how they can enhance collaborative design for science communication. The digital realm already offers a versatile range of tools and spaces for stakeholders in science communication research and practice to engage in collaborative efforts. Viewing these platforms through the lens of social learning, they can become dynamic environments for sharing, discussing, and co-creating content. Research can offer insights into applying Design Thinking to shape user-centric digital spaces leading to a more collaborative and participatory approach to science communication user experience and interface design.
3. **User involvement and collaboration readiness:** Moreover, we need a deeper understanding of how to actively engage target audiences in designing science communication products. How can we effectively include user insights, preferences, feedback, and co-design phases into the design process? To explore this, there is much to learn from existing user involvement and co-design methodologies, such as toolboxes and co-creation canvases. It is essential to identify methods that work well in our field and develop new approaches tailored to the unique challenges of science communication. From our experience, the readiness of professionals and the role of brokers [Schuijer, van der Meij, Broerse & Kupper, 2022] in adopting collaborative design approaches in science communication are vital for implementing the strategies discussed in this essay. Empirical studies can explore the preparedness of science communication professionals for collaboration, recognizing both the challenges and opportunities in the current landscape. Navigating this evolving field requires addressing contextual nuances and power dynamics [Halpern & O'Rourke, 2020].

Through continuous research, careful documentation, and dedicated resource allocation to collaboration, we envision the evolution of science communication into an evidence-based and user-centered design arena that seamlessly integrates theory and practice in our dynamic field.

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References

Bailey, J., Salmon, R. & Horst, M. (2022). The 'engagement incubator': using design to stimulate reflexivity about public engagement with science. *JCOM 21* (04), A01. doi:10.22323/2.21040201

Bannan-Ritland, B. (2003). The role of design in research: the integrative learning design framework. *Educational Researcher 32* (1), 21–24. doi:10.3102/0013189x032001021

Barab, S. & Squire, K. (2004). Design-based research: putting a stake in the ground. *Journal of the Learning Sciences 13* (1), 1–14. doi:10.1207/s15327809jls1301_1

Brown, T. (2008). Design thinking. *Harvard Business Review 86*, 84–92. Retrieved from https://hbr.org/2008/06/design-thinking

Chiu, M.-L. (2002). An organizational view of design communication in design collaboration. *Design Studies 23* (2), 187–210. doi:10.1016/s0142-694x(01)00019-9

Cobb, P., Confrey, J., diSessa, A., Lehrer, R. & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher 32* (1), 9–13. doi:10.3102/0013189x032001009

Collins, K. & Ison, R. (2009). Jumping off Arnstein's ladder: social learning as a new policy paradigm for climate change adaptation. *Environmental Policy and Governance 19* (6), 358–373. doi:10.1002/eet.523

Design Council U.K. (2024, February 28). The Double Diamond. A universally accepted depiction of the design process. Retrieved from https://www.designcouncil.org.uk/our-resources/the-double-diamond/

Halpern, M. K. (2012). Across the great divide: boundaries and boundary objects in art and science. *Public Understanding of Science 21* (8), 922–937. doi:10.1177/0963662510394040

Halpern, M. K. & O'Rourke, M. (2020). Power in science communication collaborations. *JCOM 19* (04), C02. doi:10.22323/2.19040302

Ind, N., Iglesias, O. & Markovic, S. (2017). The co-creation continuum: from tactical market research tool to strategic collaborative innovation method. *Journal of Brand Management 24* (4), 310–321. doi:10.1057/s41262-017-0051-7

Jensen, E. A. & Gerber, A. (2020). Evidence-based science communication. *Frontiers in Communication 4*, 201. doi:10.3389/fcomm.2019.00078

Kalmár, É. & Stenfert, H. (2020). Science communication as a design challenge in transdisciplinary collaborations. *JCOM 19* (04), C01. doi:10.22323/2.19040301

Kleinsmann, M. S. (2006). *Understanding collaborative design* (Doctoral Thesis, Technical University Delft, Delft, The Netherlands). Retrieved from http://resolver.tudelft.nl/uuid:0a7a57d4-c846-4458-a59f-24c25acbafa9

Kujala, S. (2003). User involvement: a review of the benefits and challenges. *Behaviour & Information Technology 22* (1), 1–16. doi:10.1080/01449290301782

Kujala, S. (2008). Effective user involvement in product development by improving the analysis of user needs. *Behaviour & Information Technology 27* (6), 457–473. doi:10.1080/01449290601111051

Lee, Y. (2008). Design participation tactics: the challenges and new roles for designers in the co-design process. *CoDesign 4* (1), 31–50. doi:10.1080/15710880701875613

Magalhães, J., Guasch, B., Arias, R., Giardullo, P., Elorza, A., Navalhas, I., … Luís, C. (2022). A methodological approach to co-design citizen science communication strategies directed to quadruple-helix stakeholders. *JCOM 21* (04), A05. doi:10.22323/2.21040205

Mark, G., Lyytinen, K. & Bergman, M. (2007). Boundary objects in design: an ecological view of design artifacts. *Journal of the Association for Information Systems 8* (11), 546–568. doi:10.17705/1jais.00144

Marzavan, D. (2021). A praxeological perspective on Innovation Management and Design Thinking. In *Proceedings of the 16th European Conference on innovation and Entrepreneurship ECIE 2021*. Retrieved from https://www.researchgate.net/publication/358642622_A_praxeological_perspective_on_Innovation_Management_and_Design_Thinking

McGregor, S. L. T. (2017). Transdisciplinary pedagogy in higher education: transdisciplinary learning, learning cycles and habits of minds. In *Transdisciplinary higher education: a theoretical basis revealed in practice* (pp. 3–16). doi:10.1007/978-3-319-56185-1_1

Mckenney, S. & Reeves, T. C. (2012). *Conducting educational design research*. New York, NY, U.S.A.: Routledge.

Micheli, P., Wilner, S. J. S., Bhatti, S. H., Mura, M. & Beverland, M. B. (2019). Doing design thinking: conceptual review, synthesis and research agenda. *Journal of Product Innovation Management 36* (2), 124–148. doi:10.1111/jpim.12466

Moirano, R., Sánchez, M. A. & Štěpánek, L. (2020). Creative interdisciplinary collaboration: a systematic literature review. *Thinking Skills and Creativity 35*, 100626. doi:10.1016/j.tsc.2019.100626

Nguyen, M. & Mougenot, C. (2022). A systematic review of empirical studies on multidisciplinary design collaboration: findings, methods and challenges. *Design Studies 81* (2), 101120. doi:10.1016/j.destud.2022.101120

Owen, C. (2007). Design thinking: notes on its nature and use. *Design Research Quarterly 2* (1), 16–27. Retrieved from https://dl.designresearchsociety.org/design-research-quarterly/2

Plattner, H. (2015). *An introduction to design thinking process guide*. Stanford, CA, U.S.A.: Institute of design.

Rhinow, H., Koeppen, E. & Meinel, C. (2012). Design prototypes as boundary objects in innovation processes. In P. Israsena, J. Tangsantikul & D. Durling (Eds.), *Research: Uncertainty Contradiction Value — DRS International Conference 2012*, 1st–4th July 2012. Bangkok, Thailand. Retrieved from https://dl.designresearchsociety.org/drs-conference-papers/drs2012/researchpapers/116

Rock, J., McGuire, M. & Rogers, A. (2018). Multidisciplinary perspectives on co-creation. *Science Communication 40* (4), 541–552. doi:10.1177/1075547018781496

Rödder, S. (2017). The climate of science-art and the art-science of the climate: meeting points, boundary objects and boundary work. *Minerva 55* (1), 93–116. doi:10.1007/s11024-016-9312-y

Sadler, K., Eilam, E., Bigger, S. W. & Barry, F. (2016). University-led STEM outreach programs: purposes, impacts, stakeholder needs and institutional support at nine Australian universities. *Studies in Higher Education 43* (3), 586–599. doi:10.1080/03075079.2016.1185775

Sánchez de la Guía, L., Puyuelo Cazorla, M. & de-Miguel-Molina, B. (2017). Terms and meanings of “participation” in product design: from “user involvement” to “co-design”. *The Design Journal 20* (S1), S4539–S4551. doi:10.1080/14606925.2017.1352951

Sanders, E. B.-N. & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *CoDesign 4* (1), 5–18. doi:10.1080/15710880701875068

Sarasvathy, S. D. (2001). Causation and effectuation: toward a theoretical shift from economic inevitability to entrepreneurial contingency. *The Academy of Management Review 26* (2), 243. doi:10.2307/259121

Schmiedgen, J., Rhinow, H., Köppen, E. & Meinel, C. (2015). *Parts without a whole? — The current state of design thinking practice in organizations*. Retrieved from http://thisisdesignthinking.net/why-this-site/the-study/

Schuijer, J. W., van der Meij, M. G., Broerse, J. E. W. & Kupper, F. (2022). Participation brokers in the making: intermediaries taking up and embedding a new role at the science-society interface. *JCOM 21* (01), A01. doi:10.22323/2.21010201

Smith, R. C., Bossen, C. & Kanstrup, A. M. (2017). Participatory design in an era of participation. *CoDesign 13* (2), 65–69. doi:10.1080/15710882.2017.1310466

Star, S. L. & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: amateurs and professionals in Berkeley's museum of vertebrate zoology, 1907–39. *Social Studies of Science 19* (3), 387–420. doi:10.1177/030631289019003001

Steen, M., Manschot, M. & De Koning, N. (2011). Benefits of co-design in service design projects. *International Journal of Design 5* (2), 53–60. Retrieved from http://www.ijdesign.org/index.php/IJDesign/article/view/890/346

Stempfle, J. & Badke-Schaub, P. (2002). Thinking in design teams — an analysis of team communication. *Design Studies 23* (5), 473–496. doi:10.1016/s0142-694x(02)00004-2

Stokols, D., Misra, S., Moser, R. P., Hall, K. L. & Taylor, B. K. (2008). The ecology of team science: understanding contextual influences on transdisciplinary collaboration. *American Journal of Preventive Medicine 35* (2), S96–S115. doi:10.1016/j.amepre.2008.05.003

The Design-Based Research Collective (2003). Design-based research: an emerging paradigm for educational inquiry. *Educational Researcher 32* (1), 5–8. doi:10.3102/0013189x032001005

Tosey, P., Visser, M. & Saunders, M. N. K. (2012). The origins and conceptualizations of 'triple-loop' learning: a critical review. *Management Learning 43* (3), 291–307. doi:10.1177/1350507611426239

Trischler, J., Pervan, S. J., Kelly, S. J. & Scott, D. R. (2018). The value of codesign: the effect of customer involvement in service design teams. *Journal of Service Research 21* (1), 75–100. doi:10.1177/1094670517714060

Tschimmel, K. (2012). Design thinking as an effective toolkit for innovation. In *XXIII ISPIM conference. Action for innovation: innovating from experience*, 17th–20th June 2012. Barcelona, Spain. doi:10.13140/2.1.2570.3361

van der Sanden, M. & Meijman, F. J. (2012). A step-by-step approach for science communication practitioners: a design perspective. *JCOM 11* (02), A03. doi:10.22323/2.11020203

von Hippel, E. (2005). Democratizing innovation: the evolving phenomenon of user innovation. *Journal für Betriebswirtschaft 55* (1), 63–78. doi:10.1007/s11301-004-0002-8

Wang, F. & Hannafin, M. J. (2005). Design-based research and technology-enhanced learning environments. *Educational Technology Research and Development 53* (4), 5–23. doi:10.1007/bf02504682

Wehrmann, C. & van der Sanden, M. (2017). Universities as living labs for science communication. *JCOM 16* (05), C03. doi:10.22323/2.16050303

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