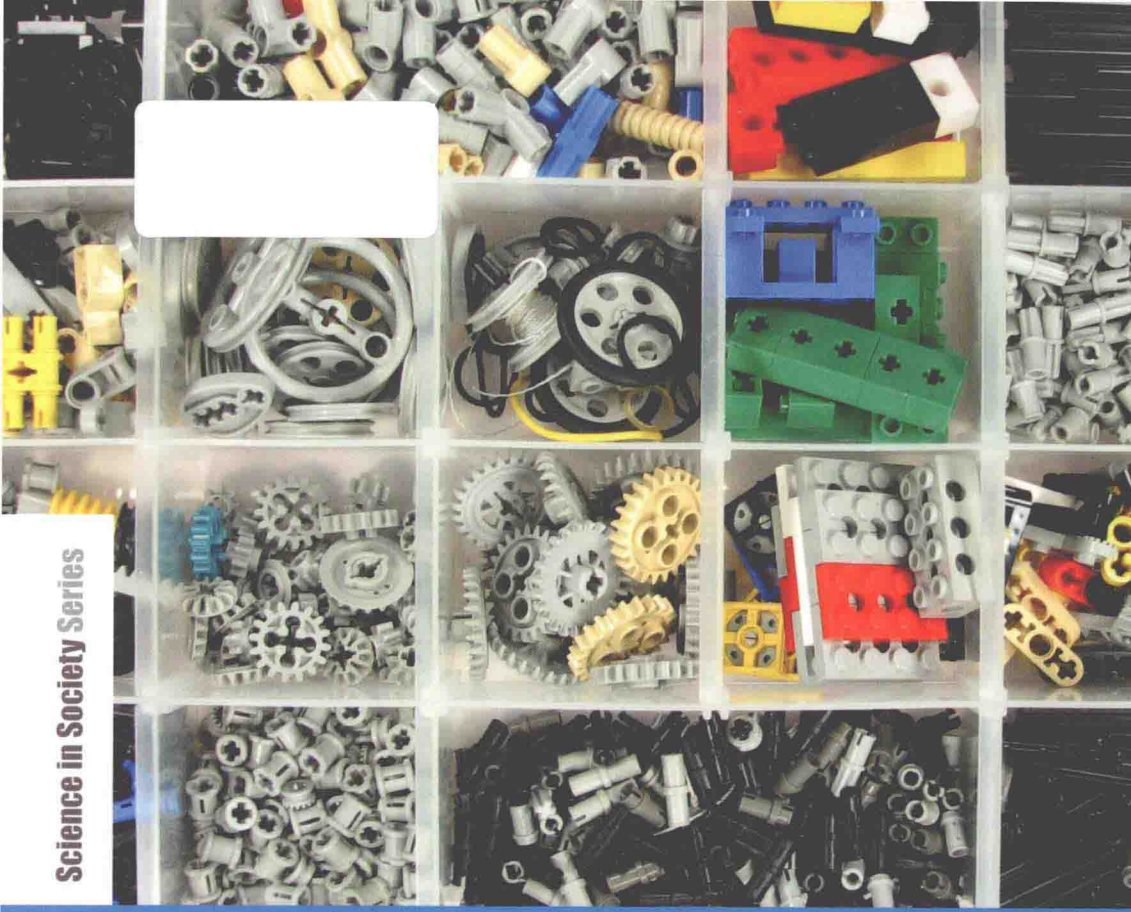

Science in Society Series

# INTERNATIONAL SCIENCE AND TECHNOLOGY EDUCATION

## EXPLORING CULTURE, ECONOMY AND SOCIAL PERCEPTIONS

EDITED BY ORTWIN RENN, NICOLE C. KARAFYLLIS, ANDREAS HOHLT AND DOROTHEA TAUBE

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# International Science and Technology Education

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# International Science and Technology Education

Education in science, technology, engineering and mathematics (STEM) is crucial for taking advantage of the prospects of new scientific discoveries initiating or promoting technological changes, and managing opportunities and risks associated with innovations. This book explores the emerging perspectives and methodologies of STEM education and its relationship to the cultural understanding of science and technology in an international context.

The authors provide a unique perspective on the subject, presenting materials and experiences from non-European industrialized as well as industrializing countries, including China, Japan, South Korea, India, Egypt, Brazil and the USA. The chapters offer a wide scope of interpretations and comparative reviews of STEM education by including narrative elements about cultural developments, considering the influence of culture and social perceptions on technological and social change, and applying innovative tools of qualitative social research.

The book represents a comprehensive and multidisciplinary review of the current status and future challenges facing STEM education across the world, including issues such as globalization, interdependencies of norms and values, effects on equity and social justice as well as resilience. Overall the volume provides valuable insights for a broad and comprehensive international comparison of STEM philosophies, approaches and experiences.

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# Introduction

*Andreas Hohlt, Nicole C. Karafyllis, Ortwin Renn and Dorothea Taube*

## International STEM education—rising in importance and significance

Whether digitalization, nanotechnology, renewable energies or wireless communication–science and technology are the key factors in global change. Education in STEM (science, technology, engineering and mathematics) is thus a main source of technological development, promising to enhance national wealth and social welfare.

The Western world has long been seen as the cradle of modern approaches to science education and served as a model for STEM education worldwide, somehow justified by what is referred to as 'scientific progress' and 'modernity.' However, the last decades have also seen a strong rise in scientific output by non-Western societies, often followed by new political priority-setting and alternative methods of scientific investigation and inquiry. STEM education as a tool of technologization and social advancement has thus led to new variations on the Western model and innovative, culture-based forms of STEM education in Asia, South America and the Arab countries. In addition, the United States and European countries face their own challenges in the field of STEM education, such as motivational problems leading to inadequate student recruitment, underrepresentation of women and minorities or drawbacks from adapting to a widely internationalized working space—problems that seem partially resolved or do not even necessarily exist in some non-western nations. Given these new developments, the learning experience is starting to become mutual rather than one-sided; and countries from all parts of the world can benefit from a direct exchange of approaches and experiences.

The debate on STEM education as a subject of international comparison and cross-cultural analysis started in the second half of the twentieth century and was an integral part of the overall pursuit of scientific achievement during the Cold War. One of the first international studies on educational research to take into account STEM education was known as the 'Pilot Twelve-Country Study' and was conducted in the USA, several European countries and Israel (Foshay *et al.* 1962). Since then, more and more countries have been included and a vast amount of literature has been produced based on projects such as the First International Mathematics Study (FIMS), Second International Science Study

(SISS), Relevance of Science Education (ROSE) or Trends in International Mathematics and Science Study (TIMSS) and PISA (see e.g. Husén 1967, Eckstein 1982, Rosier and Keeves 1991, Sjøberg and Schreiner 2010, Martin *et al.* 2012, OECD 2014).[1] Research in this area (OECD 2014) was also fostered by the anticipation of the various challenges STEM education would have to meet in a globalizing world, and this led to further studies and considerations. The most important of these challenges as identified by this publication are as follows:

*Globalization:* How can STEM education prepare young professionals to respond to the far-reaching globalized challenges of our time? In a world of interdependency, acceleration and the far-reaching and often-irreversible consequences of human interventions, as in the example of climate change research and policy, STEM and STEM education have to meet new demands with respect to problem grasping and problem solving.

*Interdependency*: How can science, technology and society better interact and mutually inspire each other's development? In the editors' view, STEM education should lead to a more technologically literate civil society and to an improved capacity building in interdisciplinary education and science communication. There is still no clear recipe for how scientific and technological literacy can be linked to cultural and social self-images of different societies and how this interaction can be made productive for economic as well as cultural objectives.

*Norms/Values*: How can STEM education include insights from ethics, risk assessment and the histories of science and technology? Science and technology are not goals in themselves; they are developed to serve human needs, to improve our knowledge about the impacts of human actions on nature and society and to meet moral objectives and principles.

*Motivation*: How can young people be motivated to study STEM and to pursue a professional career in the STEM field? Which types of motivation exist, and how should young people be addressed accordingly to their type of motivation?

*Employability*: How can job opportunities be assured and—in particular for less industrialized countries—how can trust in home-grown graduates be strengthened?

*Equity/Equality*: How can we reach a more balanced proportion of women and other underrepresented social groups among STEM students, graduates and professionals?

*Flexibility/Resilience*: How can educational systems be flexible enough to adopt new teaching methods and develop the role of the teacher?

This book is an attempt to address these issues from a comparative but qualitative international perspective. To our knowledge, there is no other study available that addresses STEM education and its main challenges in such a broad international and extra-European perspective. Usually, particular issues within the overall field of STEM education are analysed in studies focusing on one country exclusively, or from a comparative perspective focusing on a larger regional context or a selection of a limited number of countries (e.g., Bauer, Shukla and Allum 2011, or the project EQUALPRIME[2], research undertaken by the Centre for Research in Education in Science, Technology, Engineering and Mathematics at King's College in London[3] or the International Centre for

Classroom Research[4]). Rarely is STEM education, its characteristics and its challenges discussed comparatively within a broader framework, and when it is, the comparison is often triggered by economic criteria, such as the countries of the OECD and with a primary focus on quantitative data. Of course, all these approaches provide valuable information. However, they tend to leave the readers and decision-makers with a bare-bones approach to educational data that does not produce a wider meaning for interpretation or comparative review. In contrast, this book includes narrative elements, descriptions of country situations from different scientific disciplinary backgrounds, the influence of 'soft factors' such as culture and social perceptions, and innovative tools of qualitative social research such as the Delphi study.

The present study is a first step in expanding the international view on STEM by collecting materials and experiences from non-European industrialized as well as industrializing countries. Therefore, it by no means represents a complete and finalized picture of STEM in the world, but rather provides useful components and insights for a broad and comprehensive international comparison of STEM philosophies, approaches and experiences.

## International spotlights in a comparative perspective: this volume's approach

This book explores new and unusual perspectives and methodologies of STEM education based on special investigations into STEM structures in the Arab GCC-countries, Brazil, Egypt, India, Japan, South Korea and the United States of America. China was one of the study's countries of focus from the beginning, but although we included it in all expert talks, workshops and in the Delphi study (see Chapter 14), we were regretfully unable to include an expert chapter on the STEM-education situation of China in the present publication for reasons beyond our control.

The seven countries and regions were identified for reasons of—extra-European—geographic representation, but also for reasons of specific relevance as global players with recent STEM education reforms or as quickly industrializing countries with a lot of interest in STEM advancements. The book unites a multitude of interdisciplinary perspectives on STEM education in the different countries and regions, bringing together internal perspectives of authors who are citizens of or working in the respective countries, as well as external evaluations and perspectives of international external experts.

Understanding and comparing different national approaches to STEM education quickly raises the question of the relationship between the universality of science and cultural or national differences, which is discussed in the first part of the book: *STEM education between universalism and cultural relativism*. From two different perspectives, Randolf Menzel, Heinz Duddeck and Nicole C. Karafyllis explore the question of to what degree science education is characterized by the culturally invariant laws of nature and/or complemented by cultural discursivity, e.g. cultural specifications, social validations of knowledge and traditions of teaching.

The text by Randolf Menzel and Heinz Duddeck on *Universals in STEM education* (Chapter 2) is structured as an interview and discusses aspects that have universal relevance within the overall field of STEM education. For instance, there is a broad consensus that scientific method cannot be determined by national cultures or preferences. The core standards of experimental research as a necessary prerequisite of reproducibility of results do not vary between, for example, Brazil, Egypt and the United States. Additionally, the acceptance of international assessment projects such as PISA, which provide comparative data on young people's skills and competences in different countries, points to the importance of a universal quality of STEM education.

Still, there might be important differences in the structure and process of how discourses on knowledge are organized and shaped by national patterns and cultural worldviews. What is socially accepted as a valid stock of knowledge may differ culturally, as may the ways scientific knowledge co-exists with other knowledge forms, such as religion.

In her article on *Why 'technology' is not universal—philosophical remarks on the language and culture issue of STEM education* (Chapter 1), Nicole C. Karafyllis explores the different meanings surrounding the concept of technology, using the example of the Arab world. In contrast to highly industrialized countries, the culture of technology in the Arab world is not driven primarily by functionality, but by beauty or public utility. In this context, artefacts from the West are not simply imported as given objects, but are adjusted to the different cultural context. Furthermore, the author illustrates how concepts of technology that strongly relate to arts and craftsmanship leave traces in the language, leading back to cultural traditions and norms that have historically accompanied the making and usage of technology in specific regions.

In view of the importance of the specific cultural and national context, it becomes clear that even though STEM is rooted in modelled universalities and in internationalized scientific methodology and language, STEM education always has a social dimension. It is embedded in regional cultures and influenced by social representations, by a given political and economic structure, and by narratives woven through a cultural fabric that might or might not interconnect people's views on STEM across national borders.

The second part of the book, *STEM education worldwide: perspectives on situations in six countries*, provides background material for how STEM education is organized and structured in six countries (Japan, South Korea, India, Egypt and Gulf region, Brazil and the USA), explains the cultural background of these approaches and reports on the experiences and outcomes that each national approach has produced. Articles in this section provide a comprehensive study on each country written by an expert from the specific country followed by a shorter contribution that sheds light on a particular aspect in the field of STEM education of the country.

Japan, which is the first country discussed, faces similar challenges to several Western societies when it comes to insufficient recruitment of young STEM professionals, especially women. In his article *The shift in public perception of science and science education in post-war Japan* (Chapter 3), Takuji Okamoto

focuses on how, historically, Japanese science has developed a self-image. From this angle, he establishes links to the contemporary situation of STEM education. He shows that culturally and historically rooted changes in social perceptions of science and in human relationships to nature can correlate with changes in the perception of STEM and in whether young people choose to invest in it.

In her article *Gunpla robot toys and the popularization of robotics in Japan* (Chapter 4), Cosima Wagner offers a closer look at the specific role of robotics in Japan. The author shows that robot figures are deeply embedded in popular culture in Japan and have been used to trigger interest and positive attitudes towards science and technology in the Japanese population. These insights highlight the importance of specific historically and culturally based priorities and developments and their role in the field of STEM education.

Jung-Ok Ha also applies a historical approach in her article *From national mission to what? Shifts in the implication of science and technology in South Korea* (Chapter 5). Using the example of the Korean Advanced Institute of Science and Technology (KAIST), the author discusses the historical development of science and technology in South Korean society. She characterizes the current status of science and technology in South Korea as 'transitional,' since past images of science and scientists have lost their significance and popularity and no replacement of these is in sight. A nation that has emerged as a major player in science and technology (e.g. through Samsung) has become insecure about its own role in the STEM fields—a situation that might yet, nevertheless, provide ample room for new innovations and approaches in STEM practice and education.

Particularly in emerging countries such as India, Brazil and Egypt, the field of science and technology has been influenced by historical developments resulting from colonialism and external domination. In his contribution on *Challenges for STEM education in India* (Chapter 6), Sundar Sarukkai uses a multifaceted approach to provide general information on the current status and attitude towards science and technology, but also provides a historic overview of the development of Indian science, partially in contrast to and partially in cooperation with Western influences. He traces the cultural roots of modern scientific tradition and describes how it has been strongly associated with a purely Western enterprise in the past, thereby rejecting traditional Indian knowledge systems and promoting the very idea of rationality, progress and societal change. Later on, these ideas on modern science became a fundamental pillar of India after independence and, since then, have led to the country's intensive and impressive development as a global player, particularly in the field of information technology and space research. However, the author reflects critically on the multicultural facets of modern science, and demands a stronger appreciation and remembrance of great scientific contributions by Indian scientists as a source for alternative reflections on the value and importance of science and technology for the development of the India of today.

Against the backdrop of this comprehensive picture of the development of the field of science and technology, Nagalakshmi Chelluri and Mohan Avvari—in their contribution on *Corporate social responsibility programmes for STEM education: Cases from the Indian technology cluster city of Hyderabad* (Chapter 7)—address the

impact of the private sector on STEM education. Using examples of corporate social responsibility strategies of a technology cluster in Hyderabad, they argue that public education in India needs to be supplemented by private initiatives if the country should manage to become a successful innovator in the future.

Valuable insights into the meaning and role of Islamic religious beliefs as a framework that informs both Egyptian culture and its educational system are given by Ghada K. Gholam and Nasser Mansour in their study *Highlights of STEM education in Egypt* (Chapter 8). The authors shed light on the different characteristics of the Egyptian education system, including the role and relationship of culture and religion, gender differences and the pervasive role and implications of the overall examination system. They make clear that the debate between proponents of Western secularization and the Egyptian Islamic culture will strongly influence future development of science and technology education. Reflecting on current developments and outlining future prospects in light of the changes brought about since the Arab Spring, they conclude that current initiatives need the strong support of government authorities in order to foster scientific innovation and, through this, the overall development of the country.

In a complementary and comparative manner, Nicole C. Karafyllis (who has worked as a professor in the United Arab Emirates (UAE)) extends the focus from Egypt to the Arab Gulf region in her article *Tertiary education in the GCC countries (UAE, Qatar, Saudi Arabia): How economy, gender and culture affect the field of STEM* (Chapter 9). She demonstrates that states such as the UAE and Qatar serve as role models for the biggest player in the region, Saudi Arabia, and that—despite the fact that these countries still face serious challenges in the field of STEM—they are driving forces for education programmes and implementation, especially in the research fields of renewable energy, environmental management and sustainability and genetics. Karafyllis addresses the latest changes in STEM curriculum development, language and gender issues and the role of culture and religion.

Similar to GCC states that are characterized by very low levels of respect for teachers, Brazil also faces serious challenges regarding the status and quality of the teaching profession as a whole. This is a particular issue in STEM education. Simon Schwartzman explains, in his contribution on *Science culture in Brazilian society* (Chapter 10), the historical factors that affect the current educational system in Brazil, and points out the various challenges Brazil is currently facing with regard to the quality of its public education. He illustrates that the country is currently in a state of major changes in making science and technology more popular among the young generation and in working to provide economic incentives—as well as a non-material incentive system—to improve the attractiveness of scientific and technological careers.

Elizabeth Balbachevsky and Edilene Cruz, in their contribution on *Policy controversies in science education in Brazil* (Chapter 11), provide an analysis of curricula content and learning strategies for STEM fields in higher education and its discussion as part of a broader policy controversy in Brazil. They reflect on current developments, particularly on the pressure for change that the major universities' entrance examination (ENEM—National Exam of the Secondary Education) poses for the curricula of STEM education at the higher education level in Brazil.