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Nanotechnologies — Vocabularies for science, technology and innovation indicators

Nanotechnologies — Vocabulaires pour la science, la technologie et les indicateurs d'innovation

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Foreword

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The committee responsible for this document is ISO/TC 229, *Nanotechnologies*.

Introduction

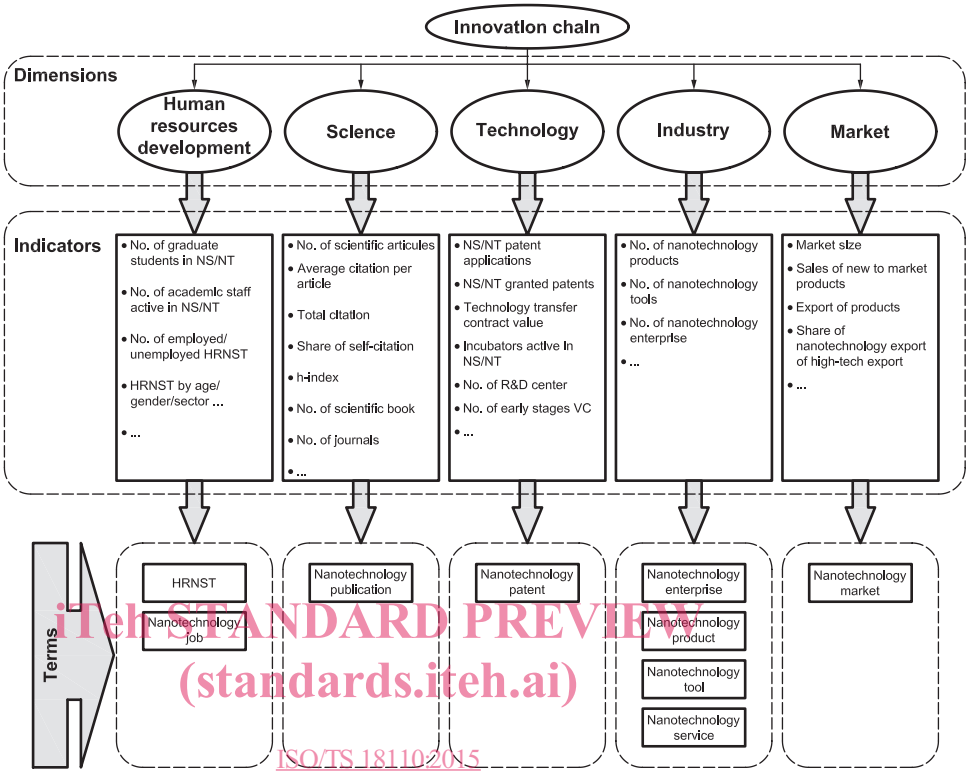
Emerging nanotechnologies are moving towards commercialization and will in future create extensive economic benefits in various industrial sectors. In this field, monitoring trends and the rate of changes in science, technology and industry at global, regional and domestic levels is an important consideration. Due to the high levels of investment by the private, public and industrial sectors and the substantial increase in nanotechnology-based publications, inventions and products, a unified approach is required to evaluate the impact of these investments, as well as the overall progress and impact of nanotechnology.

Understanding the socio-economic impacts of nanotechnology is important among communities. Investors, for example, require the assessment of scientific and technological advancements, while policy makers are interested in the assessment of results and impacts of their policies and programs.

The basic efforts of ISO/TC 229 for the standardization of nanotechnology-related terms were an important step towards the creation of a common language to inform people of nanotechnology development worldwide. Most of the terminology projects have focused on the development of scientific and technological vocabularies and terms. The creation of terms and core terms for science, technology and innovation indicators are of great interest, especially where existing indicators are inadequate for applications relating to nanotechnology. Such terms would help transparent and trustworthy comparison of international activities in this area. Unfortunately, due to the lack of such globally agreed vocabularies/definitions, the released economic, scientific and innovation statistics should be considered with caution.

Figure 1 typically demonstrates the major dimensions of the nanotechnology innovation chain as human resources development, science, technology, industry and market. For each of these dimensions, there are several relevant indicators, which are utilized to varying degrees in some analytical reports related to nanotechnology.

Generic indicators that are descriptive of innovation dimensions are already well defined; however, the bounds of these indicators as they relate to nanotechnology need to be defined and harmonized to ensure consistent reporting.



Key

NS nanoscience

NT nanotechnology

NOTE Adopted from References [15] and [28].

Figure 1 — Demonstration of innovation chain dimensions, indicators and defined terms

Nanotechnologies — Vocabularies for science, technology and innovation indicators

1 Scope

This Technical Specification aims to provide the necessary definitions that specify the bounds of key innovation indicators as they relate to nanotechnology, in order to facilitate and unify the global assessment of nanotechnology activities in different areas.

The availability of these terms can help the measurement and comparison of various indicators in this field. This Technical Specification does not intend to redefine terms that are already defined in other ISO documents. Furthermore, there is no intention to show how the indicators can be used as an assessment tool.

2 Terms and definitions from ISO 14040, ISO 14041 and ISO/TS 80004-1

The terms and definitions in this Clause are from ISO 14040, ISO 14041, and ISO/TS 80004-1. They are reproduced here for context and better understanding.

2.1
engineered nanomaterial
nanomaterial (2.8) designed for a specific purpose or function

[SOURCE: ISO/TS 80004-1:2015, 2.8]

2.2
final product
product which requires no additional transformation prior to its use

[SOURCE: ISO 14041:1998, 3.6]

2.3
intermediate product
output from a unit process that is input to other unit processes that require further transformation within the system

[SOURCE: ISO 14040:2006, 3.23]

2.4
manufactured nanomaterial
nanomaterial (2.8) intentionally produced to have selected properties or composition

[SOURCE: ISO/TS 80004-1:2015, 2.9]

2.5
nano-enabled
exhibiting function or performance only possible with *nanotechnology* (2.13)

[SOURCE: ISO/TS 80004-1:2015, 2.15]

2.6
nano-enhanced
exhibiting function or performance intensified or improved by *nanotechnology* (2.13)

[SOURCE: ISO/TS 80004-1:2015, 2.16]

2.7
nanomanufacturing process
ensemble of activities to intentionally synthesize, generate or control *nanomaterials* (2.8), or fabrication steps in the *nanoscale* (2.9), for commercial purpose

[SOURCE: ISO/TS 80004-1:2015, 2.12]

2.8
nanomaterial
material with any external dimension in the *nanoscale* (2.9) or having internal structure or surface structure in the nanoscale

Note 1 to entry: This generic term is inclusive of nano-object and nanostructured material.

Note 2 to entry: See also *engineered nanomaterial* (2.1), *manufactured nanomaterial* (2.4) and incidental nanomaterial.

[SOURCE: ISO/TS 80004-1:2015, 2.4]

2.9
nanoscale
length range approximately from 1 nm to 100 nm

Note 1 to entry: Properties that are not extrapolations from larger sizes are predominantly exhibited in this length range.

[SOURCE: ISO/TS 80004-1:2015, 2.1]

2.10
nanoscale phenomenon
effect attributable to the presence of nano-objects or *nanoscale* (2.9) regions

[SOURCE: ISO/TS 80004-1:2015, 2.13]

2.11
nanoscale property
characteristic of a nano-object or *nanoscale* (2.9) region

[SOURCE: ISO/TS 80004-1:2015, 2.14]

2.12
nanoscience
study, discovery and understanding of matter where size- and structure-dependent properties and phenomena manifest, predominantly in the *nanoscale* (2.9), distinct from those associated with individual atoms or molecules, or extrapolation from larger sizes of the same material

[SOURCE: ISO/TS 80004-1:2015, 2.2]

2.13
nanotechnology
application of scientific knowledge to manipulate and control matter predominantly in the *nanoscale* (2.9) to make use of size- and structure-dependent properties and phenomena distinct from those associated with individual atoms or molecules, or extrapolation from larger sizes of the same material

Note 1 to entry: Manipulation and control includes material synthesis.

[SOURCE: ISO/TS 80004-1:2015, 2.3]

3 Terms and definitions for science, technology and innovation indicators

Further information relating to definitions in this Clause can be found in informative Annexes A to G.

3.1
human resources for nanoscience and nanotechnology
HRNST
people who have:

a) successfully completed education at the university level in *nanoscience* (2.12) (NS) or *nanotechnology* (2.13) (NT) majors, or

b) successfully graduated in majors other than NS/NT majors, but completed a requirement of the major in the field of NS/NT, or

c) not formally qualified as above, but are employed in a *nanotechnology job* (3.2)

3.2
nanotechnology job
job whose main tasks and duties use *nanotechnology* (2.13)

Note 1 to entry: Regarding the potential of nanotechnology to establish new enterprises and facilities, an indicator may be measured as "*job created by nanotechnology*". This indicator includes nanotechnology jobs as well as other job opportunities in these establishments which do not necessarily use nanotechnology.

3.3
nanotechnology publication
science-based publication that publishes information about *nanotechnology* (2.13), its applications and implications

Note 1 to entry: Those publications may also include socio-economic aspects of nanotechnology.

3.4
nanotechnology patent
any patent related to *nanotechnology* (2.13)

Note 1 to entry: Such patents include *nanotechnology product* (3.5), *nanotechnology tool* (3.6), production process of nanotechnology product and *nanomanufacturing process* (2.7).

Note 2 to entry: Such patents would be considered under the IPC/CPC classes and related subclasses, such as B82, or contain at least one claim related to *nanotechnology* (2.13).

3.5
nanotechnology product
one or more of:

a) *manufactured nanomaterial* (2.4) or *engineered nanomaterial* (2.1)

b) *nano-enhanced* (2.6)/*nano-enabled* (2.5) *intermediate product* (2.3)

c) *nano-enhanced* (2.6)/*nano-enabled* (2.5) *final product* (2.2)

Note 1 to entry: Within supply chains, an intermediate product may be considered as a final product, however, process intermediates are excluded.

Note 2 to entry: Final products which are assembled with one or a number of nanotechnology final products as components or parts should not be considered as nanotechnology products. This exclusion prevents multiple counting of nanotechnology final products in a product value chain.

3.6
nanotechnology tool
means for analysis, manipulation or fabrication of *nanomaterial* (2.8) or *nanotechnology product* (3.5)

Note 1 to entry: Analysis of nanomaterial includes studying and measuring *nanoscale phenomena* (2.10) and *nanoscale properties* (2.11).

Note 2 to entry: In some instances fabrication may include *nanomanufacturing processes* (2.7).

3.7
nanotechnology enterprise
enterprise with at least one of the following:

— production of a *nanotechnology product* (3.5), or *nanotechnology tool* (3.6)

— provision of a *nanotechnology service* (3.8)

Note 1 to entry: Some nanotechnology enterprises may have a small share of total economic activity related to nanotechnology, while some are dedicated nanotechnology enterprises of which nanotechnology is their principal activity.

3.8
nanotechnology service
technical service that needs knowledge of *nanoscience* (2.12) and *nanotechnology* (2.13)

Note 1 to entry: Includes performance of R&D in the field of *nanotechnology* (2.13).

3.9
nanotechnology market
market including:

— *nanotechnology products* (3.5),

— *nanotechnology tools* (3.6), and

— *nanotechnology services* (3.8)

Annex A
(informative)

Human resources for nanoscience and nanotechnology (HRNST) and nanotechnology job

A.1 General

A number of important indicators related to NS/NT can be classified under the category "Human resources". In this respect, the terms "human resources for nanoscience and nanotechnology (HRNST)" and "nanotechnology job" need to be defined.

It should be mentioned that the term "human resources devoted to science and technology (HRST)" has previously been defined in the OECD manual known as the "Canberra Manual"[20]. This manual was developed collaboratively among the OECD, Eurostat of the European Commission, UNESCO, and the International Labour Organization (ILO). Here, in this work, the term "HRNST" has also been defined in close harmony with the already mentioned definition of "HRST".

The Canberra Manual introduces its classification by qualification and occupation. The basic ideas are described as follows:

"In order to obtain a complete picture of both supply and demand for HRST, the definition is based on two dimensions, qualification and occupation. The qualification axis tells us about the supply of HRST, i.e. the number of people who are currently or potentially available to work at a certain level. The demand for HRST, i.e. the number of people who are actually required in S&T activities at a certain level, is related to the occupation dimension. Because demand does not always match supply and because skills can be obtained outside the formal education system, the following combined definition is proposed.

HRST are people who fulfil one or other of the following conditions:

a) Successfully completed education at the third level in a S&T field of study;

b) Not formally qualified as above, but employed in a S&T occupation where the above qualifications are normally required."

A.2 Description of the term HRNST

In harmony with the Canberra Manual, both approaches can be utilized to define HRNST.

A.2.1 Identification by qualification

In some countries, highly focused NS/NT specific curricula are provided by universities/research institutes. People who graduated in these majors are recognized in those countries as HRNST [category a) in the abovementioned definition].

In addition, in many countries, there are people who graduated in majors other than NS/NT majors, but completed their dissertation or any other main requirement in the field of NS/NT. They may be acknowledged as HRNST, since they normally have appropriate knowledge and skills for scientific and technological activities in the field of NS/NT. The inclusion of these two categories is justified by the level of quality of the trained people in this field, since highly skilled educated human resource is a major requisite for future development of NS/NT.

Nonetheless, people who have attended a few days' workshop, a brief training or passed a few intermittent courses in the field of NS/NT are not recognized as HRNST. On one hand, such people have

insufficient skills for scientific and technological activities in the field of nanotechnology. On the other hand, to be an easily measurable indicator, HRNST could not include this group of people.

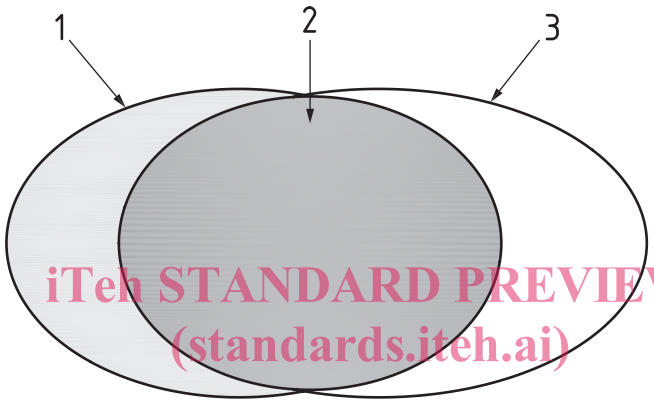
A.2.2 Identification by occupation

On the demand side of human resources, people who are not formally qualified as mentioned in Clause A.1, but employed in an occupation related to nanotechnology, are recognized as HRNST.

The ILO has introduced a definition for occupation in the International Standard of Classification Occupation (ISCO) standard.[9] According to ISCO-08 the definition of occupation is as follows:

"Occupation refers to the kind of work performed in a job. The concept of occupation is defined as a set of jobs whose main tasks and duties are characterized by a high degree of similarity."

It is worth mentioning that one cannot ignore the possible overlap between HRNST by qualification and occupation as shown in Figure A.1.



Key

1 HRNST by Occupation but not by Qualification
2 HRNST by both Qualification and Occupation
3 HRNST by Qualification but not by Occupation

NOTE Reproduced with permission from *Canberra Manual*,[20] page 17, Figure 3.1 with minor modifications.

Figure A.1 — Three main categories of HRNST

A.3 Description of the term *nanotechnology job*

Job creation as a direct socio-economic outcome of nanotechnology commercialization is an important indicator for the effectiveness of nanotechnology policies.

The ISCO standard defines the term "*job*" as follows:

"A job is a set of tasks and duties performed, or meant to be performed, by one person, including for an employer or in self-employment."

Jobs, whose tasks and duties use some special technical skill related to nanotechnology, should be considered as nanotechnology jobs. As an example, in a nanomaterial production workplace, a safety specialist must be aware of safety aspects of nanomaterials and be able to apply appropriate measures and procedures. Therefore, his/her job is a nanotechnology job.

Besides nanotechnology job, many job opportunities are created in institutions related to nanotechnology which do not necessarily need technical skills in the field of NS/NT. These jobs are important from an economical perspective and show the potential of nanotechnology in creating

