

From an early age, children explore concepts of mathematics and science (Gopnik, Meltzoff and Kuhl, 1999). They naturally notice patterns, compare quantities, explore relationships and solve problems as they seek to make sense of the world and the experiences which contribute to the development of mathematical and scientific understanding (NAEYC and NCTM, 2010). Furthermore, Isaacs (1930) argued that children develop understanding through investigation, experimentation and first-hand experiences. Her observations highlighted children's natural tendency to question, explore and develop theories about the world around them. This is particularly evident within outdoor environments, where children encounter authentic opportunities to observe change, make comparisons and solve problems using real materials and experiences (Maynard and Waters, 2007).

Historically, outdoor learning has been recognised as an important context for children's development, particularly through the lens of science and mathematics. It provides opportunities for exploration, investigation and problem-solving through authentic experiences (Dewey, 1938; Bilton, 2010; Maynard and Waters, 2007). This reflects Froebel's (1887) belief that nature is a powerful teacher, offering children opportunities to observe, enquire and make sense of the world around them. Pecaski McLennan (2017) similarly suggests that these experiences can support the development of mathematical and scientific concepts, including measurement, pattern, number, change and enquiry, through meaningful engagement with natural materials and phenomena. Likewise, Piaget (1952) argued that children actively construct knowledge through exploration and experimentation, developing understanding through direct interaction with their environment. This perspective is reflected in Tinney's (2023) view that natural environments provide rich opportunities for children to learn through exploration, discovery and enquiry, supporting the development of curiosity, problem-solving and higher-order thinking skills.

Enabling adults play a pivotal role in transforming outdoor experiences into meaningful opportunities for mathematical and scientific learning (Welsh Government, 2024). Through observation, responsive interactions and sustained shared thinking, practitioners support children to extend their knowledge, develop higher-order thinking skills and engage more deeply with mathematical and scientific concepts (Welsh Government, 2022). This reflects Vygotsky's (1978) theory of social constructivism, which suggests that learning occurs within the Zone of Proximal Development (ZPD), where children can achieve a higher level of understanding with the support of a 'more knowledgeable other.' Building on this, Bruner (1983) proposed that adults scaffold children's learning by providing appropriate support and gradually withdrawing it as their competence develops.

The role of the enabling adult extends beyond simply supporting learning. Effective practitioners create environments that provoke curiosity, encourage risk-taking and promote enquiry. Rather than directing learning, they observe children's interests, recognise learning potential and respond in ways that deepen thinking (Welsh Government, 2024). This aligns with the ECPLC framework, which identifies enabling adults as a key component of high-quality early years provision (Welsh Government, 2024). By carefully balancing support and independence, practitioners help children to become confident problem-solvers and independent learners.

Within outdoor environments, practitioners can extend children's mathematical and scientific thinking through questioning, discussion and shared problem-solving. For example, when children discover snails after rainfall, an adult might ask, 'Why do you think the snails came out today?' or 'How could we find out where they live?'. These interactions encourage children to observe, predict, investigate and draw conclusions, supporting the development of scientific enquiry skills. Similarly, when children explore puddles, adults can introduce mathematical concepts such as measurement, capacity and comparison through questions including, 'Which puddle is bigger?' or 'How could we find out which holds more water?'. Through these interactions, children move beyond simple

exploration to develop increasingly sophisticated mathematical and scientific understanding. Similarly, when children transport water between containers, practitioners can encourage mathematical thinking by asking children to estimate which container will hold the most water, compare quantities and discuss concepts such as full, empty, more and less. Scientific enquiry can be extended through questions such as, 'What happens when we pour the water into a narrower container?' or 'Why do you think the water level changed?'. Through observation and experimentation, children develop an understanding of capacity, volume and conservation while testing their own theories about how water behaves.

As they compare capacity, make predictions and test their ideas, children develop the characteristics of ambitious, capable learners who are curious, questioning and able to apply knowledge in different contexts (Welsh Government, 2022). Through investigating solutions, solving problems and evaluating outcomes, they also demonstrate the attributes of enterprising, creative contributors, using creativity and critical thinking to make sense of their experiences (Welsh Government, 2022).

This approach aligns closely with sustained shared thinking, identified by Siraj-Blatchford et al. (2002) as a defining characteristic of effective early years practice. Research suggests that children are more likely to develop reasoning, problem-solving and enquiry skills when adults engage alongside them, model language and encourage them to explain their thinking rather than simply providing answers (French, 2004). Consequently, whilst outdoor environments naturally provide opportunities for exploration, their educational value is enhanced when practitioners actively extend children's thinking through purposeful interaction.

In addition to extending children's conceptual understanding, practitioner interactions can influence children's motivation and disposition towards mathematics and science. Positive encouragement, shared enthusiasm and genuine curiosity help to create a learning culture in which children feel confident to ask questions, test ideas and learn from mistakes. Consequently, adults support not only the development of knowledge and skills, but also the attitudes and dispositions associated with lifelong learning in STEM-related areas (White, 2014).

This highlights that the educational value of outdoor learning depends largely on the skill of the practitioner. Siraj-Blatchford et al. (2002) argue that sustained shared thinking occurs when adults and children work together in an intellectual way to solve a problem, clarify a concept, evaluate activities or extend a narrative. Within outdoor environments, this may involve adults and children jointly investigating why leaves float on water, discussing how to build a stronger den or exploring why some objects roll further than others. Such interactions encourage children to articulate their thinking, consider alternative explanations and engage in deeper reasoning, all of which support mathematical and scientific understanding.

However, some researchers caution against excessive adult intervention (Moyle, 2015; Anning and Edwards, 2006). Child-led approaches influenced by Reggio Emilia emphasise children's agency and competence as learners, recognising that knowledge is constructed through exploration, enquiry and collaboration (Edwards, Gandini and Forman, 2012). Similarly, Bruce (2021) argues that children benefit from opportunities to pursue their own interests through self-initiated play. This suggests that practitioners need to make careful professional judgements about when to intervene and when to step back, ensuring that adult support extends children's thinking without reducing opportunities for independent exploration and discovery.

Piaget (1952) also emphasised the importance of independent discovery, yet Vygotsky (1978) argued that children benefit from guidance from more knowledgeable others. This suggests that neither

unrestricted play nor direct instruction alone is sufficient. Rather, effective outdoor pedagogy requires a balance between child-led exploration and sensitive adult support that enables children to construct and deepen their understanding.

Furthermore, the Curriculum for Wales emphasises that learner progress is heavily dependent on the quality of interactions between practitioners and children (Welsh Government, 2022). While many practitioners demonstrate effective enabling adult practices, evidence suggests that developing the skills required to observe, notice, analyse and respond to children's learning remains an ongoing area of professional development across Wales (Estyn, 2024). Consequently, opportunities for sustained shared thinking and the extension of children's mathematical and scientific ideas may be missed when practitioners lack the confidence, subject knowledge or pedagogical skills required to identify and capitalise on teachable moments, particularly within outdoor and natural environments (Ephgrave, 2018).

The EPPE (Effective Provision of Pre-School Education) study found that high-quality early years settings were characterised by frequent sustained shared thinking between adults and children, with practitioners skilfully combining child-initiated activities with intentional teaching to extend learning (Sylva et al., 2004). This suggests that mathematical and scientific understanding develops most effectively when children are provided with opportunities for autonomous exploration alongside responsive adult support. Open-ended resources and natural materials, such as stones, sticks, mud and water, enable children to investigate ideas, solve problems and test theories through meaningful first-hand experiences (Bruce, 2021). For instance, children exploring large stones may investigate weight, size and balance by comparing and arranging them in different ways. Adults can extend this learning by introducing mathematical vocabulary such as heavier, lighter, taller and shorter, whilst encouraging scientific thinking through questions including, 'Why do you think this stone stayed balanced?' or 'What might happen if we add another stone on top?'. This suggests that high-quality outdoor learning is not achieved through access to outdoor spaces alone but through practitioners' ability to combine child-led exploration with intentional teaching strategies.

However, the learning potential of outdoor environments in early years settings is not always fully realised. Contemporary Welsh guidance highlights that high-quality provision depends upon the interaction between enabling adults, engaging experiences and effective environments (Welsh Government, 2024). Similarly, Estyn (2024) emphasises the importance of practitioners being able to notice, analyse and respond to children's interests, while NDNA (2025) argues that effective STEM learning develops when enabling adults nurture children's curiosity and enquiry within authentic contexts. Consequently, the educational value of outdoor experiences is shaped not simply by the environment itself, but by the ability of practitioners to recognise and extend learning opportunities through purposeful interactions.

Despite the recognised benefits of outdoor learning, several challenges can affect its effectiveness in practice. One significant barrier is practitioner confidence. Research suggests that some adults feel more secure supporting literacy than mathematics or science, which can limit the depth and quality of interactions that promote learning in these areas (Johnston, 2014). For example, practitioners who lack confidence in mathematics may overlook opportunities to introduce concepts such as measurement, capacity or pattern during water play, while limited scientific knowledge may restrict discussions about forces, weather or life cycles. As a result, rich learning opportunities may remain unexplored despite the potential offered by the outdoor environment.

Similarly, risk-averse cultures may restrict opportunities for exploration and investigation. As scientific enquiry often involves experimentation, uncertainty and manageable risk, excessive

concerns about safety can reduce opportunities for meaningful experiences with water, natural materials and loose parts. This is particularly significant in relation to STEM learning, where practitioners may lack confidence in their own mathematical or scientific knowledge. As a result, opportunities to extend children's thinking through effective questioning or explanation may be missed. Consequently, professional learning and ongoing development remain crucial in ensuring practitioners can maximise the potential of outdoor environments for mathematical and scientific learning (Johnston, 2014).

Environmental factors, including adverse weather conditions, limited outdoor space and restricted resources, may also influence provision. However, evidence suggests that successful outdoor learning is determined less by the availability of expensive resources and more by practitioners' attitudes, knowledge and pedagogical approaches. Time pressures and curriculum demands can present further challenges, particularly where outdoor learning is viewed as separate from educational outcomes rather than as a context through which mathematical and scientific concepts can be developed. Ultimately, opportunities for learning may be missed when adults focus primarily on supervision rather than observation, interaction and the extension of thinking. Therefore, the quality of adult engagement remains one of the most influential factors in determining whether outdoor experiences lead to meaningful mathematical and scientific learning.

Conclusion

Outdoor environments provide powerful opportunities for young children to develop mathematical and scientific understanding through exploration, enquiry and play. However, theory and research consistently suggest that these opportunities do not automatically lead to meaningful learning. Rather, the quality of adult interactions is a key factor in determining the depth of children's understanding. Through observation, questioning, scaffolding and sustained shared thinking, practitioners encourage children to investigate, reason, solve problems and test theories within authentic contexts. Whilst barriers such as practitioner confidence, resource limitations and risk-averse cultures can restrict learning opportunities, effective enabling adults are able to recognise and extend teachable moments. Therefore, it is not the outdoor environment alone that supports mathematical and scientific learning; rather, it is the skilled practitioner who acts as the 'golden thread', connecting children's interests, experiences and emerging understanding through purposeful interactions and sustained shared thinking.

