STEM education and the curriculum: Issues, tensions and challenges

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1949 (12th session of the ICE, *Introduction of natural science in primary schools*) → develop the scientific spirit of observation and experiment; develop the intellect by the use of activity methods based on observation and experiment and by undertaking group research; foster all activity tending to protect and conserve nature; correlated with the teaching of other subjects if taught as separate subject.

1952 (15th session of the ICE, *Teaching of natural science in secondary schools*) → modern life requires everyone to have a common core of basic scientific knowledge and the study of natural science is also important for the development of moral qualities; important for adopting a scientific method and develop general culture and sensitiveness; pay attention to regional needs and potential, focus on actual problems, allow teachers to use local resources, use activity methods and start from concrete cases instead of abstract laws; safeguarding nature; encourage students to express their thoughts in correct and precise language; taught by well-qualified teachers and in coordination with other subjects.

*Source:* Recommendations of International Conference on Education (IBE archive and webpage).
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1950 (13th session of the ICE, Introduction to mathematics in primary schools) → essential for objective and accurate judgment; exercises and problems be taken from everyday life and related to the child’s environment; taught step by step also paying attention to verbal expression and correct vocabulary; allow for practical and group activities; associated as closely as possible with other subjects; is one of the most difficult subjects.

1956 (19th session of the ICE, Teaching of mathematics in secondary schools) → undisputed cultural and practical value and an important role in scientific, technical and economic progress and in world prosperity; essential part of the education of a modern person; no reason to believe that girls are less able to study mathematics than boys; necessary to understand the real-life problems raised by technical, economic and social activities; also serve to increase accuracy, clarity and concision of language; learning by active participation and being aware of its applications; allowing students to question and discover and to develop their reasoning skills instead of learning by heart, foster individual research as much as team work; teachers acting as leaders and guides.

Source: Recommendations of International Conference on Education (IBE archive and webpage).
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Regional conferences of Ministers of Education and those responsible for economic planning (Singapore, Mexico City, Harare, Abu Dhabi, Sofia in the 1970s and early 1980s) stressed the importance of adequate science education → equip future citizens for an increasingly scientific and technological world, offering an opportunity to explore their environment logically and systematically.

1984 (39th session of the ICE, *Renewal of primary education in the perspective of an appropriate introduction to science and technology*) → develop scientific attitudes, creativity, a critical approach, objectivity and precision, and acquire basic scientific and technical knowledge; develop positive attitudes towards science and technology, understand and be sensitive to the purposes and social implications of new technologies and scientific applications, develop sound attitudes to nature; the approach should be as interdisciplinary as possible, based as far as possible on active methods, observation and experimental methods; ensure integration of concepts and ideas of science and technology into the content of other subject areas; out-of-school experiences and extra-curricular activities should be organized.

*Source: Recommendations of International Conference on Education (IBE archive and webpage).*
Science and technology education increasingly emphasized

“A sound foundation of science and technology education among the citizens of a country is an absolute prerequisite for its economic development and ability to compete with other nations” (UNESCO-IBE, 1987)

“Value creation depends increasingly on a better use of knowledge, whatever the level of development, whatever its form and whatever its origin” (UNESCO 2010)

“More engineering professionals will be required to address the sustainable development issues, for example the development of renewable energy sources, advancements in technology, solutions for sustaining the environment and improving healthcare” (UNESCO 2010)

STEM-related issues: a central concern of policy makers

STEM disciplines are increasingly viewed as essential for work and citizenship (‘science for all’). Economic policy agenda driven by the need to enhance the quality of human capital in general and enlarge the high skill base for research, innovation and effective response to technological change → ensure long-term, sustainable economic growth and competitive advantage (growth in terms of the overall wellbeing of the population and not only the wealth of economy)

STEM-based learning and disciplines are also seen as essential to support effective learning in non-STEM areas (creativity, critical thinking, problem solving, communication, collaboration…) and to become competent and capable citizens in a technology-dependent society and globalized world
STEM policies: some common features

→ Generally conceived in human capital terms, but also with a focus on increasing scientific and technological literacy

→ Promote a positive image of science and mathematics (and STEM) and increase public knowledge and awareness of science

→ Support increased student engagement and participation (in school-based and tertiary-level STEM disciplines and workforce) as well as increased learning achievement in STEM disciplines

→ Address gender disparities and under-representation of specific groups in STEM disciplines and workforce

→ Establish coordination mechanisms across ministries, agencies, organizations, stakeholders, programmes and initiatives
**STEM: evolving curricular and pedagogic approaches**

<table>
<thead>
<tr>
<th>From traditional...</th>
<th>to innovative approaches</th>
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<td>Discipline-based</td>
<td>Integrated, interdisciplinary</td>
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<td>Integrated, interdisciplinary</td>
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<tr>
<td>Knowledge-based &amp; content-led (memorizing abstract concepts)</td>
<td>Practice-based &amp; process-led (solving real-world problems)</td>
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<td>Didactic transmission (passive, rote learning)</td>
<td>Interactive, engaging (active, experiential learning)</td>
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<td>Individual work</td>
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<td>Reproduction (simply applying procedures)</td>
<td>Adaptation / Transformation (acting creatively)</td>
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<td>Conformity / Compliance</td>
<td>Critical interpretation &amp; action</td>
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<tr>
<td>For future scientists (somewhat ‘elitist’)</td>
<td>For future citizens (‘science for all’)</td>
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Example: integrated science and science subjects (early 2000s)
STEM: issues, tensions and challenges (1)

→ STEM is an heterogeneous cluster of subjects (it may include health professions, agriculture, computing, medicine, environment-related fields, depending on the country); issues are not necessarily the same for each discipline

→ There is a lack of international standardized data, especially for the upper secondary level STEM fields of study

→ Paradox of decreasing student interest and participation in STEM disciplines the more the country is developed and industrialized and the more they progress in education

→ There are gender disparities and imbalances and issues related to limited participation of specific groups (for example, indigenous people) in STEM study and occupations; stereotypes and well-rooted beliefs (e.g. STEM disciplines are hard and only for the talented, mathematics is only for a few)

→ STEM education alone is not enough to enable and support innovation
Knowledge (content) becomes rapidly obsolete and outdated; at the same time, the level of detail within each discipline has become unmanageable: defining the ‘basics’ is challenging.

Innovation increasingly requires collaborative and interdisciplinary knowledge (and in a globalized world this involves intercultural understanding and collaboration).

Integrated and interdisciplinary approaches to STEM disciplines can be problematic (teachers insufficiently prepared, strong traditional disciplinary boundaries, low status of integrated learning areas compared to single subjects…).

Tensions: between early and late specialization/streaming; between early differentiation into several disciplines and integration into broad learning areas; between traditional pedagogical approaches and competency-based approaches…
 Median instructional time (in accumulated number of hours) allocated to mathematics and science over the first nine years of schooling, by EFA region (early 2000s, 113 countries)
How to:

- Define the ‘basics’
- Select the content
- Deal with integration and specialization
- Promote effective collaboration between scientists and teachers
- Attract and retain sufficient numbers of STEM graduates into the teaching profession
- Ensure that decisions regarding STEM disciplines are taken in a context of comprehensive approach to the curriculum as a whole
In recent years different organizations, including partnerships and consortia, have defined and endorsed key competences or core skills frameworks using different emphases, groupings and terminologies. This may contribute to generating ambiguity and uncertainty.
key competences, competencies, competences, cross-curricular competencies, generic competencies, transversal competencies, core competencies, basic competences…

essential skills, basic skills, foundation skills, core skills, cross-curricular skills, life skills, key skills, 21st century skills, 21st century competencies…

general/essential capabilities, transversal capacities, citizenship skills, overarching learning outcomes…

cognitive and ‘non-cognitive’ skills

ways of thinking, ways of working, tools for working, living in the world

4 Cs, 7Cs

soft and hard skills
Why competences?

- Profound transformations in the economy and society (knowledge economy)
- Globalization (commerce, finances, economy, migrations... increasing interdependence)
- ICT development
- Progressive shift of attention → from educational inputs to outcomes (from access to learning)
- A more integrated approach to learning → not only academic knowledge and cognitive development, but also social and emotional learning, values, attitudes...) and growing attention devoted to the applied dimension of what has been learned
• Most competences frameworks emphasize: Collaboration, Communication, Digital literacy-ICT, and Social and civic competences;

• Many frameworks also make reference to: Creativity, Critical thinking, and Problem solving.
The most emphasized competences (88 countries)

- Communication
- Social competence
- Problem solving
- Creativity
- Digital competence (ICT)
- Numeracy
- Civic competence
- Collaboration
- Critical thinking
- Entrepreneurship
- Literacy
- Basic competences in science and technology
- Information processing and enquiry skills
- Learning to learn
- Environmental awareness
Issues relating to competences

- Depending on the context, the same competences can be interpreted in many different ways (‘critical thinking’, ‘creativity’)

- Many competences are viewed as being, to some extent, transferable, even if it is not yet clear the range of contexts across which these competences should transfer and how teachers can support learners in transferring competences across disciplines

- Some competences tend to be seen as closely related to traditional subjects, while others tend to be viewed as more transversal in nature: the distinction between subject-based and transversal competences is not yet clear

- The role and place of competences within the existing discipline-based curriculum and how core subjects and other subjects are expected to contribute to their development: still an open and controversial issue
Competences: pending challenges

- It is necessary to change the organization of the teaching and learning process as well as teacher education and professional development (if teachers have to support students in developing competences, they are expected to have acquired those competences).

- Need to establish and implement new assessment systems (personal attributes and attitudes are rarely assessed, and the focus is still concentrated on knowledge and skills in a few disciplines).

- It is essential to assess all the components of a competence (knowledge, skills, attitudes and values) to the greatest extent possible in the range of ‘real-life’ contexts.
An approach to curriculum integration

Typically cross-cutting/cross-curricular themes or issues are viewed as a means to:

- reduce fragmentation and connect programmatic content across disciplinary boundaries
- enrich the curriculum without overloading it through the introduction of additional teaching subjects
- facilitate interdisciplinary thinking and collaborative learning
- promote teamwork among teachers from different disciplines and facilitate collaborative approaches to planning learning experiences (especially in general lower and upper secondary education)
- deal with issues that are relevant to students’ future and also contribute to the development of transferable competences
Some issues relating to the implementation of cross-curricular themes

- Quite often teachers already have to deal with a ‘congested’ or overloaded curriculum: difficult to find enough time and space for cross-curricular themes

- Teachers, students and parents may have the perception that these themes are an addition, and therefore not really relevant, especially if what students have learned is not formally assessed or is not a component of high stake examinations (which is frequently the case)

- Limited teacher awareness, experience and expertise may represent a sizeable obstacle to the implementation of an interdisciplinary or multidisciplinary approach

- At the secondary level, the well-rooted disciplinary structure of the curriculum and the discipline-based qualifications of teachers can represent a powerful barrier to cross-curricular teaching and learning
Challenges

- Necessity of adopting and implementing a holistic approach to learning
- Need to consider the applied dimension of knowledge (what we know is as important as what we can do with that knowledge)
- Necessity of revising the traditional structure of the curriculum, the organization of learning experiences, the teaching approaches, and the assessment systems
Thank you!
Terima kasih!

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