Part 2 / Strand 2

Learning Science: Cognitive, Affective, Aesthetic, And Social Aspects

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Science learning from multi-facet dimensions that go beyond conceptual understanding. Theories, models, methodologies, and empirical results about the cognitive, affective, aesthetics and social dimensions in learning science; design of learning environments; studies of learning processes concerning cognitive, affective, aesthetic and social engagement of scientific contents; forms of representational languages and knowledge organisation, including methods of collaborative construction of knowledge.

Sub-themes:

1) The Role of Emotions in Science Learning and Teaching
2) Developing and Validating Instruments for Measuring Affective Construct
3) Interventions to Enhance Motivation and Interest in Science
4) Theoretical Perspectives on Attitudes and Beliefs in Science Education

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Strand 2: Learning Science: Cognitive, Affective, Aesthetic, And Social Aspects

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Reclaiming Attention To Attitudinal Dimensions In Science Education

Strand 2 focuses on science learning as a multidimensional endeavour extending beyond conceptual understanding. Research in this strand examines how learners think, feel, value, experience, and interact while engaging with science-related issues. It brings together theoretical, methodological, and empirical work addressing the *cognitive, affective, aesthetic*, and *social dimensions* of science learning, while building on the longstanding tradition of attitudinal research in science education. Indeed, research within the strand draws on cognitive science, educational psychology, and the sociology of education. The contributions included in this volume reflect the breadth of research represented within the strand. Collectively, they demonstrate that learners' interests, emotions, values, identities, aesthetic experiences, and social interactions are integral components of engagement with science.

Across different educational levels and countries, including Spain, Germany, Denmark, Turkey, and Italy, the contributions explore how these dimensions shape learning processes and how educational interventions can support more meaningful and sustained participation in science. Learning is examined in diverse settings, including classrooms, out-of-school laboratories, natural environments, and collaborative educational programmes and interventions. *Authenticity* emerges as a particularly important aspect of science education. Learning environments that connect scientific ideas to real-world contexts, societal challenges, or personally meaningful experiences are shown to support engagement and participation. This emphasis on authenticity aligns with broader efforts in science education research to bridge the gap between *school science* and learners' *lived experiences*.

A prominent theme across the contributions concerns the *affective dimensions of science learning*. Several studies investigate factors that influence learners' interest, motivation, self-efficacy, and beliefs about learning. These papers address the longstanding challenge of maintaining and strengthening learners' engagement with science across educational stages. They highlight the importance of designing learning experiences that connect scientific content to learners' interests, experiences, and perceptions of relevance. The findings suggest that affective factors are central to participation, persistence, and achievement in science learning.

Another significant theme is *the role of emotions in scientific thinking and inquiry*. The contributions extend affective research by examining epistemic emotions associated with knowledge construction, problem solving, and scientific discovery. This focus reflects growing recognition that emotions are closely intertwined with cognitive processes. Curiosity, surprise, uncertainty, satisfaction, and other epistemic emotions influence how learners engage with scientific questions, evaluate evidence, and construct explanations. The development of analytical tools for identifying and visualising such emotions also points to emerging methodological innovations in this area of research.

A further theme concerns the *aesthetic dimensions of science education*. While aesthetic engagement has received less attention than affective outcomes, several contributions highlight the potential of sensory and experiential forms of engagement with science-related issues to strengthen learners' connections with science. These include supporting appreciation of biodiversity and encouraging reflection on relationships between humans and other living beings.

Taken together, the contributions in this strand present science learning as a complex process involving cognition, emotion, aesthetics, values, identity, and social participation. As a whole, the volume advances understanding of science learning beyond narrow cognitive perspectives. The contributions offer valuable insights into how science education can support learners in engaging meaningfully and responsibly with science in contemporary society. Therefore, the strand *Learning Science: Cognitive, Affective, Aesthetic, and Social Aspects* is well positioned to contribute to ongoing discussions about the future directions of science education research.

Factors Influencing The Aesthetic Appreciation Of Biodiversity: An Exploratory Study With Pre-Service Teachers

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The present study aimed to explore the factors influencing the aesthetic appreciation of landscapes with relevant biodiversity, emphasizing the role of scientific knowledge. To achieve this, a questionnaire was administered to a group of pre-service teachers of a Portuguese institution. Participants were asked to rate their preferences for four landscapes with different biodiversity using a Likert scale and to provide justifications for their choices. Two landscapes featured native vegetation, while the other two included exotic and invasive vegetation. The teachers were divided into two groups, with only one group participating in a session focused on the scientific exploration of the landscapes prior to completing the questionnaire. The results showed that the group attending the session demonstrated a greater preference for landscapes with native vegetation, more frequently using scientific arguments to justify their aesthetic appreciation. Nevertheless, other important factors influencing landscape appreciation were identified, such as the presence of specific characteristics of the species and the participants' familiarity with the presented landscapes. Thus, deepening scientific knowledge about biodiversity and engaging directly with landscapes appear to positively influence participants' preferences. The link between higher aesthetic appreciation and the desire for nature preservation seems plausible, although further research is needed.

Keywords: Aesthetic Appreciation, Biodiversity, Pre-service teachers

Introduction

Recent research has increasingly highlighted the emotional and perceptual benefits associated with natural environments. Empirical evidence suggests that natural landscapes, particularly those with minimal human interference, tend to elicit stronger emotional responses (Bethermy & Corraliza, 2019). Within landscapes, specific environmental features play a decisive role in determining preferences, as the presence of water and vegetation is consistently associated with higher levels of appreciation, whereas predominantly sandy or rocky environments tend to receive lower preference ratings (Corraliza, de Frutos & Moll, 2023).

According to Tieskens *et al.* (2017), nearly all rural areas in Europe have been shaped or modified by human activity and can be regarded as cultural landscapes, many of which are now recognized as cultural heritage, indicating that the concept of a "natural landscape" scarcely exists outside a few highly restricted areas. Even in ostensibly natural landscapes, the presence of exotic species is common, further demonstrating that the "human touch" is nearly ubiquitous.

Understanding the factors that influence the aesthetic appreciation of biodiversity can be relevant to uncovering the reasons that motivate people to act in favour of nature preservation. This knowledge can also be valuable for both pre-service and in-service teachers, as it can assist in defining strategies to foster positive attitudes toward nature among students.

According to Carlson (2009), there are two forms of aesthetic appreciation, regardless of the object in question. One of them can be referred to as "free beauty," where the individual simply appreciates the object based on its formal characteristics. The other form, known as "dependent beauty," assumes that knowledge about the object is fundamental to its appreciation. This second form, although controversial in the field of aesthetics, is particularly relevant to science education, as it links the appreciation of a natural object to the scientific knowledge one has about it.

This perspective, supported by diverse authors such as Frank Muir, Aldo Leopold, and Holmes Rolston, all leading figures in the field of environmentalism, is based on the following principle: the more we know, the more we can observe, admire, appreciate, and ultimately, strive to preserve. As Rolston III (1995) explains, this knowledge allows one to find beauty where it was not previously perceived: "when you understand the harshness of an arid or an alpine climate, you will find the plants' clinging to life aesthetically stimulating" (p. 378).

For this reason, Thompson (1995) argues that the appreciation of nature cannot rely solely on subjective elements but must also include objective elements that underpin this appreciation. From this perspective, the aesthetic appreciation of nature requires scientific knowledge, particularly in fields such as geology, biology, and ecology. This knowledge can also help put destructive events, such as fires, into perspective. According to Brady and Prior (2020), understanding their importance to forest ecology allows us to recognize the value of something that was previously seen only as a force of destruction, turning vibrant landscapes into desolate ones.

The Present Study Area

The present study involved pre-service teachers from a higher education institution in the Lisbon metropolitan area, Portugal. It aimed to achieve the following objectives:

1. To identify the factors that may influence the aesthetic appreciation of landscapes with diverse biodiversity elements.

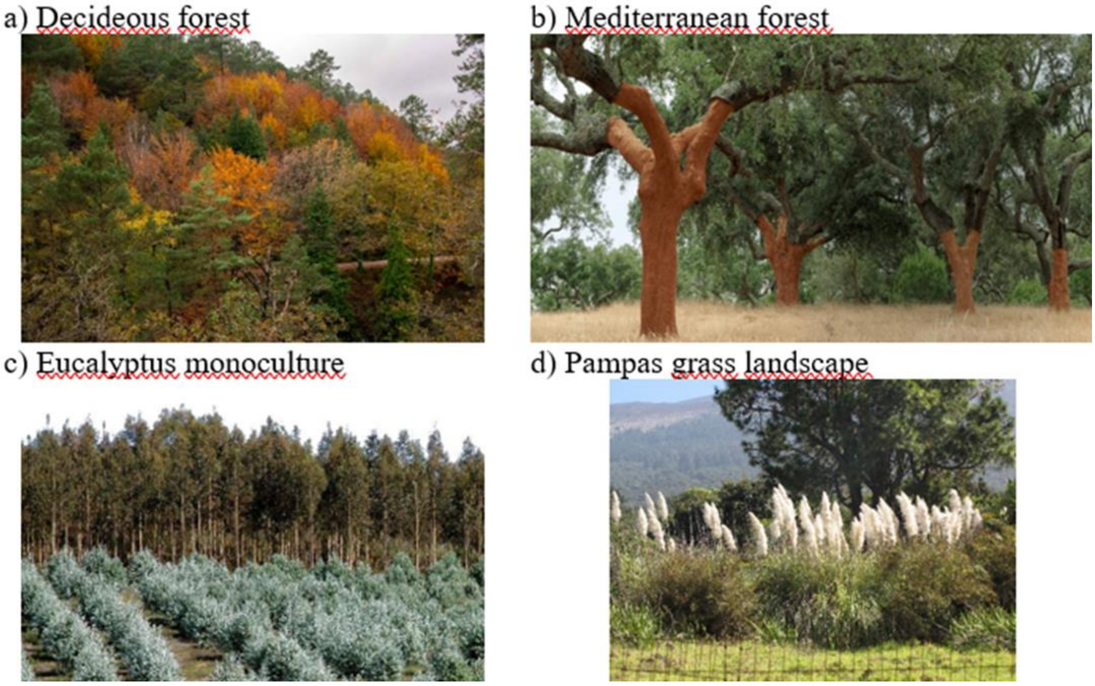
2. To examine the influence of scientific knowledge on the appreciation of landscapes and of the biodiversity elements they contain.

3. To discuss strategies that enhance the aesthetic appreciation of nature, which may prove significant in motivating for its preservation.

Methodology

The present study had an exploratory nature due to the lack of similar research at least in Portugal. A total of 93 pre-service teachers participated (83 – 89.2% female), all enrolled in primary education training courses (master's degree), with a mean age of 23.9 years (SD = 6.067). The data collection instrument was a questionnaire that, in addition to sociodemographic information, presented four photographs of landscapes with varying biodiversity characteristics. Two of the photos featured native Portuguese vegetation: a) A deciduous forest typical of northern Portugal, minimally affected by human intervention; b) A Mediterranean forest (known as *dehesa* or *montado* in Portuguese), a centuries-old human-shaped landscape where nature is sustainably managed. The other two photos depicted exotic and invasive vegetation: c) A eucalyptus monoculture, a tree from Australia that depletes the soil and prevents the establishment of other plant species. Despite these negative impacts, it is widely cultivated due to its rapid growth and is used for paper pulp and timber in the construction industry; d) A landscape dominated by pampas grass (*Cortaderia selloana*), a plant from South America introduced for ornamental purposes that has become invasive due to its rapid propagation (Figure 1).

Figure 1. The four landscapes (a,b,c and d) appreciated by the pre-service teachers.



After the presentation of each photo, the questionnaire included the following questions: 1. According to your preference, rate this landscape on a scale of 1 to 5, where 1 means "I do not like it" and 5 means "I like it very much"; 2. Justify your answer. The questionnaire was validated by two experts in Didactics of Science and considered appropriate for the outlined objectives. The students were randomly divided into two groups (G1 = 48 and G2 = 45), and all completed the questionnaire. However, the students in G2 participated in a prior 45-minute session during which the landscapes were analysed from a scientific perspective. In this session, the main species present in each photo were identified, along with their classification as native or exotic. Additionally, the positive and negative impacts of these species on ecosystems and humans were analysed. For each landscape, the median and mean values of the preference ratings were calculated for each group. To determine if the differences in appreciation were statistically significant, the Mann-Whitney U test was applied with a significance level of 0.05. The justifications provided by the students were subjected to content analysis and categorized according to the nature of the reasons given. The incidence of the different reasons across the two groups was counted and presented in percentages.

Results

The degree of preference expressed for each landscape by each group (median, mean, and standard deviation) is summarized in Table 1, along with the verification of statistically significant differences.

Table 1. The appreciation of the four landscapes by the two groups of participants.

	Median		Mean		SD		
	G1	G2	G1	G2	G1	G2	*p.*
Landscape 1 - Decideous forest	4	5	3.97	4.40	0.956	0.914	0.01
Landscape 2 - Mediterranean forest	3	4	3.14	3.73	1.110	1.268	0.01
Landscape 3 - Eucalyptus monoculture	3	3	3.16	2.73	0.974	1.175	0.04
Landscape 4 - Pampas grass landscape	4	3	3.68	3.26	1.013	1.213	0.09

The results show that participants in G2, who attended the scientific session on landscape analysis, exhibited a stronger preference for landscapes dominated by native vegetation than those featuring exotic and invasive species. The differences between the groups were statistically significant for three of the four landscapes. The exception was the landscape dominated by pampas grass, which still received a higher median score (four, instead of three) in the group that did not attend the session.

The analysis of the participants' justifications from both groups is presented briefly due to space constraints. For Landscape 1 (Deciduous Forest), the responses were predominantly positive. The variety of colours in the landscape was the most frequently cited reason for landscape appreciation by participants in both groups (G1: 72.9%; G2: 57.8%). Additionally, several participants in G2 noted that it represented an ecosystem with native vegetation of high biodiversity (27.9%). The few negative justifications highlighted only one issue: one participant from each group mentioned the excessive vegetation density.

While predominantly positively appraised, Landscape 2 (Mediterranean Forest) also elicited some negative aspects from the participants. Significantly, 20% of G2 participants emphasized the integration of natural and cultural elements within the landscape, a perspective not expressed by G1 participants. The familiarity of the landscape was mentioned by participants from both groups (G1: 8.3%; G2: 20%). In G1, 16.6% of respondents identified the cork oak (Quercus suber) as a beautiful tree, whereas 11.1% of G2 participants emphasized the tree's tolerance of other species. Negative aspects were more prominent in G1, where 20.8% of the participants stated that stripping the tree of its bark reduced its beauty, and 18.8% considered the landscape ordinary. Interestingly, no G2 participant deemed the cork oak's debarking process as negative. This may be because in the session it was highlighted that cork harvesting is a key factor in the preservation of this species in Portugal.

Landscape 3 (Eucalyptus monoculture) received the most negative appreciations, especially from G2 participants. Among G2 respondents, 35.6% pointed out that eucalyptus is an invasive species that depletes resources (soil and water) and is highly flammable, reasons mentioned by only 4.2% of G1 participants. In G1, 29.6% described the landscape as monotonous with little colour variation. Positive justifications highlighted the symmetry in the arrangement of the trees in both groups (G1: 4.2%; G2: 11.1%), with an additional 10.4% of G1 participants noting that the landscape conveyed tranquillity.

Landscape 4 (Pampas grass landscape) garnered more positive than negative assessments from both groups, with this trend being more evident among participants in G1. In G1, 22.9% highlighted the beauty of the pampas grass, a justification also noted in G2 (13.3%). Both groups appreciated the variety in the landscape (G1: 16.7%; G2: 11.1%). Negative justifications were primarily provided by G2, which pointed to the presence of an invasive species (20%) or mentioned its toxicity (4.4%).

Discussion And Conclusions

The study findings demonstrate that scientific exploration of landscape characteristics significantly enhances their aesthetic appreciation. Differentiating between native, exotic, and invasive species, coupled with understanding their ecological and human impacts, proved highly influential. Consequently, this research underscores the crucial role of scientific knowledge in appreciating landscapes and emphasizes the need for a deeper understanding of natural aspects within both classroom settings and outdoor experiences.

Nevertheless, this knowledge is not the only factor contributing to such appreciation. The features of the observed species, referred to as "free beauty" in the introduction section, also played a role and seem to explain the high appreciation of pampas grass by both groups, though more markedly in the group that did not experience the scientific exploration of landscapes. In essence, the aesthetic appeal of this invasive species seems to somewhat diminish its perceived negative impacts. Therefore, future educational exploration of the present issue should place greater emphasis on the detrimental consequences of this species.

Experiential factors exert both positive and negative influences on landscape appreciation. Familiarity, when associated with positive past experiences, can significantly enhance appreciation. Conversely, when perceived as excessive and lacking novelty, familiarity can have a detrimental effect. While less frequent, some participants expressed feelings of insecurity in landscapes perceived as visually enclosed, a phenomenon previously documented in other research (Ulrich, 1993; Kirillova *et al.*, 2014). The perception of human intervention in landscapes proved to be a nuanced factor, eliciting both positive and negative responses from participants, with no significant differences between groups. This was exemplified by the presence of some symmetry in the arrangement of eucalyptus trees, which was appreciated differently by individuals.

As stated initially, this study is exploratory in nature, but it appears to confirm the importance of scientific exploration for a more effective appreciation of landscapes and biodiversity in general. This aspect should receive special attention in the training of science teachers. The connection between increased knowledge and the desire to preserve nature requires further and more targeted investigation, but the present study suggests that this relationship may be plausible.

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GREENLINK

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Theories Of Intelligence And How They Depend On Students' Definition Of Intelligence

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The theory of growth and fixed mindsets provides a framework for understanding how beliefs about intelligence influence learning and academic performance. A growth mindset reflects the belief that intelligence can be developed through effort and persistence, whereas a fixed mindset views intelligence as innate and unalterable. To identify whether individuals have a more growth-oriented or more fixed view, the Theories of Intelligence Scale (Dweck, 2000) is used in most reported studies. This scale contains statements like, "You have a certain amount of intelligence and really can't do much to change it." However, we consider it a limitation that these mindset surveys often ask for students' views on the malleability versus fixedness of intelligence but do not define intelligence itself. The present study investigates how German middle-school students' definitions of intelligence may influence their physics-specific mindset. In addition to the mindset survey, students were asked about their definition of intelligence, and the findings reveal distinct differences that are in line with a similar study by Limeri et al. (2020). Students associating intelligence with knowledge were more likely to agree with growth mindset statements, potentially reflecting the perceived adaptability of knowledge. In contrast, those defining intelligence as ability demonstrated more variability in their mindset responses, suggesting differing perceptions of the fixedness or malleability of abilities. Additionally, reasoning power emerged as the most common definition of intelligence, highlighting its role as a widely recognized yet complex concept within cognitive performance. The study contributes to refining the theoretical understanding of mindsets and supports the need for further exploration of how definitions of intelligence influence the measurement of mindsets and what this implies for measuring and interpreting students' learning attitudes, particularly in subject-specific contexts.

Keywords: Belief Measurement, Educational Psychology, Learning Theories

Motivation

The concept of growth and fixed mindsets provides a framework for understanding how individuals perceive their abilities and potential. These mindsets are grounded in beliefs about the nature of intelligence and abilities, that people hold unconsciously. A fixed mindset is characterized by the belief that intelligence is innate, while a growth mindset reflects the idea that intelligence can be developed through effort and learning. These unconsciously held beliefs can significantly influence students' engagement in learning and show an impact on academic outcomes (Dweck, 2000; Yeager & Dweck, 2020). Success in school is not solely dependent on mindsets, however, students with a fixed mindset tend to give up more easily when faced with difficulties or setbacks. In contrast, students with a growth mindset are more likely to choose challenging tasks (Rege et al., 2021) and exhibit a mastery-oriented behaviour in learning situations (Blackwell et al., 2007). Some studies even show better academic results for students with a growth mindset (Paunesku et al., 2015). In general, a growth mindset can be considered supportive in an academic context.

While the majority of mindset research focuses on beliefs about general intelligence, some studies suggest that mindsets can manifest in specific domains (e. g. Hong et al., 1999). Particularly, in STEM fields, a tendency towards a more fixed view has been reported (Dweck, 2008; Leslie et al., 2015; Rattan et al., 2012), which aligns with similar psychological concepts such as the 'talent habitus' (Archer et al., 2020). However, whether the studies target a general or domain-specific mindset, they usually inquire about beliefs related to intelligence. Mindset questionnaires typically include items like "You have a certain amount of intelligence and really can't do much to change it" (Dweck, 2000), which assess beliefs about the malleability versus fixedness of intelligence but do not define intelligence itself.

Limeri and colleagues (2020) conducted a study with undergraduate students, analysing their definitions of intelligence in relation to their growth mindset scores. They found a significant difference in students' mindset scores based on a dichotomous definition of intelligence: students who defined intelligence as knowledge were more likely to believe in the incremental nature of intelligence than those who defined it as abilities. This may lead to inaccurate mindset assignments, as students who define intelligence as knowledge might answer growth mindset items affirmatively but not exhibit the behaviour patterns typically associated with such a mindset (Limeri et al., 2020). In another study, researchers compared first year STEM students' answers to the typical mindset questionnaire based on the *Theories of Intelligence Scale* depending on their level of agreement to different definitions of intelligence (Diederich & Spatz, 2024). And Sun et al. (2021) observed differences in surveyed mindset patterns when students referred to the model of fluid or crystalline intelligence. The conclusion is similar: measuring mindset based on the Theories of Intelligence scale may not lead to reliable mindset assessment depending on students' intelligence definition.

This research focuses on domain-specific mindsets in physics with the aim to gain a better understanding of subject-specific beliefs. Therefore, a physics-specific mindset questionnaire has been developed and evaluated. This tool contains items of the *Theories of Intelligence Scale* but also incorporates questions about students' beliefs regarding *Giftedness in Physics* and the impact of *Effort in Physics* on learning success. Using these scales, students can be classified into three mindset types: a physics-specific growth mindset (which supports growth mindset statements related to intelligence, giftedness, and effort in physics), a fixed mindset based on general intelligence beliefs, and a fixed mindset based on giftedness in physics (the belief that physics talent predicts success in learning the subject). Students whose answers do not fit any of the three mindset categories are classified into the mixed mindset type (Goldhorn et al., 2023; Goldhorn et al., 2022). Due to the design of this survey instrument, our physics-specific mindset research does not focus on students' intelligence beliefs alone, but these beliefs remain a key element. The influence of students' definitions of intelligence in this context, however, is still unknown.

Research Method

The data presented here aims to investigate differences in students' physics-specific mindset patterns based on their definition of intelligence and is part of a paper-based growth mindset intervention study with N = 210 participating German middle-school students. Before they got to work on the intervention material, students completed the physics-specific mindset questionnaire (Goldhorn et al., 2023) and were asked to define intelligence. First, they answered a single-choice item with the following options: "Intelligence is the sum of what I know," "Intelligence is what I can do," and "Intelligence is reasoning power." The first two options are based on the study by Limeri et al. (2020), while the option about reasoning power is derived from interview studies conducted during the development of the physics specific mindset questionnaire (Spatz & Goldhorn, 2021). In the second step, students were given the opportunity to write their own definition of intelligence if none of the provided options aligned with their understanding.

Results

To simplify the following report and discussion of the results, the intelligence definitions are categorized as reasoning power, knowledge, and ability. A total of N = 191 students answered the single-choice item about intelligence: 55 % agreed with the definition of reasoning power, 25 % chose the option ability, and 20 % selected knowledge. For N = 98 students, the intelligence item could be matched with the growth mindset questionnaire.

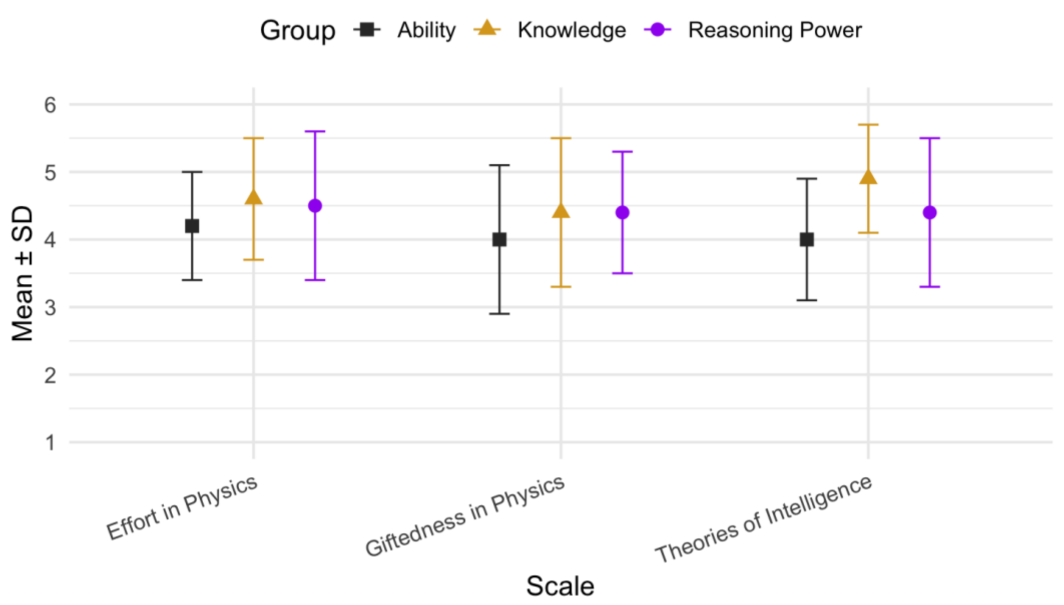
Only the items of the Theories of Intelligence Scale contains the term ‘intelligence’, therefor possible influences of students’ intelligence definitions are expected to appear mainly on this part of the mindset questionnaire. Table 1 presents the mean values and standard deviations for all three scales (Likert scales from 1 to 6, higher values indicating a more growth mindset) that are part of the mindset questionnaire (see Goldhorn et al. (2023) for more details of that mindset questionnaire and the items used). Figure 1 provides an additional visual display on possible group differences based on the mean values and standard deviations.

Table 1: Comparing mean values and standard derivations for each scale of the mindset questionnaire, according to students' intelligence definitions.

Mindset scale / Intelligence definition	Theories of Intelligence ($M \pm SD$)	Giftedness in Physics ($M \pm SD$)	Effort in Physics ($M \pm SD$)
reasoning power	4.4 ±1.1	4.4 ± .9	4.5 ± 1.1
knowledge	**4.9 ± .8**	4.4 ± 1.1	4.6 ± .9
ability	**4.0 ± .9**	4.0 ± 1.1	4.2 ± .8

As expected, a one-way ANOVA reveals a significant effect of students’ intelligence definition, $F(2, 95) = 3.89$, $p = .024$, $\eta^2 = 0.76$ for the *Theories of Intelligence Scale*. Post-hoc comparisons using the Bonferroni correction show that students who define intelligence as knowledge ($M = 4.92$, $SD = .83$) score significantly higher ($p = .002$, $d = .90$) than students who define intelligence as ability ($M = 4.03$, $SD = .95$), i.e. they believe more in the changeability of intelligence. For the other scales, no statistically significant differences can be reported.

Figure 1: Visual display of the mean values and standard deviations of the three scales Effort in Physics, Giftedness in Physics and Theories of Intelligence according to students’ intelligence definitions.



The participating students could also describe intelligence in their own words, and 31 students took that option. Eighteen of them added their own description to their chosen option, for example, two student who chose *reasoning power* wrote "IQ score" as their own description of intelligence. In general, students' descriptions of intelligence show a broad variety in their perception of intelligence. They include different perspectives from "intelligence is the ability to learn something new and how fast you can learn" to "intelligence means being smart" and "intelligence means how distinctive your brain is".

In our research regarding physics-specific mindsets the mindset questionnaire is used to assign students to different mindset types (see Goldhorn et al. (2023)). To examine possible influences of students' definition of intelligence on those mindset assignments, Table 2 presents the mindset distributions based on students' intelligence definitions. From all N = 98 students, 41 % were assigned to the physics-specific growth mindset, 17 % aligned with the criteria for the fixed mindset 'general intelligence', and 13% identified with the fixed mindset 'giftedness in physics'. The remaining 29% were classified as having a mixed mindset. Slightly more than half of the students who define intelligence as knowledge (53 %) are assigned as holding a growth mindset, while only 24 % of the students who define intelligence as ability are sorted to this mindset group. This difference would support the findings of Limeri et al. (2020) how students' definition of intelligence may shift their mindset assignment, still it is not statistically significant in the presented study.

Table 2: Mindset distribution sorted by students' intelligence definition. Numbers in brackets show the actual numbers of students, N = 98.

Mindset distribution / Intelligence definition	growth mindset (40)	fixed mindset 'general intelligence' (16)	fixed mindset 'giftedness in physics' (14)	mixed mindset (28)
reasoning power (56)	45 % (25)	20 % (11)	9 % (5)	26 % (15)
knowledge (17)	**53 %** (9)	6 % (1)	12 % (2)	29 % (5)
ability (25)	**24 %** (6)	16 % (4)	28 % (7)	32 % (8)

Discussion

Nearly half of the participating students agreed with one of the two concepts of intelligence (knowledge or ability) suggested by Limeri et al. (2020). And sorting students by this dichotomous differentiation of intelligence definition shows a significant difference on how they answered on the *Theories of Intelligence Scale*. The knowledge group is scoring higher ($M = 4.92$, $SD = .83$) than the ability group ($M = 4.03$, $SD = .95$), which means, these students answer more towards a growth mindset on that part of the mindset questionnaire (see Table 1 and Figure 1). This result aligns with the findings of Limeri et al. (2020). They explained that students who define intelligence as knowledge tend to agree with growth mindset items because it is a common understanding and also the students' experience that knowledge increases over time and can be expanded from any current state. On the other hand, students who define intelligence as abilities show more variation on the mindset scale, depending on whether they view abilities as more fixed or more malleable, which explains more variety on the *Theories of Intelligence Scale* and therefor a lower mean value. Limeri and colleagues conclude that measuring students' mindsets using only the *Theories of Intelligence Scale* might lead to incorrect assignment for those who define intelligence as knowledge. Our sample supports this hypothesis, as the knowledge group scores higher on the theories of intelligence scale and has relatively more students assigned to a physics-specific growth mindset.

The mindset distributions based on students' definition of intelligence (see Table 2) shows differing percentages for the knowledge and the abilities group. Within the knowledge group, there are relatively more students assigned to a growth mindset compared to the abilities group. The student numbers are very small, and the occurring differences are not statistically significant, but they do align with the result about a tendency towards a growth mindset for those students who define intelligence as knowledge. Also, the higher number of students with a *fixed mindset (giftedness in physics)* compared to those with a *fixed mindset (general intelligence)*, especially for students who define intelligence as abilities, supports the findings about a more fixed view of abilities in STEM fields that has been reported by Dweck (2008), Leslie et al. (2015) and Rattan et al. (2012).

The differing scores on the *Theories of Intelligence Scale* related to students' definition of intelligence as knowledge versus intelligence as abilities is the main finding of the presented research. Still, the intelligence definition with the highest level of agreement is reasoning power. This might be equivalent to analytical intelligence and is a very common understanding of intelligence, especially since it aligns with what can be measured in IQ testing (Carpenter et al., 1990). However, there is no specific data on how students really refer to reasoning power and if it is a concept that can be aligned with the mindset theory. From the 31 students who wrote their own description of intelligence the main result is that they show a broad variety and do not refer to a similar concept of intelligence. To clarify students' perception of the word intelligence more qualitative research is needed.

Conclusion

Students' definitions of intelligence seem to influence how they respond to typical mindset statements, such as those found in the *Theories of Intelligence Scale*. In particular, students who define intelligence as knowledge may occur as having a growth mindset, since their perception of intelligence aligns with an incremental concept. But answering the mindset items based on that does not mean they truly believe in an incremental theory of developing one's individual potential. Mindsets are a powerful predictive tool, especially when students can be shifted to a more growth mindset approach to academic learning through mindset interventions. However, to effectively do this, the commonly used instrument with its sole focus on intelligence, should be critically evaluated. Based on our research, domain-specific scales that do not use the term 'intelligence' appear more reliable for identifying students (domain-specific) mindsets and there are no statistically significant differences in a mindset assignment based on all three scales as we propose in our research (Goldhorn et al. (2023)). This finding highlights the importance of using mindset measures that do not focus exclusively on intelligence.

The present study is a small sample, but it supports the hypothesis proposed by Limeri et al. (2020) and Sun et al. (2021): students' definitions of intelligence do matter when investigating mindset and warrant further exploration to ensure all the possibilities regarding mindset research.

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Enhancing Students' Interest And Self-Efficacy In Science Through A Large-Scale Teaching Program

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Globally, a lack of student interest in science education remains a critical challenge, particularly among primary and secondary students. This poses difficulties in fostering scientific literacy and meeting workforce demands for scientific competencies. Existing programs that enhance interest and self-efficacy often lack scalability, requiring significant resources and time commitments from schools and teachers. To address these limitations, a large-scale teaching program was developed with the aim of improving science education. In 2024, over 135,000 students participated in this program. We study one of the teaching units that are part of the program. The teaching unit includes a 1.5-month in-school teaching unit as well as a one-day out-of-school lab activity and is based on an inquiry and Socio-Scientific Issues approach. It aims to increase student interest, engagement, and self-efficacy in science. A quasi-experimental difference-in-differences design evaluated the unit's impact across 1,951 students in 189 classes. The results show medium effects on situational interest (0.64 SD) and students' ability to relate science to societal challenges (0.55 SD). Confidence in mastering content-specific tasks showed large effects (0.98–1.59 SD), though improvements in general motivation and broader scientific competencies were limited. The study shows that it is possible to develop a scalable approach to science education that combines minimal preparation time from teachers with significant improvements in student outcomes. However, the study indicates that a 1.5-month program alone is insufficient to significantly improve students' general motivation for science or develop general scientific competencies. Future impact evaluations will explore different possibilities for improvement.

Keywords: Interest. Self-Efficacy. Student Engagement

Context And Relevance

Students' lack of interest in science education remains a significant global challenge, particularly among primary and secondary school students. The lack of interest in science poses challenges both in terms of motivating and strengthening students' general scientific literacy and in educating enough students with scientific competencies to meet workforce demands (Griethuijsen et al., 2015).

While various educational programs have demonstrated effectiveness in enhancing students' interest and self-efficacy in science, these interventions often face critical limitations: they are resource-intensive, lack scalability, and demand substantial time commitments from schools and teachers. These constraints often result in participation being limited to a small, self-selecting group of motivated educators and schools, making it difficult to generalize findings or achieve widespread impact.

A recently funded program, organized externally from schools, has developed science teaching units to address these barriers. Unlike many traditional programs, this initiative is designed to be scalable and accessible, reducing demands on teachers' time and resources. This model enables broad participation across diverse schools and student populations. In 2024, more than 135,000 students participated in a teaching unit, most of them in middle or lower secondary schools.

As part of the grant, an ambitious impact evaluation strategy has been developed. The first evaluation was conducted on one of the teaching units targeting 9th-grade students. The teaching unit, based on an inquiry-based approach, consists of a 1.5-month in-school activity and a one-day follow-up out-of-school lab event. The evaluation measured effects on 9th-grade students' interest and self-efficacy in science across different student groups, including those traditionally less motivated in science. Evaluating whether a large-scale science program can effectively improve students' interest and self-efficacy in science is crucial for understanding how more students can access high-quality science education.

Research Questions

The research questions are:

1. Can the teaching unit improve students' situational interest and general motivation for science?
2. Can the teaching unit enhance students' content-specific self-efficacy and their self-efficacy in conducting experiments?
3. Are the program's effects consistent across different student demographics and academic backgrounds?
4. What lessons can be drawn about the scalability of high-quality educational interventions?

Theoretical Framework For The Development Of Outcomes

The impact evaluation is based on seven survey scales measuring students' interest and motivation for science, and science self-efficacy. The survey scales were developed and validated following the seven steps recommended by the Association for Medical Education in Europe (Artino et al., 2014). These steps include a thorough literature review of international research, expert validation by science researchers, cognitive interviews with students, and statistical validation. Our scales draw from established science education research and are adapted to a domestic school context. The scales were statistically validated using the Rasch model with pilot data collected in 2023 (Rambøll, 2024).

Situational Interest

Two scales measure students' situational interest in science lessons. These are based on Hidi and Renninger's (2006) four-phase theory of interest development and inspired by Linnenbrink-Garcia et al.'s (2010) Situational Interest Measures survey instrument. The two scales measure the first two phases of the theory. Are students more inclined to participate and more engaged (called Triggered situational interest), and do they find the teaching unit more relatable and meaningful (called Maintained situational interest) than their regular science lessons.

General Motivation For Science

Two scales measure students' broader motivation for science, focusing on intrinsic and extrinsic motivation. These scales are based on Ryan & Deci's (2020) Self-Determination Theory and adapted from validated scales developed by Makransky et al. (2020) students in grades 4–9 in the relevant country.

Content-Specific Self-Efficacy

Two scales measure students' confidence in mastering the specific academic content covered in the teaching unit. The items broadly align with the program's learning objectives and national science curriculum goals. The scales draw on Albert Bandura's (1997) concept of self-efficacy and related studies (e.g., Fidan & Tuncel, 2021).

Self-Efficacy In Conducting Experiments

This scale measures students' self-efficacy in conducting experiments and evaluates whether the teaching unit impacts their more general scientific inquiry skills. The scale is inspired by Hu et al.'s (2022).

Research Method And Data

The impact evaluation employs a robust quasi-experimental difference-in-differences (DiD) design. In the intervention group, students' interest and science self-efficacy are measured both before and after participating in the teaching unit. Similarly, in the control group, students are measured twice within the same timeframe as the intervention group. The effect is calculated as the difference in outcome development between the intervention and control groups. The design employs a kind of 'wait-list' design, where the control group consist of classes that has enrolled but had not yet started the teaching unit. This approach was used to avoid self-selection bias. Pre-scores show no substantial difference between the control- and intervention groups.

The DiD estimator is calculated using a simple regression model (a two-way fixed-effects model): $Yit = \beta i + \beta t + \rho Tit + uit$

where T equals 0 for the control group and 1 for the intervention group, uit represents the unobserved error term, and βi and βt are individual and time fixed effects. The parameter ρ captures the average causal effect of the teaching unit. As a sensitivity analysis, we tested a model that controlled for students' background variables (gender, ethnicity, grades, parental education, and income). The results did not yield substantially different results compared to the simpler model.

The dataset includes 1,951 students across 189 classes, with each student completing the survey twice. The analytical sample does not differ significantly from the entire population of 9th-grade students in the relevant country.

Findings

Figure 1 (next page) shows the results of the impact evaluation.

Improved Interest, Engagement, And Relevance

Students taught in the teaching unit were more interested and showed a greater desire to participate in science lessons compared to students in the control group (Triggered situational interest, medium effect: 0.64 SD). Additionally, students found that the teaching unit, more than regular science lessons, could be related to daily lives (Sustained situational interest, small effect: 0.25 SD). When directly asked if the teaching could be related to societal or global challenges, there was a medium effect (0.55 SD).

Weak Improvement In General Motivation For Science

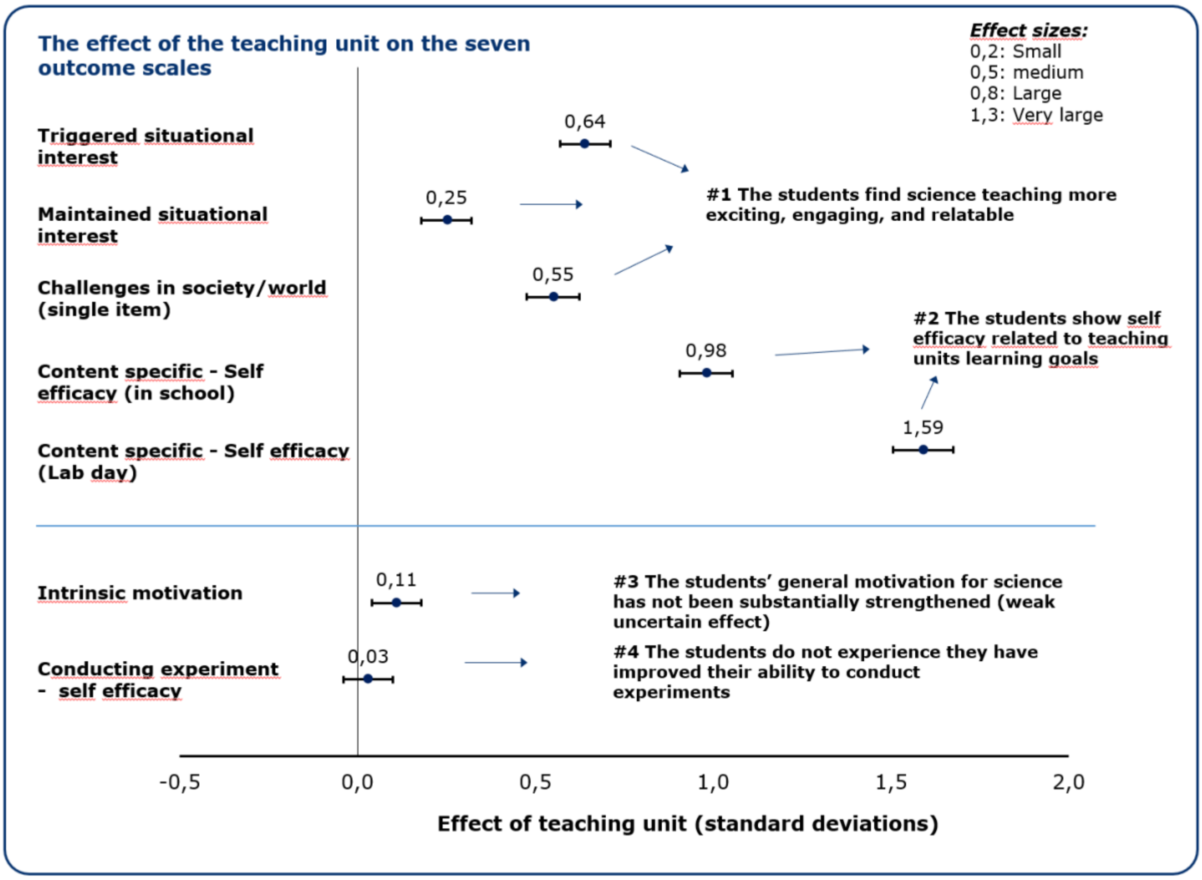
Despite students finding the teaching unit far more engaging and relevant than regular science lessons, it did not substantially enhance their broader motivation for science (Intrinsic motivation, small uncertain effect: 0.11 SD).

Enhanced Content-Specific Self-Efficacy

Students demonstrated greater confidence in their ability to perform science-related tasks, linked to the teaching units learning objectives (Content-specific self-efficacy, large effect: 0.98–1.59 SD). This outcome is not surprising, as the design does not ensure that the control group worked on the same topic as the intervention group. Other effect studies typically show effects on outcomes that relate directly to the teaching units learning goals (Slavin et al., 2014).

Nevertheless, the effect sizes suggest that students generally achieve the nationally established objectives addressed by the program.

Figure 1: Results Of Impact Evaluation. Standardized effect estimates from regression models, with cluster-robust standard errors at the class level. Lines indicate 95% confidence intervals around point estimates (n=3,876 observations). Source: Rambøll, 2024.



Lack Of Improvement In Conducting Experiment Self-Efficacy

Students did not assess they had improved in their ability to conduct experiments. Regarding the development of broader scientific competencies, such as inquiry skills, either the teaching program was not sufficient, or different approaches are needed.

Equity Across Student Groups

Subgroup analyses revealed that the improvements in situational interest applied across various groups, including students of different genders, ethnic backgrounds, academic performance levels, and socioeconomic statuses. However, students with higher initial academic performance showed slightly greater gains in content-specific self-efficacy.

Discussion Of Findings And Implications

The study shows that it is possible to develop a large-scale science program for teachers that requires minimal preparation time and increases students' interest, participation, and engagement in science. This effect was measured on a representative group of schools and students, and the results demonstrate that the increased interest and engagement in science benefited all student groups, including those who traditionally show less interest in science.

The study indicates that a 1.5-month program alone is insufficient to significantly improve students' general motivation for science or develop general scientific competencies. Future impact evaluations will explore whether multiple teaching units can achieve more general and long-term effects, incorporating survey data and registry-based measures such as 9th-grade exam scores and enrolment in science-focused education.

Observations and interviews with students and teachers collected as part of the impact evaluation suggest that some teachers face challenges in implementing its inquiry-based approach (LIFE Fonden, 2024). Exploring whether more direct support for teachers could lead to broader student outcomes is therefore warranted. Such support could improve the program's implementation and potentially enhance teachers' instruction across other science lessons. To address this, a research project is underway to develop teacher support tools that raise awareness of inquiry-based didactics and enable practice of its key elements during the program.

The teaching program exemplifies a scalable approach to science education that combines minimal time investment from teachers with significant improvements in student outcomes. By addressing barriers to participation and achieving broad reach, the program demonstrates the feasibility of providing student access to high-quality educational experiences. This evaluation provides valuable insights into how scalable models can maintain effectiveness while expanding their impact across diverse educational contexts. However, more research is needed to understand what is required to create broader and more lasting effects.

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Enhancing Students' Interest In Chemistry Through Authentic Contexts

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Despite the immense amount of research findings concerning interest and motivation, the successful transfer of these findings into educational practice could be doubted when studies continuously reveal a lack of interest in STEM subjects, especially in chemistry. The authors take the persistent interest deficit as an opportunity to discuss a new way of promoting interest in chemistry based on a combined conceptual framework that draws from various theories connecting interest, authenticity and constructivism. Aiming to create an authentic, context-structured learning environment to enhance situational interest in chemistry, an out-of-school laboratory course for middle school level using authentic medical cases was developed. During the course, students are confronted with an authentic file of a patient after an asthma attack. Drawing on both medical background information and chemical concept knowledge, they conduct different experiments with carbon dioxide and carbonic acid to eventually diagnose the patient with respiratory acidosis. Before the course, individual dispositions and prior situational interest were assessed with a questionnaire. After the course, situational interest was assessed again, as well as the perceived authenticity of the whole course. Analysing the quantitative data of 155 students, indications arose that the relationship between individual interest and situational interest is partially mediated by perceived authenticity. Perceived authenticity is displayed as a crucial factor for potential interest enhancement, especially for learners with low individual interest in chemistry.

Keywords: Interest, Learning Environments, Out-of-School Learning, Authenticity

Introduction

Situational as well as individual interest have been one focus of educational research for over half a century but the transfer of such findings into educational practice could be questioned: Looking at Germany and Austria alone, latest studies show a strongly decreasing gradient from perceived competence, over interest, to the career aspirations in science subjects (SINUS Markt- und Sozialforschung GmbH, 2024). This trend can be found throughout the Western European countries (van Griethuijsen et al., 2015). Chemistry is particularly unpopular. Apart from a shortage of skilled workers in STEM disciplines (Anger et al., 2024), a lack of interest is also problematic for learners who do not aspire a career in science. STEM (here: chemistry) education should therefore not only appeal to future researchers but should also be designed to be attractive to all learners to enable participation in our society and informed everyday decisions (Hüfner et al., 2025). Students often name everyday references and practical knowledge as potentially interesting facets of chemistry (Fleischer et al., 2024; SINUS Markt- und Sozialforschung GmbH, 2024). Yet, these aspects are hardly anchored in (Western European) chemistry curricula, even though various teaching concepts for interest enhancement already exist. Making chemistry more appealing still presents a challenge that needs to be addressed by finding a suitable way to combine approved methods with research findings as well as with the individual learners' views and needs.

Conceptual Framework

Constructivism In Science Lessons

Modern educational systems and educational research are based on the fundamental assumptions of (social) constructivism as the prioritized approach to successful learning. Impactful theories, such as Situated Cognition, Cognitive Apprenticeship or Anchored Instruction, laid the foundation for our understanding of the conditions for the independent construction of knowledge during learning processes. To enable situated learning and to fight inert knowledge, authentic contexts and activities play a central role (Ghefaili, 2003). It has been well researched that people of all ages tend to neglect the personal relevance of science in their lives (Kantar, 2021). Given that situated learning always relies on creating meaningful learning environments with authentic real-world complexity (Honebein et al., 1993; Ghefaili, 2003), this widespread neglection seems disadvantageous for learning (and liking) science. It has been found that strictly following constructivist design guidelines does not alone make a difference regarding interest in learning situations (Xu et al., 2024; Yeung et al., 2025). It therefore remains to be refined to what extent situated learning, interest and authenticity interact.

Interest And Learning

A stable preference for topics or activities is referred to as individual interest, describing an individual trait. Interest can also show in form of temporary engagement, referred to as situational interest. Individual interest is often seen as the most important predictor of situational interest (Rotgans & Schmidt, 2018), while there is also research describing important “triggers” for situational interest arising from a learning environment (Renninger et al., 2019). The so-called person-object theory of interest (POI) states a bipolar unit of person and situation (Krapp, 1999). Both interest as a personal disposition and interestingness as a feature of learning environments can lead to the psychological state of being interested in something (Krapp et al., 1992). The four-phase model of interest development (FPM) “describes phases of situational and individual interest in terms of both affective and cognitive processes” (Hidi & Renninger, 2006, p. 113), therefore proposing a structured process in which individual interest evolves based on experiencing situational interest. Hidi and Renninger (2006) assume situational interest to be triggered in certain situations with the potential to be maintained through personal relevance of the topics or materials. Both POI and FPM are frequently used as theoretical backgrounds for current research.

Situational interest is composed of an emotional, a value-related, and an epistemic compound, stating that besides experiencing meaningfulness and positive emotions during learning, curiosity and engagement contribute to being interested (Prenzel et al., 1986). Research shows that increased situational interest can lead to more positive affect as well as higher cognitive engagement and therefore contribute to knowledge acquisition through intensifying and maintaining effort (Su, 2020). Research provides scattered results concerning STEM contexts that seem interesting to students (Hoffmann et al., 1998; Sjoberg & Schreiner, 2005) and therefore illustrates that interestingness does not follow universally applicable rules for every individual learner, highlighting the importance of integrating individual perceptions. It is suggested that one context can affect different learners in different ways (Habig et al., 2018; van Vorst & Aydogmus, 2021; Yeung et al., 2025). Some researchers discuss a balance between dispositional and situational (environmental) facets when it comes to enhancing situational interest (Schäfer & Habig, 2024). Such a balance is strongly supported by the constructivist approach that learning equals the behaviour of individuals, bringing their own larger context with them, engaging in a local (learning) environment where tasks are situated (Honebein et al., 1993). Unfortunately, research still provides only limited explanations as to *why* interest develops which way for different learners.

Interest, Authenticity, Contextualization, And Their Link To Constructivism

Chemistry is often perceived difficult or abstract. One reason for low interest in science could be contextualization not fitting highly individual values and preferences. According to the situational expectancy-value theory (SEVT, Eccles & Wigfield, 2020), low situational interest could be explained by science seeming non-enjoyable and far from useful. As a result, a learning context may be perceived as not compatible with oneself. According to the Person-Environment Fit Theory (PEFT, van Vianen, 2018), only a good alignment between individual characteristics and the (learning) environment leads to engagement and better performance. This fit is therefore directly linked to interest. A similar concept of "fit" is used by Zualkernan (2006). Following this framework for constructivist learning environments, the learner "adapts" to an environment in such a way that she can be "fit" for the tasks in question (Zualkernan, 2006). Especially the "structural fit" seems similar to the PEFT as it describes "how closely the cognitive constraints and learning styles of the learner 'match' to the information present in the environment" (Zualkernan, 2006, p. 200). If complete dissonance occurs, individuals might refuse all information presented in a learning environment. If these models are joined with the concept of authenticity, it could be inferred that a good fit is reflected in a high perception of authenticity before it results in increased (situational) interest.

That is, *perceived* authenticity plays a central role in stimulating and maintaining situational interest (Betz et al., 2016). It has been proven that the *intended* level of authenticity neither had effects on perceived authenticity of the students nor on their situational interest, providing us with the necessity to include the learners' personal views. All components connected to the individual feeling of authenticity have been linked within the Model of Authenticity in Teaching and Learning Contexts, stating that the feeling of authenticity manifests as a product of an individual authentication process which is itself influenced by personal dispositions as well as characteristics of the environment (Betz et al., 2016). Aiming to design authentic learning materials means enabling students to make connections of the learning content to real life (Fougt et al., 2019). *Authentic* has been used extensively, but not consistently, to describe learning situations connected to real life. Shaffer & Resnick (1999) state that different kinds of authenticity may overlap to create "thick" authenticity, a strong perception of authenticity. They include criteria like alignment with the outside world, with a specific discipline, or with what learners really want to know (Shaffer & Resnick, 1999). Other authors suggest various design principles for authentic learning environments, e.g. authentic contexts, expert performance, collaboration or scaffolding (Herrington & Oliver, 2000). Real-world problems, inquiry, discourse among the community of learners as well as empowerment of the learners are seen as components of authentic learning (Rule, 2006). A feeling of relevance and usefulness (in these terms: a feeling of "fit") is supposed to arise when students perceive learning environments as authentic (Nachtigall et al., 2018), making authentic contexts a promising approach to effectively use situated learning for interest enhancement. Yet, findings about what really induces perceived authenticity in the individual learner remain ambiguous, e.g. concerning instruction methods and guidance (Hohrath et al., 2024; Nachtigall & Rummel, 2021).

Aims And Research Questions

Although the theoretical foundation suggests that perceived authenticity has a key role in the constructivist view of situated learning processes concerning the development of situational interest, studies often do not integrate *perceived* authenticity in interest assessments of (context-based) learning environments (Nachtigall et al., 2022, 2024). The individual learner's personal perspective is of ultimate value for determining if constructivist pedagogies reach their goal of presenting fitting situated learning environments because "not only is [the learner] entitled to make judgements about what counts as authentic for her but, in the final analysis, it is her authenticity which really matters" (Splitter, 2009, p. 143). One way to examine such a fit is through authenticity (Betz et al., 2016). Learning materials that are perceived as authentic would enable students to make credible connections between the learning content and real life (Fougt et al., 2019).

This gives rise to the hypothesis that an increased fit and thus an increased perception of authenticity is a positive starting point for the enhancement of situational interest yet depends on the individual learner. Consequently, the following research questions arise:

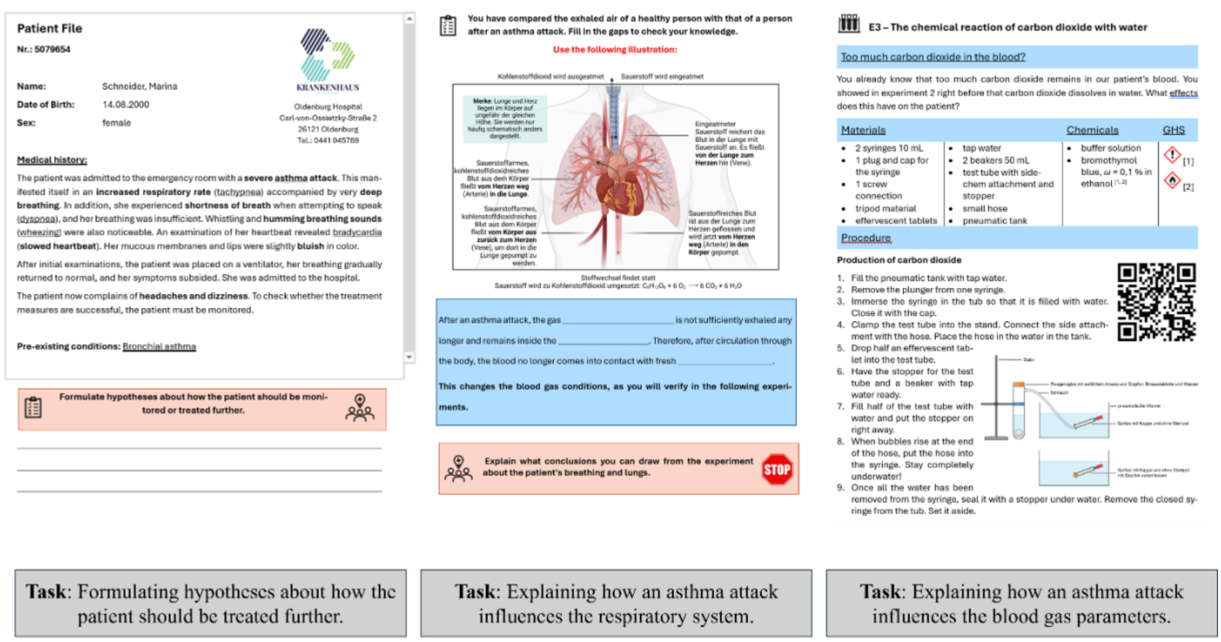
1. How is the perception of authenticity linked with other interest-determining factors?
2. Does our design of a context-based learning environment seem more authentic, or more interesting, to learners with a special set of dispositions?

Research Design And Methods

Designing An Authentic Context-Based Learning Environment

To examine the connections between situational interest, perceived authenticity and individual dispositions in a context-based learning environment, we decided on conducting a survey in an out-of-school student laboratory. Trying to obtain a high level of *intended* thick authenticity in alignment with Shaffer & Resnick, we searched for a context that connects chemical knowledge with problems from the real world, that is aligned with a specific discipline and with topics learners want to know about. Because various studies confirmed young people's universal interest in medical topics (Hoffmann et al., 1998; Sjoberg & Schreiner, 2005), and because chemical concepts are of essential use for medical cases, we picked a medical context. To align our learning environment with real-world problems, we reconstructed an authentic patient's case in collaboration with experts in medicine from the local clinic. As a result, a learning environment using a patient file as contextual structure was designed (see Figure 1).

Figure 2. Exemplary screenshots from the (translated) learning material.



The patient file and the respective diagnosis to be made served as the initial problem the students would encounter. Our patient, a young girl with bronchial asthma, came to the hospital after a severe asthma attack, and was administered oxygen. Now, the causes of her ongoing headaches and dizziness following the treatment should be identified. The students start making suggestions for suitable medical examinations and are supported by additional medical information and scaffolding, concluding that a blood gas analysis should be arranged. In the laboratory, they conduct simple and easy chemical experiments to model the steps of a blood gas analysis. Conducting chemical experiments for the detection and quantification of carbon dioxide as well as the acidic reaction of carbon dioxide in aqueous solutions, the students are guided towards diagnosing the patient with respiratory acidosis as a condition following the severe asthma attack (Boemke et al., 2012).

Survey Instrument And Methods

The three-hour course was accompanied by a questionnaire in a pre-post format (Dietel & Wilke, 2025). To assess dispositions in the pre-test, five and three items on five-point Likert scales were used to measure individual interest in chemistry (*ind(ch)*) and medicine (*ind(med)*). Situational interest was assessed in both the pre- and post-test using five items on a five-point Likert scale (*sit(pre)* and *sit(post)*). In the post-test, perceived authenticity was also assessed using three items (*auth*). Additionally, the students could deliver a short, written statement on why they felt that way about their authenticity perception. Table 1 shows exemplary items with the original sources and the reliability of the scales.

Table 1. Questionnaire Details.

Scale	**Exemplary Item (translated)**	**Source**	**Cronbach's α**
ind(ch) (5 items)	I like working on tasks from chemistry lessons.	Frey et al., 2015; Habig, 2017 (adapted)	.907
ind(med) (3 items)	I enjoy exploring medical topics.	Frey et al., 2015; Habig, 2017 (adapted)	.898
sit(pre) (5 items)	Learning chemistry with this topic will be fun.	Habig, 2017 (adapted)	.863
sit(post) (5 items)	Understanding this topic is important for me.	Habig, 2017 (adapted)	.868
auth (3 items)	I have learned something from everyday life of real people today.	Finger et al., 2022 (adapted)	.792

A correlation analysis was carried out in SPSS. Assumptions concerning mediating effects of different constructs on the development of situational interest were tested using the PROCESS macro by Hayes (Hayes & Little, 2018). Group differences were analysed using ANOVAs.

Findings

The data from 155 students aged 14-16 years were analysed. 79 participants identified as female, 69 as male, and 7 stated another gender. All scales showed good or very good reliability (see Table 1). The participants reported medium-high situational interest in both pre-test (3.61 ± 0.67) and post-test (3.59 ± 0.84) as well as medium-high perceived authenticity after the intervention (3.77 ± 1.06). Individual interest in chemistry (3.05 ± 1.04) was rather low while individual interest in medicine was on a higher level, as expected (3.60 ± 1.11).

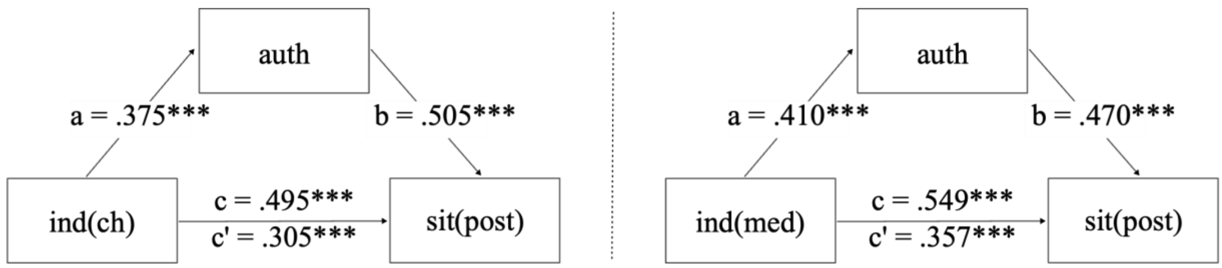
To answer the first research question, a correlation analysis as well as mediation analyses were performed. From a correlation analysis (Spearman's rho, see Table 2), it arises that perceived authenticity is correlated with every surveyed construct, and it is especially highly correlated with situational interest in the post-test. Both *ind(ch)* and *ind(med)* are highly correlated with *sit(pre)* as well as with *sit(post)*. Nevertheless, the correlation remains constant (*ind(ch)*) or decreases (*ind(med)*) from pre-test to post-test, while the correlation of *auth* with situational interest increases from pre-test to post-test. This suggests that perceived authenticity became relevant for situational interest during the intervention while indicating that the dispositions may play a more foundational, rather than dynamic, role in interest development.

Table 2. Correlation Analysis.

	ind(ch)	ind(med)	sit(pre)	sit(post)
ind(med)	$\rho = .300$ $p < .001$			
sit(pre)	$\rho = .555$ $p < .001$	$\rho = .649$ $p < .001$		
sit(post)	$\rho = .555$ $p < .001$	$\rho = .593$ $p < .001$	$\rho = .701$ $p < .001$	
auth	$\rho = .380$ $p < .001$	$\rho = .430$ $p < .001$	$\rho = .424$ $p < .001$	$\rho = .714$ $p < .001$

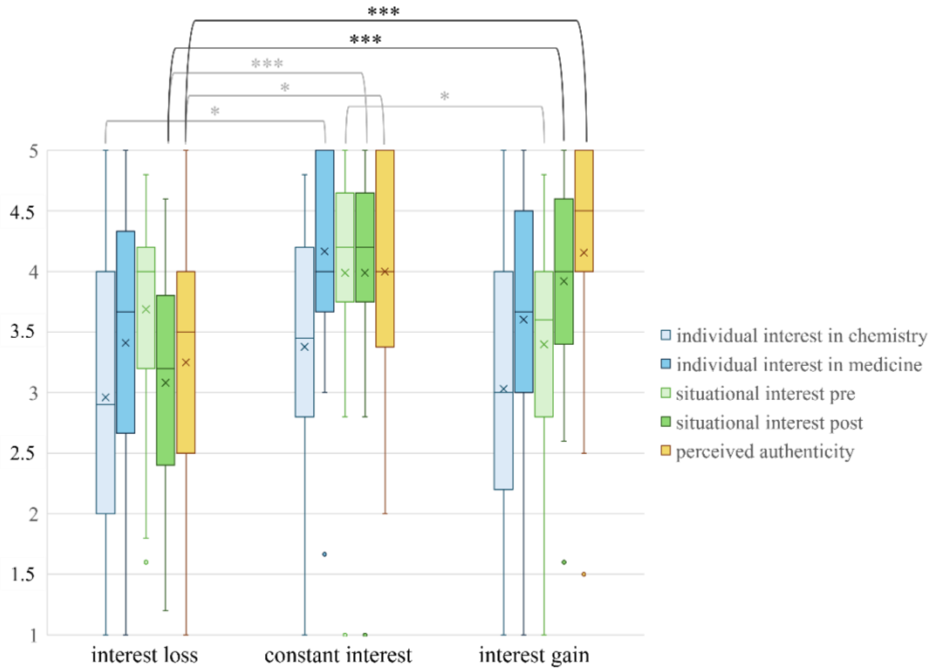
The correlation analysis prompted a further examination of the initial hypothesis: the central role of perceived authenticity for interest enhancement. This is why the effects of different dispositions on the post-test value of situational interest were checked for a mediating influence of perceived authenticity. All relationships were approximately linear, as assessed by visual inspection of the scatterplots after LOESS smoothing. A simple mediation was performed. An effect of *ind(ch)* on *sit(post)* was observed. After entering perceived authenticity into the model, *ind(ch)* predicted this mediator *auth* significantly, which in turn predicted *sit(post)* significantly. We found that this relationship is partly mediated by *auth*. Also, the effect of *ind(med)* on *sit(post)* was significant and got partly mediated by *auth*. The mediation paths are visualized in Figure 2.

Figure 3. Mediation figures (* - significance p < .001).**



To answer our second research question, we divided the data into three groups according to the development of situational interest from pre-test to post-test. This resulted in the groups “interest gain” (*sit(post)* - *sit(pre)* > 0, N = 71), “interest loss” (*sit(post)* - *sit(pre)* < 0, N = 62), and the group “constant” (*sit(post)* - *sit(pre)* = 0, N = 18). Levene’s test revealed equal variance among the groups regarding the constructs *ind(ch)*, *ind(med)*, *sit(pre)* and *sit(post)*. An ANOVA showed significant differences in the areas of *ind(med)*, *sit(pre)* and *sit(post)*. A Tukey test specified that significant differences between the “interest gain”-group and the “interest loss”-group only occurred concerning *sit(post)* ($F(2, 148) = 19.54$, $p < .001$, $\eta^2 = .209$). Other significant differences were found only in comparison to the “constant”-group. For perceived authenticity, variance inequality over the three groups had to be assumed. Here, a Welch-ANOVA followed by a Games-Howell test also revealed significant differences between the “interest gain”-group and the “interest loss”-group ($F(2, 46.25) = 14.42$, $p < .001$, $\eta^2 = .174$). These large effects suggest that, given similar dispositions and similar starting points in terms of situational interest, perceived authenticity is the only factor surveyed here that contributes to divergent interest development comparing "interest gain" and "interest loss". Significant differences are visualized in Figure 3.

Figure 4. Boxplots for the group comparison (development of situational interest).



Additionally, data from male and female participants were included to determine gender differences. Levene's test confirmed the homogeneity of variance between the two groups regarding all constructs. An ANOVA revealed significant differences for *ind(med)* (F(1, 146) = 12.22, p < .001, η^2 = .077) well as *auth* (F(1, 145) = 6.99, p = .009, η^2 = .046) in favor of girls. For *ind(med)*, the effect (η^2 = .077) was moderate to large, indicating a practically relevant difference between girls and boys. For *auth*, the effect was moderate (η^2 = .046), indicating a clear but less pronounced difference. Both results emphasize that gender might be an additional significant factor for the constructs examined.

Discussion

The present study examined the role of perceived authenticity in the development of situational interest during a context-based out-of-school chemistry intervention among early adolescents (aged 14–16). While individual interest in chemistry was relatively low, interest in medicine was notably higher, aligning with the study's intentional focus on medical contexts.

Correlation analyses revealed that perceived authenticity was strongly associated with all key constructs, particularly suggesting it being increasingly important for interest development over time. Mediation analyses confirmed that perceived authenticity partially mediated the effects of both *ind(ch)* and *ind(med)* on post-test situational interest. This supports the hypothesis that perceived authenticity acts as a key psychological mechanism for interest enhancement.

The ANOVA results underline that the perception of authenticity could play a central role in the development of situational interest during the intervention, as no significant difference between learners from the "interest gain"-group and "interest loss"-group could be found in the other constructs examined. Gender also appears to be related to the perception of authenticity, albeit with smaller effect sizes. It is noteworthy that, despite their significantly higher perception of authenticity compared to boys, girls do not show a generally higher level of situational interest. Here, the hypothesis could be put forward that different learners may require different levels of "threshold authenticity" to experience an increase in their situational interest, especially if their dispositional starting position already favours an increased perception of authenticity. Partial mediation was found for both mediation analyses, suggesting that an increased experience of authenticity, in parallel with the existing dispositional situations, promotes an increase in situational interest.

The increasing relevance of authenticity over time may reflect a growing sense of personal relevance and connection to the content. This claim is additionally supported by data from the written statements about the individual authenticity perception. Students from the "interest gain"-group who expressed high perceived authenticity often stated that they had the feeling that the patient file is an example of a phenomenon experienced by a lot of people in daily life. They also often noted that the experiments were only modelling medical procedures but helped them understand important steps towards the diagnosis.

Together, these results suggest that interventions aiming to enhance situational interest should not only focus on content relevance but also on fostering students' perception of authenticity. Future research should explore how authenticity can be intentionally cultivated in classroom settings, particularly through narrative-based, or real-world connected learning experiences.

Conclusion And Outlook

The results of the mediation analysis and group comparisons show that although the perception of authenticity plays a decisive role in the development of interest, the relationship appears to be much more complex than what can be described by a linear relationship or group classification. Accordingly, an increased experience of authenticity could promote an increase in situational interest even if the initial situation in terms of individual interests is not considered favourable per se. At this point, next steps would involve testing the correlations and mediations already identified with a larger sample size in a structural equation model to consider the weighing of the individual items for the distal variables and to be able to draw causal conclusions at the same time. An analysis of possible clusters or profiles also seems promising for identifying gradual developments, as smaller and larger changes in situational interest are currently being considered collectively.

For optimization of our learning environment, it seems highly promising to include steps of guidance for students struggling with drawing the connections between the learning content (the case file) and their own life experiences. To exploit the potential of perceived authenticity as a mediator in the development of situational interest, it seems advisable to keep the contexts linked strongly to authentic relevance in daily life to successfully to mitigate the non-profitable influence of low individual interest. A qualitative follow-up study could provide information on the exact conditions or triggers of the feeling of authenticity to make the findings usable across contexts and disciplines. If authenticity can be used adaptively for learners with different sets of individual dispositions in future learning environments, our approach of authentic contexts seems suitable to make chemistry appealing even for students with lower individual interest.

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Using The Four-Quadrant Model To Examine The Character And Value Development Of Pre-Service Primary Teachers About Global Warming

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Due to the alarming consequences of environmental issues, moral dilemmas, and the rapid advancements in science and technology, researchers are now doubting the effectiveness of character and values education. In order to solve current issues and promote a just and peaceful global society, there is an increasing focus on educating people to have an ecological worldview, social and moral compassion, and socio-scientific accountability. Given the significance of the early years in the formation of character and values, the goal of this study was to assess and improve pre-service primary school teachers' character and values holistically using Wilber's four-quadrant model. The study was carried out utilizing a multiple case study methodology and featured two individuals. The pre-service teachers' responses to interview questions both before and after the implementation served as the data sources. Deductive content analysis showed that participants demonstrated enhancement by incorporating more character and value elements in their explanations or by offering more detailed elucidations on these characteristics across all quadrants after the implementation. Therefore, Wilber's four-quadrant model provides a new and effective perspective for assessing and developing the character and values that people of the twenty-first century are supposed to have.

Keywords: pre-service primary teachers, character and value, four quadrant model

Introduction

21st-century character and values include ecological worldview, social and moral compassion, and socio-scientific accountability (Choi et al., 2011). To train individuals who promote social virtue, other people's rights, and the common good (Singh, 2019); behave responsibly on global concerns; and make effective ethical judgments, these characters and values must be fostered.

The ecological worldview addresses interconnectedness and sustainability, as well as being conscious of ecological issues (Lee et al., 2013). Empathy, respect for life, and compassion for the environment and individuals impacted by environmental issues are social and moral compassion. It involves moral and ethical sensitivity, empathy, and perspective-taking (Choi et al., 2011). Socioscientific accountability requires recognition of stakeholder duties (responsibility), the science and society relationship, and action (willing to act) (Choi et al., 2011).

Science education may incorporate character and values through group discussions, argumentation, inquiry, and field excursions (Lee et al., 2012). Many believe character and value development should encompass cognitive, emotional, and behavioural elements in a more holistic way (Khobir & Hasanah, 2021). Comprehensive character education helps students identify their identities and aspirations via social, moral, and environmental links (Khobir & Hasanah, 2021). Wilber's (2000) four-quadrant method develops personalities individually, collectively, internally, and externally in terms of "I (thoughts, emotions, memories)," "We (material body, visible behaviour)," "It (shared value and meanings)," and "Its (systems and government)" perspectives.

This study used Wilber's (2000) model to develop and assess pre-service teachers' character and values by focusing on global warming. Global warming might have dire consequences for the environment, economy, and society (Guterres, 2024). Ecological education, moral and social awareness, and socio-scientific responsibility can prevent global warming. This study intends to develop the character and values of pre-service primary teachers in each quadrant in light of global warming. The guiding question is:

How does the four-quadrant model of global warming help pre-service primary school teachers to develop an ecological worldview, socioscientific accountability, and social and moral compassion?

Method

We employed qualitative multiple case studies with two female pre-service primary teachers studying at a state university in Türkiye. TEAMS and Classroom were used for the lessons in ten weeks after two severe earthquakes hit Türkiye in 2023. Through implementation, the four-quadrant model structured global warming teaching, including activities that support character and values. For instance, sharing information about countries most and least affected by and contributing to climate change was carried out to foster empathy, calculating and discussing individual carbon footprints was realized to foster responsibility, and discussing the consequences of global warming was realized to foster an ecological worldview.

Data Collection And Analysis

The current study adapted Nolan's (2021) perspective-taking questions to collect data. Questions were adapted in four quadrants to represent character and values. Students uploaded their answers in the classroom before and after implementation. The gathered data underwent deductive content analysis. The replies of the participants (Fatma and Leyla) were assessed on the character and value components in each quadrant.

Findings

The findings are presented within the context of each quadrant under the headings of ecological worldview, social and moral compassion, and socio-scientific accountability.

Ecological Worldview

Q1: Fatma presented her ideas in terms of sustainability before implementation. She made explanations regarding sustainability and interconnectedness after implementation.

Initially, Leyla expressed her opinions without considering sustainability or interconnectedness. After implementation, she addressed them.

Q2: Fatma first did not evaluate her behaviours in terms of sustainability and interconnectedness. After implementation, she highlighted that her actions may affect future generations and underprivileged nations (sustainability and interconnectedness).

Leyla originally ignored her behaviour's impact on sustainability and interconnectedness. After the implementation, she said she minimizes her carbon impact for future generations (sustainability).

Q3: Fatma initially lacked sustainability and connectedness explanations for people's shared beliefs. She stated her society recognized global warming and its effects after implementation (interconnectedness).

Leyla never highlighted people's sustainability and connectedness values before or after implementation.

Q4. Fatma said industrialized nations' policies adversely affect non-global warming countries. (interconnectedness). She discussed nations' policies in terms of ecological balance following the implementation (interconnectedness).

Leyla initially explained population growth causes global warming (interconnectedness). Following the implementation, she named various global warming factors and held wealthy nations liable (interconnectedness).

Social And Moral Compassion

Q1. Initially, Fatma expressed her deep concern and sadness about the effects of global warming (emphatic concern). Following implementation, she emphasized that human actions that cause global warming are immoral and unethical, demonstrating her sensitivity to moral and ethical issues.

Initially, Leyla demonstrated empathy for global warming's detrimental repercussions. After the implementation, she made explanations regarding emphatic concern, moral and ethical sensitivity, and perspective taking.

Q2. Fatma explained moral and ethical sensitivity because of her behaviours both initially and after the implementation.

Initially, Leyla did not evaluate her behaviours in terms of social and moral compassion; after implementation, she made explanations regarding moral and ethical sensitivity and emphatic concern by referring to her behaviours.

Q3. Initially, Fatma showed moral and ethical sensitivity because of people's behaviour around her. After implementation, in addition to moral and ethical sensitivity, she stated that people feel sad because of the effects of global warming (emphatic concerns).

Leyla noticed that people don't examine how their activities affect global warming (perspective-taking) and feel awful for those impacted (emphatic concern). After implementation, she only made explanations regarding perspective taking for her society's values.

Q4. Fatma stated that countries do not tackle global warming with moral and ethical sensitivity. After the implementation, she said developed nations felt morally responsible because of their activities contributing to global warming (moral and ethical awareness).

Leyla also said that countries do not act with moral and ethical sensitivity but later stated that they feel ethical and moral sensitivity.

Socioscientific Accountability

Q1. Fatma initially stated her responsibility to care for living things affected by global warming. After implementation, in addition to responsibility, she stated her desire to be willing to act.

In addition to the responsibility stated initially, Leyla expressed a willingness to participate in efforts (willingness to act) after implementation.

Q2. Fatma stated that she wants to join activities that would help her become more conscious of global warming before and after implementation.

In addition to the willingness to act stated initially, Leyla explained her contribution to global warming (responsibility) and desire to change her habits (willingness to act).

Q3. Fatma stated that the people around her are aware of global warming and are willing to act in preventive actions. After implementation, she remarked many around her want to act but don't.

Initially, Leyla stated people around her don't feel responsibility for global warming. After implementation, none of these people has a desire to act, she said.

Q4. Initially, Fatma didn't know what other nations were doing to address global warming. She added, following the implementation, that other countries are taking responsibilities and creating environmental protection measures (willing to act).

Leyla had no idea how other nations viewed global warming. After implementation, she noticed that other countries are planning for climate change (willing to act) and feel responsible.

Discussion

Following implementation, participants discussed their ecological worldview and opinions on global warming, indicating a development. This increase was sometimes observed by addressing more environmental worldview sub-elements and sometimes by providing more explanations for these elements. Information-oriented and reflective activities may have supported the development of participants' ecological worldviews. Participants can develop awareness of their mental state and reflect on their ideas, responses, and emotions surrounding global warming by focusing on the inner world (Esbjörn-Hargens, 2006; Tønnesvang et al., 2015). In addition, the fact that scientific explanations offered are advanced by the information acquired on a subject (Hakyolu & Ogan-Bekiroğlu, 2016) supports this finding.

Other findings of the study are about social and moral compassion. The study reveals that teaching complex scientific issues like global warming enhances students' empathetic concern and moral and ethical sensitivity in accordance with Fowler et al. (2009). Especially, pre-service teachers could discuss additional aspects of social and moral compassion of their behaviours and other countries, possibly due to their moral and ethical assessments of self-behaviours and gathering new information during the study. However, participants' ability to take perspective was lacking. This could be as a result of the present study's increased focus on studying global warming and its reduced number of decision-making-related tasks.

Other findings of the study are about socioscientific accountability. Fatma focused on educating individuals to increase awareness about global warming, while Leyla declared her readiness to take personal action. This suggests that people's approaches to global warming are influenced by their values and character elements. Studies indicate that personal perspectives significantly influence teachers' selection and presentation of information on global warming (Sadler, 2004). Both Fatma and Leyla expressed that society is prepared to combat global warming, but they gave different justifications for this. This may be because people at different educational and socio-economic levels may not be consciously concerned about environmental issues or engage in environmentally friendly behaviours when little is known about the problem or its solutions (Gifford & Nilsson, 2014). They also discussed how nations approach the problem in terms of being willing to act and feeling responsible after implementation. Gaining information about policies and agreements in other countries could have allowed for inferences about countries' socioscientific accountability.

Conclusion And Implications

Participants showed improvement by including more character and value elements in their explanations or by providing more explanations about these elements in all quadrants after the implementation. Therefore, this study's findings offer a new and holistic perspective on developing and assessing character and value elements using a four-quadrant model. Future research might examine the effects of teaching various subjects. Both quantitative and qualitative data may also support these conclusions, and various decision-making exercises may encourage participants to adopt new perspectives.

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Technology Blindness: The Loss Of Affinity And Awareness For Technology

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*In recent years, the number of first-year students in STEM subjects, particularly in engineering and technical degree programs, has been declining in Germany. This development is worrying in view of the growing shortage of skilled workers, as falling student numbers can impair Germany's innovative strength and competitiveness in the long term. This paper proposes that this trend can be attributed to a general loss in the perception of technology. This loss is referred to as "technology blindness", an adaptation of the existing term "plant blindness" from biology. One approach to counteracting this is Inspir**ING**®, an elective course at Karlsruhe University of Applied Sciences in which students prepare and carry out a teaching unit for pupils based on an experiment. The didactic methods such as storytelling, didactic reduction and experiments form the foundation of these units. Participants in the conference workshop experienced such a teaching unit live as an example. This workshop aimed to introduce the concept of "technology blindness" and demonstrate to participants how the Inspir**ING**® methodology can reduce it and sharpen awareness of technology.*

Keywords: STEM, engineering, technology blindness, awareness, interest

Note

In order to distinguish between secondary school students and students of engineering subjects at the university, secondary school students are referred to as *pupils* and students at the university as *students*.

Introduction

As one of the world's leading industrial nations, Germany is facing a critical challenge: the number of first-year students studying STEM subjects (science, technology, engineering and mathematics) is falling, particularly in engineering disciplines (Anger et al. 2024). This is an alarming development as it correlates directly with the growing shortage of skilled workers. According to reports, there is already a shortfall of around 140.000 STEM professionals (Plünnecke, 2023). This could permanently weaken Germany's innovative strength and international competitiveness. In the long term, this trend could undermine the country's ability to respond to technological upheaval and maintain its position at the forefront of research and development (Shambaugh et al. 2017; BDI et al. 2024).

This paper proposes that one cause of this problem is a social phenomenon introduced as "technology blindness". Similar to the term "plant blindness" in biology (Wandersee and Schussler, 1999), "technology blindness" describes the growing lack of awareness of and appreciation for the constantly present technology in our modern world. Due to the apparent limitless availability of technology, awareness of its complexity, history, and fundamental contribution to our daily lives and solving global problems is dwindling.

To help address this issue, Karlsruhe University of Applied Sciences developed the elective Inspir**ING**® in 2019. The program takes an innovative didactic approach: engineering students become role models for pupils in eighth grade and above. The students design and lead 45-minute, experiment-based teaching units.

This paper first sets out the theoretical foundation of the concept of technology blindness. Then, the Inspir**ING**® program's didactic trio of storytelling, didactic reduction, and experimentation is explained in detail. Next, the practical implementation of this methodology is demonstrated using the workshop held during the ESERA conference in Copenhagen 2025. Lastly, this approach's implications for STEM education are discussed, and a future research outlook is provided.

Theoretical Framework: Definition Of "Technology Blindness"

The concept of "technology blindness" is a direct adaptation of the term "plant blindness," which was coined by biologists Wandersee and Schussler in 1999. These scientists used the term to describe the human tendency to ignore the plants in our environment, underestimate their importance to the biosphere, and regard them as passive, static backdrops. It is argued that an analogous phenomenon exists in the context of technology. To draw attention to this problem, a clear and precise formulation is necessary.

"Technology blindness" refers to the inability to consciously perceive technology in one's living environment, recognize its importance to society, and appreciate the complexity and ingenuity of technical objects. To define the term precisely, the characteristics that Wandersee and Schussler formulated for "plant blindness" are transferred to the technical context.

The specific characteristics of "plant blindness" are listed in Table 1 in the left-hand column; the transfer to "technology blindness" is listed in the middle column. The third column lists concise examples of technology blindness characteristics. These examples were used in the workshop held during the ESERA conference in Copenhagen 2025.

Table 1. Adapted features and examples.

plant blindness (Wandersee, Schussler, 1999, p. 82)	*technology blindness*	*Everyday example*
"The inability to see or notice the plants in one's environment	The inability to see or perceive technology in one's own environment	"I never consciously realized that even a simple light switch is technology."
the inability to recognize the importance of plants in the biosphere and in human affairs	the inability to perceive technology as an opportunity to solve environmental and human problems	"I have seen solar panels but never realized that they actively contribute to solving environmental problems."
the inability to appreciate the aesthetic and unique biological features of the life forms that belong to the Plant Kingdom	the inability to perceive, understand and appreciate unique features of technical objects in a wider technological context	"I often used GPS without understanding how complex the technology behind it actually is."
the misguided anthropocentric ranking of plants as inferior to animals and thus, as unworthy of consideration"	the perception of technology as self-evident and limitless availability, thus neglecting its true value and impact.	"I only realized how much I take technology for granted in everyday life when my Wi-Fi went down."

These four characteristics of "technology blindness" manifest as a passive consumer attitude toward technology. The smartphone becomes a "black box", electricity just comes out of the socket, and complex infrastructure systems remain invisible as long as they function properly. This lack of awareness results in a diminished basic understanding of technical principles, which ultimately leads to less interest in actively shaping the technological future. This directly impacts the choice of study and career fields.

Elective Program InspirING®

The elective program Inspir**ING**® at Karlsruhe University of Applied Sciences is a possible approach to counteracting technology blindness. Launched in 2019, the program creates practiceoriented educational units that aim to raise awareness of technology among pupils, as well as stimulate their fascination with it.

A central aspect of the Inspir**ING**® program is its use of peer tutoring, as essential didactic element. Engineering students develop and teach a 45-minute lesson to pupils in the eighth grade and above. This format appeals to two target groups simultaneously, generating double the added value.

First, the program provides pupils with low-threshold access to technical topics by introducing them to young, authentic role models. The small age gap and comparable social status of learners and tutors promote interaction on an equal footing and reduces the hierarchical barriers that exist in traditional teaching and learning situations. In this way, technical content becomes accessible not only cognitively, but also emotionally. Second, students also benefit in several ways from their role as peer tutors. Reducing complex technical content to key principles and communicating it appropriately promotes didactic and communication skills. At the same time, this process deepens their understanding of the subject. Additionally, students reflect on their personal motivations for studying and actively take on the role of ambassadors for their field of study. (Struck, 2023)

The Inspir**ING**® program's overarching goal is to counteract technological blindness by providing positive, self-effective learning experiences that spark long-term interest in STEM education and careers.

Didactic Methodology

The efficacy of Inspir**ING**® is predicated on the synergistic interaction of the three didactic elements storytelling, didactic reduction, and an experiment (see Figure 1). These methods are closely intertwined, mutually dependent and form an inspiring and sustainable learning experience. The individual methods are described in more detail below.

Storytelling

Storytelling is known to establish an emotional and narrative framework. This can give teaching units a vibrant and exciting structure that appeals to pupils emotionally, arouses their curiosity and thus mesmerizes them. (Heering, 2016; Hadzigeorgiou et al. 2011) The program uses this to effectively capture the viewer's attention and to successfully embed the seemingly arid scientific subjects in meaningful contexts. The intention is to spark a greater interest in technology among pupils, not least as an incentive for a future career in science and engineering (Blum & Heering, 2014). Within the framework of Inspir**ING**®, storytelling is employed on two distinct levels:

1. Narrative framing: The scientific topic is embedded in a narrative that is designed to spark curiosity and interest among pupils. Rather than initiating the lesson with formulaic explanations, students begin the lessons with a challenge, an analogy, or a captivating observation, to name a few possible options.

2. Personal stories (peer learning): Students share their own enthusiasm and career paths. The incorporation of personal narratives into the educational experience serves to render abstract concepts and professional disciplines more accessible and relatable to pupils. These authentic narratives about motivation, challenges, and fascination act as a powerful incentive, break down barriers and establish an emotional connection with the pupils.

Didactic Reduction

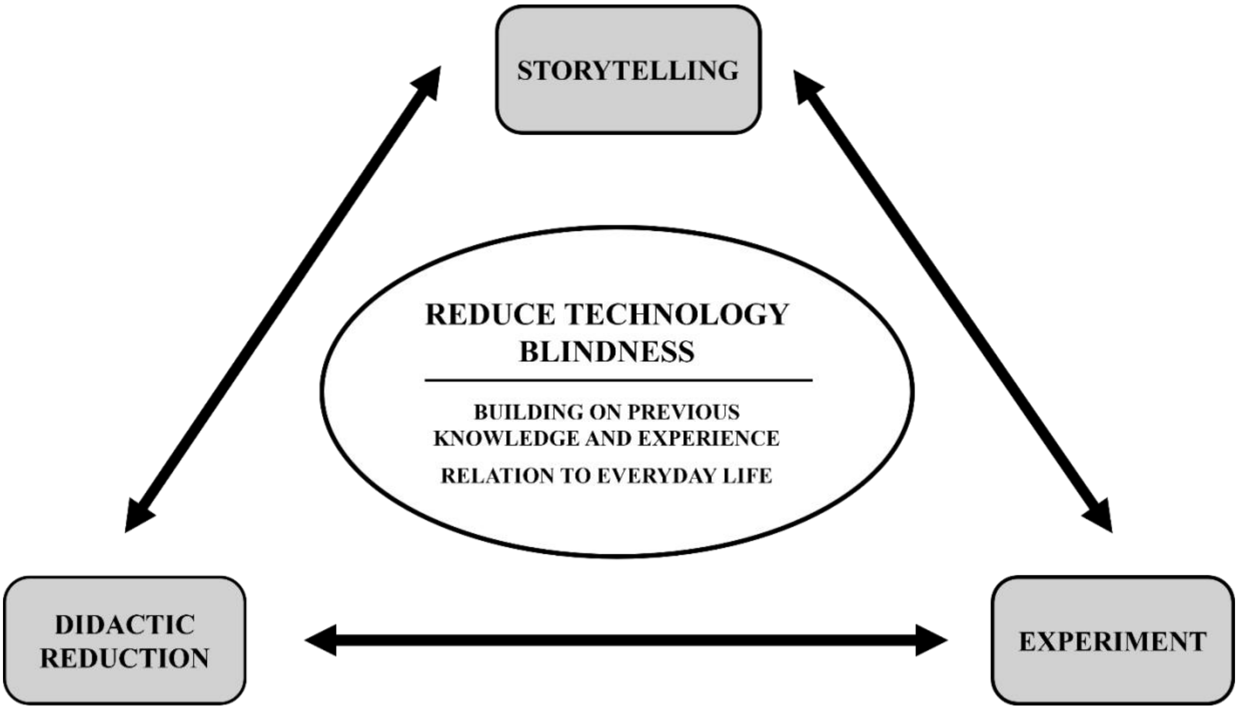
Didactic reduction functions as a link, ensuring the experiment´s complexity and the underlying theory becomes understandable, manageable, and applicable to the target group. Complex technical and scientific topics are often inaccessible to pupils. The concept of didactic reduction can be defined as the art of simplifying complex subjects without compromising technical accuracy. According to Lehner (2024), this process entails the selection of essential content, an emphasis on the core principle, and the simplification of the presentation. For students, this necessitates the process of distilling the theoretical framework of their experiment to a comprehensible level, suitable for pupils in grade 8 and above, without requiring any prior knowledge. This process also benefits students, as it requires a deep understanding of the topic in order to reduce it to its essential elements.

Experiment

Knowledge and insights are best gained by linking theory and empiricism helping students to understand technical phenomena better (Pusch et al. 2024; Pfangert-Becker, 2010). Thus, the experiment is the central element of the lesson. Active participation and self-directed discovery have been shown to result in a deeper and more lasting understanding than traditional frontal teaching methods. By establishing the experiment, conducting the tests, and ultimately completing the project independently, pupils can achieve a sense of self-efficacy and enthusiasm, often accompanied by a moment of profound realization. This shift enables them to transition from a passive stance as listeners to an active role as creators.

The common goal of these three approaches is to reduce technology blindness and raise pupils' awareness of technology. Also linking the content to familiar contexts, such as specific references to everyday life, and taking into account the target group's level of experience in order to build on existing knowledge are essential for a successful integration in long term memory (Hadzigeorgiou et al. 2011).

Figure 1. Interdependence of methods with the aim of reducing "technology blindness", own illustration.



Workshop At The ESERA Conference

A workshop called "Technology blindness – The loss of affinity with technology and how to counteract it" was held at the ESERA conference in Copenhagen 2025. The workshop demonstrated the practical application of Inspir**ING**® using an experiment with electromagnetism as an example to explain the idea of technology blindness and to sensitize participants to this particular technology. The subsequent section delineates the workshop's structure and methodology in detail, as it was implemented as a constituent element of the conference program.

Background

> Any sufficiently advanced technology is indistinguishable from magic. (Clarke, 1973, p. 21)

The phenomena of electromagnetism largely elude our senses. Apart from the small fraction visible to the human eye, it is imperceptible to us. Yet the effects caused by electromagnetism are omnipresent. They range from experiences in our daily lives to enable technologies such as wireless communication, electric drives and navigation systems.

The fact that the cause of these effects is not observable, but quasi "invisible", can give reason for a certain fascination. What at first sounds a little magic has been commonplace in the natural sciences for centuries: observing things and processes that remain hidden from the eye (Kube, 2019).

This is where the workshop comes in, using a storytelling approach to convey the topic. For example, magnetism becomes visible in everyday life when magnets attach notes or pictures to some metallic surfaces. A compass that is aligned with the earth's magnetic field makes the natural magnetic field directly tangible. By comparing it to magic and the analogy to invisible forces that work like magic, an emotional connection is created, curiosity is aroused and access to the topic is made easier (Heering, 2016; Hadzigeorgiou et al. 2011).

To demonstrate this, magnets are provided at the beginning of the workshop so that participants can experience the phenomenon of magnetism by themselves.

During the workshop, participants are engaged with the didactic methodology of Inspir**ING**®.The invisible force of magnetism is presented as a form of "modern magic" that can be understood through science. The personal narrative of a former Inspir**ING**® student and employee, from his dream of becoming an inventor to studying engineering and technology entrepreneurship, makes the engineering profession tangible and human. This use of storytelling aims to make people curious and excited to learn.

The following section describes the setup and underlying principle of the workshop experiment. The point of the experiment was to keep a permanent magnet suspended in mid-air using an electromagnet (see Figure 2). This requires an active control system to maintain the unstable balance between magnetic attraction and gravity. The setup has four main parts:

1. Permanent magnet: The object that is made to levitate.

2. Electromagnet: A coil that is used to create a magnetic field. The strength of the magnetic field depends on the electric current flowing through the coil.

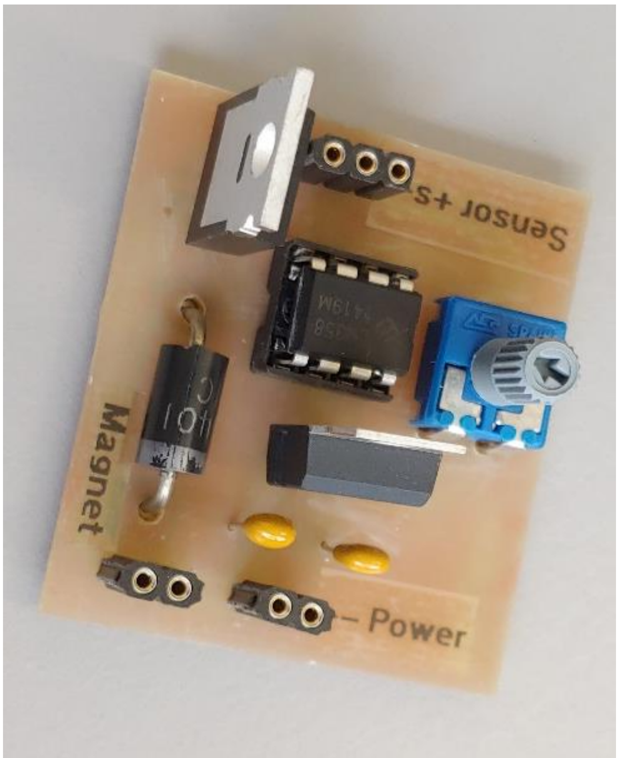
3. Magnetic sensor (Hall sensor): It measures the strength of the magnetic field and thus indirectly the distance between the permanent magnet and the electromagnet.

4. Control circuit (see Figure 3): An electronic circuit that processes the signal from the sensor and switches the electromagnet on when the distance becomes too great (the magnet threatens to fall) and off when the distance becomes too small (the magnet threatens to jump onto the electromagnet).

The task of the participants was to calibrate the switching threshold on a potentiometer on the circuit board so that the magnet is held in a stable levitation.

Figure 2. Floating ball magnet, own photography.

Figure 3. Control circuit, own photography.



Schedule And Implementation

The workshop followed a clear structure that integrates didactic principles:

1. Awareness check (beginning): At the beginning, participants are asked to rate their own perception of electromagnetism in everyday life on a scale (see Figure 4). This serves as a baseline measurement and makes the phenomenon of technology blindness directly tangible.

2. Introduction and story: The moderators introduce themselves (personal story), introduce the topic using the "magic" narrative and briefly explain the fundamental principles of the experiment.

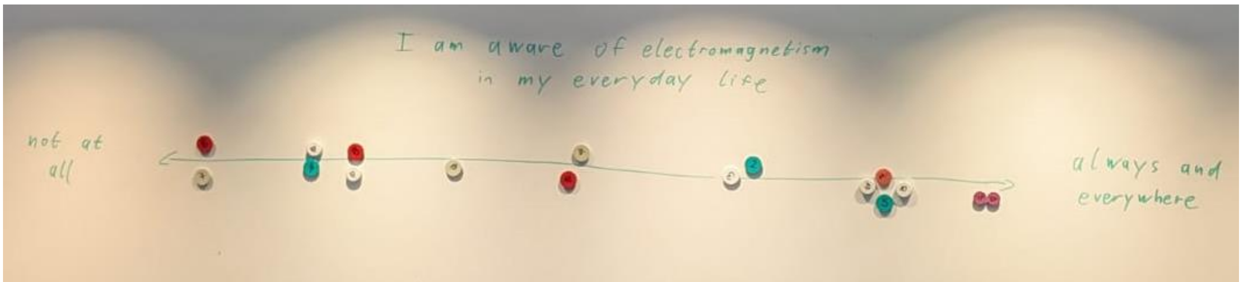
3. Experiment phase: Participants receive boxes with components and instructions. They set up the experiment, connect the components, and begin the crucial calibration process. This phase requires patience and dexterity and promotes problem-solving skills.

4. Levitation (moment of success): The success of the experiment (the floating magnet) is the highlight and creates a strong sense of self-efficacy.

5. Transfer to everyday life: Working in pairs or groups, participants collect examples of how electromagnets are used in everyday life. Examples such as electric motors, loudspeakers, scrapyard magnets, and magnetic levitation trains are then presented to illustrate the relevance of the principle learned.

6. Awareness check (end): Participants reevaluate their perception of electromagnetism. The expected increase in awareness serves as evidence of the success of the intervention and as a basis for discussion.

Figure 4. Awareness scale, own photography.



Outlook

The workshop described, which incorporates the Inspir**ING**® program, offers valuable ideas for STEM education and shows a possible way to increase interest in STEM subjects.

It also showed that it is possible to raise awareness of complex technical phenomena in a short period of time. The before-and-after comparison of self-assessment in the workshop serves as a simple but effective indicator of a shift in perception away from technological blindness and toward a more sensitive perception. The program thus addresses a previously little-noticed but plausible cause of the current shortage of young talent in the engineering sciences.

The pedagogical triad of storytelling, reduction, and experimentation proffers a substantial and adaptable template for the design of inspiring STEM learning units. The paradigm shift from pure knowledge transfer to the creation of meaningful and motivating experiences is evident in the impressive demonstration of the floating magnet, which transforms abstract physical principles into tangible and fascinating learning experiences.

A more thorough examination of the long-term effectiveness of such brief interventions on study and career choices is necessary, and this can be best accomplished through longitudinal studies. However, the preliminary outcomes in terms of interest and perception indicate that initiatives such as Inspir**ING**® can serve as a pivotal foundation for cultivating the next generation of engineers, researchers, and technically proficient citizens. It is therefore imperative to deliberately address technological blindness to ensure the future of STEM talent and fortify Germany as a hub for innovation.

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Species Portraits As A Means Of Crossing Boundaries To Other Life Forms

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The aim of this study is to identify aspects of nature connectedness in the personal experiences of participants while engaging with the natural world. In this contribution we will introduce the concept of aesthetic species portraits as a method for facilitating an experienced personal connection between human and non-human life forms in their natural environment. We report qualitative fieldwork in the form of interviews, video recordings, photographs and creative work from a summer school held at a rewilding project area in Denmark. During a four-day intervention pre-service science teachers and science educators participated in co-creation of art-based artifacts using aesthetic methods of representation of species encountered in the area. We employed four young passionate experts to introduce the pre-service science teachers to the high diversity environment focusing on its natural inhabitants. This introduction created an immersive engagement with place. During the next days we chose subjects among the encountered species and created portraits. We identified the key themes in our data using an abductive thematic analysis with intercoder reliability checks. We discuss empirical findings from our intervention in the light of the concept of nature connectedness. We found that the process of co-creation, the immersive nature of the intervention and the personal encounters with species had transformative effects on the participant's perception of nature.

Keywords: Affective dimensions, Field experience, Pre-service teacher education

Introduction

> Doing science with awe and humility is a powerful act of reciprocity with the more than human world. I've never met an ecologist who came to the field for the love of data or for the wonder of a p-value. These are just ways we have of crossing the species boundary, of slipping off our human skin and wearing fins or feathers or foliage, trying to know others as fully as we can. (*Kimmerer 2020, p. 252*)

Science education focuses increasingly on aesthetic learning processes, particularly in relation to education for sustainable development (Heras et al. 2017). The concept of nature connectedness has been proposed by psychological research as a prerequisite of environmental engagement. In these contexts, aesthetics often enters the science teaching discourse as part of STEAM pedagogy, introducing aesthetics as concept from the humanities aimed at increasing participation and engagement (Peppler and Wohlwend 2018).

Nature connectedness is regarded as an emotional driver and has been suggested to be independent of the cognitive dimensions of science (Lumber et al. 2017). However, both aesthetics and the concept of nature connectedness have deep historical roots within the field of biology.

The natural historians who inspired Darwin and seeded the development of modern biology as a scientific field had a deep aesthetic involvement in their fields of research: In 1805, Alexander von Humboldt published his groundbreaking work on the relation between climate, elevation and botany under the title "Naturgemälde" – painting of nature – and in 1899 Ernst Häckel meticulously described numerous species new to science in his book “Kunstformen der Natur” – artforms of nature.

The concept of nature connectedness can be traced back to the ecologist E. O. Wilson’s book “Biophilia” from 1984, in which he argues that biology, as a field of science, offers an approach to understanding the living world that aligns with our innate tendency to affiliate with other organisms. Wilson invites the naturalist approach, field biology, as a formula to reengage with the natural world: “To the extent that each person can feel like a naturalist, the old excitement of the untrammelled world will be regained” (Wilson 1984, p. 147). The perspective offered by biology allows observation of other life forms as subjects formed by the same natural processes as the observer themselves: A subject-to-subject encounter, so to speak, since humans are, biologically, one species among many, with our capacities of logic and reflection being one adaptive outcome among all the adaptations outlining the various species of our biosphere.

We explore species portraits as a way of engaging with other life forms, in which aesthetic representation of a species is interwoven with the aim of understanding the life forms we encountered. The aim was to identify aspects of nature connectedness in the personal experiences of participants while engaging with the natural world.

RQ: How do the facilitated species encounters help direct the focus of participants towards knowing a species as a non-human subject?

We will explore this research question through empirical data from a summer school held in the summer of 2024 at an unmanaged natural area in Denmark.

Method

We obtained our data from a four-day intervention during a summer school with the title: “Species, experiences and aesthetics”. The course enlisted 12 pre-service biology teachers, two early career in-service biology teachers, and three teacher educators (with a disciplinary background in biology) participating in designing species portrait activities. We took inspiration for co-creation and co-design from Sanders and Stappers (2008).

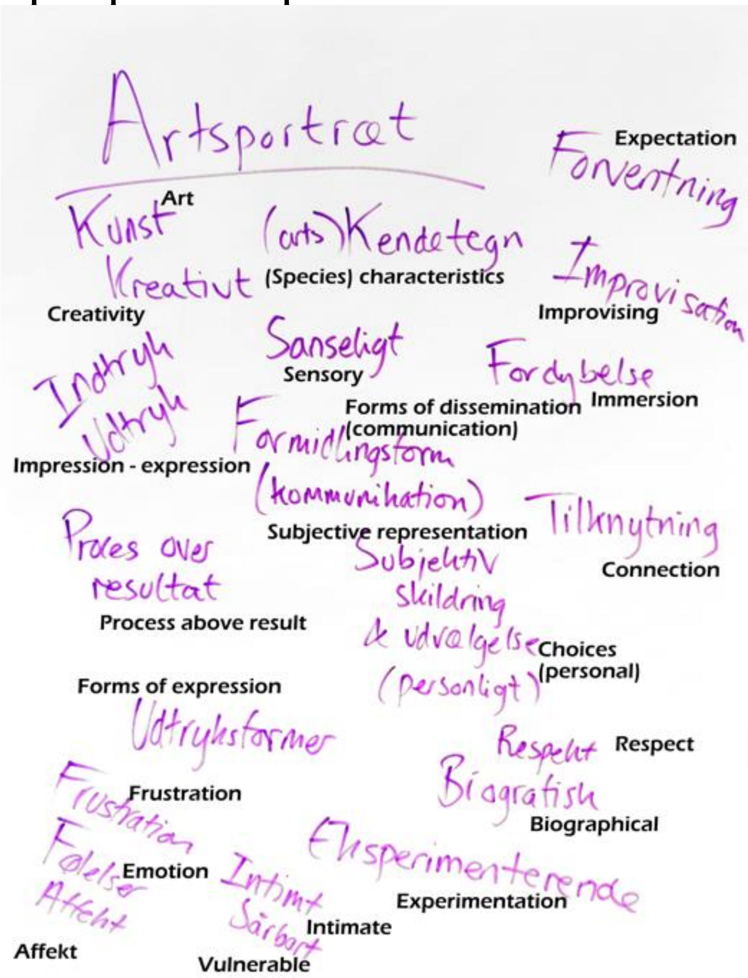
We collected qualitative data in the form of interviews, photographs, video recordings and creative artifacts produced during the summer school. At the end of the second and third day of the course, we presented portraits at a “vernissage” event where participants introduced their exhibited portrait, described meeting their species, how they chose their creative media, and the process of constructing the portrait.

In this contribution we report an analysis of a 55-minute video sequence recorded while co-creating a definition outlining the concept ’species portrait’ (video 1), as well as two group interviews with participants at the end of the course, lasting 23 minutes (interview 1) and 40 minutes (interview 2). Interviews were semi-structured, following a simple interview guide based on the course title: Respondents were invited to reflect on species they had encountered and portrayed, experiences they had encountered and their view on the aesthetic processes they had engaged in.

While co-creating the concept definition, one of the authors of this contribution wrote keywords from the dialogue on a flip-over, creating an open coding of points emerging from the conversation. A picture of the flip-over is shown in figure 1. From these codes the authors employed a thematic analysis and developed a coding scheme (Braun and Clarke 2006). Using these themes and codes from the flip-over to code, sequentially, video 1, interview 1 and interview 2, we broke down and reassembled our code structure through an abductive analysis

(Brinkmann 2014), which allowed us to recognize and include patterns emerging throughout the coding process.

Figure 1. A photo of the outcome of co-creating a definition of "species portraits" with course participants. English translations of the concepts emerging from the dialogue are superimposed on the photo.



Findings

Throughout the dialogue in the videos, the motif of sensory experiences emerged as a recurrent and dominant theme when describing species encounters: Respondents reported having engaged their senses in new ways, and they referred to the sensory experience of their particular species. Reports of the encountered species were highly affective, using a vocabulary of deeply personal connections, in several cases in relation to species encountered for the first time.

When asked about their experiences during the course, time and immersion became recurrent elements: Respondents reported a wide range of situations of solitude, absorption, increased awareness and meticulous studies of their chosen species. Many of the experiences reported were intimately related to place, indicating immersive engagement.

Discussion And Conclusion

We were able to mediate species encounters in a particularly rich natural environment, facilitated by young enthusiastic species specialists, and our participants were able to let these initial impressions grow and mature through a generous, curriculum free and immersive aesthetic engagement with their surroundings. But while this intervention does not reflect a common school reality, it did allow us to explore the potential offered by what Wilson called “the naturalist approach” (Wilson 1984). Our participants did not arrive with a deep knowledge of field biology, but the saturated experience of an inhabited environment, and their aesthetic engagement with particular species initiated transformative processes.

Table 1. This table outlines main themes emerging through our abductive analysis of the interviews, exemplified through selected participant quotes.

	Selected quotes
Sensory engagement	Vanessa:*"Well, I thought it was a bit crazy, that the bees had actual scents […] they smelled like onions or… lemon. And then how you were able to get up that close. I think it was crazy, getting that close to a tiny little animal, such a tiny little bee"*
Time, place, immersion	Erica: *"Well, this is connected to the dung. So, well, the scarabs. I simply find them cute. I didn't know a thing about them. It's not that I am that knowledgeable now, but this, to sit and paint them. I ended up – because I was sketching, I think I drew the same one five times or so. And then you become… it's a really good way to learn to identify the species"*
Affective species descriptions	Birk: "*I think it has resulted in a much more personal affection for specifically the species you went after. You have really been chasing them for a reason, and personally I really want to learn more about them, and I think it is super interesting to capture them in a creative, an aesthetic fashion, making it more, I don't know, personal. That is cool"*.
Transformative experiences	Bjørn: *"O told me about sundew, so I thought […] I will go hunting for this one. And I couldn't find my way, and I got lost, and I was alone, and it was sort of magic to come down there and see how, well, like, the bog was there, the quaking bog was there and you had to go out there, and you could feel how it was, like, suspended, and it was embraced by the forest. And there were these tiny sundews, and I was all alone, and I nearly shed a tear, actually."*

Bjørn, a participant describing his own science teacher identity as "sort of a molecular biologist and physiologist by nature, so I never really delved into the species thing" ended up being so affected by an encounter with sundew, that he "nearly shed a tear", while Erica described going from "not knowing a thing" about scarabs to spending a whole day with repeated sketching of one scarab, and concluding that she "just found them cute" (full quotes in table 1).

In spite of their self-declared low initial level of knowledge about field biology or species, and the lack of any assessment of knowledge or specified requirements of biological facts in the aesthetic products, participants embedded many perspectives of biological knowledge in their portrayals of species, from morphological details through life cycles and habitat requirements to effects of the species on ecosystem dynamics. In the interviews, several participants expressed enthusiasm not just for the species itself, but also for the knowledge gained while working on the portrayal. The cognitive side of learning about the species emerged as interwoven with the affective connection, the aesthetics of the creative process and the awareness of the subject of the portrait as a life form in its own right. In the words of Birk: "I really want to learn more about them, and I think it is super interesting to capture them in a creative, an aesthetic fashion, making it more, I don't know, personal. That is cool" (full quote in table 1)

A professional field biologist could be considered to be engaging in, as our opening quote from Kimmerer (2020) reads, "crossing species boundaries" by finding significant patterns in scientific data describing other species. This level of insight is not readily available in a school science setting, or even in the educational setting of a teacher training program. Our species portraits can be considered short-cuts for creating this transcendent experience of a personal bond to a non-human life form in its natural environment.

Aesthetics has an inherently transcendental aspect in that it communicates affect and emotion from one human to another. The natural sciences, on the other hand, allow us to attempt understanding non-human life forms as subjects in their own right, thus representing another type of transcendence. Bringing the two together adds depth to the concept of nature connectedness by qualifying emotional attachment with curiosity and a desire for knowledge: Science can help us understand who they are, and aesthetics can help us feel that understanding is important.

We see indications of this transformative process in our participants' perception of nature, as reflected through the interviews.

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Detect, Define And Visualize Epistemic Emotions For Science Education

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Learning science is not solely a cognitive endeavour. The affective dimension has increasingly become a focus of science education research. Within this domain, growing attention is being given to constructs such as epistemic emotions and to novel methodologies used to investigate them. This contribution focused on an NLP (Natural Language Processing) analysis aimed at detecting epistemic emotions in the context of the discovery of the Theory of Special Relativity. The study was conducted by analysing a special text based on historical interviews with Albert Einstein, carried out by Gestalt psychologist Max Wertheimer in 1916, and published in 1945. From this analysis, the following results emerged: an operational definition of the construct of epistemic emotions, developed through three markers that can be applied to analyse other texts or interviews; the creation of a list of epistemic emotions, designed to facilitate their consistent classification and detection in future researches; a dynamic mapping and visualization of the epistemic emotions involved in the cognitive processes associated with the key phases of the genesis of the Theory of Special Relativity, using James Russell's circumplex model of affect. These findings offer tools to bring out and visualize the emotional dimension of problem-solving and scientific research activities. These tools can be both diagnostic and teaching resources, aimed at unpacking affective dynamics in educational contexts.

Keywords: Epistemic Emotions, Physics Education Research, Interdisciplinarity

Introduction

Recent special issues and handbooks have highlighted and formalized the relationship between affect and cognition in science education (Jaber et al., 2023; Vea & Jaber, 2026). Major cognitive theories — such as conceptual change theory (Posner et al., 1982) — have progressively emphasized the multi-layer landscape that has been progressively built to unpack the multiple dimensions and types of knowledge involved in conceptual change. The current research on conceptual change offers a landscape, that is grounded in the foundational work on the nature of concepts and conceptual change, and articulates in further four layers: the role of representations (such as language, visual representations and simulations, equations, and gesture) in concept representation and learning; the interplay between the epistemological practices of explaining, modelling and arguing and conceptual change; the relationship between conceptual change, metacognition, and student's epistemologies; the relation between identity development and conceptual learning in disciplinary domains (Amin et al., 2023). The last two layers point out the need to enrich the research on conceptual change with affective and emotional dimensions (Pintrich, 1993).

In this context, one of the ways of developing the affective dimension is focused on the epistemic emotions, namely the emotions engaged in the cognitive dynamics of learning (Jaber et al., 2023). These studies on epistemic emotions are shedding light on novel theoretical and methodological challenges.

As for the theoretical issues, the emotional dimension challenges the pure rational assumptions that stay behind the earlier theories of conceptual change (Amin et al., 2023) based, more or less explicitly, on a strict separation between the apparatus of rationality and that of biological regulation (Damasio, 1994).

As for the methodological issues, the debate is still very open and lively, being the emotional dimension particularly subtle and implicit. The wide variety of methods and approaches currently employed to "capture" epistemic emotions has led Jaber and colleagues to refer to a "generative non-convergence" typical of an expanding field of research. In fact, the state of the art shows a great effort to search for new creative methodological approaches aimed to keep a high level of rigour (Jaber et al., 2023). Video-interviews are a typical explored method for multi-modal analyses aimed to investigate the degree of connection between the emotion and the identified cognitive event. For instance, Jaber and Hammer use video interviews to uncover "entangled" emotions that characterize a general attitude toward engaging in science among very young subjects (Jaber & Hammer, 2016), while Gupta and colleagues examine video interviews to capture moment-by-moment epistemic emotions, focusing on short timescale local coherences in high school students (Gupta et al., 2018). More generally, it is recognized that text and natural language are primary vehicles for emotions, emphasizing the need for methods capable of analysing such datasets.

This study has been carried out to explore a pilot methodological approach for detecting and visualizing epistemic emotions, drawing on machine learning techniques for text processing and analysis. The method was tested using a historical text that examines the emotional dimension in the development of a scientific theory. Our goal is to refine and adapt this approach for use in classroom settings as well.

This pilot study was guided by the general research questions of how Epistemic Emotions can be recognized and operationally defined, and how they can be represented and visualized, including which models may be used; these questions were explored through the specific case study described below.

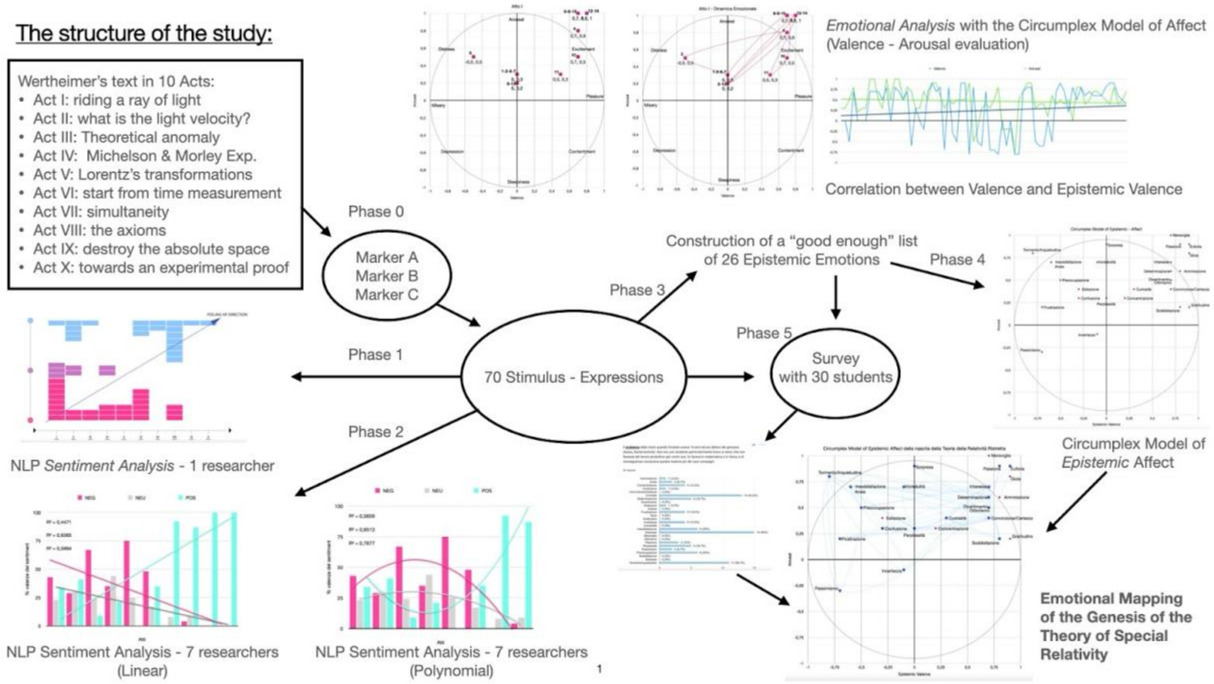
The Source Of Data On Epistemic Emotions

For the pilot study, the textual source of data we chose is the seventh chapter Einstein: The thought that led to the theory of relativity of the book Productive Thinking (Wertheimer, 1945, 2020; Miller, 1975). Max Wertheimer's text collects conversations with Albert Einstein on the genesis of Special Relativity. The conversations refer to a series of meetings that Max Wertheimer, exponent of Gestalt, had with Albert Einstein in Berlin since 1916. This chapter appeared as a suitable text for the analysis for three main reasons. The first reason is that the scientist also describes difficulties and emotional impulses in the genesis of a new scientific theory. The second reason concerns the text structure, organized into ten acts that delineate the pivotal phases of this specific research process. This format allowed the identification of moment-by-moment epistemic emotions (Gupta et al., 2018) and, owing to the open and conversational nature of the interview (Pussetti, 2010), also captured entangled emotional nuances (Jaber et al., 2023) that influenced the direction of inquiry (Jaber & Hammer, 2016). The third reason concerns the topic per se of the conversations: Special Relativity (SR). In fact, SR has been already widely investigated in its historical and philosophical dimensions (e.g. Pais, 1982) in the research on conceptual change (Posner et al, 1982; Hewson, 1982; Villani & Arruda, 1998; Levrini & diSessa, 2008; Levrini, 2013) and, more in general, in physics education (Sherr et al., 2001, 2002; Alstein et al., 2021; Miani, 2022). This constellation of studies, together with Einstein's metacognitive reflections, offers the possibility to triangulate the results obtained by a novel methodological approach to investigate epistemic emotions, that integrates psychological, conceptual, and epistemological dimensions.

Methods And Results

From a methodological point of view, the study was inspired by natural language processing (NLP) techniques (Das & Singh, 2023) to process Wertheimer's text. Through an initial exploration — individually conducted —, 70 specific linguistic expressions linked to emotions and associated with the phases of scientific research were detected. Examples of linguistic expressions highlighted are: "to trouble him", "intensely concerned", "Puzzling to think"... These expressions, termed stimulus-expressions, were identified to elicit and associate specific epistemic emotions. This preparatory phase also included the extraction of three markers — concise indicators designed to systematically detect stimulus-expressions within the text — essential for distinguishing, conceptualizing, and objectifying epistemic emotions linguistically. These markers through which epistemic emotions can be recognized and operationally defined are: A. emotional sound; B. epistemic sense and connection to a specific phase of the construction of the theory; C. liquid lexical structure (Figure 1 Phase 0).

Figure 1. Design and structure of the study. Phase 0: construction of the three markers for operationally defining epistemic emotions within the text. Phase 1 and 2: Visualization of Einstein's "feeling of direction" through an NLP-sentiment-analysis. Phase 3 and 4: Construction of the Circumplex Model of Epistemic Affect. Phase 5: emotional mapping of the genesis of SR.



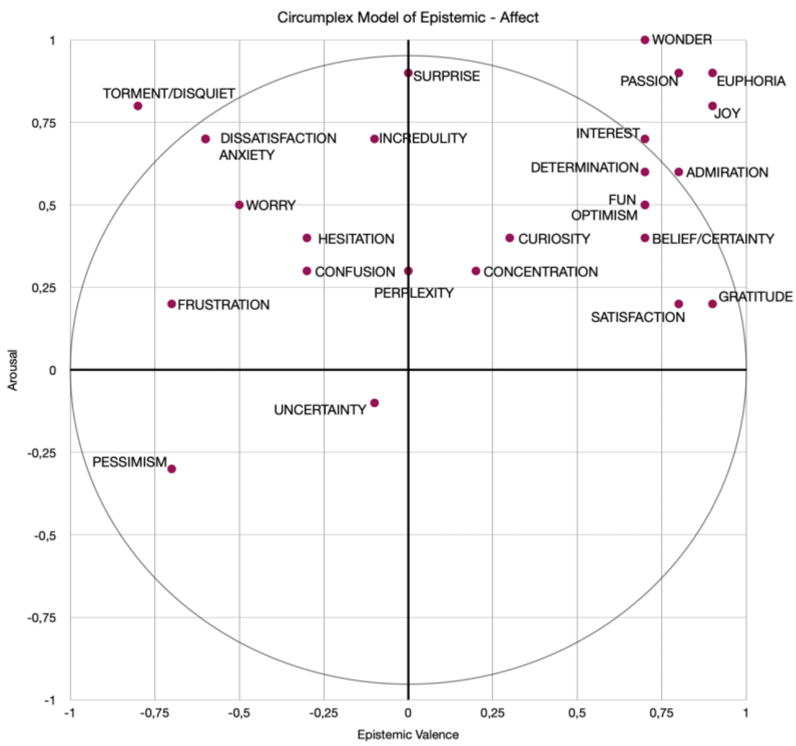
Thus a primary action was to extrapolate the visualization of Einstein's "feeling of direction" through an NLP-sentiment-analysis (positive-negative-neutral), which took place by processing 70 stimulus-linguistic-expressions extracted from the text, first of all individually and then — to make the result more robust — with the collaboration of 7 researchers in Physics Education, who evaluated again the stimulus-expressions through the three connotations (Figure 1 Phases 1 and 2).

It was found, using linear interpolation, that positive sentiment has an increasing trend while negative and neutral sentiment decreases as the theory develops. We also found the correlation between the positive sentiment and the solving phases of the research path. Using polynomial interpolation, it was surprisingly found that positive sentiment has a trend similar to that relating to the Denning-Kruger Effect (Dunning, 2011) as skills increase.

The preliminary results obtained in phases 0, 1, and 2 have corroborated the plausibility of the hypothesis that the text is rich in epistemic emotions and that these emotions can be detected. The following research phases led us to achieve the main findings.

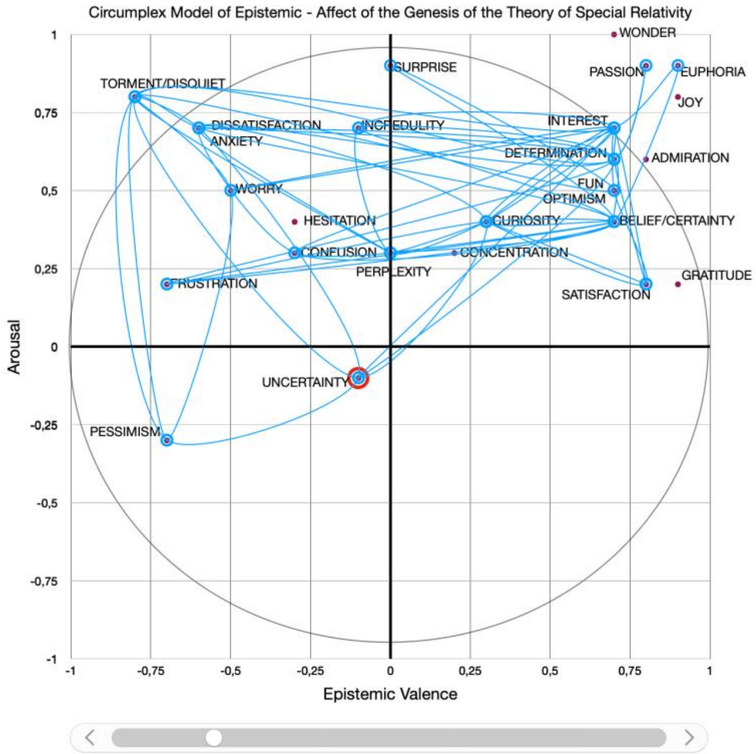
Going on in “dialoguing” with the text, considering the previous scientific literature on the topic of epistemic emotions and using a strong knowledge of Albert Einstein’s work, a list of 26 epistemic emotions linked to problem-solving was created to refine the connotation of the 70 stimulus-expressions. This list is not supposed to be exhaustive, but it represents our first original finding: a novel plug-in that widens and extends the original functions of Russell’s Circumplex Model of Affect (Russel, 1980). This model is used in disciplinary fields such as psychology and emotional robotics engineering and represents each emotion with a pair of coordinates — ranging from -1 to 1 — called Valence (from sadness to happiness) and Arousal (degree of activation, from sleepiness to excitement). Each epistemic emotion of the list has been positioned in the Circumplex Model of Affect (Figure 1 Phase 3 and 4; Figure 2), by assigning the values of Valence and Arousal. The assignment has been supported by AI as a stimulus and/or a check of the researchers’ qualitative hypothesis. The process led us to turn the Circumplex Model of Affect into our second original finding: a draft of a Circumplex Model of Epistemic Affect (Figure 1 Phase 3 and 4; Figure 2).

Figure 2. Circumplex Model of Epistemic Affect.



Finally, through statistics on a sample of 30 students of a Physics Education university course, a correspondence was constructed between the 26 epistemic emotions in the list with the 70 stimulus-expressions in the text. Going into more detail, the survey took place by administering to the 30 students a format that highlighted each stimulus-expression and asked the subjects to associate every specific stimulus-expression with one or more epistemic emotions of the list. This allowed us to select the epistemic emotion that best characterized every specific stimulus-expression, and to insert all the 70 stimulus-expressions into the Circumplex Model of Epistemic Affect to arrive at the final emotional mapping of the genesis of the theory of SR, with a visualization and an animation on the circumplex showing its dynamics (Figure 1 Phase 5; Figure 3).

Figure 3. Emotional dynamics of the genesis of Special Relativity Theory built in the Circumplex Model of Epistemic Affect.



Conclusions

This research has corroborated the feasibility of constructing an increasingly specific definition of epistemic emotion through the analysis of a text with interviews with scientists. A novel methodology highlights the potential of an interdisciplinary research approach, which brings to light the affective dimension within scientific research processes. The Circumplex Model of Epistemic Affect (CMEA), born from the synergy between the circumplex model of affect and the development of a reference list of epistemic emotions, emerges as a novel tool designed to detect, define, and visualize epistemic emotions, offering a structured approach to assess the affective dimensions of scientific research and learning processes. Further studies will test and revise both the list and the Circumplex. We expect that the evaluation of Valence and Arousal of the single emotions can be made more and more robust. However, by leveraging the CMEA, researchers and educators can systematically identify and categorize these emotions, thereby making them more accessible and actionable within both research and classroom dynamics. The CMEA can operate as both a pedagogical and diagnostic tool and it could represent a significant step forward in integrating affective and cognitive dimensions into educational research and practices. From a pedagogical perspective, the visualization of Albert Einstein's scientific theorizing suggests that emotional trajectories in scientific inquiry are not linear or progressively cumulative, as often implicitly assumed, but rather characterized by fluctuations and reversals. Making such alternating emotional dynamics visible within a classroom pathopoietic process may be particularly illuminating for students, as it foregrounds the affective complexity inherent in authentic scientific problem solving. To check its diagnostic potential, the tool has been used to emotionally evaluate different phases of a classroom problem-solving process to elicit and make visible the affect dynamics associated with an experimental kinematics activity in a second-year upper secondary school class (Rimediotti, 2025). The results show the tool's effectiveness in unveiling students' emotional development throughout their learning processes.

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