Journal of Physics:
Conference Series

PURPOSE-LED PUBLISHING™

PAPER • OPEN ACCESS

Developing and Evaluating a Learning Arrangement on Wind for Primary Education

To cite this article: Ingrid Krumphals *et al* 2026 *J. Phys.: Conf. Ser.* **3280** 012024

View the article online for updates and enhancements.

Enabling Electrochemistry Inside and Outside the Lab

PalmSens

Discover our diverse range of Potentiostats engineered to support your research wherever it takes you

- Intuitive software for Windows and Android
- Proven in over 4000 scientific publications
- Single-channel and multi-channel
- Benchtop, portable and wearable

Discover More



This content was downloaded from IP address 134.130.185.56 on 25/11/2026 at 15:02

Journal of Physics: Conference Series **3280** (2026) 012024 doi:10.1088/1742-6596/3280/1/012024

Developing and Evaluating a Learning Arrangement on Wind for Primary Education

Ingrid Krumphals[0000-0002-0085-3615, 1,2], **Lisa Nusser**[0009-0009-1043-7381, 2], **Magdalena Zivithal**[0009-0006-4027-2061, 2], **Thomas Plotz**[0000-0002-7265-8149,3] **and Bianca Watzka**[0000-0002-3867-9683, 4]

[1] Engineering & IT, Carinthia University of Applied Sciences, Villach, Austria
[2] Institute for Secondary Education, University College of Teacher Education, Graz, Austria
[3] Institute for Research & Development, Private University College of Teacher Education of Christian Churches Austria, Austria
[4] Institute of Physics (IA), RWTH Aachen University, Aachen, Germany
i.krumphals@cuas.at

Abstract. Understanding weather phenomena such as wind plays a crucial role in fostering scientific literacy from an early age. Within the binational project "Understanding Weather", this study focuses on the design and evaluation of a learning arrangement on wind for primary education, developed following a design-based research approach. Grounded in the Model of Educational Reconstruction, the intervention was implemented in four third-grade classes (N = 89). Post- and follow-up questionnaires indicated positive learning outcomes, as e.g. 50% of students correctly identified the asked wind direction. Additionally, after three weeks, a slight improvement in knowledge was detected, but solely on descriptive levels and not significantly. Furthermore, 87% of students demonstrated an intuitive understanding of wind strength, even though it was not an explicit focus of the learning arrangement. The findings support the conceptually grounded design. The study contributes to evidence-based primary science education and provides implications for the iterative development of a spiral curriculum on weather phenomena.

1. Introduction

Weather is a fundamental aspect of everyday life that influences human activities, decision-making, and interactions with the environment. Children encounter weather phenomena daily and often construct intuitive explanations for them (see e.g. [1, 2]). These early experiences provide a powerful entry point for fostering scientific thinking and understanding, especially when it comes to scientific literacy (see e.g. [3]) in terms of understanding weather and climate and their effects on everyday life [4]. The binational project "Understanding Weather" [5] addresses this focus. Further it aims to develop a research-based spiral curriculum on weather from primary to higher secondary school level.

Since wind is such an everyday phenomenon and convection in particular is one of the basic concepts for many other weather and climate phenomena [4], the project began with the first building block of wind. Therefore, against the background of design-based research (DBR) [6–9]

Content from this work may be used under the terms of the Creative Commons Attribution 4.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

a spiral curriculum for the weather phenomenon wind has been developed. This learning arrangement, focusing on wind direction, was implemented in primary school in 3rd grade. The creation of the learning arrangement, the results of this DBR cycle, the evaluation of the implementation and insights gained from this iteration, as well as the resulting refinement of the materials, are the focus of this article.

2. Theoretical Background

2.1 The Project "Understanding Weather"

"Understanding Weather" is a German–Austrian project that aims to create an empirically grounded spiral curriculum on weather, spanning from primary to upper secondary education. It is based on the Model of Educational Reconstruction (MER) [10] and a design-based research approach [6–9]. Within the project, learning arrangements on core weather topics were developed, tested and refined. Further, fundamental research findings (e.g., on students' conceptions) were derived. By systematically linking learners' conceptions with scientific models and curricular goals, the project seeks to build a coherent progression of meteorological understanding across educational levels. Collaborations with meteorologists ensure scientific accuracy, while classroom implementation and evaluation cycles yield evidence-based materials and findings on teaching and learning processes that support sustainable science learning about weather and its scientific concepts.

2.2 The Projects' Design-Based Research Background

The "Understanding Weather" project follows a DBR approach, which integrates systematic design, implementation and analysis of educational interventions in authentic learning environments. DBR aims to generate both practical solutions and theoretical understanding by iteratively developing and testing interventions in real classrooms rather than controlled laboratory settings [7]. This dual orientation enables researchers to address complex educational problems while simultaneously refining domain-specific theories. Rather than seeking universal prescriptions, DBR aims to create usable, transferable design knowledge that can inform both practice and research [8]. Recent developments in DBR emphasize the importance of explicitly documenting and reflecting on design decisions to increase methodological transparency and comparability between projects [11]. Accordingly, the project systematically records how each design choice, ranging from learning objectives to instructional activities, is grounded in prior empirical findings and contextual constraints. This reflexive process supports a coherent link between theoretical models of learning.

2.3 The MER as a Framework for Designing Learning on Wind

The MER [10] provides a theoretical framework that connects research, learners' conceptions (see section 2.4), and instructional design. It integrates three complementary perspectives: (1) the clarification and educational analysis of scientific content, (2) the investigation of learners' conceptions and learning processes, and (3) the design and evaluation of learning environments. Following this model, science content must be reconstructed for teaching, balancing scientific accuracy with learners' perspectives, pre-conceptions and educational aims. Within the project "Understanding Weather", the MER serves as the guiding framework for transforming complex meteorological and physical concepts into meaningful, developmentally appropriate learning experiences. The reconstruction of the topic draws on meteorological and physical models that describe wind as the movement of air caused by pressure differences and influenced by forces

such as pressure-gradient force, Coriolis force, and frictional force. This disciplinary perspective provides the long-term reference frame for a coherent learning progression on wind [12]. While this perspective belongs to secondary education, it forms the conceptual horizon towards which students should gradually progress. Therefore, the present primary-level learning arrangement represents the first step in this progression: introducing "wind as moving air" as a tangible, experiential entry point that can later be connected to formal reasoning about forces and motion.

2.4 Learners' Conceptions on Weather and Wind

Existing studies on learners' conceptions of wind reveal a broad range of intuitive but fragmented ideas. Learners often describe wind as something that carries pressure, is blocked by clouds or blows in the named direction [1, 13, 14]. Other explanations are mechanistic or anthropomorphic, such as wind being produced by breathing, machines or moving tree branches.

Recent research [15] investigated learners' conceptions of wind across primary, secondary and tertiary levels. The study revealed that nearly all participants have vivid, sensory-based ideas of wind: often describing it as moving air, something that blows, flows or moves objects or as a feeling of coldness on the skin. However, when explaining the origin of wind, substantial conceptual gaps emerged: few learners referred to temperature or air pressure differences, while many attributed wind to external motion such as cars, clouds or the Earth itself [15]. These findings highlight the importance of instructional design that makes invisible meteorological processes visible, connects sensory experiences with causal reasoning and scaffolds a gradual shift from phenomenological to scientific understanding.

3. Design of the Learning Arrangement "Let's Play Wind"

Guided by the MER, these empirical insights were directly translated into the design of the learning arrangement "Let's Play Wind" [10]. The work assignment, worksheets and materials can be found here: [16].

3.1 Main Learning Objectives

The learning objectives of the learning arrangement were defined first, against the background of basic scientific concepts and second, the framework conditions, i.e., the curriculum and main conceptions concerning scientific literacy aspects (see AAA Map). Consequently, the main elementary scientific ideas that guide the learning arrangement are:

i. Wind is moving air.
ii. Wind can set objects in our environment in motion.
iii. Wind has a specific direction.
iv. Wind is named according to the cardinal direction it comes from.
v. A compass rose can be used to show the direction of wind.

Furthermore, the detailed learning objectives below, along with their indicators, were derived and formulated from the learners' perspective (see Table 1).

3.2 The Learning Arrangement

The learning arrangement, designed for Grade 3, unfolds over approximately three instructional hours and progresses through five interconnected stages. Each stage corresponds to one of the core processes of MER – activating prior ideas, introducing and modelling core concepts, and consolidating and transferring understanding.

Table 1. Detailed list of learning objectives for the learning arrangement.

Main Aspect [a]		Detailed Learning Objective
1. Observation and Identification	a)	Observe and identify wind movements in your immediate environment.
	b)	Recognize the effects of wind on various objects (e.g., trees, flags, leaves).
2. Orientation and Classification	a)	Name and distinguish the four cardinal directions (north, east, south, west).
	b)	Describe the relationship between cardinal directions and wind directions.
3. Representation and Modelling	a)	Construct a simple wind rose and correctly label the cardinal directions.
	b)	Use the wind rose to represent wind directions graphically and symbolically.
	c)	Recognize and state that wind is named after the direction it comes from.
4. Experimental Skills	a)	Explore and describe how wind acts as a force that can move objects.
	b)	Conduct simple, playful experiments to test how wind influences movement.
	c)	Use models (fan, flag, arrows) to simulate wind directions and reflect on their function as simplified representations of reality.
5. Conceptual Understanding and Transfer	a)	Develop an understanding that wind is air in motion and justify that wind is not a separate substance.
	b)	Explain how wind direction can be determined and communicated.
	c)	Apply learned concepts in new contexts, e.g., identifying wind direction on maps or in everyday life.
6. Communication and Reflection	a)	Use appropriate terminology (wind, air, direction, wind rose, force) to describe observations and communicate scientific concepts.
	b)	Reflect on several (own) ideas and distinguish between everyday experiences and scientific explanations.
	c)	Express what you have learned in words, drawings, or written tasks.

[a] For the sake of simplicity and clarity, the learning objectives are classified according to these aspects, yet naturally, the aspects overlap.

1. **Activation of Prior Knowledge** – Through a running dictation ("What is Wind?") and image-based sorting, students articulate their existing ideas about wind. These activities reveal preconceptions such as "trees make the wind" or "wind is something you feel", which serve as the starting point for conceptual reconstruction.
2. **Creating a Prototype** – This stage aims to introduce core concepts. Using visual and tactile material (large floor map, directional cards, fan, and flag), learners are introduced to the idea that wind is air in motion and that wind is named according to the direction it originates from.
3. **Revealing New Aspects –** This part focuses on playful modeling and conceptual development with 'Let's Play Wind'. Students embody the process of wind movement: one child acts as the wind (fan), another as the flag, representing the object in motion, and a third holds directional cards. Together, the class determines where the wind comes from and where it goes. Thereby, constructing an understanding of wind direction and the function of the wind rose as a model representation.
4. **Practicing and Applying –** This stage emphasizes application and transfer. Students create their own wind roses and apply their knowledge using smaller maps, fans and flags in pairs. Through guided comparison and discussion, they transfer the model-based understanding to different spatial contexts.
5. **Combining and Transferring** – This part focuses on reflection and pedagogical diagnosis. The lesson concludes with a diagnostic questionnaire and reflective discussion, enabling learners to express their understanding of wind as a physical phenomenon.

Throughout the sequence, model-based reasoning plays a central role. Learners are guided to understand that a model represents selected aspects of reality and can be used to test and communicate ideas. The teacher explicitly discusses why a fan is used as a model for real wind

and how symbolic representations, such as arrows or wind roses, simplify complex meteorological processes. “Let’s Play Wind” aims to enable a gradual shift from experiential, sensory engagement to abstract, system-oriented understanding; making the invisible phenomenon of air movement accessible through embodied and visual learning experiences.

4. Design of the Study

4.1 Implementation

The learning arrangement “Let’s Play Wind” was implemented in four third-grade classes at an Austrian primary school. The lessons took place within the regular “Sachunterricht” curriculum, which integrates natural and social science content in Austrian primary education. The participating classes represented typical mixed-ability groups, selected through convenience sampling, based on existing collaboration with the research team. To ensure fidelity of implementation, two members of the research team conducted the three-hour teaching unit.

4.2 Research Question and Evaluation Design

Within this DBR iteration, the evaluation focused on identifying how the implemented learning arrangement supported or constrained learners’ conceptual ideas of wind. Specifically, the research question was: How does participation in the learning arrangement influence primary students’ ideas about wind, wind direction and wind strength?

To investigate this, a mixed-methods approach was applied, combining quantitative and qualitative data. Quantitative data were collected through post- and follow-up questionnaires (three weeks later), to measure students’ understanding on wind-related terminology, wind direction, designation and strength. Qualitative data included classroom observations and students’ written and drawn artefacts (e.g., wind roses, worksheets). Observation notes were used to identify potential design flaws or organisational challenges (e.g. classroom and time management). For this paper, the focus lies on the quantitative data, with minor qualitative insights considered for suggestions to refine the learning environment.

In total, 89 students aged 8-9 years participated in the study; 83 completed the post- and follow-up questionnaires. The sample consists of 47 males (57 %) and 36 female students (43 %). German is the first language for 64 students and the second language for 19 students.

The questionnaire consisted of twelve closed multiple-choice items derived from a validated instrument developed in previous parts of the “Understanding Weather” project [17]. The decision to limit the survey to post- and follow-up questionnaires was made to avoid testing fatigue. Prior students’ perspectives, from earlier studies within the project, served as a solid baseline [15]. The questionnaire included six items on term knowledge (combined with an image) related to wind (weather vane, wind chime, windmill, anemometer, wind turbine, windsock), four items covering wind direction and its’ designation (two-tiered) and two items on wind strength (all items are based on [17]). The items on wind strength were added, even though this was not the main focus of the learning environment. They should provide initial insights for developing the next learning environment (for 4th graders) on wind strength.

5. Results

The post- and follow-up data consistently show positive results regarding students’ understanding of wind terminology, wind direction and its designation, and wind strength (see Figure 1).

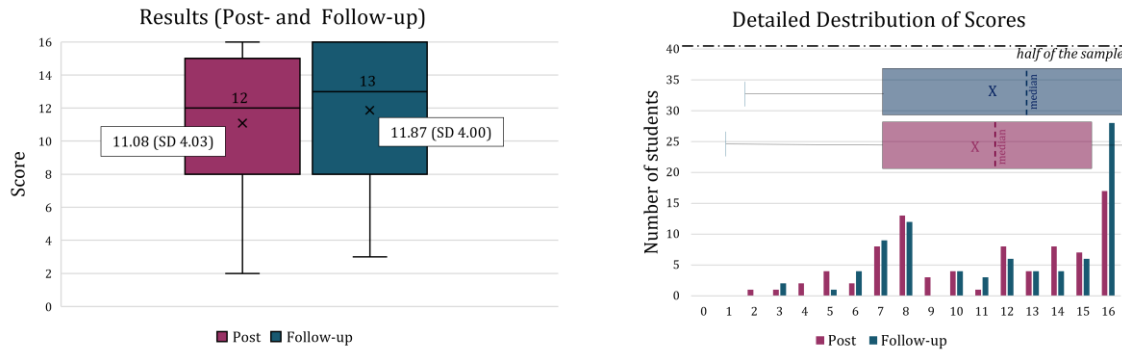


Figure 1. Results of the post- and follow-up questionnaire presented in an overview and per score

Overall performance. Figure 1 shows a boxplot on the left indicating a slight increase in overall test scores from the post-test (M = 11.08, SD = 4.03) to the follow-up test three weeks later (M = 11.87, SD = 4.00). Although the difference was not statistically significant (Wilcoxon z = 1.46, p = .144, n = 83, r = .16), the higher median score (12 → 13) and stable score distribution suggest a modest consolidation of understanding over time.

Terminology. Learners' ability to identify wind-related terms (Items 1–6) improved significantly from post- to follow-up-test (Wilcoxon z = 2.947; p = .003, n = 83, r = .32, see Figure 2). Mean scores increased from M = 4.84 (SD = 1.54) to M = 5.28 (SD = 1.29), indicating a small to moderate improvement in wind-related vocabulary.

Wind direction and designation. Figure 3 presents the results on students' understanding of wind direction (left) and wind designation (right). The data reveal consistently positive learning outcomes from post- to follow-up testing. This indicates that the learning arrangement effectively supported students in distinguishing and naming wind directions accurately. For the recognition of cardinal wind directions (north, east, south, west), students demonstrated moderate to high accuracy, with values ranging from approximately 58% to 64% at the follow-up questionnaire. A similar pattern emerged for wind designation (e.g., north wind, east wind), with follow-up scores between 57% to 61%. This suggests that students were able to transfer their spatial understanding to the linguistic convention of naming wind according to its origin. The strong correspondence between the two representations**,** direction and designation**,** was statistically confirmed by a highly significant dependency ($\chi^2(16) = 218.1$, $p < .001$, Cramer's V = .81 for post-test; $\chi^2(16) = 143.9$, $p < .001$, Cramer's V = .66 for follow-up-test).

Wind strength. Regarding students' understanding of wind strength, mean scores remained stable between the post-test (M = 1.86, SD = 0.39) and the follow-up-test (M = 1.83, SD = 0.46), with no significant difference between the two measurement points (Wilcoxon z = –.535, p = .593, n = 83, and with a negligible effect of r = –.06). This indicates that students maintained their conceptual level over time. The chi-square analyses revealed a significant relationship between both wind strength items at follow-up-test (χ^2 = 12.097, df = 1, p = .001), while no significant association was found in the post-test (χ^2 = 0.859, df = 1, p = .354). These results indicate a consolidation of response patterns over time, suggesting that students' intuitive understanding of wind strength became more consistent after the intervention, even though the topic itself was not directly addressed. Nevertheless, the majority of students achieved the highest possible score at both testing points, demonstrating that they correctly identified and compared different wind strengths by referring to visible indicators, such as the movement of the windsock. This suggests that students already had intuitive ideas about wind strength.

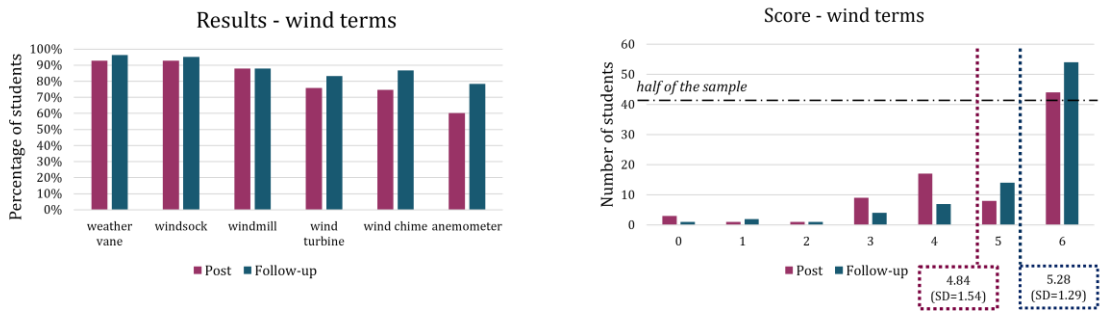


Figure 2. Results of the post- and follow-up questionnaire concerning wind terms

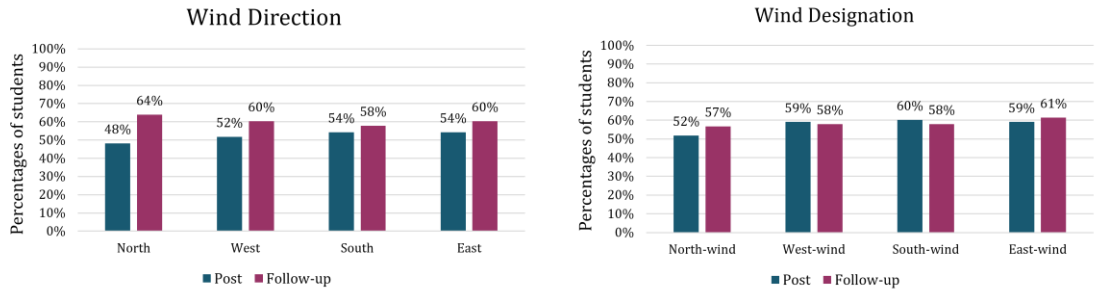


Figure 3. Results of the post- and follow-up questionnaire on wind direction and designation

6. Discussion and Conclusion

This study investigates how the research-based learning arrangement '*Let's Play Wind*' supports primary school students in developing an understanding of wind, with a focus on wind direction. Implemented in four third-grade classes, as part of a DBR cycle and grounded in the Model of Educational Reconstruction, the intervention yielded stable to slightly improved outcomes from post-test to follow-up. The most pronounced change concerned wind-related terminology (small to moderate effect), whereas overall performance showed only a small, non-significant change.

A key finding is that students successfully linked spatial direction to the conventional linguistic designation of winds. The association between direction and designation was strong, both immediately after the intervention and three weeks later (Cramer's $V = .81$ at post-test; $V = .66$ at follow-up), indicating a stable integration of model-based representations (here: the wind rose) with established naming conventions. These results suggest that embodied activities combined with visual models can support the acquisition of culturally established conventions that are not readily derivable from everyday experience.

In contrast, the results for wind strength—a construct not explicitly targeted in the learning arrangement—remained stable, with a negligible effect ($r = -.06$). Given the high proportion of correct responses already observed in the post-test, this pattern is most plausibly explained by a ceiling effect, as the distinctions between "strong" and "weak" wind are readily grounded in everyday experience. From an instructional perspective, these intuitive resources can serve as productive precursors for subsequent teaching that introduces scientific framing and quantification.

From a theoretical perspective, the results confirm the potential of combining MER with DBR. The MER framework provided a strong foundation for reconstructing the complex scientific concept of wind into elementalized components that are cognitively accessible to young learners (e.g., "wind is moving air", "wind has a direction", "wind can move objects"). Simultaneously, the DBR approach enables iterative refinement through authentic classroom implementation and empirical feedback, generating both theoretical insights and practical design knowledge.

The study was limited to four classes within a single school and did not include a pre-test or additional measures of cognitive ability. While this design reduced testing fatigue, it restricts conclusions about individual learning trajectories. Future iterations will address these limitations by expanding the sample and integrating deeper qualitative analyses of student artefacts and classroom discourse.

In summary, this study provides empirical evidence for the long-term impact of a MER based learning arrangement in primary science education. The stability of results between post- and follow-up testing suggests conceptual integration rather than short-term recall. Therefore, by linking the theoretical framework of the MER with the iterative design-based research, the study contributes to a growing body of research that demonstrates how theory-driven design can lead to tangible and sustainable learning gains in authentic classroom settings.

7. References

[1] Henriques L 2002 Children's ideas about weather: A review of the literature *School Science and Mathematics* **102** 202–15 https://doi.org/10.1111/j.1949-8594.2002.tb18143.x

[2] Bar V and Galili I 1994 Stages of children's views about evaporation *International Journal of Science Education* **16** 157–74 https://doi.org/10.1080/0950069940160205

[3] OECD 2017 *PISA 2015 assessment and analytical framework: Science, reading, mathematic, financial literacy and collaborative problem solving (PISA)* (Paris: OECD Publishing) https://www.oecd.org/content/dam/oecd/en/publications/reports/2017/08/pisa-2015-assessment-and-analytical-framework_g1g81b0f/9789264281820-en.pdf

[4] American Association for the Advancement of Science 2007 *Atlas of science literacy* (Washington, DC: American Association for the Advancement of Science; National Science Teachers Association)

[5] Krumphals I, Plotz T and Watzka B 2023 Ein deutsch-österreichisches Entwicklungsprojekt zum Thema Wetter *Lernen, Lehren und Forschen in einer digital geprägten Welt: Gesellschaft für Didaktik der Chemie und Physik, Jahrestagung, Aachen, 2022* ed H van Vorst (Essen: GDCP) 584-587

[6] Barab S and Squire K 2004 Design-Based Research: Putting a Stake in the Ground *Journal of the Learning Sciences* **13** 1–14 https://doi.org/10.1207/s15327809jls1301_1

[7] McKenney S E and Reeves T C 2012 *Conducting educational design research* (New York: Routledge)

[8] Hoadley C and Campos F C 2022 Design-based research: What it is and why it matters to studying online learning *Educational Psychologist* **57** 207–20 https://doi.org/10.1080/00461520.2022.2079128

[9] Guisaola J, Zuza K, Sarriugarte P and Ametller J 2023 Research-based teaching-learning sequences in physics education: A rising line of research *The international handbook of physics education research: special topics (scitation.org/books)* ed M F Taşar and P R L Heron (Melville, New York: AIP Publishing Books) 26-1-26-26 https://doi.org/10.1063/9780735425514_026

[10] Duit R, Gropengießer H, Kattmann U, Komorek M and Parchmann I 2012 The Model of Educational Reconstruction – a framework for improving teaching and learning science *Science education research and practice in Europe: Retrospective and prospective (Cultural perspectives in science education* vol 5*)* ed D Jorde and J Dillon (Rotterdam: Sense Publ) pp 13–27 https://doi.org/10.13140/2.1.2848.6720

[11] Obczovsky M, Bernsteiner A, Haagen-Schützenhöfer C and Schubatzky T 2024 Systematizing Decisions in Design-Based Research: From Theory to Design *Science Education* https://doi.org/10.1002/sce.21915

[12] Watzka B, Omarbakiyeva Y, Hahn L, Klein P, Krumphals I and Rubitzko T 2025 Wind as a context for Newton's first and second law and force diagrams *Phys. Educ.* **60** 15006 10 https://doi.org/1088/1361-6552/ad8a0f

[13] Dove J 1998 Alternative Conceptions about the Weather *School Science Review* **79** 65–9

[14] Piaget J 2001 *The Child's Conception of Physical Causality* (London: Taylor and Francis) https://doi.org/10.4324/9781351305082
[15] Krumphals I, Schwarz M T, Plotz T, Omarbakiyeva Y and Watzka B 2024 Lernendenvorstellungen zu Wind von Primar- bis Oberstufe *Frühe Naturwissenschaftliche Bildung: Jahrestagung Hamburg 2023* ed H van Vorst 478-481
[16] Nusser L, Zivithal M, Watzka B and Krumphals I 2024 *Mein Windrichtungs-Heft.* https://doi.org/10.18154/RWTH-2025-06061
[17] Watzka B, Omarbakiyeva Y, Schwarz M T and Krumphals I 2024 Winddarstellungen verstehen im Primarbereich: Eine Eye-Tracking-Studie *Frühe Naturwissenschaftliche Bildung: Jahrestagung Hamburg 2023* ed H van Vorst 482-485