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Scientific observation for developing children's scientific practice skills and sensitivity: A perspective from science education

Summary

Scientific observation is one of the elementary methods of learning about the world, especially in biology and geography. Meanwhile, its understanding is still colloquial and superficial, and its presence in school science is quite marginal. I present the theoretical assumptions of scientific observation and how it differs from everyday observation. In addition, I present a short description of how children's observation skills develop and argue why it is worth introducing scientific observation into the educational process. I support these considerations by presenting basic assumptions that can be implemented when designing an educational process intended to facilitate the implementation and development of scientific observation skills, which considers the features of scientific observation and its stages. Since life sciences should be largely conducted through direct experience and observation, I also present the benefits of conducting observations in the natural environment. Finally, I present some reflections on the absence and presence of scientific observation in schools.

Keywords: scientific observation, observational skill, direct experience, scientific practices

Słowa kluczowe: obserwacja naukowa, bezpośrednie doświadczanie, praktyki naukowe

What is an observation?

One of the first human learning methods is through observation, which is sometimes described as a universal learning strategy. However, I will limit my reflection to scientific observation and how it can be developed during education.

Historically, observation was the first scientific method used by many before the idea of experiments was created – and it was used by great naturalists such as Aristotle, Epicurus, Francis Bacon, and Leonhard Fusch. However, observation from an educational point of view is not always easy to define since observation is a rather broad concept. When taking a closer look, observation **is fundamental to all scientific activity and disciplines** (Norris 1984). As Elizabeth Hammerman states, "Observation includes the use of one or more of the senses to identify properties of objects and natural phenomena" (Hammerman 2006: 15). It is thus one of the key science process skills. Such a definition seems to be simple, but at the same time, Hammerman claims that observation is embedded in other science process skills such as measurements, making inferences, and scientific investigations/experiments. It is considered one of the scientific methods and practices (García-Carmona, Acevedo-Díaz 2018). Observation is: "the conduit through which the 'tribunal of experience' delivers its verdicts on scientific hypotheses and theories" (Boyd, Bogen 2021). It might serve as a foundation for a hypothesis, data collection method, or scientific discovery stimulus (Mayr 1997). Observation also aids in the recall of details of an investigation and supports problem-solving (Grambo 1994).

Observers use simple or more sophisticated tools to enhance their observational range. Such tools include magnifying glasses, microscopes, or telescopes to see things that are too small or far away (Boyd, Bogen 2021). Observations are obtained either **directly through our senses or indirectly** through instruments that are extensions of our senses. Additionally, observations differ in the features one is observing, and thus can be either:

– **qualitative** – described using words or terms rather than numbers and includes subjective descriptions within variables such as colour, shape, and smell, often recorded through photography or drawing;
– **quantitative** – numerical values obtained from counting or measuring variables, often requiring some measurement tool (Jones et al. 2007). In the latter meaning, the distinction between observation and measurements can be challenging.

At the same time, all observations and uses of observational evidence are theory-laden (e.g., Hanson 1958; Chalmers 1997). Norwood Hanson claimed that even seeing is theory-laden, which can apply just as well to equipment-generated observations (Hanson 1958). Michael Polanyi (1973) describes the differences and changes in how X-ray photographs are observed and interpreted by novice students and experienced doctors, for whom the mere shadows in the image carry meaning.

What is an observation in the context of science education? The nature of observation

Observation is a complex skill, is not unidimensional, and does not always lead to learning. Scientific observation is a scientific skill and a component of other scientific skills. It is also essential to science curricula (Bybee 2011; NRC 2012; NAAEE 2019). Research has shown that observation can lead to conceptual understanding under metacognition and social construction (Shayer, Adey 2002). One's previous ideas influence observation because everything we perceive depends on personal knowledge (Polanyi 1973; Greven et al. 2016). Once children perceive objects using their sight, hearing, smell, touch, and/or taste, and even balance, they construct a concept of their identity (Tomkins, Tunnicliffe 2001, 2015). Then, they may develop an interest in an observed object (Tunnicliffe, Litson 2002) so that children observe what interests them.

From the perspective of science education, observation is a fundamental cognitive ability – it is the purposeful theory-driven process of making sense of the world, directly or indirectly, using one's senses and/or interpreting other data. Popper (1972) stated that a question or problem always precedes observation. For educators, it means that good observation is purposeful. Simply observing a biological object does not necessarily lead to learning or metacognitive reflection. Hence, when conducted for science education purposes, observations should start with a purpose since they are motivated, guided, and meaningful in relation to questions or problems about natural phenomena (Lederman 2018).

In everyday life, observations are connected with noticing or sensing. However, observations go beyond merely seeing or sensing things, in particular, when we focus on scientific observation. While sensing is a concrete and important part of observation, it is only one aspect of the process (Eberbach, Crowley 2009). Norris (1984: 134) noticed that so-called observational competence consists of three proficiencies:

– in making observations well (which includes good access to the thing observed, satisfactory medium of observation, many opportunities to observe, and usage of adequate instruments);
– in reporting observations well (making a report close to the time of observing, doing it personally, reporting it precisely);
– in assessing the believability of observation reports (checking whether the first two were done well, whether the report is corroborated, is not emotionally loaded, is based on records, etc.).

Eberbach and Crowley (2009) created a model of observation which involves four elements:

1. **noticing** – involves perception, supports complex hypothesis testing, and leads to reasoning;
2. **expectations** – connected with asking questions, usually practical questions;
3. **observation records** – connected with documenting observations, where the role of the inscription is visible and tangible, might have identifiable or abstract forms (such as graphs);
4. **productive disposition** – connected with internal motivation and commitment to the observable object or phenomenon.

As Eberbach and Crowley (2009) claim, expert observation involves all four elements and addresses specific questions and problems. They also highlight that expert observation is a complex practice that requires coordination of disciplinary knowledge, theory, practice, and attention habits. They also proposed a framework for a transition from everyday to scientific observation. The characteristics of everyday and scientific observation are shown in Figures 1 and 2.

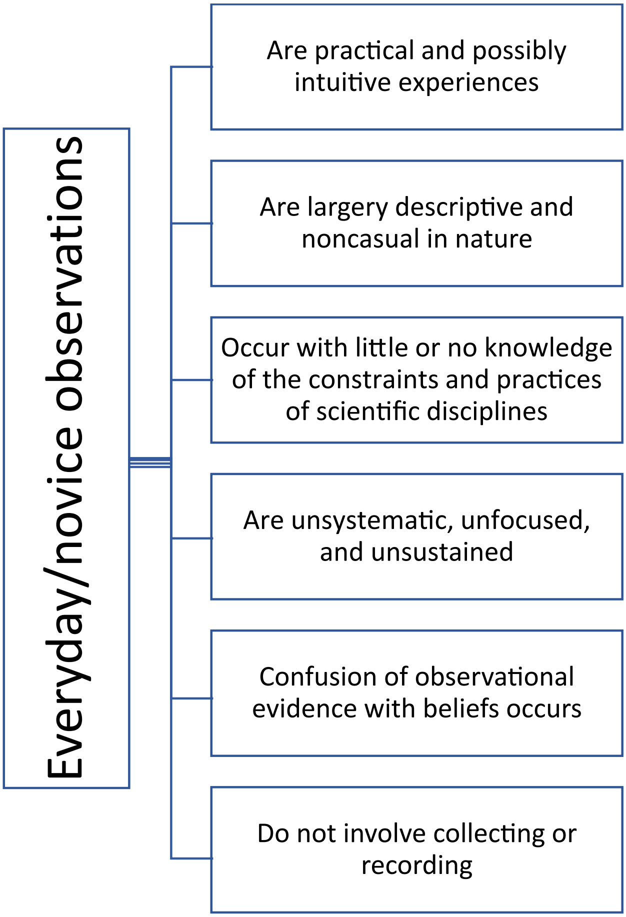

Figure 1. The characteristics of everyday/novice observation.

Source: own elaboration based on Eberbach and Crowley (2009).

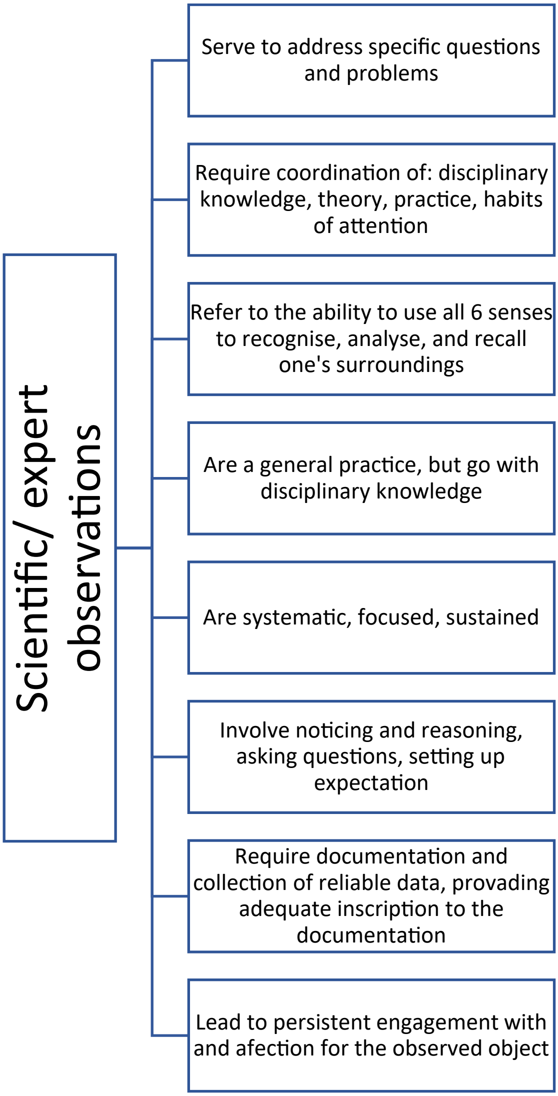

Figure 2. The characteristics of scientific/expert observation

Source: own elaboration based on Eberbach and Crowley (2009).

The framework does not include all the aspects and complexity of observation, mainly when we focus on an individual child. It shows two extremes, where at one end, we might see a naïve, novice observer and, on the other, an experienced scientist – since authentic scientific observations are always situated within a specific discipline. Pupils learning scientific methods will locate themselves somewhere between the two extremes. One advantage of the approach presented by Eberbach and Crowley (2009) is showing the difference between everyday and scientific observations. Furthermore, this framework provides an understanding of how educational environments can be designed to foster the development of scientific practices and critical thinking within scientific disciplines and to help children to learn how to observe more scientifically (Eberbach, Crowley 2009).

Who? – children's observations skills

Jane Susan Johnston examined how general observation skills develop in young people. Most children begin to observe using multiple senses simultaneously (Johnston 2011, 2013). As children develop their perception of objects, using their basic six senses – sight, hearing, smell, touch, taste, and balance, they quickly construct a concept of object identity (Tomkins, Tunnicliffe 2015). With age, children also develop and improve the ability to recognize similarities and differences between objects, observe patterns, identify sequences and events in their environment, and interpret their observations (Johnston 2011). Johnston (2009) also described children's observation skills as developing usually in two ways:

– by engaging in more distinctive, close observation, and interpreting this observation;
– utilising previous knowledge and experience to help explain and interpret previous observations. Children might apply their previous knowledge to their observations and more complex explanations.

Johnston described the transition from simple observations to more complex ones in the group of children she studied. When observing the ability to explain what has happened with observed objects and/or phenomena, she noticed that with age, simple explanations of observations gradually develop into complex interpretations (Johnston 2009). She also showed that children's observation skills include comments, actions, and questions that can fit into four categories:

– affective, showing emotions, motivation, or interests;
– functional, connected with the noticing how "things" work;
– social, involving interactions between peers and with teacher/adult;
– exploratory, that leads to further scientific explanations and inquiry.

She reported that children's observation skills increase with age. Older children tend to move past affective aspects more quickly and engage in more individual close observation for longer. They also tend to move from broad to more specific observations. It is also worth noticing that with age, interacting with peers seems to challenge children's ideas, fostering the development of new and more scientifically oriented thinking. Moreover, because children see the world through their own conceptual spectacles, a significant factor in developing their critical thinking skills is to allow them to critically evaluate evidence in the light of their expectations (Driver 1983). So, even though scientific observation is always done concerning disciplinary knowledge, this knowledge alone is not enough for children to effectively develop scientific observation skills (Eberbach, Crowley 2009). They also need supportive learning environments and appropriate tools.

Why should we introduce scientific observation practices into early education? And how can they be supported?

One might argue that, in teaching science, learning to observe systematically is as important as manipulating apparatus and analysing data. As mentioned above, it requires coordination of disciplinary knowledge, theory, practice, and habits of directing attention (Eberbach, Crowley 2009). Using well-developed observation skills leads to other scientific process skills such as classification, prediction, hypothesis, explanation, and interpretation (Johnston 2009). Tomkins and Tunnicliffe (2001) showed that sustained observations might provide a base for clearer hypothesis-making. Systematic observation also helps children to compare and contrast and to find and organize patterns in the observed natural world, which are fundamental scientific activity (Norris 1984; Klemm, Neuhaus 2017). It is also documented that for children to learn from science investigations effectively, two key factors are essential (Tomkins, Tunnicliffe 2001):

- Motivation to explore: children need to be interested in exploring the subject matter. If they are motivated, they are more likely to engage deeply with the investigation and be open to discovering new things. Ashbrook (2007) pointed out that motivating scientific phenomena or objects helps children make observations that they perceive as close.
- Practical and process skills: scientific investigations require "hands-on" abilities and systematic approaches. Practical skills include handling equipment, conducting experiments, or making observations. Process skills involve thinking critically, following procedures, and analysing results. Without these skills, even a motivated child may struggle to learn successfully from an investigation.

Thus, children need both the desire to explore and the necessary skills to effectively conduct and learn from scientific investigations (Tomkins, Tunnicliffe 2001).

Although observation has been recognized as an essential initial skill in early years and primary school science (Harlen 2000; Johnston 2009), it is often perceived as unproblematic, an activity carried out almost involuntarily, which does not require much refinement or attention (Metz 1995; Eberbach, Crowley 2017). Educators and researchers may underestimate systematic observation and see it as "an effortless, everyday practice that requires little more than noticing and describing surface features" (Eberbach, Crowley 2017: 609). This approach may lead to a situation when unexperienced observers mainly observe in order to collect data (Eberbach, Crowley 2009) and do not develop new knowledge since they usually do not even reflect on their observations, do not have a driving question, nor do it systematically (Ford 2005; Eberbach, Crowley 2017; Lederman 2018). An interesting example of missing the opportunity to raise systematic observation skills among participants was described by Trumbull and co-workers (2005). During Cornell Ornithology Lab's Classroom Feeder Watch programme, students were asked to observe living birds, count the number of specimens of each species, record the time, etc. Although it seemed simple for ornithologists, it became a major problem for students who could not recognize the species during flight. Without knowledge, skills of recognizing bird species, and practice in making ornithological observations, these students could not engage in such activity, recognize meaningful patterns, or develop new knowledge about the birds. An additional lesson from that project is that there is a need for the presence of a significant adult (Brzezińska 2008). As Ewa Filipiak (2011) highlights – a significant adult through whom the child's world makes sense is an intermediary – between the linguistic world of the child and the scientific language, who organizes the space for thinking and acting, for asking questions, creates a climate of mutual and individual learning, who interacts actively with students, but at the same time provides scaffolding, when necessary.

What is needed to develop more scientific observation skills – designing a learning environment that supports the development of observational skills

One of the crucial concepts in an educational setting is the learning environment or the context of learning. Gardner (2006) describes the context of teaching/learning as a composition of three elements: activities, environment, and resources, where there are opportunities to practise multiple skills, and calls such context a nurturing environment. Eberbach and Crowley (2009) similarly argued that children can develop observation skills only when they have specific disciplinary knowledge, tools, a supportive learning environment, and experience to support their reasoning. In the context of developing scientific observation skills, such a nurturing environment provides many educational opportunities to:

- observe adults and peers in the role of experts (more experienced) as role models while learning;
- observe and interact with a wide range of objects, materials - stimulating different senses (as part of multimodal communication).

A question that can be posed here is how to design such a nurturing environment. As mentioned above, referring to Popper's view (1972), **a question or a problem** should lead to scientific observation. Thus, making observations purposeful would be one requirement of such an environment.

A theoretical framework needs to be applied in such a design learning environment that can support the development of scientific observation skills (Hodson 1996). Without such a framework, children may either miss the studied phenomenon or misperceive it. For example, lacking the necessary background knowledge can result in misinterpreting what they see under a microscope. Hodson suggests that before a microscopy lesson, it is essential to ensure that students can use the microscope and provide a visual reference, such as a drawing of the object they will observe. He further notes that being a skilled observer involves knowing what to look for, how to look for it, and having the ability to compare expectations with actual observations. He also believes that well-designed learning experiences that improve critical observation skills will have the following stages:

- selecting relevant features and deciding what to pay attention to in the observed piece of reality;
- identifying, controlling, and manipulating variables;
- deciding on the equipment and materials needed;
- taking measurements;
- describing observations;
- establishing links between individual observations and identifying trends and patterns;
- ensuring repeatability;
- reaching consensus through criticism and adequately evaluating the information collected.

The next element would be building a **community of learners**. Research shows that creating an intergenerational learning community is among the most influential factors in successful learning and developing skills. Such a community should support situations where shared noticing and conversations of adults and children appear (Johnston 2011; Eberbach, Crowley 2017) as well as peer-interaction and conversations (Johnston 2009; Tomkins, Tunnicliffe 2001) especially as talking is an important element of thinking and doing science (Hanley et al. 2020), and essential for developing scientific observation skills (Eberbach, Crowley 2009). Talking creates opportunities for students to share knowledge and co-reason and creates opportunities to experience science as a process of revision (Driver et al. 2000; Cervetti et al. 2014). Eberbach and Crowley (2017) have shown in their research how elaborative conversational strategy helped in developing observation skills among students aged 6–10 years. In their study, they trained half of the cohort of parents in an elaborative conversational strategy (that involved asking wh- questions, focusing on the child's interests, linking present to past experiences, and providing positive feedback). Then, they recorded visits to a botanical garden. As a result, they showed that a conversation, also in a child-parent pair, where a parent was not specialized in biology or plants in general, increased the amount of disciplinary talk in the garden. The degree to which families engaged in disciplinary discussions in the garden significantly influenced what children learned from the experience. This example demonstrates how shared family observations and conversations can enhance children's ability to observe nature.

Constantinou and Rybska (2024) recently proposed a framework for designing principles for integrating science practices with conceptual understanding. They pointed out five crucial elements in such design: integrating epistemic practices, making evidence-based inferences, competence-oriented design, authentic and relevant context, and scaffolding for engagement and reflection. The examples of the implementation of the design principles in the learning environment shaping observational skills are presented in Table 1.

Table 1. Examples of design principles' implementation in the learning environment shape observational skills

Design principle	Implementation examples
Integration of epistemic practices	Starting with relevant (for observation) questions, (e.g. *wh*-questions) Selecting relevant features/variables to be observed Evaluation of evidence in shared discussion
Making evidence-based inferences	Connecting observed evidence with theory Inferring function and behaviour Analysing observed data and concluding in the light of asked question
Competence-oriented design	Using observational evidence as a basis for investigation, argument, and explanation Jointly identifying a set of characteristics that make an observation reliable, more scientific, and meaningful Building a community of learners Developing a habit of attention Developing a habit of recording observations and conducting observations systematically
Authentic and relevant context	Making observations close for students Providing opportunities for direct experiences in nature Linking observation with previous experience Allowing students to choose – the object/phenomenon to be observed Starting with relevant and local context that recently appeared in media
Scaffolding for engagement and reflection	Using adequate representations (graphs, maps, descriptions, drawings) while reporting observations and analysing the results Offering individualised and small group peer feedback on actual student work

Source: own elaboration, adopted from Constantinou and Rybska (2024)

Physical environment – why observing nature is important

Observations constitute a fundamental methodology in the life sciences, serving as the foundation for empirical inquiry (Tunnicliffe, Ueckert 2011). Fieldwork, likewise, plays a pivotal role in enhancing scientific understanding of the environment. These experiences allow for direct engagement with natural environments, facilitating the development of essential skills such as systematic observation, data collection, and hypothesis generation. Even an intervention lasting one week should significantly affect science observation skills (Van der Graaf et al. 2018, 2019) and children's scientific reasoning, knowledge, and pro-environmental attitude (Fančovičová, Prokop 2011). Fieldwork provides a context for knowledge construction, enabling students and researchers to apply observational techniques in situ and reinforcing the acquisition and retention of critical scientific competencies. Therefore, it might be natural to provide opportunities to learn how to observe scientifically, at least partially in natural environments. Such environments create many possibilities for **direct** instead of vicarious **experiences**. Klofutar and co-workers (2020) designed a quasi-experiment in which some preschool children learned about the forest ecosystem by being in it (direct experience). Another group was taught through vicarious experiences (where children learned in the classroom through videos, books, and games). Although both groups improved their observational skills and learned a lot, direct experiences led to a greater increase and longer retention of these skills. Direct experiences are essential for developing specific scientific skills, such as observing and classifying forest organisms, and lead to a higher increase and persistence of acquired observation skills than when children are exposed to vicarious experiences. These skills can also be developed with vicarious experiences, but only to a certain degree, since they are not effectively using multiple senses (Klofutar et al. 2020). What is also worth mentioning is that nature observation also influences the affective zone and provides a sense of belonging to nature. Children judge nature not by its aesthetics, but by how they interact with it and their sensory experiences, so physical and emotional bonds can be formed (White, Stoecklin 1998).

Children have an innate tendency to explore and form bonds with the natural environment (if given the opportunity) (Kellert 2002). Among the three types of experience, direct, indirect, and symbolic or vicarious experience, Keller suggests that direct experience is most effective in positively influencing cognitive, affective, and evaluative (values-related) learning modes. The experiences in natural environments enable students to effectively use multiple senses at once, which is how children initially begin to observe (Johnston 2011, 2013). Such experiences also affect the imagination and build a sense of belonging to a place and nature since nature can attract, stimulate, and retain the child's attention and thus have a significant effect on childhood maturation and development (Kellert 2002). But, what is valid for learners of all ages is that outdoor education enables students to experience natural objects more holistically and to correctly relate observations of various elements together, connecting separate concepts (Klofutar et al. 2020). Nature has a place, space, and pedagogical potential and is also a place to satisfy existential needs. As Michalak and Parczewska wrote: "the practice of being human in nature has been and continues to be a reflection of the degree of social consciousness, how existential needs are valued and fulfilled, and the shaping of socioeconomic relations, which remain in close connection with historical and cultural conditions" (Michalak, Parczewska 2019: 79). The presented perspective is a different (from what science education offers) aspect of holistic thinking about holistic child development.

The problem with many environmental education programmes is that they try to impart information and develop an attitude of responsibility for the environment before children can develop a solid affective engagement with the natural world (Sobel 1996; Wilson 2004). Additionally, the outdoor space around the typical Polish school is arranged permanently, with ready-made equipment that prevents free action, decision-making, independence, spontaneity, or creativity. Adults always arrange the space. Also, not all the space is always available – mowed lawns, for example, are meant to look nice, not to serve children

(Michalak, Parczewska 2019). In such a situation, it is difficult for children to make such a space their own and get involved in transforming it (Majcher 2015), and such situations prevent direct experience of the environment. In addition, as Michalak and Parczewska (2019) show, even extracurricular activities are characterized by a transmissive style of teaching, by poverty of methods and forms and learning situations, and, above all, by teachers' inflexibility in responding to students' current needs and difficulties. All this, combined with the extinction of experience (Pyle 1978, 1993), or the disappearance of direct experience of nature (Kellert 2002), indicates the low quality and poor educational value of extracurricular activities.

A few reflections

Teachers and environmental educators may think that hands-on experiments should be implemented as the first scientific activity from a very early age. In contrast, there is a lack of real opportunities to improve scientific practices, including observation. One noticeable issue is the lack of systematic observations in Polish educational materials and textbooks. In the two nature textbooks available for the fourth grade of elementary school in Poland, observations are presented superficially. One book presents observation as a process of looking closely at a selected object, which can be done anywhere. By doing so, one gathers and completes knowledge about nature. One can predict and explain phenomena. On top of that, observation is treated here colloquially – interchangeably with the result of an experiment – where in place of result comes a statement: I observed that. There is more about observation in the second book. The authors of this textbook state that observation is an essential scientific method, a planned and systematic activity that involves repeatedly observing the phenomenon under study and recording the information gathered. However, there are no scientific observations in the proposed activities. Most activities only focus on the initial observation phase (noticing) without encouraging students to ask further questions. In such an environment, it is difficult to imagine the development of a productive mindset or any emotional engagement.

As I mentioned above, it would be beneficial for students to make close and personally meaningful observations. One strategy to achieve that would be by referring to Montessori's approach: "It is true that one adult – the directress – is in a sense a part of his environment, but the function of both the directress and environment is to assist the child to reach perfection through his own efforts" (Standing 1998: 267).

Meanwhile, while observing the authenticity of teachers' curriculum implementation activities in kindergarten, Kallery and Psillos (2002) found that among classroom practices, an observation made up 5% of activities, with teachers primarily conducting the observations while children mostly watched. Similar findings were reported by Dorota Klus-Stańska (2023), where students described a typical lesson course in which the critical element is the absence of independent student activity. This approach not only contradicts the assumption of activity but prevents negotiation of meanings or use of personal knowledge in "taming" public knowledge (Klus-Stańska 2019), assuming that the child can passively assimilate verbal messages and knowledge as coming from following the teacher's "footsteps" (Klus-Stańska 2002).

Some good examples of an observation activity were given by Constantinou et al. (2002), e.g., a year-round observation of a tree of the child's choice. Even in kindergarten, children set up drawing notebooks to record the changes they observe on the chosen tree. The preschoolers mark a tree of their choice with a ribbon, name it, and make observations throughout the year, noting the results as a drawing. They then compare them with the changes others in their groups have observed. In this way, they construct their knowledge through discussions with peers and a teacher serving as a significant adult (Brzezińska 2008), especially since it is up to adults to decide how much time children spend observing, learning how to observe scientifically, or interacting with nature. Not only are regular, developmentally appropriate experiences with nature important for shaping pro-environmental values, but adults, both parents and teachers, should model joy, comfort, and respect for nature (Phenice, Griffore 2003; White 2004; Wilson 2007; Chawla 2015) and appreciation and value of scientific methods of exploring the world.

References

Ashbrook P. (2007), *Science tickets*. "Science and Children", 45(3).

Boyd N.M., Bogen J. (2021), *Theory and Observation in Science*, "The Stanford Encyclopedia of Philosophy", Winter Edition, https://plato.stanford.edu/archives/win2021/entries/science-theory-observation/, 15.07.2024

Brzezińska A. (2008), *Nauczyciel jako organizator społecznego środowiska uczenia się*. In: Filipiak E. (ed.), *Rozwijanie zdolności uczenia się. Wybrane konteksty i problemy*. Bydgoszcz, Wydawnictwo Uniwersytetu Kazimierza Wielkiego.

Bybee R.W. (2011), *Scientific and Engineering Practices in K-12 Classrooms: Understanding a Framework for K-12 Science Education*. "Science and Children", 49(4).

Cervetti G.N., DiPardo A.L., Staley S.J. (2014), *Entering the conversation: Exploratory talk in middle school science*. "The Elementary School Journal", 114(4).

Chalmers A.F. (1997), *Czym jest to, co zwiemy nauką?: rozważania o naturze, statusie i metodach nauki: wprowadzenie do współczesnej filozofii nauki*. Wrocław, Siedmioróg.

Chawla L. (2015), *Benefits of nature contact for children*. "Journal of Planning Literature", 30(4).

Constantinou C.P., Feronymou G., Kyriakidou E., Nicolaou Ch. (2002), *Natural Science in the Kindergarten: A Resource for Teachers*. Cyprus, Ministry of Education and Culture [in Greek].

Constantinou C.P., Rybska E. (2024), *Design principles for integrating science practices with conceptual understanding: an example from a digital learning environment on microbial resistance to antibiotics*. "Humanities & Social Sciences Communications" 501(11).

Driver R. (1983), *The pupil as a scientist.* Milton Keynes, Open University Press.

Driver R., Newton P., Osborne J. (2000), *Establishing the norms of scientific argumentation in classrooms*. "Science Education", 84.

Eberbach C., Crowley K. (2009), *From everyday to scientific observation: How children learn to observe the biologist's world*. "Review of Educational Research", 79(1).
Eberbach C., Crowley K. (2017), *From seeing to observing: How parents and children learn to see science in a botanical garden*. "Journal of the Learning Sciences", 26(4).
Fančovičová J., Prokop P. (2011), *Plants have a chance: outdoor educational programmes alter students' knowledge and attitudes towards plants*. "Environmental Education Research", 17(4).
Filipiak E. (2011), *Z Wygotskim i Brunerem w tle: Słownik pojęć kluczowych*. Bydgoszcz, Wydawnictwo Uniwersytetu Kazimierza Wielkiego.
Ford D. (2005), *The challenges of observing geologically: Third graders' descriptions of rock and mineral properties*. "Science Education", 89(2).
García-Carmona A., Acevedo-Díaz J.A. (2018), *The nature of scientific practice and science education: rationale of a set of essential pedagogical principles*. "Science & Education", 27(5).
Gardner H. (2006), *Multiple intelligences: New horizons.* New York, Perseus Books.
Graaf J. van der, Segers E., Verhoeven L. (2018), *Individual differences in the development of scientific thinking in kindergarten.* "Learning and Instruction", 56.
Graaf J. van der, Sande E. van de, Gijsel M., Segers E. (2019), *A combined approach to strengthen children's scientific thinking: Direct instruction on scientific reasoning and training of teacher's verbal support*. "International Journal of Science Education", 41(9).
Grambo G. (1994), *The art and science of observation*. "Gifted Child Today Magazine", 17(3).
Greven I.M., Downing P.E., Ramsey R. (2016), *Linking person perception and person knowledge in the human brain*. "Social Cognitive and Affective Neuroscience", 11(4).
Hammerman E. (2006), *Eight Essentials of Inquiry-Based Science, K-8.* Thousand Oaks, California, Corwin Press.
Hanley P., Wilson H., Holligan B., Elliott L. (2020), *Thinking, doing, talking science: The effect on attainment and attitudes of a professional development programme to provide cognitively challenging primary science lessons*. "International Journal of Science Education", 42(15).
Hanson N.R. (1958), *Patterns of Discovery*. Cambridge, Cambridge University Press.
Harlen W. (2000), *The teaching of science in primary schools*. London, David Fulton.
Hodson D. (1996), *Rethinking the role and status of observation in science education*. "European Education", 28(3).
Johnston J. (2009), *What does the skill of observation look like in young children?* "International Journal of Science Education", 31(18).
Johnston J. (2011), *Early explorations in science*. Maidenhead, Open University Press.
Johnston J. (2013), *Emergent science: teaching science from birth to 8*. London, Routledge.
Jones A.M., Reed R.H., Weyers J., Weyers J.D. (2007), *Practical skills in biology*. Harlow, Pearson Education.
Kallery M., Psillos D. (2002), *What happens in the early years science classroom? The reality of teachers' curriculum implementation activities*. "European Early Childhood Education Research Journal", 10(2).
Kellert S.R. (2002), *Experiencing nature: affective, cognitive, and evaluative development in children.* In: P. Kahn, S. Kellert (eds.), *Children and nature: Psychological, sociocultural, and evolutionary investigations*. Cambridge, MA, MIT Press.
Klemm J., Neuhaus B.J. (2017), *The role of involvement and emotional well-being for preschool children's scientific observation competency in biology*. "International Journal of Science Education", 39(7).

Klofutar Š., Jerman J., Torkar G. (2020), *Direct versus vicarious experiences for developing children's skills of observation in early science education*. "International Journal of Early Years Education", 30(4).

Klus-Stańska D. (2002), *Konstruowanie wiedzy w szkole*. Olsztyn, Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego

Klus-Stańska D. (2019), *Wiedza osobista uczniów jako punkt zwrotny w teorii i praktyce dydaktycznej.* „Kwartalnik Pedagogiczny", 1.

Klus-Stańska D. (2023), *Zakazana samodzielność poznawcza: Kształcenie początkowe pod przymusem rozumowania zapożyczonego*. „Studia Edukacyjne", (70).

Lederman N.G. (2018), *Nature of Scientific Knowledge and Scientific Inquiry in Biology Teaching*. In: Kampourakis K., Reiss M.J. (eds.), *Teaching Biology in Schools*, London, Routledge.

Majcher I. (2015), *Teren przyszkolny w projektach studenckich*. In: T. Sadoń-Osowiecka (ed.), *Miejsce, przestrzeń, krajobraz – edukacyjne znaki*. Gdańsk, Wydawnictwo Uniwersytetu Gdańskiego.

Mayr E. (1997), *This is biology*. Cambridge, MA, The Belknap Press of Harvard University Press.

Michalak R., Parczewska T. (2019), *(Nie)obecność outdoor education w kształceniu szkolnym*. Lublin, Wydawnictwo Uniwersytetu Marii Curie-Skłodowskiej.

NAAEE (2019), *Guidelines for Excellence: K-12 Environmental Education*. Washington, DC, North American Association for Environmental Education.

Norris S.P. (1984), *Defining observational competence*. "Science Education", 68(2).

NRC (2012), *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. National Research Council. Washington, DC, National Academies Press.

Phenice L.A., Griffore R.J. (2003), *Young children and the natural world*. "Contemporary Issues in Early Childhood", 4(2).

Polanyi M. (1973), *Personal knowledge*. London, Routledge and Kegan Paul.

Popper K.R. (1972), *Objective knowledge: an evolutionary approach*. Oxford, The Clarendon Press.

Pyle R.M. (1978), *The extinction of experience*. "Horticulture", 56.

Pyle R.M. (1993), *The Thunder Tree: Lessons from an Urban Wildland*. Boston, USA, Houghton Miffin.

Shayer M., Adey P. (2002), *Learning intelligence. Cognitive acceleration across the curriculum from 5 to 15 years*. Buckingham, Open University Press

Sobel D. (1996), *Beyond ecophobia: Reclaiming the heart in nature education*. Vol. 1. Great Barrington, MA, Orion Society.

Standing E.M. (1998), *Maria Montessori: Her life and work.* New York, A Plume Book.

Tomkins S., Tunnicliffe S.D. (2001), *Looking for ideas: Observation, interpretation and hypothesis-making by 12-year-old pupils undertaking scientific investigations.* "International Journal of Science Education", 23.

Tomkins S.P., Tunnicliffe S.D. (2015), *Naming the living world: From the infant's perception of animacy to a child's species concept*. In: C.J. Boulter, M.J. Reiss, D.L. Sanders (eds.), *Darwin-inspired learning*. Rotterdam, SensePublishers.

Trumbull D., Bonney R., Grudens-Schuck N. (2005), *Developing materials to promote inquiry: Lessons learned*. "Science Education", 89.

Tunnicliffe S.D., Litson S. (2002), *Observation or imagination*. "Primary Science Review", 71.

Tunnicliffe S.D., Ueckert C. (2011), *Early biology: the critical years for learning*. "Journal of Biological Education", 45(4).

White R. (2004), *Young children's relationship with nature: Its importance to children's development & the earth's future*. "White Hutchinson Leisure & Learning Group", 1(9).
White R., Stoecklin V. (1998), *Children's outdoor play & learning environments: Returning to nature*. "Early Childhood News", 10(2).
Wilson E.B. (2004), *Environmental education: goals and challenges.* Doctoral dissertation, Carleton University. https://repository.library.carleton.ca/downloads/qn59q4449, 5.09.2024.
Wilson R. (2007), *Nature and young children: Encouraging creative play and learning in natural environments*. London, Routledge.