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How can we ensure visibility and diversity in research contributions? How the Contributor Role Taxonomy (CRediT) is helping the shift from authorship to contributorship

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Key points

- The structured Contributor Role Taxonomy (CRediT) taxonomy, introduced in 2014, is now used in over 120 journals and set to grow substantially in the next couple of years.
- CRediT responds to calls for greater transparency and recognition of author contributions and is increasingly being used to investigate authorship.
- Whilst initially implemented in the life sciences, identification of contributorship is increasingly being seen as important in all disciplines.

INTRODUCTION: THE EMERGENCE OF CREDIT

In 2015, *Learned Publishing* published an article introducing the Contributor Role Taxonomy (CRediT), in which the authors proposed a shift to a more holistic way for authors to describe their contributions to published scholarly output, moving beyond a static concept of authorship. Specifically, the paper recommended the use of a simple, but comprehensive, taxonomy that could be used by authors when submitting an article for publication to allow the range and nature of contributions to scholarly published output to be captured transparently and in a structured format (Brand, Allen, Altman, Hlava, & Scott, 2015).

The case for a shift to *contribution* to complement (or replace) the concept of authorship emerged following increasing dissatisfaction with established bibliographic conventions for describing and listing authors on scholarly outputs, which have become outdated and unable to convey the diversity of contributions that researchers make to published work today (Rennie, Yank, & Emanuel, 1997). The emergence of the 'impact agenda' for research, and the importance of published research works as currency for researchers to support academic research career progression, makes it vitally important that any information about specific and valuable contributions to research are visible and verifiable (Dance, 2012).

Providing accessible information about contribution is also a way to address a number of well-described problems with author lists and orders, among the most important: to provide more accountability to prevent questionable, guest, and 'ghost' authorship on research articles (Rennie & Flanagin, 1994); to provide a way to make sense of the increasing number of authors listed in research articles in many areas of science; and to provide visibility to early career researcher contributions where a 'first author' paper may be elusive. Furthermore, in fact, there are no

consistent name-ordering conventions from one field to the next (Einav & Yariv, 2006).

Alongside calls for the responsible use of research-related metrics (Hicks, Wouters, Waltman, de Rijcke, & Rafols, 2015; Wilsdon *et al.*, 2015), and more holistic and tailored approaches to research and researcher assessment, as advocated by DORA (San Francisco Declaration on Research Assessment; https://sfdora.org/), it is simply a good time to bring greater transparency to research. In a world where collaborative and open science is becoming the norm, providing visibility to contributions can help to incentivize researchers contemplating a move into a large team (Academy of Medical Sciences, 2016). In addition, for the readers and users of research, being able to decipher the contributions, origins, and context of what they are reading can influence how much – or how little – they might want to use, or even trust, the research being described.

In summary, being able to access and use descriptions of contribution more systematically can bring a range of benefits, including (but not limited to):

- Providing visibility and recognition for researchers working in large teams whose individual contributions are lost in an expansive author list.
- Providing visibility for a diverse range of research contributions that are key to research output being published beyond a traditional focus on writing and drafting (e.g. data curation, statistical analysis, etc.).
- Supporting research institutions and authors to resolve author disputes by providing more transparency around individual author roles and responsibility.
- Supporting research and researcher evaluation by providing a more holistic and nuanced view of the contributions of researchers to research output.
- Improving the ability to track the outputs and contributions of individual research specialists and grant recipients.
- Easy identification of potential collaborators and opportunities for research networking
- Supporting identification of potential reviewers, experts, and specialists for a variety of roles across research.

Prior to the introduction of CRediT, if journals required or allowed the provision of details about contributions, these were typically described in a contributor statement (or sometimes in an acknowledgment section). Such statements were not provided in a structured or consistent format across journals and publishers and therefore not a usable piece of metadata associated with a specific research output, not searchable, and not surfaced by indexers. However, relatively small adjustments to the technology platforms that support article and manuscript submission and publishing could enable the capture of contributor roles as part of an article metadata, and since the launch of the taxonomy for use and implementation in 2014, this is what has started to happen.

CREDIT IMPLEMENTATION – GATHERING STEAM

During its development, CRediT (see Table 1) was the subject of various tests in practice and feedback from authors publishing initially across the life and physical sciences. Overall, CRediT has been well received as a practical and non-burdensome way to improve the visibility and access to information about author contributions with a variety of potential uses (Allen, Scott, Brand, Hlava, & Altman, 2014). The Consortia for Advancing Standards in Research Administration Information (CASRAI) has served as the custodian of the taxonomy since its launch and has been working through a volunteer programme committee to raise awareness, to support implementations, and to capture community feedback.

As with any new publishing or editorial policy or guidelines, the devil is in the detail, and with policy, that typically means *in the implementation*. Since CRediT's emergence onto the scene, CASRAI and the CRediT programme committee members have been keenly advocating the use of CRediT. However, implementing the taxonomy, in most cases, required publishers to make changes to their article submission workflow. Good fortune for CRediT was the decision by the Public Library of Sciences (PLOS) to switch their established 5-role contributor roles to the expanded 14-role taxonomy that CRediT offered and across all their journals (Atkins, 2016).

The PLOS implementation proved relatively pain free for authors and provided the proof in practice and confidence for other publishers to follow. Around the same time, Cell Press endorsed the use of the roles among their authors, initially as an option (www.cell.com/pb/assets/raw/shared/guidelines/CRediT-taxonomy.pdf), and importantly, in 2015, Aries Systems introduced CRediT into its Editorial Manager (EM) manuscript submission and peer review system as a configurable option for any journal using EM to capture CRediT information from authors (Aries Systems Newsletter, 2015). Today, just over 120 individual journals, publishers, open research platforms, and system integrators have already implemented the taxonomy for their authors, and that number is set to increase substantially during 2019 following Elsevier's decision to use CRediT in many more of its journals (Fennell, 2018). The CASRAI CRediT website now lists the expanding number of adopters (see https://casrai.org/credit/). Going forward, it is essential to ensure that further implementations of CRediT ensure that the terms are captured as metadata in any final published article to allow all the benefits of CRediT to be realized. There is also increased interest and potential to use CRediT to capture contributions beyond the life and physical sciences.

SO WHAT NEXT FOR CREDIT?

CRediT has almost taken flight on its own – there continues to be significant endorsement of CRediT and as a simple but

TABLE 1 Contributor Roles Taxonomy (CRediT).

Term	Definition
Conceptualization	Ideas; formulation or evolution of overarching research goals and aims
Methodology	Development or design of methodology; creation of models
Software	Programming, software development; designing computer programs; implementation of the computer code and supporting algorithms; testing of existing code components
Validation	Verification, whether as a part of the activity or separate, of the overall replication/ reproducibility of results/experiments and other research outputs
Formal analysis	Application of statistical, mathematical, computational, or other formal techniques to analyse or synthesize study data
Investigation	Conducting a research and investigation process, specifically performing the experiments, or data/evidence collection
Resources	Provision of study materials, reagents, materials, patients, laboratory samples, animals, instrumentation, computing resources, or other analysis tools
Data curation	Management activities to annotate (produce metadata), scrub data and maintain research data (including software code, where it is necessary for interpreting the data itself) for initial use and later re-use
Writing – original draft	Preparation, creation and/or presentation of the published work, specifically writing the initial draft (including substantive translation)
Writing – review and editing	Preparation, creation and/or presentation of the published work by those from the original research group, specifically critical review, commentary or revision – including pre- or post-publication stages
Visualization	Preparation, creation and/or presentation of the published work, specifically visualization/data presentation
Supervision	Oversight and leadership responsibility for the research activity planning and execution, including mentorship external to the core team
Project administration	Management and coordination responsibility for the research activity planning and execution
Funding acquisition	Acquisition of the financial support for the project leading to this publication

practical way to shed light on the diversity of researchers' contributions to published output. As noted, many publishers and journals already capture contributor information, and examples exist for expressing this information in structured ways as some of the current implementers are already tagging CRediT contributions coded in JATS xml v1.2. However, there is more to do.

CASRAI recently became a Duraspace project (Duraspace, 2018) but remains the custodian of CrediT, and the programme committee is now seeking designated resources to manage and lead an awareness and implementation drive; many publishers are simply not aware of CRediT and its potential benefits. Encouragingly, a group of senior scientific journal editors recently recommended the adoption for CRediT for a whole raft of reasons completely in line with CRediT's raison d'etre (McNutt *et al.*, 2018).

As with any taxonomy, being used as a standard, it is important for it to have value as part of metadata that is used consistently. The CRediT programme committee have been developing a case for CRediT to be lodged as a formal standard with NISO. As the previous *Learned Publishing* paper described, CRediT was initially developed and tested as a taxonomy for life and physical sciences, although many of the current implementers are using it to capture contributions in other disciplinary areas. However, we are aware that one size may not fit all. In addition, the current taxonomy may need to evolve as science and the types of contributions that may become less or more important change. For now, however, we want to encourage usage of 'CRediT 1.0' and work with CASRAI and the programme committee to capture user feedback and plan updates of the taxonomy to better reflect the needs of multiple disciplines.

Finally, to facilitate and optimize adoption by researchers, new tools could be created that allow a research team to record the CRediT contributions collaboratively and upstream in the research cycle as the research project is ongoing or the results drafted. Early and frequent discussions about authorship is the most effective way of avoiding author disputes, and CRediT, whilst not dictating which contribution determines authorship, still provides a framework to facilitate these discussions (Marušić *et al.*, 2014).

AN OPPORTUNITY TO KNOW MORE ABOUT THE SCIENCE OF SCIENCE

It is somewhat ironic that there remains a dearth of evidence on how research is best funded and supported. There has been a focus on analysing the outputs of science as indicators of the effectiveness of research. This is evident from the huge range of bibliometric analyses that exist. The focus on research outputs ignores the importance of the *inputs* to science and the context and activities undertaken – such as funding information and access to resources, diversity of the team, skill mix, location, and so on. Differences, of course, apply across fields of science. However, we now have DOIs for a widening array of research outputs beyond articles published in a journal, including preprints, policy documents, datasets, software, and code. We also have ORCID iDs as persistent identifiers for researchers. More precise information on a researcher's contributions to those outputs through CRediT allows the precise, standardized human- and machine-readable expression of researchers' contributions to these

research outputs. Add to this funding and institution data, and you have a potential gold mine of information to shed light on the 'science of science'.

There have been a number of recent calls for investment in meta-research and studies to provide more evidence to support research funder and policymakers about how best to support science and research, and particularly to support reproducibility of findings, reduce research waste, and accelerate impact (Ioannidis, 2018).

Collaborations are increasingly considered by policymakers and funding agencies to be essential to tackle complex scientific and global problems. Availability of contributor role information could, for example, be an important ingredient to support the analysis of team size and team science; researchers at Massachusetts Institute of Technology describe the concept of 'consortium fatigue' arising, whereby large-scale research may result in, for example, low productivity (Papadaki & Hirsch, 2013). Other studies have sought to describe and understand patterns and the value of diversity across teams in research, for example, attempted by providing insight into gender differences in roles and across team (Macaluso, Larivière, Sugimoto, & Sugimoto, 2016); such studies can help to inform how best to support women, or early career researchers, through a research career. If we can understand how collaborations work and when, or how to optimize the best team mix, then we may be able to incentivize the sorts of behaviours and activities that can bring about and accelerate discovery. More information on the contributions to science provides another important piece of the puzzle.

AUTHOR CONTRIBUTIONS

Liz Allen performed writing – original draft and conceptualization. Alison O'Connell and Veronique Kiermer performed writing – review and editing; conceptualization.

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