Soil Colour as Physics — Pedagogical Framework

Earth Pigments from the Soils of Müllrose

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Earth Pigments from the Soils of Müllrose

Erdpuls Müllrose — Living Laboratory & Makerspace Garden

Part of the "Brücken bauen durch Boden — 13 Questions to the Soil" project

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Overview

This Framework document defines the pedagogical principles, learning progressions, cross-curricular connections, BNE quality alignment, and structural logic governing the three grade-band lesson plans (Classes 1–4, 5–8, and 9–12) for the Soil Colour as Physics unit. It is the architectural document that explains *why* the lesson plans are designed as they are.

Guiding Principles

1. Body First, Then Instrument

All learning in this unit begins with direct sensory engagement before any measuring tool, vocabulary, or explanation is introduced. Students handle soil with their hands, observe colour with their eyes, and smell the difference between fen soil and sandy soil before they open a textbook. This principle is non-negotiable across all grade levels.

The instrument — whether that is a sieve, a spectrometer, or a CIELAB colour formula — is always introduced as a way to confirm and deepen what the hands already know, not as a replacement for direct experience.

This approach has a direct parallel in the work of Gerd Wessolek (Emeritus, TU Berlin), whose concept of *Soil Art* as a mediating practice argues that soil science needs sensory and artistic means to reach beyond the specialist community and become genuinely felt knowledge. His co-edited volume *Field to Palette* (Toland, Noller & Wessolek 2019) provides the most comprehensive documentation of this principle across disciplines. The Erdpuls WP4 exhibition (104 soil paintings) is an independent instantiation of exactly the same idea.

2. The 4A-Pathway

Every educational sequence at Erdpuls follows the 4A-Pathway. This unit is designed so that the four stages map onto the four experimental phases of the full sequence, but each individual lesson unit also contains a micro-version of the complete pathway.

Stage	Description	Question it answers
Awareness	Direct sensory encounter with the phenomenon — before explanation	*"What do I notice?"*
Acknowledgment	Recognition that the impression can be measured and explained	*"Is this real? Can I verify it?"*
Attitude	Formation of a personal position through investigation	*"What do I think this means?"*
Action	The finding becomes material for something beyond the classroom	*"What do I do with this?"*

3. Three-Stream Pedagogy

Each lesson engages all three streams simultaneously wherever possible:

Stream	What it means in this unit
Head	Optics, mineralogy, colour physics, chemical concepts, data analysis
Hands	Grinding, sieving, painting, measuring, observing through instruments
Heart	The soil as a record of care; the pigment as the soil's voice in the exhibition; the act of making as a form of knowing

4. Authentic Output

Students produce real pigments for a real exhibition (WP4, "104 Answers"). The pedagogical power of this cannot be replicated by a simulation. Every lesson should carry a strand of awareness that the work matters beyond the school.

5. Proxemic Progression

Drawing on Proxemics Theory (Hall, 1966), the unit deliberately moves students through different relational distances to the soil:

- **Intimate distance** (< 45 cm): Hands in the soil, face close to the sample, wet grinding on glass.
- **Personal distance** (45–120 cm): Observing samples on the lab bench, discussing with a partner.

- **Social distance** (1.2–3.6 m): Presenting findings to the class, comparing sample sets from different farms.
- **Public distance** (> 3.6 m): The exhibition — the pigment now at a distance from the student, entering the public world.

This spatial progression is not accidental. It mirrors the 4A-Pathway: intimate encounter (Awareness) → personal investigation (Acknowledgment) → social dialogue (Attitude) → public action (Action).

Learning Progression Across Grade Bands

The unit is structured as a developmental spiral. Each grade band revisits the same phenomena — soil colour, wet-dry effects, grinding, binder behaviour — at a progressively more abstract and quantitative level.

Dimension	Classes 1–4	Classes 5–8	Classes 9–12
Cognitive mode	Sensory-phenomenological	Observational-experimental	Hypothetical-deductive
Primary question	"What colours are in the soil?"	"Why does the colour change?"	"What does the colour tell us?"
Physics concepts	Colour, light/dark, wet/dry	Light scattering, particle size, binder	Mie scattering, spectroscopy, CIELAB, ligand field theory
Mathematics	Colour sorting, counting	Graphing, sieve fractions as percentages	Regression, ΔE values, statistical correlation
Primary method	Discovery, play, making	Structured experiment, measurement	Independent research design
Output	Personal colour painting	Class pigment set + binder comparison chart	Correlation dataset + research report
4A emphasis	Awareness + Action	Acknowledgment + Action	Attitude + Action

Dimension	Classes 1–4	Classes 5–8	Classes 9–12
BNE Gestaltungskompetenz	4.1.1 (new perspectives), 4.1.3 (interdisciplinary)	4.1.4 (risk recognition), 4.2.1 (collaborative planning)	4.1.2 (forward-looking analysis), 4.3.1 (self-motivation)

Lesson Unit Structure

All lessons follow a consistent internal rhythm, regardless of grade level. This predictability helps students enter the work quickly and allows teachers to manage transitions cleanly.

The 45-Minute Unit Template

Phase	Duration	Purpose
Opening / Anchor	5 min	Connect to previous learning; pose the question for today
Direct Experience	10–15 min	Hands-on engagement with the material — observation, handling, first impressions
Investigation	15–20 min	Structured experiment, measurement, discussion, or model-building
Synthesis	8–10 min	What did we notice? What does it mean? How does it connect?
Closing / Forward	3–5 min	Journal entry, preview of next unit, contribution to the colour library

Cross-Curricular Connections

Classes 1–4

Subject	Connection
Sachunterricht (General Science)	Soil as part of the natural world; seasonal change; local landscape
Art (Kunst)	Colour mixing, painting with natural materials, making marks

Subject	Connection
German (Deutsch)	Descriptive language for colour and texture; journal writing
Mathematics	Sorting, counting, comparing dark/light

Classes 5–8

Subject	Connection
Physics	Light-matter interaction, Mie scattering, particle size effects
Biology	Soil as a living system; role of organic matter
Chemistry	Introduction to iron compounds, molecular explanation of colour
Geography	Soil types of the Oder-Spree region; Pleistocene geology
Art	Earth pigment tradition; paint media; colour composition
Mathematics	Data recording, graphing, percentage calculations

Classes 9–12

Subject	Connection
Physics	Optics, electromagnetic spectrum, spectroscopy, CIELAB colour space
Chemistry	Ligand field theory, iron oxide mineralogy, crystal chemistry
Biology	Soil ecology, humus formation, microbial activity as colour indicator
Geography / Earth Science	Pedogenesis, soil classification, climate archive in soils
Mathematics	Statistics, regression analysis, ΔE calculation
Research methods	Experimental design, hypothesis testing, scientific communication

SDG Integration

SDG	How it appears in the unit
SDG 4 Quality Education	Interdisciplinary science education grounded in place and authentic practice
SDG 13 Climate Action	Soils as climate archives; correlation of sensor data (moisture, temperature) with pigment colour variation
SDG 15 Life on Land	Soil as a living system; iron oxide mineralogy as an indicator of soil health
SDG 2 Zero Hunger	Three farming system comparison (conventional / organic / biodynamic) as an inquiry into soil vitality

BNE Quality Framework Alignment (Brandenburg Catalogue)

This unit directly addresses the following criteria of the *Qualitätskatalog für außerschulische Anbieterinnen und Anbieter von BNE im Land Brandenburg* (MLUK, April 2023):

Criterion	How it is met
1.1.1 Lebenswelt-Bezug	Content is grounded in Müllrose soils, local farms, and the Naturpark Schlaubetal
1.2.1 Target groups concretely described	Three grade bands with distinct objectives, methods, and cognitive demands
2.1.1 Multidimensional	Ecological, economic, social, and cultural dimensions explicitly connected
2.1.2 Interdisciplinary	Physics, chemistry, art, ecology, and agronomy integrated throughout
2.2.1 Controversial thesis	The central project thesis (attitude → soil → colour) is a hypothesis, not a given fact
3.1.1 Action-oriented	Students physically collect, grind, measure, and produce real pigments
3.1.2 Experience-oriented	Fieldwork phase grounds all learning in direct sensory encounter

Criterion	How it is met
3.1.3 Discovery-based	Sorting samples by colour "without explanation" (Grades 5–8) as explicit discovery methodology
3.1.4 Cooperative	Partner farm sampling; group correlation study design
3.1.5 Reflective	Wet–dry diagrams, binder comparison, spectroscopy all require explanation of observations
3.2 Theoretical grounding	Full theoretical background in the concept document (Sections 3 and 9)
4.1.1 New perspectives	Three farming systems compared; iron oxide pigments as shared global heritage
4.1.4 Risk recognition	Silicosis safety protocol explicitly teaches precautionary behaviour
4.3.1 Self-motivation	Each student's pigment production contributes to a real public exhibition

The Central Project Thesis as a Pedagogical Device

The project thesis — *"A farmer's inner attitude toward the soil is reflected in measurable soil quality"* — is unusual in school science because it is:

- **Not provable by any single experiment.** It remains a hypothesis.
- **Genuinely contested.** Reasonable scientists and farmers disagree.
- **Open to multiple disciplines.** Physics can measure colour; ecology can measure humus; philosophy can question what "inner attitude" means.

This is an intentional pedagogical choice. Students at all grade levels encounter the thesis at an appropriate level of complexity, and they are never told "the answer." The unit ends with the question more open, not more closed.

For Classes 1–4: the question is implicit — "why do different farms have different colours?" For Classes 5–8: the question is introduced and discussed but not resolved. For Classes 9–12: the question is the basis of an independent research investigation.

Seasonal Integration

The unit is most powerful when conducted across the school year, allowing students to return to the same sites as conditions change:

Season	Activity	What it reveals
February–March	Initial soil sampling	Winter colours, high moisture, baseline measurements
April–May	Lab processing, spectroscopy	Spring drying, colour shift as soils warm
May–June	Pigment production for WP4	Correlation with sowing season
September	Deepening experiment	Post-summer colour comparison; drought effects on colour

Even if your group can only complete one visit, try to photograph the sample sites in multiple seasons for comparison. The colour archive is itself a seasonal record.

Further Reading

On the science-art bridge (core Wessolek references): - Toland, A., Noller, J.S. & Wessolek, G. (Eds.) (2019): *Field to Palette — Dialogues on Soil and Art in the Anthropocene*. CRC Press / Taylor & Francis. 681 pp. [The single most important reference for the pedagogical philosophy of this unit. Over 100 scientists, artists, and educators in dialogue; includes DIY experiments, soil recipes, and visual methodologies for making soil knowledge felt] - Feller, C., Landa, E.R., Toland, A. & Wessolek, G. (2015): Case studies of soil in art. *SOIL* 1: 543–559. DOI: 10.5194/soil-1-543-2015 [Open access; covers earth pigments and soil as cultural material across history. Freely downloadable] - Wessolek, G. (2021): Böden in Kunst und Gesellschaft neu positionieren. *Handbuch der Bodenkunde*. Wiley. DOI: 10.1002/9783527678495.hbbk2021001 [In German; Wessolek's theoretical argument for soil science's role in public education and society — direct BNE relevance]

On soil science foundations: - Blume, H.-P. et al. (2018): *Scheffer/Schachtschabel: Lehrbuch der Bodenkunde*. 17th ed. Springer Spektrum. [Standard German-language soil science reference. English edition: *Soil Science*, Springer 2016] - Schwertmann, U. & Cornell, R.M. (2000): *Iron Oxides in the Laboratory*. Wiley-VCH. [Definitive European reference on iron oxide mineralogy and colour] - AG Boden / BGR (2024): *Bodenkundliche Kartieranleitung* (KA6). 6th ed. E. Schweizerbart, Stuttgart. [Official German field guide for soil description and sampling]

On pigments and painting materials: - Doerner, M. / Hoppe, T. (2011): *Malmaterial und seine Verwendung im Bilde.* 24th ed. Maier, Ravensburg. [Classic German painting-materials reference; earth pigments and binder chemistry in depth. In German] - Delamare, F. & Guineau, B. (2000): *Colour: Making and Using Dyes and Pigments.* Thames & Hudson.

Document Relationships

This Framework should be read alongside:

Document	Purpose
Teacher's Guide	Practical preparation, safety, materials, assessment
Classes 1–4 Detailed Plan	Six 45-minute units for primary school groups
Classes 5–8 Detailed Plan	Six 45-minute units for lower secondary
Classes 9–12 Detailed Plan	Seven 45-minute units for upper secondary
SoilPigments_PhysicsConcept_EN.md	Full theoretical background and BNE alignment

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