The Development of the Canadian Research and Development Classification*

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Abstract: I describe the development of a new research and development taxonomy to facilitate the reporting of granting agency investments in research and the organization of effective peer review processes in Canada, which represents a kind of classification designed to support the administrative management of research. The development of the Canadian Research and Development Classification (CRDC) is being led by the Canada Foundation for Innovation (CFI), the Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council of Canada (SSHRC), in close collaboration with Statistics Canada. This collaboration represents an unprecedented effort by the federal research funding agencies and Statistics Canada to develop a common standard for the classification of research and development activities in Canada, and is intended to meet different needs within the broader research ecosystem. The CRDC, intended to align the way research and development is categorized in Canada, is the result of months of reviews, consultations, analysis and negotiations among the agencies and the Canadian research community. Notably, the CRDC was designed to include all sectors of research and development, represent the current research landscape in Canada, support a wide range of needs within the research and development ecosystem, and increase computability with international standards.

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* Derived from the article of similar title in the ISKO Encyclopedia of Knowledge Organization, Version 1.0 published 2019-06-13. Article category: KOS, specific (general/universal). The development of the CRDC would not have been possible without the contributions from many partners and stakeholders from the research community. In particular, the author would like to thank the members from the steering committee and working groups from CFI, CIHR, NSERC, SSHRC and Statistics Canada for their continued engagement and effort, and from the Canadian research community who participated in the consultations and provided insights and expertise, and finally the Australian and New Zealand Standard Research Classification's team for their invaluable contributions and knowledge-sharing.

1.0 Research and development-oriented classification standards

The classification of sciences is a vast interdisciplinary field that has been explored in philosophy and the history of ideas, in economy[1] and in library and information science, among other fields. The basis of the different classifications has been driven by different research interests and needs, for example:

1. Understanding the different nature of different sciences, mainly philosophy (e.g., Trompf and Gary 2011);
2. Exploring the development of disciplines taught at universities, mainly the history of ideas and social history of knowledge (e.g., Burke 2000);
3. Document and information retrieval and quantification of the impact of specific scientific literatures, mainly library and information science with bibliometrics (e.g., Archambault, Beauchesne and Caruso 2011); and,
4. Administrative management of research, the topic of the present article (e.g., Vancauwenbergh 2016).

Although these categories are overlapping and contribute to each other, the "administrative management of research" category is relatively independent and mostly uses the term "research classification," which here refers to classifications developed for the purposes of the administrative management of research and research funding. Research classification is often nation- or organization-specific. As outlined by Vancauwenbergh (2016), as a consequence, the information and data are not easily interoperable and comparable to support the continued needs for reusing and disseminating research information to report and demonstrate research activities and impacts by researchers and research funding organizations. In this article I describe the attempt in the development of the Canadian research and development classification (CRDC) to standardize such classifications to increase computability, collaborations and international standards.

Efforts to standardize and classify information in the research domain have been long lasting (Glänzel and Schubert 2003). This is not surprising as the specific goal of classification is to provide insight into the organization of the data (Ruocco and Frieder 1997). As a result, efforts to standardize and classify research and development activities can be observed at the international, national, sector and organizational levels. For example, since the 1960s the Organization for Economic Cooperation and Development (OEDC) through its *Frascati Manual* has become an internationally recognized standard for measuring research and development activity. The *Frascati Manual* recently released its 2015 edition, which applies a functional distribution methodology with examples including type of research and development (basic, research, applied research and experimental development), fields of research and development (FoR) as well as socio-economic objectives. The OECD classified FoR into eight high level subject groups, and subsequently added a second tier to this classification system. The socio-economic objectives followed the United Nation's Nomenclature for the Analysis and comparison of science programs and Budgets (NABS), first using 1997 then the 2007 nomenclature. Similar standards have been developed in different part of the world, including the Common European Research Classification Scheme (CERIF 1991). Country specific initiatives aimed at standardization, such as the Australia and New Zealand Standard Research Classification (ANZSRC), also exist. Inspired by the *Frascati Manual*, the ANZSRC model uses a set of three related classifications developed specifically for the use in the measurement and analysis of research and experimental development. There are a variety of ways to categorizing research. Some research classification standards (RCS) concentrate on a specific sector—such as the Health Research Classification System (HRCS) in the UK, concentrate on classifying the full spectrum of biomedical and health research across all areas of health and disease. Scientific journal taxonomies have also been widely used in bibliometric studies. The Thomson Reuters Web of Knowledge and Elsevier's SciVal publications databases both use journal subject categories to sort and classify articles and are widely used (Archambault 2011). Lastly, many research organizations and funding agencies are now turning to private companies to help them in the automation of the management and organization of their vast databases. For example, UberResearch has developed a cloud-based decision support solution set for science funding organizations to assist funders by generating precise and consistent reports using natural language processing to identify relevant projects for reporting. Across these cases, there are large variations in the degree of specificity and aggregation, in the terminology used, and intended users. All RCS are not suitable for all purposes (Archambault 2011). For those reasons, it could be argued that no single system or research taxonomy could be developed that meets all needs and that, as a result, there should be a variety of interrelated systems to deal with the diversity (Alavi and Leidner 2001). However, as outlined by Gómez (1996), the number and diversity of RCS make it difficult to effectively and accurately combine and compare data from different sources.

Although the literature on knowledge organization and more specifically RCS reflects varying academic and research fields, three important points can be drawn from it when developing or adapting a RCS. The first is the need for a RCS to consider emerging realities to accurately reflect the research landscape, as well as with the needs of the organization. This includes, for example, updates that take into account emerging research domains and terminology that align RCS to current priorities (Cuthbert and Insel 2013); and the need for the RCS to be designed in such a way that regular updates are feasible. The second is that RCS, to an extent, cannot be neutral and may reflect certain key trends in research or priorities, while omitting research that is less popular (e.g, Hjørland 2013). To eliminate this potential bias, it is suggested to ensure that all research fields are recognized; as such, great care needs to be taken when aligning research strategies to the categories that are identified strongly within a RCS. RCS assessments may otherwise result in misinterpretations and wrongfully informed decisions (Haddow 2015). Finally, RCSs need to be comprehensive, as well as fluid, adaptable and responsive to changes, taking into account the various dimensions and indicators necessary to depict an accurate picture of the research to facilitate useful analysis. Evidence-based approaches are proposed in order to develop frameworks that are robust, that can evolve and change with the pace of new research and new priorities and take into account differences and multidisciplinary aspects (Cuthbert and Insel 2013). Recommendations often focus on building comprehensive, research-responsive models; however, there is little consensus on what such model should look like, how it should evolve and what sort of technological infrastructure will be required to support the model.

2.0 Why classify research for research granting agencies in Canada?

Increasingly, and of utmost importance for organizations that fund research from public funding, accountability and transparency are critical to demonstrate how public funds are deployed. Research stakeholders, government and the public are seeking information about which areas of research are receiving support and the level of investment in each. Furthermore, research efforts are now global, and the ability to combine and compare information about funded research with other organizations is necessary to improve collaboration, improve support for research and development (R&D) and to benchmark investments and performance nationally and internationally.

In 2017, Canada invested over 32.8 billion Canadian dollars in R&D activities (Statistics Canada 2017). That same year, R&D activities performed by the higher education sector accounted for approximately 41%, or $13.6 billion. Of the R&D performed in the higher education sector, nearly 23%, or $3.1 billion, was funded by funds from the federal government, mainly through CFI, CIHR, NSERC and SSHRC.

A common research classification is a fundamental step to understanding resource flow into R&D and its purposes and thus plays an integral role in the functioning of research funding organizations. Additionally, the ability to categorize research projects and expertise consistently by discipline, subject area and areas of application can provide insights into strengths and gaps in current research landscape.

Research classification organizes data about research into discrete categories, such as groups of research projects or individuals with expertise with closely related themes, focus or other characteristics. The Canadian federal research granting agencies require applicants to identify the field or discipline of research and the areas of application that best describe their expertise and research project. This information is used to support the peer review process by ensuring appropriate peer reviewer selection with the need to set up review committees around common disciplines, and to report on investments, research activities in specific fields as well as objectives of R&D at the organizational, national and international levels.

The Canadian federal research granting agencies currently utilize a number of different research classifications within and among their organizations. In most cases, these cover the mandate of a single agency rather than all sectors of R&D. In some cases, the same terminology is used to classify different dimensions of research, whereas in other

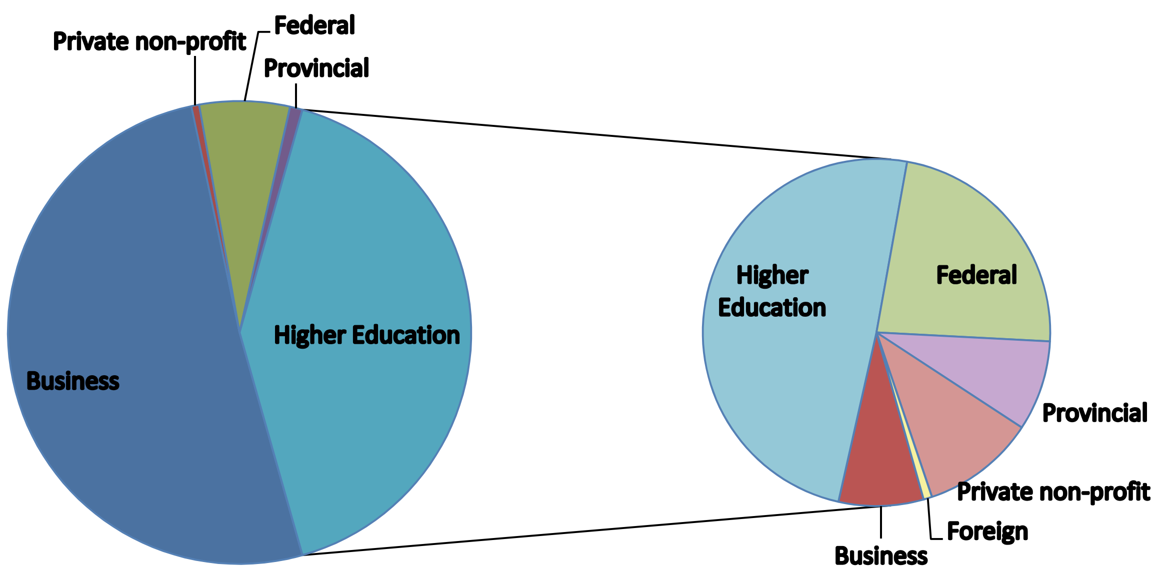

Figure 1. Canada's gross domestic expenditure on research and development (by performing sector) and sources of funds for R&D in the higher education sector (Statistics Canada 2017).

cases different terminology is used to describe the same dimensions. Research disciplines are also present, through various configurations in university departments, and to some extend the entire academic research ecosystem is built on these types of categorizations. And for those reasons, it could be argued that research disciplines in Canada are omnipresent and unsystematically categorized overall.

Furthermore, the classifications used by the Canadian federal research granting agencies often do not provide definitional descriptions and, therefore, lack the supporting information to assist users in determining the boundaries of each category. Also it is most often the case that the classifications are not updated in a systematic manner and have not been reviewed or revised in many years, resulting in classifications that do not accurately represent today's research landscape and only partially meet the needs of the different end-users.

3.0 Drivers for the development of a Canadian research and development classification

3.1 Need for greater alignment

The benefits of a common approach to classifying research were significantly strengthened by the release of the report resulting from the review of the Canadian federal government's support of fundamental science (Advisory Panel for the Review of Federal Support for Fundamental Science 2017) as it called for closer collaboration among the Canadian federal research granting agencies. Consequently, later in 2017 the agencies in collaboration with Statistics Canada, agreed to proceed with the development of a new common R&D classification. The involvement of a federal statistical bureau, such as Statistics Canada, in the project was important as it allowed for greater comparability of data among departments and with other countries and with incorporating imbedded on-going process of monitoring and maintaining the CRDC. Furthermore, improved alignment of the research classifications at the organizational and national level with international research classifications provides an opportunity to inform future international research classifications updates and revisions.

3.2 Multidisciplinarity

In today's knowledge economy, there are powerful drivers for multidisciplinary research, and as a result, world-leading research often crosses traditional knowledge and disciplinary boundaries. As was demonstrated by Van Noorden (2015), there has been a rise in multidisciplinary research over the past three decades. Furthermore, Wang et al. (2015) found multidisciplinary research to have greater impact in the long term than discipline-based research.

The ability to identify research and scholarly expertise in a truly multidisciplinary classification will assist the federal research granting agencies in developing strategies to encourage, facilitate, evaluate and support multidisciplinary research.

3.3 Emerging fields of research

The report *Investing in Canada's Future: Strengthening the Foundations of Canadian Research* (Advisory Panel for the Review of Federal Support for Fundamental Science 2017), resulting from the review of the Canadian federal government's support of fundamental science, states that, "for research to be world-leading, relevant, and impactful, it must adapt to new opportunities and to a changing social, economic, and natural environment." Therefore, it should come as no surprise that identifying emerging fields of research is a key activity in the science ecosystem. Research granting agencies and policy makers aim to promote and enhance the development of potentially promising research fields while research administrators choose which researchers to hire and which projects to support internally. Making informed decisions requires knowledge about these emerging fields of research. Unfortunately, to date, emerging research fields have not been easily identifiable, and methodologies have severe gaps. As outlined by Klavans and Boyack (2017), a detailed research classification at the field level can enable more targeted decision making by the research community.

3.4 Improved data on research and development efforts

The use of up-to-date standard classification and terminologies is important for maintaining quality and consistency across analyses and, more importantly, for allowing the aggregation of the same type of data from various sources and exploring different types of R&D together. Around the world, public and private organizations are increasingly data-driven. Data describing R&D activities is used to inform and support operational and strategic decisions, policies, reporting and to demonstrate the impact of investment on research and research training. The consequences of collecting and using data that are not representative of or consistent with the contemporary activities of the R&D ecosystem can have substantial social and economic impacts organizationally, nationally and internationally. Potential benefits from improved data quality of R&D are maximizing insights from the data, optimizing support to new and innovative R&D and ensuring a better future in Canada.

4.0 Benefits of adopting a common R&D classification

As similarly outlined by the European Science Foundation (2011), adopting a common approach for classifying research and expertise across the federal research granting agencies is intended to:

- Create a common language for discussing research in the higher education sector, as well as in the public and government sector, which enables better evidence-based decision-making for the research ecosystem;
- Improved identification of expertise and research areas in a truly multidisciplinary classification;
- Improved identification of emerging research fields;
- Increased need for enhanced collaborations to optimize research efforts and improved outcomes;
- Improved identification of gaps and opportunities in research funding;
- Provide consistent and effective support to the research community; and,
- Improve reporting on their combined contributions to a nation's research and science enterprise.

Furthermore, establishing a shared research classification will assist the federal research granting agencies to streamline operational processes for peer review, recruitment and selection of reviewers.

5.0 Methodology

Informed by the evidence gathered by the Canadian federal research granting agencies since 2013, the federal research granting agencies decided to:

1. Align with international standards, namely the recommendations from the OECD's *Frascati Manual* (2015); and,
2. Leverage the established model from Australia and New Zealand, the ANZSRC model.

5.1 OECD *Frascati Manual*

Adopted by OECD member countries in the 1960s, the manual is a methodological document for collecting and using R&D statistics. Revised most recently in 2015, the *Frascati Manual* is the most widely used internationally recognized standard. It provides a framework, definitions and indicators for the regular collection and comparable statistics on R&D amongst OECD countries, and making international comparisons on science possible. More specifically, the manual provides definitions for three types of activity: basic research, applied research and experimental development; proposes the use of a classification of fields of research and development by knowledge domain; and proposes to use of a socio-economic objectives classification to classify R&D activities according to the purpose of the project.

5.2 ANZSRC model

In 2008, Australia and New Zealand collaborated to develop the ANZSRC model. Based on the 2002 *Frascati Manual*, the model uses a set of three related classifications developed for use in the measurement and analysis of R&D in Australia and New Zealand. Consistent with the *Frascati Manual*, the constituent classifications included are: Type of Activity, Fields of Research, and Socio-Economic Objective. Fields of Research and Socio-Economic Objectives follow a hierarchical structure and offer a very detailed selection of categories. The level of detail and the three-dimensional matrix contained in this model provide a considerable degree of flexibility in meeting the needs of a wide variety of users.

5.3 Essential features of a statistical classification pursued in the CRDC

The CRDC is being developed while taking into consideration best practices and principles of statistical classifications. These include the United Nations Statistical Commission's endorsed essential components for a statistical classification (United Nations 2013):

- A consistent conceptual basis;
- A flat or hierarchical structure;
- Categories that are mutually exclusive and exhaustive;
- Definitions that are clear and unambiguous and which define the content of each category;
- Up-to-date and relevant;
- Sufficiently robust to last for a period of time;
- Meets user needs;
- Provides comparability over time and between collections; and,
- Provides guidelines for coding and output of data collected using it.

In addition, the principles outlined by the United Nations' Standards Statistical Classification: Basic Principles (United Nations 1999) and the Generic Statistical Information Model (United Nations 2015) were applied to ensure that the CRDC is a set of discrete, exhaustive and mutually exclusive categories.

5.4 Revisions and consultations

An important consideration when developing a statistical classification is ensuring sufficient robustness to allow for long-term usage. A robust classification design facilitates meaningful time series analysis of data assigned to that classification. However, there is also a need for the classification to remain representative in order by keeping pace with the continual evolution of the R&D sector and to provide data relevant to users' needs and represent reality.

ANZSRC 2008 encompasses all of the different areas of research conducted by the Canadian federal research funding agencies and allows for the ability to distinguish between subtly different types of research, as well as capture large, multi-disciplinary projects and meets the needs of different users. However, the ANZSRC 2008 model was developed based on the 2002 *Frascati Manual*, and the OECD has released a revised version of its *Frascati Manual* in 2015. Furthermore, at the more granular level, the ANZSRC 2008 model is very specific to Australia and New Zealand, making it, in some instances, not relevant to the Canadian research landscape. Finally, the ANZSRC model has not been revised since 2008, and during this time some fields of research have evolved considerably. Consequently, to ensure that the CRDC reflects the contemporary and Canadian research landscape, revisions are being applied to ANZSRC 2008 based on inputs from a series of consultations with user groups and subject matter experts. This includes consultations with:

- The Australian Bureau of Statistics, Statistics New Zealand and the Australian Research Council, as they have been using this model for ten years and can share their expertise and experiences;
- Internal staff at each Canadian federal research granting agency to ensure that the CRDC supports the full range of uses of a research classification for program delivery, monitoring and reporting;
- Subject matter experts in the research community to inform and validate the terminology and scope in specific fields of research;
- Targeted stakeholders, other federal science-based departments and agencies including provincial funding agencies and provincial statistical bureaus, to obtain feedback on the general structure and principles of the classifications; and finally,
- An open online consultation to provide an opportunity for a wider audience to provide comments on the proposed categories and terminology.

6.0 About the Canadian Research and Development Classification

The CRDC is a set of three interrelated classifications developed as a tool to facilitate the peer review process, the reporting of the R&D investments and track societal outcome or impact by these investments by agencies and by the Government of Canada. Similarly to the *Frascati Manual* guidelines and to the ANZSRC model, Canada has adopted the same three constituent classifications: Type of Activity, Fields of Research, and Socio-Economic Objectives. The CRDC, at the highest levels, aligns with international standards and offers a continuity, while at the most granular levels is comprehensive enough to represent the nuances between R&D activities and supports different needs of the research ecosystem. In addition to a robust classification design, there is also a need for the classification to remain contemporary to keep pace with the continual evolution of the R&D sector and to provide data relevant to users' needs. Therefore, in order to achieve a balance between these two competing objectives, the federal research granting agencies, in collaboration with Statistics Canada, intend to plan systematic revision of the CRDC, and will carry out updates based on issues emerging from implementation by the granting agencies and other users of the classification.

The final CRDC is expected to be published in fall 2019 and implemented with the federal research granting agencies' systems in the future. The finalized CRDC will be available on Statistics Canada's website, www.statcan.gc.ca.

6.1 Type of Activity

The structure and definition for the categories for Type of Activity align with the *Frascati Manual* 2015 definitions. It allows R&D activities to be categorized according to the type of research being undertaken, and it has a flat structure broken down into three groups, which are:

- Basic research: experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts, without any particular application or use in view.
- Applied research: original investigation undertaken in order to acquire new knowledge. It is, however, directed primarily towards a specific, practical aim or objective.
- Experimental development: systematic work, drawing on knowledge gained from research and practical experience and producing additional knowledge, which is directed to producing new products or processes or to improve existing products or processes.

6.2 Fields of Research

The Fields of Research allow R&D activities to be categorized according to the field of research; it is the methodology used in the R&D that is being considered. The categories within this classification include major fields of research based on the knowledge sources, the objects of interest, the methods and techniques being used.

The Fields of Research classification has four hierarchical levels consisting of divisions at the broadest level while groups, classes and subclasses represent increasingly detailed dissections of these categories. Resulting in a comprehensive list of fields of research, nearly 1,500 in total, to reflect the current research landscape in Canada. The divisions and groups levels are aligned with fields of research as portrayed in the *Frascati Manual* 2015. Class and subclass levels have been modeled on ANZSRC 2008 and adapted to the Canadian and current context.

The Field of Research classification is a hierarchical classification, as illustrated by the example below:

Level	Code	Description
Division	RDF10	Natural sciences
Group	RDF101	Mathematics and statistics
Class	RDF10101	Pure mathematics
Subclass (Field)	RDF1010101	Algebra

Proposed fields of research group codes and titles:

RDF101	Mathematics and statistics
RDF102	Computer and information sciences
RDF103	Physical sciences
RDF104	Chemical sciences
RDF105	Earth and related environmental sciences
RDF106	Biological sciences
RDF107	Other natural sciences
RDF201	Civil engineering, industrial engineering, and related work
RDF202	Electrical engineering, electronic engineering and information engineering
RDF203	Mechanical engineering
RDF204	Chemical engineering
RDF205	Materials engineering
RDF206	Medical and biomedical engineering
RDF207	Environmental engineering and related engineering
RDF208	Environmental biotechnology
RDF209	Industrial biotechnology
RDF210	Nano-technology
RDF211	Other engineering and technologies
RDF301	Basic medicine and life sciences
RDF302	Clinical medicine
RDF303	Health sciences
RDF304	Medical biotechnology
RDF305	Other medical and life sciences, n.e.c.
RDF401	Agriculture, forestry, and fisheries
RDF402	Animal and dairy sciences
RDF403	Veterinary science
RDF404	Agricultural and food biotechnology
RDF499	Other agricultural sciences, n.e.c.
RDF501	Psychology and cognitive sciences
RDF502	Economics and business administration
RDF503	Education
RDF504	Sociology and related studies
RDF505	Law and legal practice
RDF506	Political science and policy administration
RDF507	Social and economic geography
RDF508	Media and communications
RDF509	Other social sciences
RDF601	History, archaeology and related studies
RDF602	Languages and literature
RDF603	Philosophy studies
RDF604	Arts (arts, history of arts, performing arts, music)
RDF605	Other humanities

In most cases, researchers will be able to select multiple fields to ensure that multidisciplinary research can be identified within the structure.

6.3 Socio-Economic Objectives

The Socio-Economic Objectives allow R&D activities to be categorized according to the purpose or outcome of the R&D as perceived by the data provider, who is most frequently the researcher. It consists of discrete economic, social, technological or scientific domains for identifying the principal purposes of the R&D. The attributes applied to the design of the socio-economic objective (SEO) classification entail a combination of processes, products and other social and environmental aspects of particular interest.

The SEO is a two-level hierarchical classification, with division at the broader level and group forming the next level, as illustrated by the example below. This nomenclature aligns with the Nomenclature for the analysis and comparison of scientific programs and budgets (NABS) (Eurostat 2007).

Level	Code	Description
Division	RDS106	Industrial production and technology
Group	RDS10610	Information systems, technologies and services

Proposed socio-economic objectives division codes and titles:

RDS101	Exploration and exploitation of the earth
RDS102	Environmental protection
RDS103	Exploration and exploitation of space
RDS104	Transport, telecommunication and other infrastructures (including construction)
RDS105	Energy (except prospecting)
RDS106	Industrial production and technology
RDS107	Health
RDS108	Agriculture (including fisheries and forestry)
RDS109	Education
RDS110	Culture, recreation, religion and mass media
RDS111	Political and social systems, structures and processes
RDS112	Defence

7.0 Conclusion

Research classifications help organizations to monitor and evaluate programs, operations, investments and research policies. Although there are several existing classifications for research and development, none really fit the purpose for the federal research funding agencies. The adoption of a new common approach for classifying research and development activities across the research ecosystem in Canada facilitate peer review process by the federal research granting agencies, will improve the ability to combine and compare information about R&D and has the potential to assists in communication, consistent reporting, identification of gaps and opportunities, stronger collaborations and optimized support for new and innovative R&D activities and ensuring a better future for Canadians.

As R&D efforts are global and continuously evolving, the CRDC is leveraging the stability and international comparability provided by the OECD's internationally recognized *Frascati Manual*, and leveraging the flexibility provided by the three related classifications developed by Australia and New Zealand for use in measurement analysis of research and development activities and investments. The recent revisions and changes based on inputs from a series of consultations will ensure that the CRDC reflects the current Canadian research landscape. This new classification provides a comprehensive way to classify R&D activities and will contribute to ensure compatibility and comparability of statistics about R&D in Canada and internationally, while balancing the needs of different users and highlighting the strengths and accomplishments of Canada in specific areas of research.

Notes

1. Machlup (1980, 1982, 1984) was a major contributor to the economics of knowledge and information. Vol. 2 (1982) was dedicated to the classification of "the branches of learning." We have not been able to identify newer research by economists on the classification of research fields, but economy is, of cause, using and in other ways involved in what is here named "research classification."

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