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Science and technology literacy, thinking and STEM development

The science of scientists must converge with the science taught in schools to make it accessible.

Education is an activity where context is as important as the body of knowledge it conveys. Individually, the context is determined by the perennial developmental needs of human beings (physical, psychological and relational); socially, globalised knowledge societies have a framework steeped in science, technology and innovation as critical factors of social and occupational development. In this context, science education must contribute to the integral development of responsible and educated citizens, boosting their capacity to adapt to globalised requirements and changing needs in the personal, social and labour spheres. Delors defined those exigencies as learning how *to know, do, be* and *live together*.

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Research in science didactics at different educational levels is subject to the tension between tradition and innovation to achieve a significant contribution to these goals, providing the concept of scientific (and technological) literacy - STL - for all as one of the most relevant in recent years. STL is seen as consisting of three components: scientific and technological concepts and processes (*knowledge and know-how*), meta-knowledge about how science and technology construct and justify their knowledge and artefacts (*scientific know-how*) and social justice in STL for all (equity, access, etc.).

Specialists differ in their conceptualisations of ACT. For example, coinciding with the European and Spanish educational framework, the PISA programme (OECD) proposes ACT as the vital competence for understanding scientific and technological practice in the natural world -including science and science-based technology-: ATC plus its three sub-competencies: explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. All three operate on conceptual, procedural and epistemic knowledge. Epistemic knowledge refers to how scientific practice is and how it works: the status of scientific conclusions and the meaning of foundational terms (e.g. data, explanations, hypotheses, laws, theories, etc.), and coincides with the second ACT component.

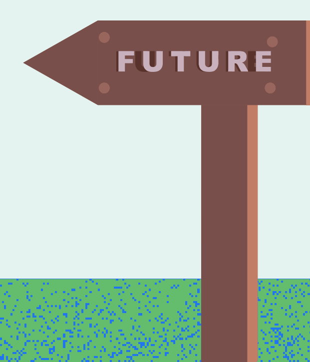
SCIENCE AND TECHNOLOGY LITERACY FOR ALL

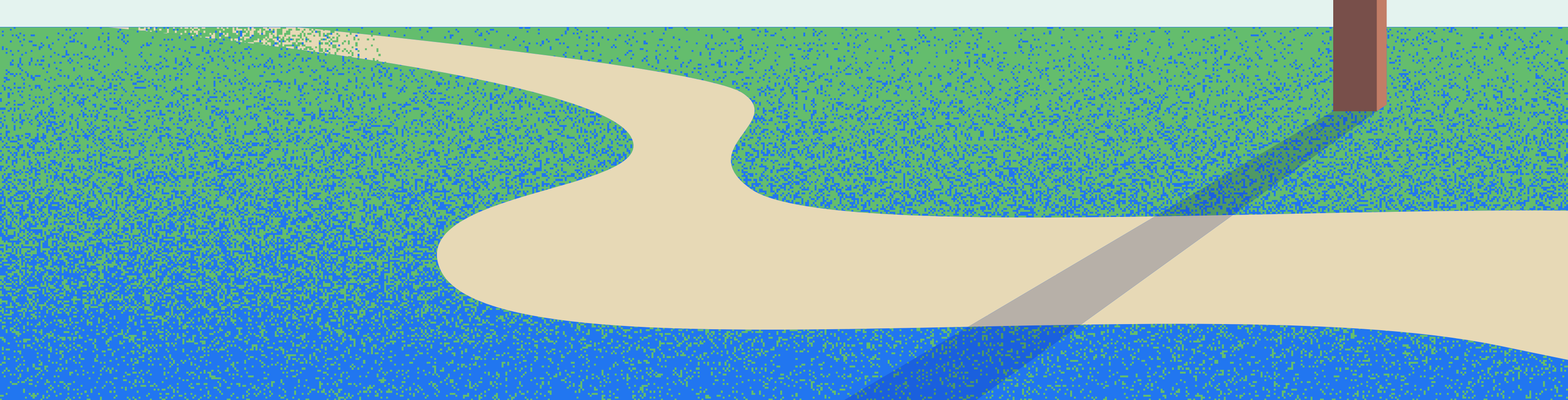
Teachers teach the core curriculum in their classrooms (competencies, objectives, content, assessment criteria), which involves making important didactic decisions (resources, methodology, activities, timing, assessment, etc.). Didactic content knowledge (TOT), or professional teaching knowledge, summarises teachers' competence to develop the curriculum; it involves the ability to dynamically combine scientific, didactic and psycho-evolutionary expertise, together with procedures, attitudes, and values achieve effective and coherent professional performance-oriented to ACT.

Scholars break down teacher TOT into sub-competencies, which are concrete and interactive with each other: knowledge of a subject and its curriculum, curriculum planning, classroom management, assessment of learning, inclusion and equity, community engagement, professional development, digital skills, linguistic communication and ethical commitments. Some authors propose the concept of didactic transposition to describe the transformation of scientific ideas by the TOT to make them teachable as ACT in school science; consequently, school science is epistemologically distinct from the science of scientists.

Teachers are free to make many developmental decisions, such as teaching methodology(ies). Of course, didactic research must inspire these choices, but we also know that teachers' beliefs are crucial and give rise to innovative trends and fashions favouring specific methodologies.

Education has produced a diversity of methodological proposals on how to teach. However, teacher-centred methodologies (mainly master classes) and student-centred methodologies (projects, centres of interest, preconceptions, globalisation, personalisation, etc.) form a fundamental polarity. On the other side, some other methods are currently in vogue in professional networks (problem-based





learning, research-based learning, evidence-based learning, thinking, competence-based learning, service learning, cooperative learning, flipped classroom, gamification, design thinking, universal learning design, etc.).

THE EMERGENCE OF SKILLS AND CRITICAL THINKING

In addition, the turn of the millennium has spawned a movement called 21st-century skills. It advocates the combined development of specific skills such as critical thinking (problem-solving, decision making, synthesis), creativity, cooperation and communication because they are considered essential to meet the personal, social and occupational needs of 21st-century citizenship.

The didactics of science assumes the previous ones and suggests other differentiated methodologies. By 1970, a procedure was already proposed: teach the four scientific disciplines (physics, chemistry, biology and geology) in an integrated way. By 1980, discovery learning advocated that students should discover scientific concepts through their autonomous work in the classroom. At that time, and based on the fundamental turn in the philosophy of science, the Science-Technology-Society (STS) movement emerged: it proposed a broader integration (science with technology plus society). It included teaching the nature of science (epistemic knowledge), particularly socio-scientific topics (a branch of STS), developing aspects of scientific thinking, argumentation, problem-solving, and projects.

Recent studies suggest a meaningful connection: learning epistemic knowledge requires students to master specific critical thinking skills. Considering that critical thinking and scientific thinking share many common skills, this conclusion is not surprising, but its implications are nuclear: the two forms of thinking complement and feed off each other, thereby enhancing their impact on learning by making thinking-based teaching a central focus for ACT.

To all this, it should be added that the so-called digital competence and media (or digital) literacy could form an integrated part of this ACT because they would naturally be included in the T for technology. In line with this idea, the Council of Europe in 2016 called for the joint development of media literacy, digital competence and critical thinking (an expression of 21st-century competencies).
In sum, critical thinking skills (creativity, argumentation, problem-solving, decision-making, and evaluation) have a broad spectrum of transversality regarding competencies, disciplines, and methodologies that make them particularly important for education and TCA.

STEM combines familiar academic concepts and integrates school, community, work and business.

THE STEAM APPROACH

In recent years, several countries have noted that higher studies in science and technology do not meet the needs of the productive system, neither in terms of numbers nor the training of graduates. Moreover, training is excessively disciplinary and poor in skills that are increasingly in demand in globalised jobs, such as transversal skills (creativity and critical thinking) and dispositions (openness, collaboration, communication and teamwork). As a countermeasure, the National Science Foundation supported some integrated, interdisciplinary, educational activities. The US administration transformed them into a policy initiative called under its acronym: STEM (science, technology, engineering, mathematics). It was planned to achieve higher educational quality, develop students' cross-cutting skills and attract more students to STEM, especially women and minorities.

As a consequence of the received economic and political support, the STEM label has become popular. It has also taken hold in many school environments, both as an educational fad and a mark of innovations aimed at a more interdisciplinary education. STEM combines familiar academic

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concepts (the integration of STS) and, in addition, integrates school, community, work and business so that STEM learning benefits from this global integration. However, there is also no shortage of critical voices that, from a conceptual perspective, consider that STEM does not provide original specific content.

In addition, some educational institutions have generated initiatives to broaden the interdisciplinary scope of STEM, incorporating new areas into the acronym. Thus, the US National Academies of Sciences, Engineering, and Medicine have included the *M* for medicine, and, for years now, their publications have referred to STEMM. But the most striking addition is the humanities, adding *A* for arts (music, design, literature and fine arts) to produce the expanded acronym STEAMM. The *A* in STEAMM prompting emphasis on creativity and innovation, problem -or project-oriented: a real-world view of education in all disciplines that develops curiosity (asking questions), communication (creating answers, designing solutions) and the use of design thinking and artistic skills, while helping to bridge the long-standing gap between science and humanities. A recent study of academies provides an optimistic vision for developing STEAMM and conceptualises progressive discipline integration as shallow (multidisciplinary), medium (interdisciplinary) or deep (transdisciplinary).

IN CONCLUSION

The market's soup of educational methodologies should not prevent us from clearly seeing the educational forest. Critical thinking skills (cognitive dimension), complemented by proactive dispositions and attitudes towards all educational elements (affective dimension), and incredibly cooperative and teamwork, are indeed transversal competencies for any learning, competencies or educational objectives. In all subjects and methodologies, thinking skills must act as interdisciplinary vectors (analogous to STEAMM or STS) towards quality education and direct into deep learning, making both learning and disciplinary competencies (ACT and others) meaningful to achieve their transfer to personal, social and working life.

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