A systematic scoping review of ethics of contributor role ontologies and taxonomies

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Abstract

Contributor Role Ontologies and Taxonomies (CROTs) provide a standard list of roles to specify individual contributions to publications. Due to the recent uptake of CROTs – CRediT taxonomy in particular, researchers from different disciplinary backgrounds have anticipated a positive impact on ethical issues related to the attribution of credit and responsibilities. Yet, they have also voiced concerns about ways in which CROTs could be abused and have provided suggestions to improve them. While these discussions explore unique ethical challenges of using CROTs from different perspectives and in different contexts, they have never been collated and consolidated. To facilitate a debate about the ethical adoption, use and future development of CROTs, the current scoping review collates and explores published viewpoints about the ethics of CROTs. Towards this end, Ovid Medline, Scopus, Web of Science, and Google Scholar were searched. In total, 30 papers met the inclusion criteria and were subsequently analyzed using an inductive approach. We identified eight themes and 20 specific issues related to the ethics of CROTs. Based on our survey and analysis, we provide four recommendations for CROT developers: 1) ***Compile and promote comprehensive instructions*** that explain how CROTs should be used and that note common pitfalls of employing them in practice, particularly about the scope and limitations of using CROTs in parallel to authorship bylines; 2) **Improve the coherence** of used terms, 3) **Provide translations of roles** in languages other than English, and 4) **Communicate a clear vision and strategy** about future development plans.

Keywords: Contributor Roles, Contributor Role Ontology and Taxonomy, Ethics, Authorship, Research Integrity

Introduction

Contributor Role Ontologies and Taxonomies (CROTs) are recent innovations developed to address ethical issues associated with the attribution of credit and responsibilities in scholarly publications. By providing a standard list of roles to specify individual contributions to publications, CROTs enhance transparency and consistency about reporting diverse research tasks and contributions to the work leading to a publication, thereby improving the attribution of credit and responsibilities [1]. The uptake of CROTs has not been limited to journals. CROTs have also been adopted by repositories (e.g., DARIAH-DE, Zenodo) and universities (e.g., University of Glasgow), and are among recommended solutions to improve research assessment, promotion, and funding processes [2]. Accordingly, CROTs are becoming a pivotal part of scholarly publications and associated workflows, as they are beneficial not only to researchers (e.g., to receive the deserved credit for their contributions) but also for publishers and their editorial teams (e.g., to enhance understanding about who did what in relation to a publication and who is responsible for each task), funding organizations (e.g., to clarify who benefitted from provided funds), universities' administration and research offices (e.g., to improve tenure and assessment processes) and libraries (e.g., to enable indexing publications based on involved contributions) [3]. Currently, CRediT – the Contributor Role Taxonomy is widely adopted (by journals) and used (by the community), has been formalized as an ANSI/NISO standard [4, 5] and also integrated into ORCID research identifiers, thereby allowing ORCIDs to be directly linked to the roles [6].

Thus far, no published study has systematically analyzed CROTs from an ethical perspective [7], which given their growing significance in scholarly publications, is a needed area of work. Indeed, with the steady increase of collaborative and international research [8], and a continuous rise of the number of diverse roles required in research projects, exploring the ethics of CROTs (i.e., the relevant obligations, values, and virtues in relation to CROTs) increases the likelihood of their ethical development and deployment [2]. Furthermore, by having ethical issues categorized under specific themes, future research will be provided with an indication of most frequently discussed themes in relation to CROTs.

The first iteration of this review was conducted in 2020 as an exploratory search of the literature about CROTs and was presented in M.H.'s PhD thesis, which was supervised by B.G. and concluded in May 2021 at Dublin City University, Ireland [9]. However, this effort was unsystematic, limited in scope (only Google Scholar and Web of Science were searched), and lacked input and validation of a librarian and a digital infrastructure expert. To address these limitations, a librarian (Q.E.W.) and a digital infrastructure expert (K.L.H) were invited to collaborate in this scoping review, which endeavors to answer the following questions:

- What ethical issues of CROTs are discussed in the literature?
- What ethical themes can be identified in the current debate about CROTs?

Methods

After developing a comprehensive search strategy, a scoping review protocol was drafted and revised when necessary [10]. The search strategy incorporated

“contribution”, “attribution” and “authorship” along with keywords and controlled vocabulary terms for CROTs. Terms for CROTs included both descriptive terminology and specific CROT models. We adapted the search strategy to Medline (Ovid), Scopus (Elsevier), and Web of Science (Thomson Reuters). No limitations were placed on document type or publication date. We also searched Google Scholar for additional studies. The bibliographic database searches were performed on January 27, 2022 and identified 979 documents (Full search strategies are available in Appendix 1 and the PRISMA-S checklist is available in Appendix 2).

Upon de-duplication, 576 documents were qualified for screening. Titles and abstracts were screened, resulting in the removal of 428 documents based on the following exclusion criteria:

- Non-English sources
- The application of ontologies and taxonomies in areas other than specification of contributions in scholarly collaborations
- CROTs intended for non-scholarly collaborations
- Publication types without a full text

Consequently, 148 documents were deemed eligible for full-text reading. After reading the selected full-text articles, 118 documents were excluded because they did not meet all three inclusion criteria:

- Must mention CROTs that are used to specify contributions to scholarly output (e.g., CRediT, TaDiRAH, CRO, DataCite contributorType).

- Must mention the application of CROTs in reporting contributions made to different scholarly outputs (e.g., manuscripts, research protocols, software).
- Ethical issues (i.e., obligations, values, or virtues) in relation to CROTs should be discussed in a significant way as determined by an ethics expert (M.H.).

Subsequently, 30 documents that met all three inclusion criteria were deemed eligible for content analysis (Figure 1).

Fig 1. The selection process deemed 30 documents eligible for content analysis.

To analyze the sample, five randomly selected documents were examined using an inductive approach, which entails labelling sections that describe an ethical issue followed by subsuming labels under ethical themes, and finally, tagging respective documents with relevant themes [11]. After reading the first five documents, thirteen labels were created. Using these labels, the rest of the sample (consisting of 25 documents) were read and labelled, and where necessary, new labels were created. This resulted in creating eleven new labels, merging three labels and overlap reduction, bringing the total number of labels to twenty. These labels were then subsumed under eight ethical themes. Upon rereading the entire sample, the titles of some issues were changed but no new themes or issues were created. Eventually, all documents were tagged with one or more themes (Figure 2).

Fig 2. Summary of the tagging process.

Results

Characteristics of the sample

Document types

The majority of 30 documents eligible for full text analysis were journal articles (Figure 3).

Fig 3. Document types of the eligible items.

Publication trend over time

The review shows a significant increase in the number of documents that discussed ethics of CROTs in 2021 (Figure 4).

Figure 4. Publication year of the eligible items.

Most common ethical issues and the associated themes

Analyzing the sample resulted in identifying eight ethical themes (Figure 5). In what follows, ethical issues related to each theme are described.

Fig 5. Ethical themes ranked based on their occurrence in the literature. Some documents are tagged with more than one theme.

1. Attribution

Attribution issues are about improving CROTs' list of roles and definitions, extending output types that should be captured by CROTs and the use of CROTs in specific contexts, all of which directly impact the scope of attributions and the extent to which specific disciplinary nuances are captured by CROTs.

Issue 1) Improving CROTs' list of roles and definitions. CROTs' list of roles should evolve "as science and the types of contributions that may become less or more important change" [12]. Indeed, keeping lists current to meet evolving user needs is paramount and among factors that promote the use of CROTs [13]. Although Ding and colleagues assert that CRediT roles "cover almost the whole process of scientific research of most disciplines" [14], several publications mention specific roles that should be added to CRediT, perhaps because as its developers note, "CRediT was initially developed and tested as a taxonomy for life and physical sciences" and thus, may not fit all other disciplines [12]. For instance, Alpi and Akers note that "CRediT does not currently describe all roles that librarians play" [15]. According to Steele, it is not clear whether CRediT accurately captures the role played by medical writers, a particularly critical issue in the field of dermatology where only ~1% of published Randomized Control Trials (RCTs) make a distinction between editing and preparing the first draft [16].

While Dappert and colleagues make a general suggestion to define roles clearer [17], others make more specific suggestions. For instance, Matarese and Shashok claim that CRediT "ignores" some non-author contributions including technical support, translation and editing the manuscript, and provide specific suggestions to improve CRediT's three current roles (Investigation, Writing—Original Draft, Writing—Review & Editing) and add two new roles (Technical support, Translating or editing the manuscript, as non-author) [18]. Zhang and colleagues note that some important roles in RCT such as "randomization, patient enrollment, and follow-up are not clearly defined" by CRediT, and suggest Contributor Roles Taxonomy for Randomized Controlled Trials (CRediT-

RCT) that includes ten roles for conducting RCT (Conceptualization, Funding Acquisition, Project Administration, Site Principle Investigator, Statistical Analysis Plan, Investigation, Data Curation, Formal Analysis, Writing—Original Draft, Writing—Review & Editing) [19]. The role of software development for research and CRediT's shortcomings in capturing involved nuances is highlighted by Alliez and colleagues [20]. They argue that since software development in research involves "significant innovations", qualified human intervention and qualitative information are necessary to ensure accurate reporting of contributions. Accordingly, they suggest nine finer categories for better representation of involved tasks (Design, Debugging, Maintenance, Coding, Architecture, Documentation, Testing, Support, Management).

Issue 2) Extending output types. Dappert and colleagues note that CROTs' scope should be extended beyond peer-reviewed journal articles [17]. While supporting this suggestion, Vasilevsky and colleagues highlight that since output types such as datasets, software, and research protocols "have less well-established workflows to collect and present structured metadata", this is not easily achieved [13]. Similarly, although two papers specifically note that capturing contributions to datasets should be improved [21, 22], others highlight the lack of a robust link between datasets and all of their contributors as a factor that "inhibits re-use, verification of research, and detection of scientific fraud" in datasets [23]. The absence of robust links between contributors and datasets could be explained by the wide range of contributors to datasets (e.g., governments, non-research organization, companies, and other professionals), which often include groups and teams as authors *in addition* to individual authors. Since there is no ORCID equivalent for groups and teams, such practices reduce consistency and

machine-readability of attributions [22, 24]. Although adding groups and teams to the authorship list is also common in peer-reviewed papers, none of the explored items in the sample mentioned this issue as a challenge.

Issue 3) The use of CROTs in specific contexts. Extending the application of CROTs to other object types could be particularly challenging in some contexts. For instance, in creating digital outputs like online dictionaries, oral stories database or a linguistic atlas, while some contributors might only be "involved for a very short time, as short even as just one recording session or consultation", others' contributions might extend to years [25]. This dynamic justifies devising *macro-credits* and *micro-credits* to account for discrepancies in terms of the time contributors were engaged in a project (Bliss and colleagues further note that in their evolving project that constantly attracts new contributors and contribution types, macro and micro credits are needed. While macro-credits are high-level "general contributor roles such as editor, director, web design, data processing, and funding", micro-credits are attached to individual items such as dictionary entry and audio files, and "include more specific contributor roles such as speaker, storyteller").

Alliez and colleagues highlight the complexities of capturing contributions made to software and question the accuracy of taxonomies that flatten out all involved contributions "on the simple role of software developer" [20]. McLaren and Dent note that some outputs such as "design protypes, experimental data sets, or methodologies designed to test a hypothesis" are not captured in a digital format during research workflows and are sometimes resulted from intangible and immeasurable contributions (e.g., experience), thereby making them complicated to capture by CROTs [26].

2. Impact on authorship

Since CROTs are currently used in parallel with authorship bylines, they are sometimes discussed within debates about ethics of authorship and promoted as a solution to resolve ethical issues.

Issue 4) Authorship disputes*.* Some publications suggest that using CROTs (and CRediT in particular) minimizes the likelihood of specific ethical issues of authorship. Using CRediT is believed not only to reduce authorship disputes [1], but also "support research institutions and authors to *resolve* author disputes by providing more transparency around individual author roles and responsibility" (emphasis added) [12]. Holcombe anticipates that since CRediT is implemented with checkboxes to choose contributions (as opposed to authorship criteria that requires reading large amounts of text and complicated inferences)*,* it is likely to induce better engagement from researchers because navigating checkboxes is easier than reading authorship criteria [27].

Issue 5) Honorary authorship. Two papers suggest that using CRediT reduces honorary authorships because it reduces ambiguity about contribution types [27, 28]. However, this view is challenged by Larivière and colleagues who argue that researchers could also adopt practices like ghost, guest, and gift authorship when using CROTs [29]. They further conclude that CROTs "systematic description of work does not, therefore, preclude invisibility, but only displaces it elsewhere. Consequently, it leaves ghostwriting of articles and potential honorary contributorship in the backrooms of scientific research" [29].

Issue 6) Authorship order. Using CRediT is believed to reduce ethical challenges regarding authorship order as well. Without alluding to *how* using CROTs will influence author order across disciplines (where order is strongly guided by specific norms), McNutt and colleagues claim that adopting CRediT would "help alleviate some of the confusion across disciplines and cultures regarding the meaning of author order" [21]. Using CRediT is also considered as a reasonable strategy to "minimize interpretation of [authorship] order and variability in perceptions of roles" [30].

Issue 7) Authorship standards. Although several articles explicitly note that CRediT improves current authorship standards [21, 28], some explain why this claim might not be always true. For example, it is argued that CRediT does not help distinguishing those who should be listed in the author byline from those who should be acknowledged [25], and it is "only applicable to byline authors" [18]. This could, in part, be because CRediT (as a model) does not resolve questions "about the quantity and quality of contribution that qualify for authorship" [29], and while some of its roles overlap with elements of authorship, they "do not fully encapsulate in any single role, the concept of authorship" [26]. Furthermore, CRediT does not provide clarity on one of the most challenging aspects of defining authorship, namely the notion of "substantial contribution" [31].

3. CROTs' design

Ethical issues about CROTs' design pertain to the overall architecture and design of CROTs that ultimately affect an ethical attribution of credit and responsibilities.

Issue 8) Open or controlled vocabularies. In their introduction of the CRediT taxonomy, Brand and colleagues stress that "a controlled vocabulary of contributor roles" is needed within the scholarly ecosystem [1]. Craig's citation of suggestions

provided by the UK Academy of Medical Sciences explains the rationale for this need: “So that individuals encounter the same system in all work, whether as a researcher or an appraiser” [32]. Those in favor of open vocabularies, however, advocate for “fast changing” fields in terms of used techniques and objects, e.g., digital humanities [33] or projects that involve a “continuously evolving” set of roles both at the project and item level, as well as the preference to prioritize “the wishes of the contributors of each project over perceived consistency” [25].

Although two papers note that CROTs’ list of roles can *never* be complete [29, 34], Borek and colleagues add that they do not have to be complete but instead, they should be “open for extensions without the need to revise existing definitions” [34]. The openness of list of vocabularies is also implied in design requirements suggested by Sauermann and Haeussler who stress that CROTs should be flexible to accommodate nuances across projects and fields and, also, “anticipate changes to scientific activity, such as growing team size and specialization, automation and commoditization of certain research activities, as well as broader participation by nonprofessional scientists” [35].

Issue 9) Strategies for selecting terms for the vocabularies. While specific terms support precision, broad terms support “consistent application, collocation and recall” [36]. Furthermore, selected terms should be reconciled with existing taxonomies (e.g., tags currently used by repositories and libraries) and strike a balance between theoretical correctness versus commonly used terms “(visualization + geospatial coordinates object vs. mapping)” [36]. Sometimes decisions must be made about

whether a role is “distinct enough to stand on its own as a separate category (e.g. storage vs. storage and dissemination)” [37].

Selecting terms for roles that are inherently related and/or roles that are conducted by the same person are discussed as well. For instance, Zhang and colleagues suggest that in RCTs, roles such as formal analysis and software (both among CRediT roles) cannot always be described with unique terms because “statisticians need to use software to perform formal analysis” [19]. Challenges of updating terms in CROTs are briefly discussed in relation to TaDiRAH, whose developers suggest using “the property skos:closeMatch” to create a mapping between old and new terms [34].

4. Impact on reporting scholarly contributions

These issues are concerned with the impact of using CROTs on reporting contributions to scholarly work.

Issue 10) Strategic and opportunistic use of CROTs. Larivière and colleagues note that since contributions and gained credit are inevitably tied to the reward system of science and the *symbolic capital* in academia, goal displacement (i.e., behavioral modification to “meet certain requirements, norms or incentives”) might happen upon wider adoption of CROTs [29]. As an example, they suggest that the disproportionately high number of PLOS Medicine authors assigned with CRediT’s roles of “Writing—Original Draft” and “Writing—Review & Editing” may be explained by authors’ attempt to demonstrate adherence to the ICMJE authorship criteria (as the ICMJE’s second criterion explicitly requires a contribution to the writing process). Furthermore, they note the risk of having financial conflict of interests disguised when using CROTs in

publications resulted from industry-academia collaborations. From an industry-partner perspective, authorship implies *intellectual intervention* whereas contribution to *tasks* might help “avoid allegations of conflicts of interest” [29].

Three publications mention the impact of CROTs on inaccurate reporting of contributions [18, 29, 35]. Matarese and Shashok note that since CRediT is only used to describe authors’ contributions (thereby omitting non-author contributors), it could induce authors to “unintentionally yet misleadingly shift credit for certain tasks from the people who did the work to people named in the byline as authors” [18]. Larivière and colleagues express concerns about disciplinary differences in terms of interpreting contributions, and the *presumed* link between the actual labor and its indicators, speculating that the discrepancy between the two could be further obscured by researchers’ strategic behavior, e.g., favoring “good working relationships” [29]. Sauermann and Haeussler highlight that using CROTs may encourage researchers to crowd into tasks that are considered more valuable and dissociate themselves with tasks considered less important or those with a greater potential for risk of error [35].

Issue 11) Responsibility and accountability. A survey to investigate contributions made by undergraduate assistants to research projects shows that since collaborators with different levels of seniority might have dissimilar assumptions about the “level” as well as “range of responsibilities over time”, mentors and students may sometimes have different impressions of individual responsibilities [38]. For example, when conducting *Data curation* and *Investigation* tasks (often involving “repetitive work guided by structured procedures and protocols”), both mentors and student researchers assume

high levels of responsibility for students. However, when it comes to tasks such as *Validation* or *Writing,* a discrepancy is reported between assumed responsibilities [38].

Two publications mention CRediT and the ICMJE criteria in the context of responsibilities [26, 28]. McLaren and Dent note that while authorship credit "carries additional layers of rights, responsibilities, and ultimate accountability for the work" and is also subject to stringent tests such as the ICMJE criteria, CRediT is only concerned with acknowledging (some of the) contributions [26]. Teixeira da Silva believes that CRediT is an improvement to the ICMJE recommendations "increasing the transparency of author contributions and stating with greater clarity the contribution of each author, potentially fortifying accountability" [28].

Issue 12) Significance and extent of contributions. Two publications highlight CRediT's inability to rate different tasks based on their significance for a project, which results in ambiguities about the overall significance of individual contributions [14, 31]. While Ding and colleagues note that knowing each role's significance in relation to the whole work helps differentiate their importance, the argument provided by Smith and Masters— i.e., that the importance or value of roles varies per project and context, implies that this clarification cannot be a default assumption built into CROTs [31]. Furthermore, Simth and Masters provide an analogy to the notion of substantial contribution in using authorship definitions and suggest that when using CRediT, "it remains unclear how much an individual must contribute" to qualify as a contributor? [31] They note that since being *fully inclusive* results in lengthy lists of names "including those individuals who provide minor contributions", some form of quantification "is, and will always be, necessary" [31]. Nevertheless, Alliez and colleagues claim that attempts

to quantify contributions, even if automated (e.g., to capture contributions to software development), could be gamed to inflate contributions to individuals' benefit [20].

5. Assessment

These ethical issues are concerned with the implications of using CROTs in academic assessments.

Issue 13) Improving academic assessment and evaluation. While Smith and Masters note that CROTs are unlikely to be used as metrics of performance without authorship [31], others argue that they may facilitate "the development of contribution-based indices to complement authorship-based indices" [35] or allow developing altogether "new metrics of individual research productivity and impact" [15]. Whether as standalone or in combination with authorship, these changes require the development of infrastructure to integrate CROTs into funding agencies' submissions and progress reports [21] and institutional hiring and assessment workflows [13]. Another aspect where CROTs can benefit research assessment pertains to peer review process. Integrating CROTs into review processes could improve efficiency by means of connecting reviewers to specific contributions based on proficiency and expertise [22 , 27, 39].

Issue 14) Improving equity and diversity in academic work and evaluation. Two publications claim that since using CROTs improves the science of science, their wide adoption could provide new insights about the distribution of labor in academia and help addressing gender and diversity challenges [12, 15]. In fact, Larivière and colleagues' use of the CRediT roles of articles published in PLOS journals between 2017 and 2018,

proves this point. Among other conclusions, they note that “men are more likely to conduct tasks associated with seniority, such as funding acquisition and supervision (30% more likely than women), contributing resources, software, conceptualization, and project administration” [29].

6. Availability

CROTs’ availability pertains to their accessibility for different members of the community and discoverability for reuse.

Issue 15) Accessibility. Since inaccessible or partially accessible CROTs might negatively impact different user groups such as researchers and institutions, conformity of CROTs and contributors’ data to FAIR principles (Findable, Accessible, Interoperable and Reusable) is essential. This could be demonstrated by e.g., using Unique Resource Identifiers (URIs) “to uniquely identify the concepts”, “using W3C Standard SKOS and the usage of CC0 1.0 licence” [34]. Although Craig emphasizes on the electronic accessibility of contributor information (e.g., in journals’ websites), Das and Das note that such developments cannot be implemented “in the print copy” of journals [40].

Availability of CROTs has also been discussed in terms of translating roles and their definitions into languages other than English. For instance, TaDiRAH’s translation into German, French, Spanish, Portuguese, Serbian, Italian and Norwegian will not only “ensure technical and professional mentoring for the use and reuse” [34], it will also make it more accessible to more users across the globe [37]. Indeed, increasing the visibility of contribution statements requires reducing access barriers and processing

costs, and could be further facilitated by editors, funding agencies, administrators, and database providers [35].

Issue 16) Machine-readability. Machine-readable contributions are readily discoverable and reusable [13, 32], improve availability of CROTs to more users and extend the application of CROTs to a “variety of contexts” [37]. This is further discussed by McNutt and colleagues who note that availability of contributor information in both machine- and human-readable forms facilitates the “transparency of author contributions in different contexts, via syndication, indexing, and abstracting services, and possibly future applications across journals” [21]. When contributor information is available in a machine-readable and consistent format, “contributions will transition from hearsay to quantifiable evidence” [21].

7. Usability

Ethical issues about usability include suggestions that improve how CROTs are used so as to ensure an ethical attribution of credit and responsibilities.

Issue 17) Improving usability. Some suggestions to improve usability require technical development. For example, linking CRediT roles to ORCID records [13, 32] and creating free web-based tools that allow journals to keep additional information in “acknowledgments, footnotes, or by other means” [21]. McLaren and Dent note that CRediT is not consistently understood and applied across the board and highlight supplementary approaches that could complement the CRediT model, e.g., the “Technician Commitment” initiative in the UK [26]. Another suggestion to improve usability is to develop and promote guidelines that describe how contributions should be

allocated [32]. For example, Larivière and colleagues suggest that since only 55% of explored articles in a sample of 30,054 included the role of validation, “journals could require validation as a mandatory contribution type for empirical work” [29].

Issue 18) Assigning roles. Three papers discuss role assignment [1, 25, 39]. Brand and colleagues recommend corresponding authors to assign CRediT roles and to provide the review and confirmation opportunity to other contributors [1]. However, in describing how to use the CRO, Ilik and colleagues propose a different workflow for role assignment, calling it the claim process [39]. In this process, which is part of the paper production stage, authors, non-authors, editors and others should report their own contributions using the list of roles (instead of the corresponding author assigning these and having contributors confirm). Once those involved have reported their contributions, all other contributors would confirm reported roles. Another approach is adopted by the Algonquian Language Digital Resources Credit System wherein an additional free-text box allows contributors to describe roles *in their own words* to ensure more transparency [25].

8. Managing CROTs

These issues are about the ethical implications of decisions made by CROTs’ administrators and management boards regarding development, maintenance and communication about their activities.

***Issue 19) Transparency*.** The transparency of involved process in the development and revision of CROTs is discussed in two publications. While CRediT developers mention the 2012 collaborative workshop held at Harvard University as an event that engaged

with experts and as a defining moment in the development of the taxonomy [1], Matarese and Shashok question the openness and transparency of this process and note that this has been “an invitation-only meeting”, and the data about the subsequent survey of life science researchers who provided “positive feedback” about the initially suggested taxa were never made available [18]. They also reflect on CRediT’s ownership structure and claim that Elsevier is “the de facto owner of CRediT” [18]. (In further inquiry about this claim, we reached out to the CRediT standing committee and asked for clarification. They disagreed with the claim and replied: “Aries and Elsevier own and sell licensed access to the software that is capable of collecting, storing, and exporting the roles. The role metadata that the system collects are property of the journal” (Personal Communication, 20 April 2022).)

Issue 20) Engagement. Two papers introduce open community-developed resources and mechanisms to collect user feedback as useful tools for engagement, which also promote collaborative approaches in managing activities related to the CRO and CRediT [13, 39]. Borek and colleagues highlight using similar strategies for maintenance of TaDiRAH and note that versioning and issue tracking features of GitHub have been conducive to their efforts [37]. Although, one challenge of open engagement pertains to receiving contradictory feedback from the community [36]. In a recent publication by Borek and colleagues, “TaDiRAH board” is introduced, which will be responsible for managing activities related to the development of TaDiRAH: “The board consists of the original core team, new developers and other contributors” [34]. This group also openly share their strategy for expanding TaDiRAH to “revise and

harmonize the structure and semantics of the model, as well as the concept terms and definitions" based on how it is used by the community [34].

Discussion

Confusion around CRediT's application and impact

While CRediT is the most widely used among the CROTs, it's correct application and possible impact on current ethical issues are not always fully clear to those who discuss it. Reviewing the literature shows a discrepancy between what CRediT developers advise, and what the community understands in terms of CRediT's scope and application – some papers in our sample have misread or misunderstood key details about CRediT (e.g., [15, 21, 38]). CRediT developers have published several journal articles to create awareness about CRediT and its intended use (e.g., [1, 12], but misinterpretations in the published literature suggest that these instructions have not always been effectively communicated and well-received or perhaps journal articles were misread.

For instance, in an editorial published in the journal of Medical Library Association, Alpi and Akers note: "Together with ICMJE guidelines, CRediT can be used to facilitate conversations and *help determine who merits authorship within collaborative teams* (emphasis added)" [15]. In a different example, Honore and colleagues claim that CRediT was "originally conceived and designed with authorship roles in mind" [38]. However, Brand and colleagues have refuted both claims when they describe the taxonomy's scope, and specifically highlighte that CRediT's parallel use with authorship definitions also caused confusion when CRediT was piloted for the first time:

> “Most of the questions that arose concerned confusion over whether the taxonomy was explicitly intended to specify which types of contribution qualify for authorship status, when in fact that was never the intention. As stated in the taxonomy header: The classification includes, but is not limited to, traditional authorship roles. That is, *these roles are not intended to define what constitutes authorship*. Rather, the roles are intended to apply to all those who contribute to research that results in scholarly published works, and it is recommended that all tagged contributors be listed, whether they are formally listed as authors or named in acknowledgements” [1].

Other examples of misunderstanding pertain to CRediT’s impact on reducing ethical issues related to authorship order. When promoting CRediT, Brand and colleagues briefly mention authorship order following a hypothetical situation in a non-existing infrastructure, and stipulate that *assessing* researchers in such a scenario would no longer depend on authorship order:

> “Imagine publishers collecting structured information about contribution in a standard format. Imagine, further, that this information is associated with the article DOI, via CrossRef, and with ORCID author identifiers. We would then have the infrastructure in place to track not only who authored which publications, but also who contributed what to each publication that names the individual as a contributor. With this infrastructure in place, it would eventually be possible to devise more precise, author-centric credit and impact tracking tools, on which the byline order of author names would have no bearing” [1].

However, McNutt and colleagues (cited by 38 and 203 articles as per August 2022 according to PubMed and Google Scholar respectively) note “Adopting the CRediT taxonomy would also help alleviate some of the confusion across disciplines and cultures regarding the meaning of author order” [21]. To back this claim, McNutt and

colleagues cite Sauermann and Haeussler's 2017 paper [35], who have not made such a claim either.

In a different misunderstanding about CRediT's impact on reducing ethical issues related to authorship order, while citing Brand et al. [1], Poirer and colleagues note "Adhering to the recommendations from Project Credits [CRediT] by clearly listing contributions of each author may be a reasonable strategy for acknowledging order. This approach would create transparency and minimize interpretation of order and variability in perceptions of roles" [30].

Examples like these or instances wherein journal instructions suggest using CRediT contrary to what is prescribed by its developers (see [2] for an example) show that communicating information about CROTs by means of peer-reviewed publications is not always effective. CROTs such as CRediT could be misused and misunderstood in many ways, and researchers will not always have the knowledge necessary to identify, read and understand the instructions embedded in peer-reviewed publications. One way of minimizing these misunderstandings, is to develop reasonably comprehensive and straightforward instructions for users (similar to those developed by the ICMJE).

Issues in relation to CRediT's current list of terms

Some CRediT roles describe tasks at the project-level while others describe tasks at the paper-level. While one of the ethical issues of CROTs' design pertained to strategies for selecting terms for the vocabularies, none of explored papers mentioned certain irregularities in CRediT's current list of terms. Here we discuss two such issues, 1)

using both performative and non-performative terms, 2) confounding paper and project-level contributions.

1) While TaDiRAH developers use a coherent and consistent set of terms for activities, arguing that these terms should be “gerundiva [i.e., verbal adjective] to represent the performativity of the activities” [34], such considerations have not been observed in developing CRediT terms. Consequently, some CRediT terms are non-performative nouns (e.g., resources, software) that strictly speaking, do not represent a specific activity.

2) CRediT currently dovetails roles that describe specific work on a paper (e.g., writing, methodology, validation) with roles that mainly occur at a project level, and that could affect (and be reflected in) several papers (e.g., funding acquisition, project administration). This inconsistency could result in project-level roles being more coveted (and preferred by senior researchers) because they can potentially yield better return on invested time: Suppose project X has eights contributors involved in investigation, data curation and writing, two contributors involved in funding acquisition and one in project administration. If project X results in five papers, those involved in roles such as investigation, data curation and writing would have to make specific contributions in relation to each paper to be listed as a contributor but those who acquired funding and performed administrative tasks for the *project*, would be automatically listed on all papers.

Given CRediT’s quick uptake and the results of recent meta research on CRediT roles showing unequal distribution of labor and gender differences in terms of conducting

specific tasks [29], it is reasonable to expect CRediT developers to improve these irregularities in future iterations.

CROTs status: complementary or stand-alone?

Are CROTs complementary to existing authorship bylines or would they ultimately become stand-alone solutions? Papers that discuss CROTs are not always clear about whether, and how, CROTs should be employed in tandem with authorship lists. Given 1) legal and 2) ethical challenges of doing away with authorship lists, currently, it seems unlikely (if not impossible) to envision scholarly publications without author lists:

1) Authorship has a legal significance – authors can readily engage in litigation in relation to a publication whereas non-authors first have to prove that they have a legitimate claim to authorship. Employing CROTs without authorship lists affects "copyrights, intellectual property rights and the process via which these rights are assigned/challenged" [9].

2) Authors' names are used for (non-numerical) citations and in reference lists. Without author names, publishers and/or the scientific community must develop and adopt completely new systems of citation and referencing based on contributors' names. In such a system, ethical issues might occur with regard to the selection of the contributor(s) whose name(s) should appear (at all/first) on in-text citations or in the reference lists. Furthermore, while using authorship lists (except those ordered alphabetically), for the most part, it is possible to implicitly infer those who made the highest degree of contribution relative to others (i.e., first author) and those responsible for the overall integrity of the work (i.e., last

author). However, CROTs cannot currently address these issues on their own [9]. Even using the Supervision role cannot always help because projects might have numerous supervisors.

Accordingly, in the foreseeable future, CRediT (and other taxonomies) must be used in parallel with author bylines. Nevertheless, the scope of this parallel use is currently vague and visions to improve or end it are not openly communicated. Specifically, since its developers suggest that CRediT should not be used to define authorship, and, CRediT does not capture the full range of scholarly contributions – even in life and physical sciences where it was initially intended for; it is unclear how the CRediT roles and authorship definitions should be employed besides each other? Answering questions like these would facilitate developing a clearer vision about the function which CRediT and other CROTs could serve in the future of scholarly publications.

CROTs are not the panacea

When looking at the ethical issues of CROTs, similarities with ethical issues of authorship are noticeable. For example, ethical issues about the attribution of credit and responsibilities when using CROTs are similar to ethical issues about the attribution of authorship credit and associated responsibilities, and ethical issues about CROTs' design and usability have similar components to ethical issues about the definitions of authorship and their application in different contexts. Given these similarities, one can argue that in discussing scholarly attributions, improving the used model (e.g., authorship definitions, CROTs) and the development of technical workflows or even the creation of a *perfect CROTs schema and workflow* may address technical (or syntax)

problems but not the human or social component of the problem (arguably much more urgent and challenging to address). Exploring the similarities between ethical issues of authorship and CROTs in future research could lead to new insights about unethical human behavior in attributions as well as challenges of recognizing scholarly work.

This review is limited by the small sample size and may not be representative of debates that took place on the blog-sphere, online forums or in print-only material. Exploring these spaces could be useful for future research. In addition, this review only used and considered English publications about CROTs, and therefore, exploring viewpoints published in other languages could be among possible directions for future research. Conducting empirical research to explore the views of researchers from different disciplinary backgrounds could be another area for future research.

Conclusions and recommendations

While our review of the debate about CROTs demonstrate a growing interest in CROTs in recent years, the community should be mindful about inaccurate published views about them, especially regarding how they should be used and the implications of their adoption. We believe that CROTs should be continuously improved to create better systems of attribution, but overemphasizing CROTs shortcomings could potentially be used to excuse unethical behavior of researchers or perverse institutional incentives; both of which continue to be urgent to address. In what follows we provide four recommendations:

1. **Compile and promote comprehensive instructions that explain how CROTs should be used and that note common pitfalls of employing them in practice.** Given the mentioned ethical issues in terms of CROTs' impact on authorship and reporting of scholarly contributions, as well as the highlighted inaccuracies in the literature, extensive and specific guidance is needed to orient scholars about the concept of CROTs and guide their responsible use. In particular, communicating the scope and limitations of using CROTs in parallel to authorship bylines seems essential.
2. **Improve the coherence of existing roles**. Analyzing existing CRediT roles shows that some roles describe tasks at the project-level while others describe tasks at the paper-level. In the long run, these incoherencies might create hierarchies among roles and result in an unfair attribution of credit.
3. **Provide translations of roles in languages other than English**. Currently, only some of the CROTs have roles translated into languages other English (e.g., TaDiRAH). Given the wide international use of CROTs, translation of roles into non-English languages improves availability and inclusiveness of CROTs.
4. **Communicate a clear vision and strategy about future development plans.** Timely communication of future plans could facilitate input and engagement from the community and democratize the process of improving CROTs.

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Appendix 1 - Database Search Overview

Database	Coverage	Date Searched	Results
Ovid MEDLINE(R) and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions(R)	1946 to present	1/27/2022	176
Scopus (Elsevier)	1788 to present	1/27/2022	468
Web of Science Core Collection (Clarivate)	1900 to present	1/27/2022	338
Total			979
Total After De-Duplication • 399 Removed by automation • 4 Removed after manual review			576

We searched the databases listed above on January 27, 2022. Records from each database were exported to EndNote. Duplicates were removed through the “Find Duplicates” function in EndNote and by manual review. Search strategies from each of the bibliographic databases are available below.

Google Scholar

Note: Click on the hyperlinks below to see results from the Google Scholar searches

Search 1 - allintitle: CROT OR CROTs OR Datacite OR "CrediT taxonomy" OR "Contributor Role Ontology" OR "Contributor Role Taxonomy" OR TaDiRAH OR OpenVIVO

Search 2 - allintitle: authorship OR contributorship OR contributor AND credit OR credits OR contribution OR contributions

Search 3 - allintitle: author OR authors AND contribution OR contributions AND credit OR role OR roles

Database(s): **Ovid MEDLINE® and Epub Ahead of Print, In-Process, In-Data-Review & Other Non-Indexed Citations, Daily and Versions®** 1946 to January 26, 2022.

Search Strategy:

#	Searches	Results
1	(CROT or CROTs or Datacite or “CrediT taxonomy” or “Contributor Role Ontology” or “Contributor Role Taxonomy” or TaDiRAH or OpenVIVO).ti,ab.	88
2	(taxonom* or ontolog*).ti,ab.	106299
3	exp Authorship/	6596
4	attribution.ti.	1815
5	(authorship or contributorship or “contributor role*” or “contributor’s role*” or “contributors’ role*” or “contributor type*” or “contributor’s type*” or “contributors’ type*”).ti,ab.	4158
6	((author or authors) adj2 (role or roles or type or types)).ti,ab.	1043
7	((attribution or author or author’s or authors or authors’ or researcher* or scholar or scholar’s or scholars or scholars’ or scholarly or publication*) adj2 (credit or credits or contribut*)).ti,ab.	2000
8	3 or 4 or 5 or 6 or 7	13411
9	2 and 8	94
10	1 or 9	176
11	limit 10 to english language	173

Scopus

(TITLE-ABS-KEY(CROT or CROTs or Datacite or "CRediT taxonomy" or "Contributor Role Ontology" or "Contributor Role Taxonomy" or TaDiRAH or OpenVIVO)) OR ((TITLE-ABS(taxonom* or ontolog*)) AND ((TITLE(attribution)) OR (TITLE-ABS(authorship or contributorship or "contributor role*" or "contributor's role*" or

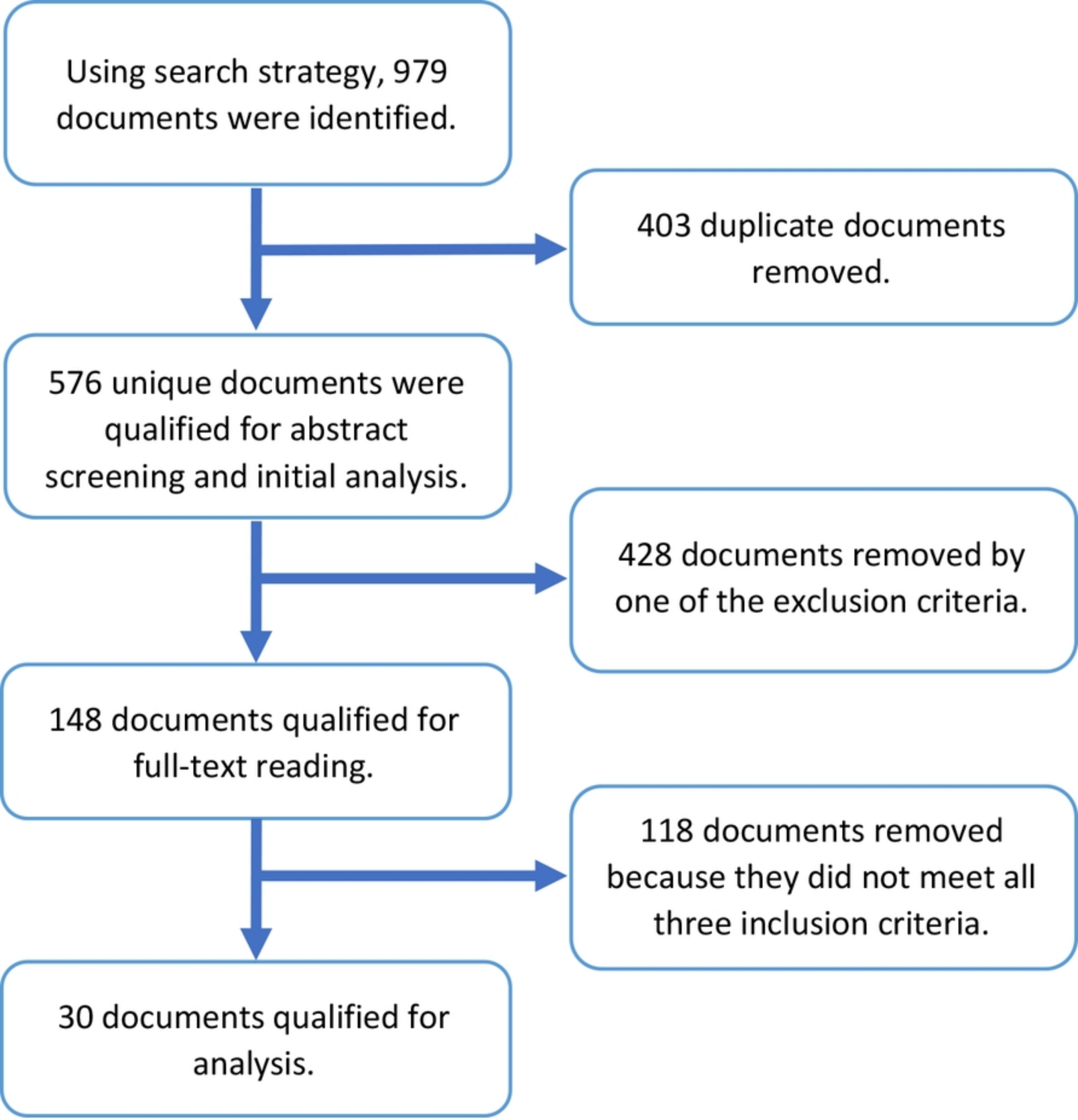
"contributors' role*" or "contributor type*" or "contributor's type*" or "contributors' type*")) OR (TITLE-ABS(((author or authors) W/2 (role or roles or type or types)))))) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (DOCTYPE,"ar") OR LIMIT-TO (DOCTYPE,"re"))

Limited to English, limited document type to Article and Review

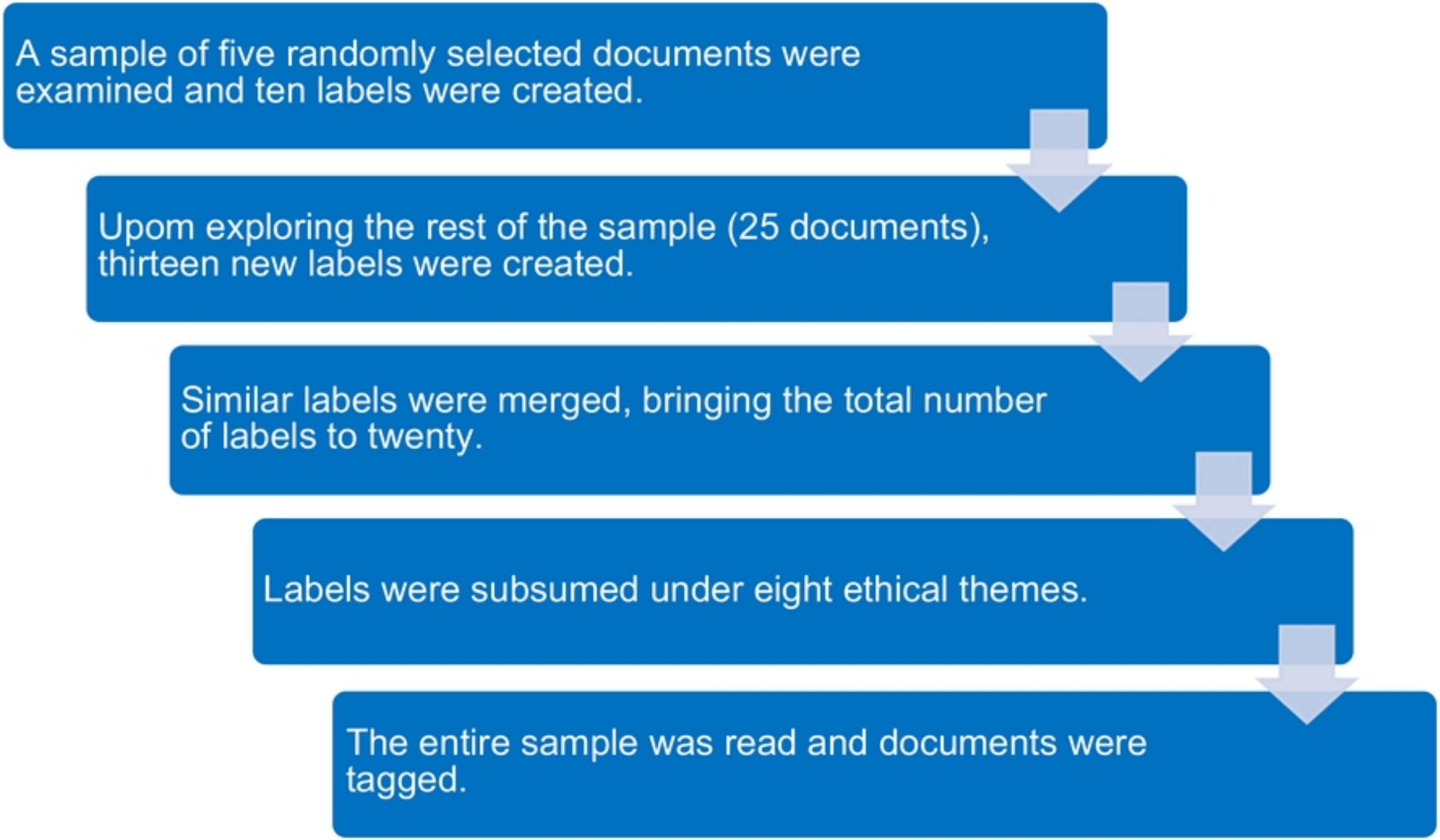
Web of Science

(TS=(CROT or CROTs or Datacite or “CrediT taxonomy” or “Contributor Role Ontology” or “Contributor Role Taxonomy” or TaDiRAH or OpenVIVO)) OR ((TI=(taxonom* or ontolog*) OR AB=(taxonom* or ontolog*)) AND (TI=(attribution) OR TS=(authorship or contributorship or “contributor role*” or “contributor’s role*” or “contributors’ role*” or “contributor type*” or “contributor’s type*” or “contributors’ type*”) OR TS=((author or authors) NEAR2 (role or roles or type or types))) OR TS=(((attribution or author or author’s or authors or authors’ or researcher* or scholar or scholar’s or scholars or scholars’ or scholarly or publication*) NEAR2 (credit or credits or contribut*))))

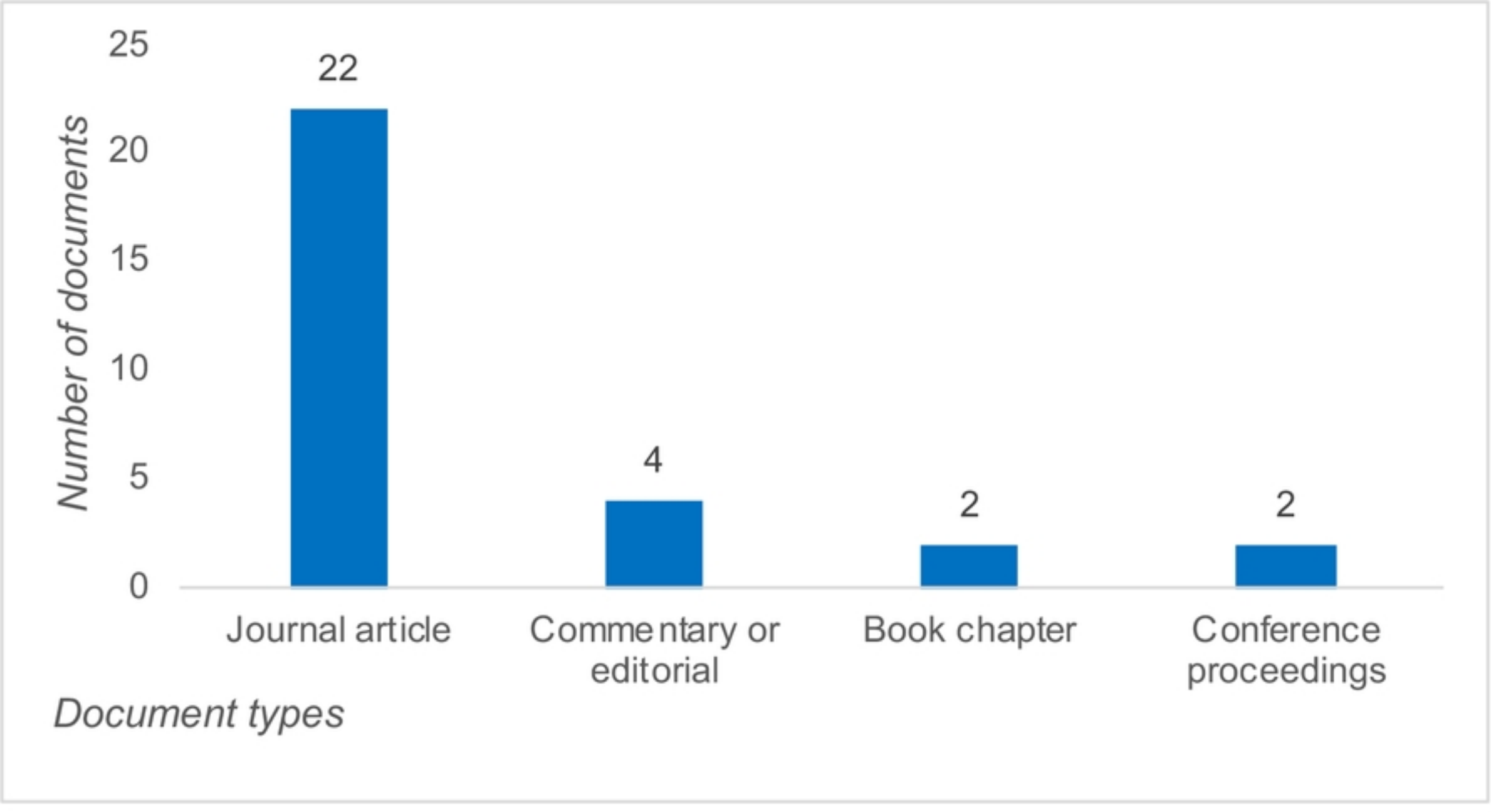
Refined By: Document Types: Articles or Review Articles | Languages: English


Using search strategy, 979 documents were identified.
403 duplicate documents removed.
576 unique documents were qualified for abstract screening and initial analysis.
428 documents removed by one of the exclusion criteria.
148 documents qualified for full-text reading.
118 documents removed because they did not meet all three inclusion criteria.
30 documents qualified for analysis.

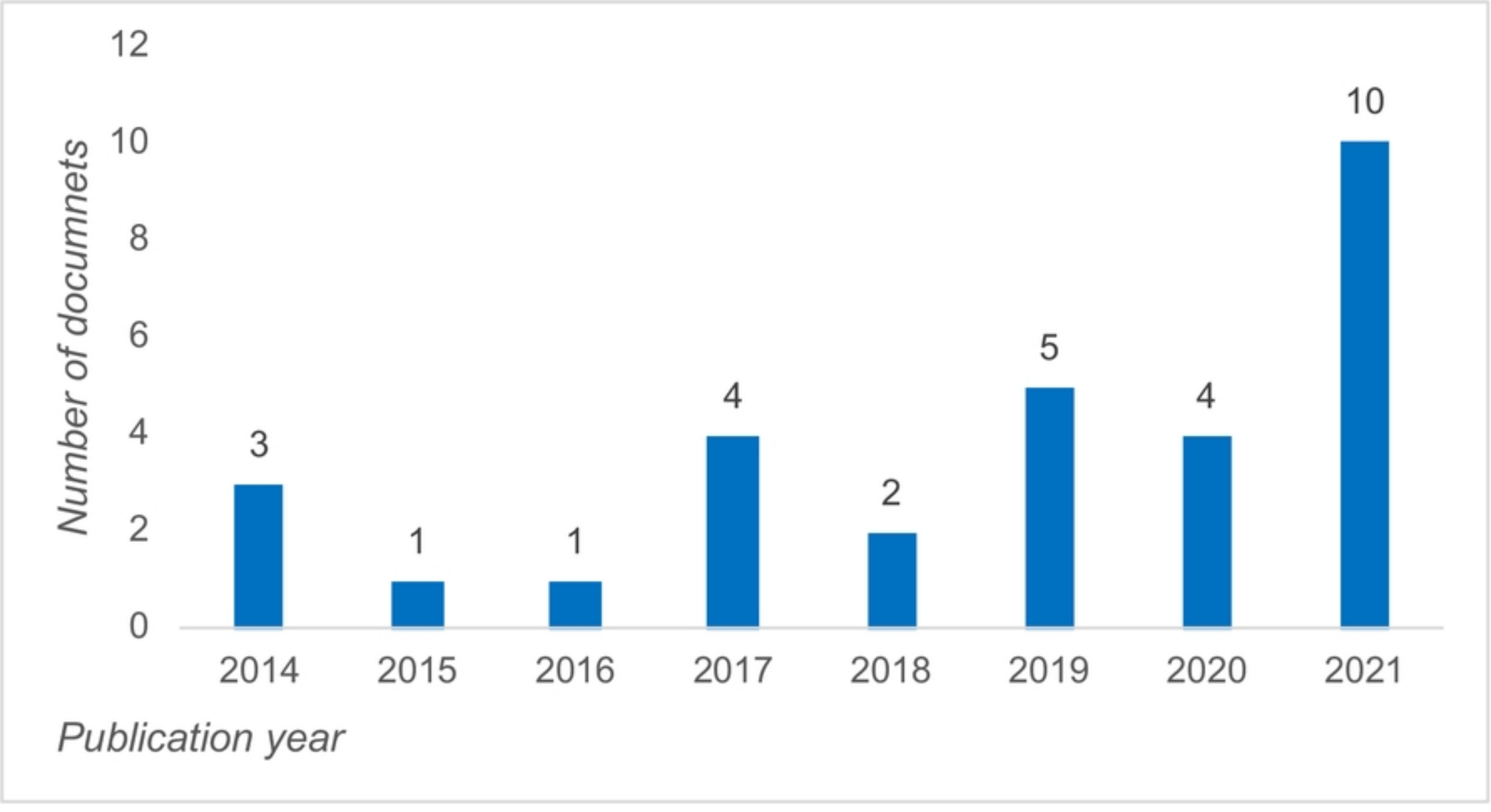
Figure


A sample of five randomly selected documents were examined and ten labels were created.
Upom exploring the rest of the sample (25 documents), thirteen new labels were created.
Similar labels were merged, bringing the total number of labels to twenty.
Labels were subsumed under eight ethical themes.
The entire sample was read and documents were tagged.

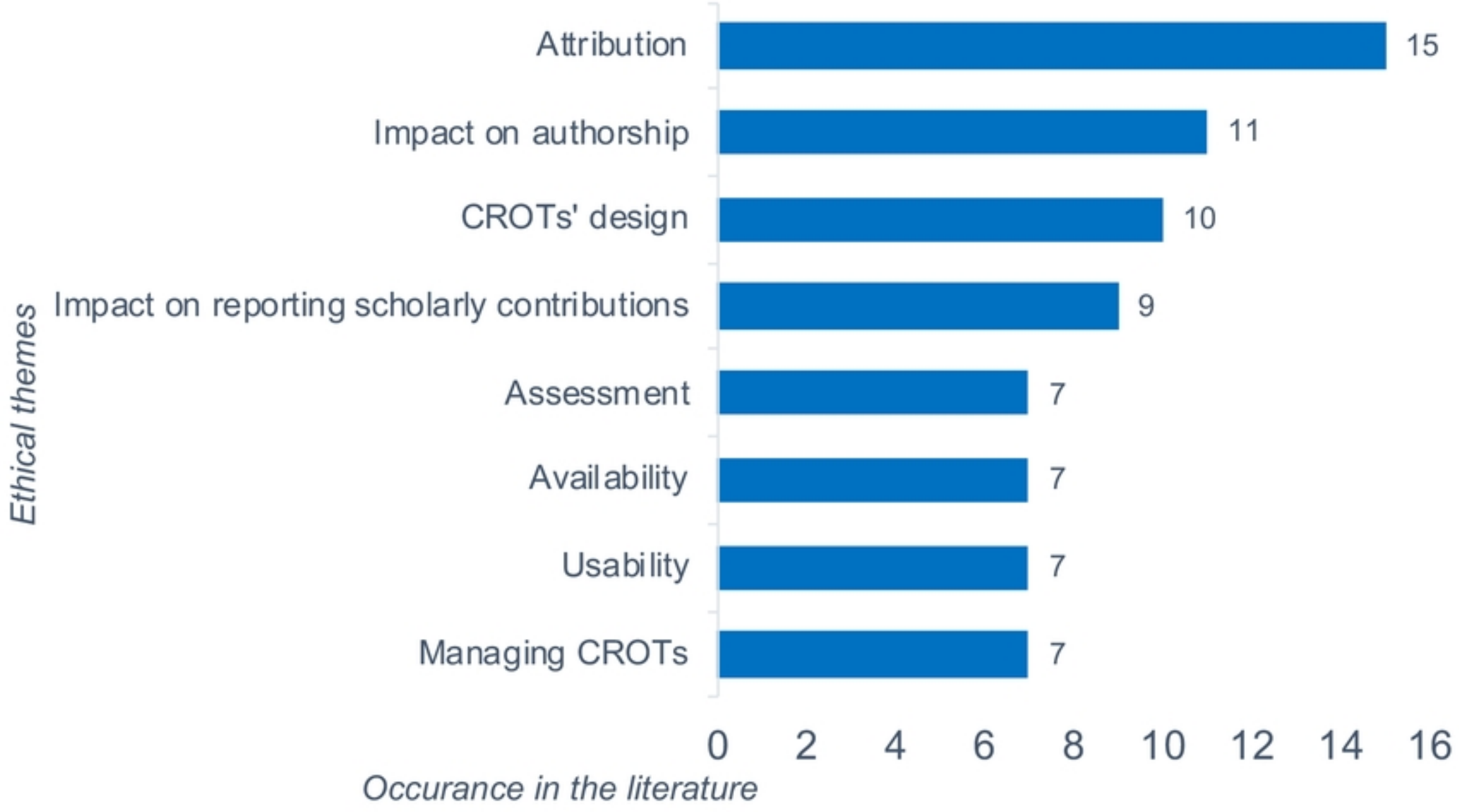
Figure


25
20
15
10
5
0
Number of documents
22
4
2
2
Journal article
Commentary or editorial
Book chapter
Conference proceedings
Document types

Figure


12
10
8
6
4
2
0
Number of documnets
3
1
1
4
2
5
4
10
2014
2015
2016
2017
2018
2019
2020
2021
Publication year

Figure


Attribution
15
Impact on authorship
11
CROTs' design
10
Impact on reporting scholarly contributions
9
Assessment
7
Availability
7
Usability
7
Managing CROTs
7
Ethical themes
0
2
4
6
8
10
12
14
16
Occurance in the literature

Figure