Towards Digital Transformation in Primary Science: Typology of Blended Learning Models

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Abstract: This paper explores the necessity for an operational typology of blended learning models in science education, emphasizing the significant role of the digital dimension in the traditional didactic triangle of learner, teacher, and curriculum. We propose the Framework for Primary Science Curriculum in the Digital Age, which considers existing student digital experiences in STEM and the necessities of the digital age. Further, we approach the Framework for Primary Science Curriculum in the Digital Age from student and teacher perspective, by illustrating aspects that become more important than others in student learning and also by an operational typology of blended learning models which can assist teachers. Throughout the paper, we discuss the potential influence of generative artificial intelligence solutions on digital transformation in education, highlighting the need for further research in this area. Overall, this paper provides insights into the complex process of digital transformation in education and offers key components for the advancement of science teaching and learning in the digital age.

1 INTRODUCTION: DIGITAL TRANSFORMATION IN EDUCATION AND BLENDED LEARNING

The students who attend school in the third decade of the 21st century are often labelled as digital natives or generation alpha – they have adopted digital technologies (DT) in their lives early, intuitively navigate various devices and apps and mostly communicate and solve their everyday problems using DT and the internet. The experience, skills, and needs that Generation Alpha students bring to school are unique and cardinally differ from previous generations of students (Rose & Thomas, 2024), therefore students learning (in the context of the present paper in the subject of primary science) starts from new and novel starting points and is based on different (compared to previous centuries) experiences, therefore the previous teaching methods and subject curriculums should be updated (Mukul & Büyüközkan, 2023). The authors of the present article also agree with the thesis, that education and schooling should change as rapidly as ever before to meet the current needs of students and society; in other words – the education system must undergo digital transformation (Huang et al., 2024). Also, with the introduction of advanced generative artificial intelligence solutions (GenAI), DTs can perform tasks that they have not been able to do before. In the educational context - numerous instructional tools, which previously have been exclusive for teachers (e.g., dialogue with students, feedback) can now be carried out in an acceptable quality by DTs (i.e., GenAI solutions; Giannakos et al., 2024).

From the authors' perspective, such a situation significantly changes schooling and more particularly teaching and learning of various school subjects. In the present paper, we operationalise the "Theoretical Framework for Digital Teaching and Learning Transformation" we have proposed before (Figure 1, (Burgmanis et al., 2024)), to create a typology of concrete teaching and learning models that include the digital dimension, further referred as blended learning (BL) models. In short - in the present

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position paper we attempt to answer the following research question: how to operationalise the digital transformation of teaching and learning into concrete models that can be used in primary science teachers' professional practice?

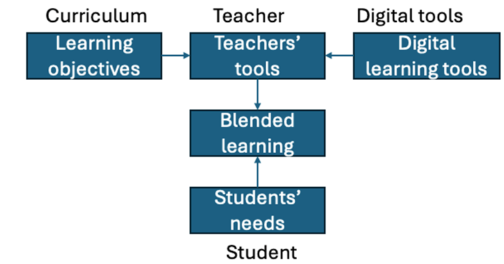

Figure 1: Theoretical Framework for Digital Teaching and Learning Transformation

2 CONCEPTUALIZATIONS OF INTERACTIONS BETWEEN TEACHER, STUDENT, CURRICULUM AND DIGITAL TECHNOLOGIES

One classical model for conceptualizing interactions throughout the schooling process is the didactic (often referred also as instructional) triangle. The basic model consists of a triad: student, teacher, and curriculum as vertices in a triangle; the mutual interactions between them are represented as the sides of a triangle. As the DTs emerge and the transformation advances, multiple authors have proposed to add a DT dimension to the instructional triangle – to transform the triangle into a triagonal pyramid (Figure 2, (Dasari et al., 2023)).

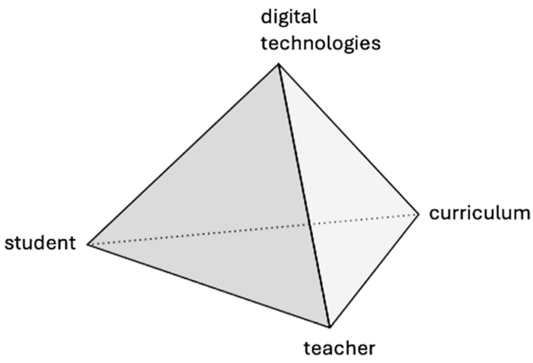

Figure 2: The didactic pyramid.

From our perspective, in the third decade of the 21st century, the digital technology dimension has become equivalent to the triad of student, teacher and curriculum. One example, which justifies this thesis in a science subject context, is students' digital experience before the schooling process. For example, nowadays students first experience digital maps before paper maps – digital maps with precise persons' locations are present in various vehicles, smartphones etc, students design and test constructions and buildings in Minecraft, not in real environments.

In the context of the didactic triangle (or now – pyramid) such students' experience importantly changes both the curriculum (new ideas and skills should be added) and also the ways the teacher presents, and the student accesses the curriculum. Also, the present example of digital maps justifies the presence of the DT dimension in the didactic pyramid – without the DT dimension, neither the curriculum is accessible to the student, nor the teacher can present it to the student.

While digital maps are just one example, the GenAI solutions also massively change the teaching and learning of science subjects as instructional tools, previously exclusive to teachers (i.e., analogies, everyday examples) can be employed by GenAI solutions. This means that students can access GenAI-led instruction and generate curriculum anywhere and anytime based on students' preferences; the importance of the teacher as a translator and preparator of the curriculum for the student decreases (Cukurova, 2024). As the example of digital maps illustrates, the primary science curriculum should change in the digital age. The following paragraph illustrates our perspective on what aspects of the primary science curriculum in the digital age should include.

3 A FRAMEWORK FOR PRIMARY SCIENCE CURRICULUM IN THE DIGITAL AGE

As the complexity of society's demands from science (including primary science) education increases, also the complexity of various science curriculum frameworks increases (Turner et al., 2023). As mentioned before, we see the novel students' experience in the digital world as a key element which influences the primary science curriculum. Besides that, we state the premise, that the curriculum should state goals for the student who has broad experience in the digital world; who daily accesses information, communicates and learns via DT.

Our view on the primary science curriculum in the digital age can be compared with a shamrock (figure 3). The shamrock emerges from the ground – private, national or global contexts, from which students obtain information (learn) by using his or her digital literacy, which consists of digital competence and the ability to learn via DT (Holincheck et al., 2022).

As currently tremendous amounts of information are available to the student, a filter, which distinguishes high-quality information from other information is needed; we see the students' scientific identity as such filter (Vincent-Ruz & Schunn, 2018). At the same time, students' scientific identity is developed by recognition and as students nowadays communicate and recognize each other via DT, we see digital aspects of students' scientific identity also as one of the keys to the primary science curriculum. The three green leaves of the shamrock (which are based on digital literacy, scientific identity and its digital aspects - the trunk of the shamrock) can be compared with key competence areas that primary science education should foster. Such an approach corresponds with the approach of the PISA 2025 science framework (OECD, n.d.) (natural science and environmental science competencies), still, we propose to add the technological and engineering competencies as vital for the digital age (also other countries (Banks, 2024) curriculum include technology aspects). The three competence areas (including 9 concrete competencies in total, please see the green circles in Figure 3) can't be achieved without solid foundations – the three leaves of the shamrock are held by three branches representing natural science, environmental science and technological and engineering knowledge. Besides knowledge, we propose the ability of reasoning (scientific, socio-scientific and engineering) as another key aspect of the primary science curriculum, as for students, GenAI solutions offer answers to various questions instantly and can lead to student learning anywhere and anytime. Still, the solutions do not always produce reliable information. To judge, whether the information is reliable, students should be equipped with core scientific knowledge and core scientific reasoning skills, which the student can use to evaluate the information provided by GenAI (Khalid et al., 2024).

In the further paragraphs, we outline how such a curriculum should be accessed from students' perspective.

4 WHAT ASPECTS BECOME MORE IMPORTANT THAN OTHERS IN PRIMARY SCIENCE LEARNING FROM STUDENTS' PERSPECTIVE?

Both scholars agree and students expect that primary science is learned largely through hands-on and

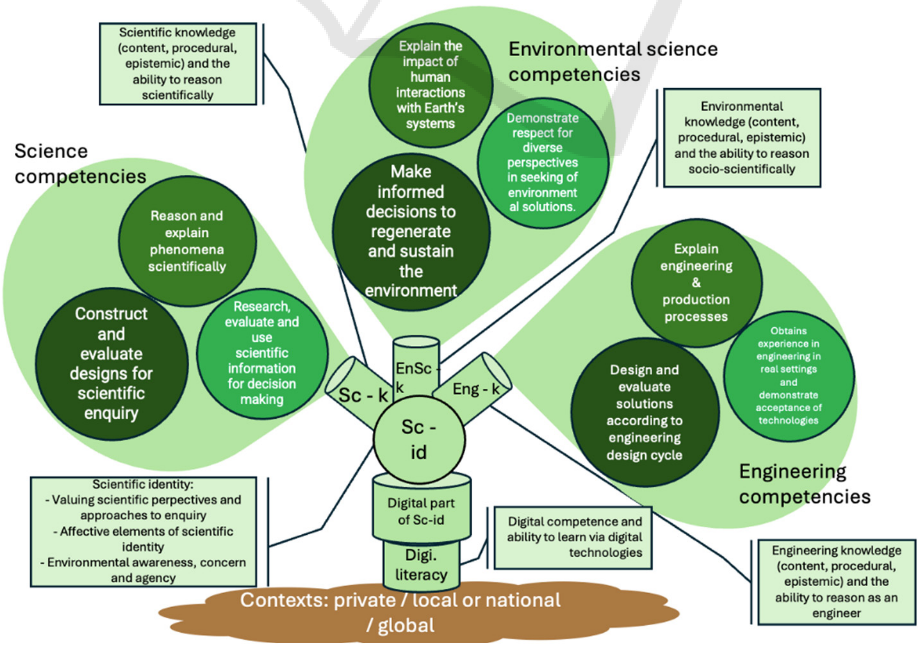

Figure 3: Framework for Primary Science Curriculum in the Digital Age.

minds-on activities in authentic environments (Fitzgerald & Smith, 2016), still the advances of DT have changed the situation. In the last decades, DT has offered possibilities that complement primary science learning and even enable students to achieve more. Digital maps and Minecraft for Education can be once again mentioned as two clear examples.

From students' perspective the use of DT can be viewed twofold (Rezat & Geiger, 2024): 1) the DT make primary science more interesting; 2) my (student) previous experience in remote learning during COVID-19 has been hard and I do not see DT in learning as effective.

In both cases, it is important, that the student learns how to learn with DT, not remain as a passive user of DT either for entertainment or with low cognitive engagement. We propose the idea, that the ability to intentionally use certain benefits of the DT to achieve certain learning outcomes is a key to students' success in the digital age (also in the subject of primary science). We see such skills as AI prompting, and the use of virtual tutors (i.e., Duolingo) as characteristic examples, of where the school should teach certain skills, otherwise inequalities between students may grow.

Recent comparative studies indicate that the duration of students' use of DT is related to their performance in learning in digital environments, therefore, the ways how students can use DT for learning should also be extensively learned in face-to-face settings (OECD, 2024). In face-to-face settings teachers can model the use of DT for learning; students can share mutual experiences, and initial troubleshooting can happen with more ease (Khalid et al., 2024).

In the digital age, students will inevitably spend more and more of their learning time in digital environments, still not only ability to learn via DT influence the outcome of such learning, but also students' self-regulated learning skills and motivation have a noticeable impact (Olokunde, 2023). As students more and more can control the time, pace, and place of their learning, there is also a clear need to support students' readiness for self-regulated learning experiences (Voskamp et al., 2022). In other words – the benefits that digital learning technologies bring can't be accessed if the student doesn't have an intention to use the technology.

The development of self-regulated learning skills requires certain settings – such as where the learning process is goal-oriented, the student has an active role in his learning and has the need to regulate his behaviour and motivation, reflect on his learning and be aware of his thinking processes. As in the case of learning with DT, and also in the case of self-regulated learning, concrete skills are efficiently learned first in face-to-face settings (Kistner et al., 2010).

To summarize - from a learner perspective the benefits of digital transformation in primary science are clear - more choice and voice are given to the student. Skills to learn with DT, self-regulated learning skills and motivation are the key aspects which ensure successful students' science learning in the digital age, teachers should support students with the mentioned aspects and ensure relevant learning experiences. Still, several questions (from teachers' perspective) remain: What are the optimal combinations between face-to-face learning and learning in the digital environment? What, why and how should happen in face-to-face learning (Lyu et al., 2024)?

5 TYPOLOGY OF BLENDED LEARNING MODELS FROM TEACHERS' PERSPECTIVE

Despite the progress of DT, the hands-on and minds-on activities in authentic environments remain the core of primary science teaching, still, as mentioned before, DT are beneficial to primary science teaching; the science teacher does not disappear from the instructional pyramid (Merikko & Kivimäki, 2022).

Science teachers should be supported in this complicated situation where he or she should orchestrate face-to-face instruction, digital tools, an everchanging science curriculum, and students' self-regulated learning and motivation. We see that a typology of various cases (further referred to as models) illustrating different interactions between teacher, student, curriculum and DT as a potential starting for such support. If a clear typology is stated, the teacher according to students' needs and the actual part of the curriculum can choose one or another model and adapt it to concrete lesson scenarios.

We use the term "blended learning models" in the title of the typology as interactions between the elements of the instructional pyramid can occur both in F2F and digital environments.

Previously published proposals for blended learning models view BL from an organisational perspective (Staker & Horn, 2012). The 7 blended learning models (e.g. flex model, self-blended model and others), proposed by Staker & Horn outline the possible combinations of F2F and online learning.

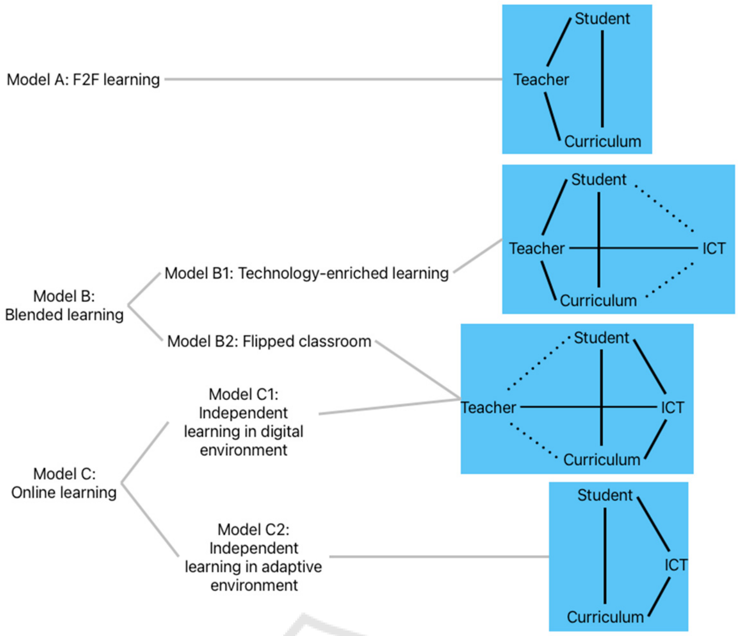

Figure 4. Typology of Blended Learning Models (bold black lines represent strong interactions between elements; dotted lines – weak interactions).

Still, the models, proposed by Staker & Horn don't outline the interactions between students, teachers and DT tools which lead to the desired learning outcomes. In other words, from our perspective, the 7 blended learning models, can't be meaningfully used to operationalise teaching and learning, as the models focus only on organisational perspective, without such conceptualizations as, for example, opportunities which students should face in online or F2F learning to achieve the desired learning goals. Such an approach can be explained by previous limitations of DT in education, which made the teacher role integral in BL.

From our perspective, various models of BL can be distinguished by the availability of instructional tools that can transform, translate and teach the curriculum to students in various learning environments (Figure 4 and Table 1). There are several variations in how instructional tools can be applied with or without the use of DT and F2F interactions between the student and teacher. The instructional tools can be employed either as in "business as usual" - by a teacher who teaches students F2F, or as in the present situation, where generative artificial intelligence solutions "bloom" - via DT.

In the following paragraphs, we outline the benefits of the BL models and their possible impact on the elements of the primary science curriculum framework in the digital age.

To draw the line, where blended learning starts and ends, we start by outlining our perspective on two extremes - F2F learning and independent online learning - and their benefits for primary science.

In primary science F2F learning is essential for providing students with experiences which build on their interest in science and stimulate their curiosity about nature – digital technologies can only hinder the authentic experiences which students encounter in various natural ecosystems (van Eijck et al., 2024). Also, digitalisation and urbanisation hinder students' experiences in nature, which in such a situation the school should compensate, to promote a comprehensive students' view of nature and science (Deehan et al., 2024). In terms of the primary science curriculum framework, F2F learning could benefit students' scientific identity (positive emotions about science) and also engineering competencies (which stem from real-life experiences).

Independent learning in the adaptive online environment – is the extreme opposite of F2F learning. At first glance the model may seem like a utopia – students learn primary science, a subject which should bring joy about natural sciences, only through technology. Nevertheless, the emerging GenAI and virtual and artificial reality solutions can bring this model to reality also in primary science. The first example of how virtual reality in tandem with dialogue with GenAI can be used in medical education to explore the human body, its inner organs

Table 1: Description of the F2F, Blended and Online Learning Models.

F2F/Blended/online learning	Model	The student's learning environment	Use of DT	Instruction	Curriculum
F2F Learning	A	Learning in a real environment	No DT use in the classroom, or DT used only by the teacher	Teacher-led, designed and controlled learning process	Student observes how the teacher represents the curriculum
Blended learning	B1	Technology-enriched learning	Students use DT in the classroom or other settings	Teacher-led learning, with elements of independent student learning	DT are used for curriculum representation, and assessment in a real environment; there are elements of students' learning in the digital environment
	B2	Flipped Classroom	Student learning in a digital learning environment dominates, with the help of digital technologies and face-to-face interactions	Semi-independent learning. Student mainly learns before the F2F lesson.	Curriculum available in a digital learning environment for independent learning, followed by a lesson to extend, comprehend and assess the learning outcomes in a real environment
Online learning	C1	Independent learning in a digital environment	The learner learns in a digital environment using digital technologies	Student Independently manages (controls) learning - at own pace, place, and time (in the learning environment curriculum is proposed by the teacher)	Curriculum available via digital technologies in a digital environment for independent learning (teacher-provided or generated by DT)
	C2	Independent learning in an adaptive environment	The learner learns in a digital environment according to his/her needs	Independently guided learning by DT	The curriculum is adapted to the student's needs by DT (differentiated learning goals and support)

and its systems (Mergen et al., 2024). Such goals are also vital for primary science and with specific adaptations can contribute to the achievement of the goals of primary science curriculum, more particular, scientific knowledge and exploratory competencies.

Models B1, B2 and C1 outline blended learning in which interactions between student and teacher occur both online (synchronously and/or asynchronously) and F2F.

The blended learning models are also valuable for the achievement of primary science education goals in the digital age – various digital representations (i.e., models, simulations) can enhance the view on scientific ideas and also enhance students' scientific reasoning and explanatory abilities (Topping et al., 2022) (elements of science and environmental science competencies from the framework), by illustrating complex processes and/or phenomena that aren't observable by the naked eye or simple instruments.

The flipped learning model– has proven effective for the acquisition of various knowledge as students can access information at their own pace and time and further the f2f learning can deepen the obtained knowledge and clarify misunderstandings (Topping et al., 2022). There are numerous reports, on how digital environments can contribute to the achievement of the goals of primary science curriculum. Several reports indicate the benefits such environments bring to learning through inquiry and/or design. One such example is the use of Minecraft for education – in this virtual world, students can design their engineering solutions and test their appropriability in a complex virtual world. Also, this virtual world can be used for scientific investigations as many natural phenomena are included (Nebel et al., 2016). Digital knowledge-rich environments are also valuable for achieving novel learning outcomes – decision-making (using scientific knowledge and skills) and appreciation of the impact of science on people and the environment, as they provide unlimited opportunities for collaboration, exploration and argumentation (Momani et al., 2023). Still, such complex activities can't be meaningfully achieved without core skills and knowledge (which substantially are acquired through other blended learning models).

To clarify our position – we don't see the four proposed models (figure 1, A to C) as a trajectory for teacher replacement by technologies; we see that the four models complement each other and should be selected by the teacher based on the curriculum aspect which is covered.

6 CONCLUSIONS

In the digital age students who are digital natives bring a wealth of digital skills into the primary science classroom, which can serve as a powerful foundation for the development of scientific identity, knowledge, reasoning and competencies. Integration of a DT, scientific identity and scientific reasoning backbone into the primary science curriculum, not only answers the challenges of the 21st century in the context of primary science but also can inform primary science educators about a logical trajectory of how students' ability to do and use science evolves. At the same time, primary science in the digital age should take into account that students' real interactions with nature and technology are diminishing primary science must also compensate for them.

To access the primary science curriculum in the digital age, the students will spend more time learning with DT, therefore, from students' perspective ability to meaningfully learn with DT and self-regulated learning skills and motivation are the key aspects which become more important than others. In addition to F2F teaching and learning (which is and will stay dominant in primary science) blended learning models are gaining ground in the digital age, which differs not only by the use of DT, environments and instructional tools but also by the presence of students and/or teachers. Flipped learning, learning in virtual worlds, and technology-enhanced learning are three examples of blended learning models which solve certain problems that students and teachers face when learning F2F.

Minecraft for Education and the use of digital maps are two examples which illustrate how the use of DT in blended learning settings can now enhance primary science teaching and learning by proposing the opportunity to reach new and novel and in the same time for the digital age relevant goals both by the student and the teacher.

Most importantly, we want to highlight that DT should be used in primary science in cases where objective problems in F2F teaching and learning exist, to solve these problems. Excessive use of DT can cause additional problems, and hinder the acquisition of goals, which can be meaningfully reached in F2F teaching and learning.

We see the proposed frameworks and typologies as a starting point for further investigation, by the outline of existing situations and practices both in science teaching and learning. In the context of science teaching, teachers' existing practice, self-efficacy, confidence and competence can be further explored. Parallelly in the context of science learning, students' accessibility to up-to-date science education, its impact and student agency and voice can be further explored.

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