Crossref metadata for preprints: Discussions and recommendations

Abstract

In 2016, Crossref launched a metadata schema for ‘posted content’ with the aim of better accommodating the metadata needs for preprints, working papers, theses, reports, and related outputs, which are not typically peer-reviewed. In 2021, Crossref formed an Advisory Group (AG) to discuss how the quality of metadata for preprints using this schema could be improved. The group focused on four topics: 1) preprints as an article type (rather than subtype of posted-content); 2) relationships to/from preprints; 3) versioning; and 4) withdrawal/removal of preprints. The recommendations that resulted from the group’s deliberations have been published previously. Here we provide further background to the recommendations and report more details of the discussions.

Contributors

Martyn Rittman	Crossref
Emily Marchant	Cambridge University Press
Johanna Havemann	AfricaArxiv
Oya Y. Rieger	Ithaka
Alainna Wrigley	California Digital library
Alberto Pepe	Authorea
Alex Mendonça	SciELO
Ben Mudrak	ChemRxiv
Bianca Kramer	Utrecht University Library
Damian Pattinson	eLife
Dasapta Erwin Irawan	RINarxiv
Ioana Craciun	Preprints
Jessica Polka	ASAPbio
Johannes Wagner	Copernicus
Michael Markie	F1000 (Taylor and Francis)
Michael Parkin	Europe PMC, EMBL-EBI
Michele Avissar-Whiting	Howard Hughes Medical Institute
Nici Pfeiffer	Center for Open Science
Patricia Feeney	Crossref

Richard Sever	bioRxiv and medRxiv
Richard Wynne	Rescognito
Shirley Decker-Lucke	SSRN
Tony Alves	HighWire Press
Wendy Patterson	Beilstein-Institut

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Background

In 2016, Crossref launched a new section of its schema for ‘posted content’, intended to cover research works falling outside of existing types such as journal articles, books, and conference papers. The aim was to better accommodate the metadata needs for items that are not routinely peer-reviewed, including preprints, working papers and theses.

Preprints have been around for several decades, but were not considered a separate content type in the Crossref schema prior to 2016. arXiv and SSRN are large, well established preprint platforms that predate this section of the schema, but there are numerous other online repositories designed for early sharing of research outputs (see https://asapbio.org/preprint-servers for a list, for example). In the early 2010s a new wave of preprint servers were

created, including bioRxiv and several subject-specific servers hosted by the Center for Open Science's open source platform. With these new platforms came the idea that preprints should be citable items that could be used in grant applications and researcher assessment. Thus, preprints should be able to have a DOI but remain easily distinguishable from journal articles. Preprints make unique intellectual contributions; they do not always lead to a journal article, and when they do the content is not necessarily the same. Crucially for Crossref, preprint versions of works are frequently cited, which is why it is recommended that they are assigned their own DOIs. To support this, the 'posted-content' type was added to Crossref's schema, intended to cover outputs including working papers, technical reports or guidelines, and preprints.

Since the launch of the 'posted content' schema Crossref has not made any changes. There are, however, areas where the metadata isn't clear or conventions have changed over time. The preprint community is diverse; in many disciplines it is still emerging and there are few globally established norms. For this reason Crossref felt that it could not unilaterally make decisions about where to make changes to the preprints schema and that a supporting Advisory Group (AG) could assist in this effort. A call was put out for advisory group members, and a number of organisations were invited to participate, with a limit of one representative for each organisation.

Since June 2021, the AG has met approximately every six weeks. The meetings have been constructive and highly engaging. The members have highlighted the diversity of practice as well as the common goals for disseminating research via preprints with high-quality metadata to support discovery and linking. Group members include representatives of Crossref members who deposit preprints, journal publishers, indexing organisations, platforms, organisations that do not yet deposit preprint DOIs, and others with a strong interest in preprints. Oya Y. Rieger, previously Program Director at arXiv and currently with Ithaka S+R, kindly agreed to chair the group. The current makeup of the group is available from the Crossref website at https://www.crossref.org/working-groups/preprints/.

Aim and purpose of the group

The stated goals of the Advisory Group (AG) are as follows:

> The aim of this AG is to support Crossref to collect and improve the quality of metadata for preprints.
>
> The AG should highlight examples of good practice and recommendations where applicable. However, the aim is not to reach consensus for how preprints should be posted or to establish standards, but to accommodate as far as possible the diversity of practice within the community.
>
> All interactions with the AG are open by default, members should state when they wish anything shared to be confidential.

The second goal has been the more challenging one to meet. There are cases where there is clear consensus among members about how to operate and general agreement that metadata

schemas should support this best practice. For example, although there is no current universal practice for withdrawal of a preprint, there is a unanimous view that there should be a standard way to capture it in the metadata. There are other areas for which a diversity of practices already exist and should be captured in the metadata. An example is versioning, where some preprint servers assign a DOI to each version and others assign a single DOI to all versions.

The AG is not being called on to establish best practice or make decisions about how Crossref handles metadata. The group is invited to contribute to the dialog around preprint metadata — which is an area still in flux — and provide examples and opinions on current practice. While Crossref has attempted to put together a group that is representative, there are likely to be important voices outside of the group that can add to the conversation. In particular, third parties such as publishers who do not post preprints, publishing service providers, and those who use metadata downstream are not well represented.

Topics identified

The starting place for discussions was to compare the metadata fields that can be registered with Crossref for preprints with those available for research articles and to identify potentially useful fields that are not yet available. The table below summarises the current fields ravailable for preprints and journal articles.

	Required	Recommended	Optional
Posted content and research articles	titles doi_data	contributors abstracts citation_list funding license JATS-formatted abstracts fundref metadata SCN_policies	
Only posted content	posted_date	group_title acceptance_date institution Item_number	
Only research articles	*Journal:* full_title ISSN or title-level DOI and URL *Issue:* issue Publication_date (year) *Article:* publication_date (year)	*Journal:* abbrev_title doi_data coden journal_issue archive_locations title-level DOI and URL *Issue:* publication_date (month and day) journal_volume contributors issue Doi_data *Article* publication_date pages crossmark metadata	publisher_item special_numbering clinical trials

Crossref is not the only DOI registration agency, and it was suggested that the metadata schema should be as consistent as possible with the schema from DataCite. When the AG was set up, 'preprint' was not an option in the DataCite schema but has been added to the most recent version (Version 4.4, https://schema.datacite.org/meta/kernel-4.4/). Preprints are, of course, only one example of non-journal-article output, and there are other diverse inputs that are not currently well supported — for example, reports, science blogs, and news articles. Crossref covers some of these with Event Data, but it could be argued that it would be appropriate to assign a DOI to them in some cases.

In the first few meetings we collected feedback on the areas that the AG should address. These fell into various categories, including some that seemed trivial and did not need much further discussion, some that seemed relevant only to a small number of organisations, and others that

needed careful consideration and further discussion. The group undertook an exercise to prioritise the topics into high, medium, or low priority. Collating the priorities gave the following:

Topic	Priority
Withdrawal/removal and Crossmark metadata	High
Preprints as an article type rather than subtype of posted-content	High
Version number	High
Relationships to/from preprints	High
Connecting preprints to non-DOI content	Medium
Documentation to support deposit	Medium
Field for preprint server/operator name	Medium
Languages	Medium
Alignment of the Crossref schema with DataCite's	Low
Pricing for preprint metadata deposit	Low
Removal of acceptance date	Low
Removal of SCN_policies	Low

Each of the four topics rated as high priority was discussed by a subgroup of the AG, which was tasked with developing draft metadata recommendations for the relevant area. The rest of this document outlines those discussions. The recommendations in full are already available (Crossref Preprint Advisory Group 2022). They only present a summary, so in the following we provide context as to how the recommendations emerged.

The primary discussion topics

Withdrawal and removal

Removal and withdrawal policies

Preprint platforms are committed to preserving the scholarly record and to avoid making changes or removing items except where strictly necessary. Two terms to describe retraction have become widespread in the preprint community and we will use them here (although note that practice varies):

Withdrawal: Stating that a preprint is no longer part of the scholarly record, although allowing access to the content and metadata. This is roughly equivalent to retraction by journal publishers.

Removal: Stating that a preprint is no longer part of the scholarly record and removing online access to the contents; the metadata may also be changed so as to remove identifying details.

There are several reasons why a preprint might need to be withdrawn or removed from the preprint server or repository to which it was originally posted. They include:

- Plagiarism, data fabrication, falsification, or other forms of scholarly misconduct.
- Inclusion of sensitive data.
- The content is out of scope of the repository it was posted to.
- Not all co-authors had agreed to posting the preprint or to the licensing terms.

In some cases, a withdrawal request is initiated by the author, while in others a reason for withdrawal or removal is reported to the service by another party. Preprint services vary in their ability to investigate allegations of misconduct, given the time and resources required to do so.

Withdrawal and removal policies vary across preprint repository services. Though some basic best practices in terms of removal policy can and should be established via cross-platform collaboration, it is expected that variation will persist. The AG therefore focused on matters of technical implementation, aiming to account for the range of policies and practices in operation at various preprint services. For further discussion on matters of preprint withdrawal and removal policy see (Beck et al 2020).

Technical considerations

Six principles were widely agreed upon by the Advisory Group:

- A DOI should always continue to resolve, even if the content has been withdrawn or removed, in order to preserve the integrity of the scholarly record. In the case of removal, a ‘tombstone’ page should give basic information noting that the preprint has been removed.
- Withdrawal and removal occur on a spectrum. At one end of the spectrum, as with a traditional journal retraction, all files and metadata are retained and a withdrawal note added to the content page. At the other end of the spectrum, all files and most of the metadata can be removed. As defined above, in the preprint space “withdrawal” is typically used to mean the former, while “removal” is used for the latter.
- In general, preprint servers should aim to remove as little information as possible while still meeting the rationale for the removal. For example, if sensitive personal data is included in a preprint’s main file the file might need to be removed entirely. However, if data is found to be flawed, this could be handled by updating the preprint’s landing page to include a notice of withdrawal.
- There should be a method for preprint services to indicate to Crossref that a preprint or its associated metadata has been withdrawn or removed. This should be done via updating the preprint’s metadata record, in order to provide a standardised technical approach.
- In addition to using the method mentioned in the previous point, preprint servers may wish to collect, store, and display additional information about a case of withdrawal or

removal. This may include publishing a journal-style withdrawal notice as a new version, replacing the preprint's abstract with a withdrawal notice, or storing a reason for withdrawal in the item's metadata. Practices are expected to continue to vary, and this is acceptable.
- Most preprint services allow versioning of preprints. In some cases, withdrawal or removal may pertain to only one or some of these versions and in others it may pertain to all of them. It was widely agreed that where DOIs exist for each version, the metadata should be updated for only the DOIs in question. Where a single DOI is used for all versions this DOI can be updated, but the server may choose to distinguish between the withdrawal context presented on each of the version pages on the site itself.

As such, the recommendations focused on providing for the following in preprint metadata records:

- A required metadata field to record whether or not a preprint or its metadata has been withdrawn or removed.
- An optional metadata field to record the reason for removal or withdrawal.

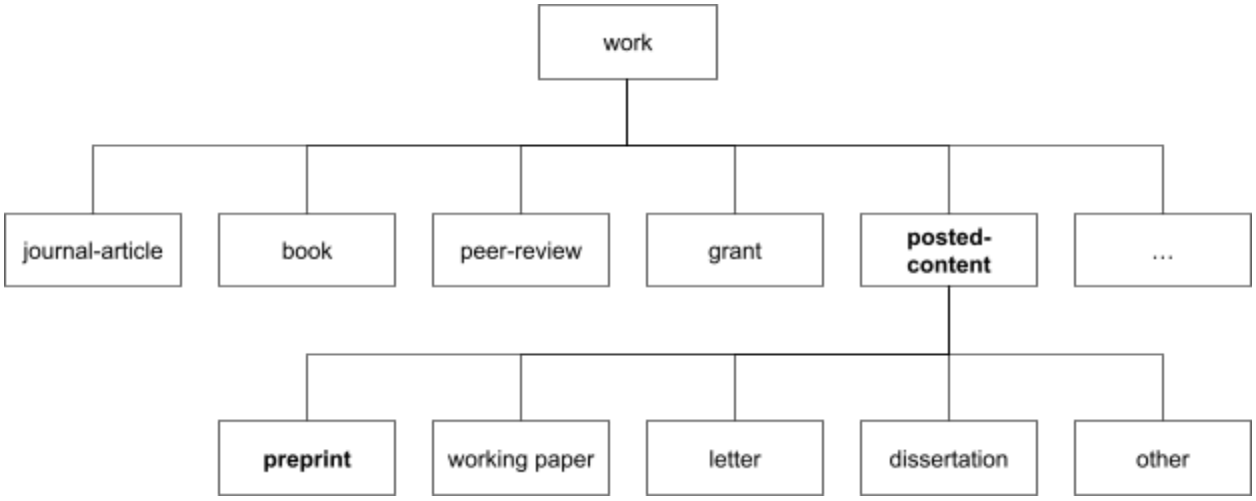
Discussions were also held about the following items, which will need further deliberation before firm recommendations can be made:

- Notification of withdrawals and removals to downstream systems is largely agreed to be helpful in order to provide optimum transparency to those discovering and reading research. However, it was noted that in some cases notification of removal might not be desirable; for example, in cases where sensitive personal data has been exposed and subsequently removed a removal notification could trigger bad actors to search for the information.
- Publishers may wish to be notified of removal or withdrawal of a preprint that was subsequently published as a version of record in a journal. Policies and methods for doing this are yet to be defined.
- Preprint servers may wish to be notified if a version of record is retracted that was previously posted as a preprint, especially as journal publishers are likely to have better resources for investigating allegations of misconduct and other reasons for retraction. Policies and methods for doing this are yet to be defined.

Preprints as an article type

Background: The status quo

Any work deposited to Crossref is assigned a type by the depositing member, such as 'journal-article' or 'book'. Preprints should be deposited with the type 'posted-content' and a subtype of 'preprint'. The posted-content type also includes 'working_paper', 'letter', 'dissertation', 'report', and 'other'. This contrasts, for example, with research articles or peer reviews, which don't have subtypes. The posted-content type was added to the schema in 2016 when Crossref started to register preprint metadata.



Hierarchy of Crosssref work types. The list of types isn't exhaustive, see https://www.crossref.org/documentation/schema-library/markup-guide-record-types/ for more details.

Crossref proposed a discussion of this topic with the AG to review whether it is still a suitable way to register preprint metadata, whether preprints should become a top-level work type, or if a different option should be explored.

Community feedback has indicated that the idea of preprints as a subtype is not well understood by Crossref members or metadata users. The term posted content is not widely used and those looking for preprints may not think to look at subtypes. In fact, where posted content is mentioned on the Crossref website it is frequently appended with "including preprints" to make it clear.

Posted content that isn't a preprint is swamped by deposited preprints. It is not a simple task to separate out items by subtype and there is no API filter for subtype. It is difficult, for example, to answer relatively simple questions such as how many preprints have been registered with Crossref or how many theses came from a certain publisher in 2019. These would be easy to answer for peer reviews reports, for example. Adding an API filter for subtype would be possible, but would add an extra level of complication for users looking for preprints, and mean a different type of search compared with searching for journal articles, conference papers, or books.

What are the characteristics of a preprint and its metadata?

Part of the discussion within the group focused on the features of preprints and how they are distinct from journal articles and other types. There is no generally accepted definition of a preprint, although a number have been proposed — see Table 1 in (Chiarelli et al. 2019). Similarly, there is a general understanding but no written definition of what constitutes a journal article.

In discussions, it was generally agreed that an important aim of preprints is to accelerate the dissemination of knowledge, even if characteristics vary between platforms. A point of unanimity was that the word ‘preprint’ should be retained, even though there is no requirement for them to precede something, nor is it expected that the content will be published in print. Like other terms, it has stuck while the concept has evolved over time and it shouldn’t be treated too literally.

Preprints tend to have different metadata than other types of posted content. Perhaps the most unique features are a structured method for versioning and the possibility to relate them to a published research article. There was clear agreement in the AG that these characteristics make them unique enough to have their own type.

On some platforms there remains content deposited as journal articles prior to the availability of the posted content schema, but which would generally be considered preprints. Metadata users would like works to be accurately categorised by type so that potential discrepancies can be properly accounted for in analyses. It is unclear whether changing the Crossref metadata schema would lead to immediate action by the Crossref members hosting this content, but having a strong idea of the set of characteristics that a preprint captures can help members decide what type their content should have.

The level of reliability of preprint metadata can be an issue. Some platforms post preprints alongside other scholarly outputs such as posters, conference papers, or author-accepted manuscripts. The type is usually designated by the author and not checked by the platform. In fact, most of the metadata that platforms know about an article comes from authors and is not verified. Some platforms are hesitant to deposit all of this metadata to Crossref because of the risk of it being unreliable. This poses a problem, because it is almost certain that some records deposited as preprints should have a different type and that not all metadata is accurate (for example author affiliations or links to datasets). On the other hand, leaving out details because of uncertainty in a small percentage of cases risks throwing out a great deal of accurate metadata. We discussed the possibility of depositing data with some comment about its reliability, or with the ability to explicitly state what has been checked by the platform and what was provided by authors. This could be done by assigning an indication of the provenance of a piece of metadata (e.g., Crossref, Crossref member/publisher, author) and allowing downstream users to select the types of provenance organisations that they trust. This would not be trivial, but it does relate to other discussions at Crossref about collecting community-sourced metadata originating from beyond its members.

Another important area of discussion was the routes that a preprint can take after being posted and whether the categorisation in Crossref metadata would accurately capture changes in state. For example, preprints may:

- Stay on a preprint server and not be published elsewhere. Sometimes this is because they are rejected by a journal publisher; other times it is a deliberate choice by the authors.

- Appear on several preprint servers, depending on checks conducted before posting the preprint and the policy of the platform hosting the preprint.
- Be updated multiple times. This behaviour is covered by the discussion on versioning.
- Be included in an overlay journal. There is a mode of publishing where preprints are not republished, but are selected by editors to be included in collections or journals.
- Be directly published in a journal. This can happen without any substantial changes being made to the preprint, meaning that essentially the same content can be cited in two different ways and has two DOIs.
- Be split or merged before journal publication, in which case the relationship between preprints and articles is not one-to-one.
- Be withdrawn or removed. There is more discussion on this case in the section on withdrawal and removal.

This is a much broader range of processes than, for example, a journal article or dissertation undergoes, but is more structured than a blog post or a website.

In light of the changing nature of preprints, can and should DOIs change type after review to indicate a change in status? We note that being an article or a preprint does not automatically convey anything about the value of a work or the way it has been processed. A preprint may be peer-reviewed and items appearing in a journal may have undergone only editorial review. Additional metadata, such as relationships to review reports, can be used to convey the steps a piece of research has undergone before and after being made publicly available. The type should be determined by the metadata fields needed to accurately describe the work, not its standing with respect to peer review or any other property. Changing type can have an effect on downstream services, which might end up with the same item multiple times; alternatively, if they do not update their metadata periodically, items can have an incorrect type. In general, Crossref recommends against changing the type, and instead recommends creating a new and related DOI when the citation for an item changes. However, as new and different procedures for publishing based on preprints emerge, this is an area that is evolving and where Crossref needs to listen carefully to the needs of the community.

To conclude, metadata needs to be convenient for both those creating it and those consuming it. Perhaps unsurprisingly for a group of preprint enthusiasts, there were no significant concerns with having preprints as an article type distinct from other types of posted content.

Versioning

“That’s the whole beauty with preprints — always and forever editable and meant to be”, a comment from one AG participant.

There are several aims of preprints. Fast dissemination often receives the most attention, however the ability to easily and quickly update preprints is another significant benefit and a feature generally missing from journal articles. Journal articles change rarely, and when they do there is a published erratum or correction that describes the changes. Preprints can be changed

by the author, usually in a matter of hours or days and with minimal oversight. The preprint update process is fast and allows authors to incorporate feedback and fix errors.

Versioning is currently captured in Crossref metadata using the is-version-of relationship. This contrasts with the relationship between a preprint and its journal article equivalent (is-preprint-of or has-preprint). There is no limit to the number of versions that can be registered and only the first two incur a registration fee.

This topic was highlighted for discussion by the group for several reasons. First, several different practices for capturing versioning in metadata have developed and there is no consensus in the community about which should be preferred. Second, while the relationship is clear, there is no way to indicate a version number or describe the changes between two versions. Third, an important aspect that became more apparent during further discussion is that there has been little done to identify or relate versions hosted on different platforms.

There is some overlap here with the section on relationships, and versioning can be thought of as a special kind of relationship that exists between preprints.

There were concerns raised during discussions that a proliferation of identifiers for the same work in different states will cause confusion and means that outdated work that contains errors remains visible, so older versions should become less visible as they are replaced. On the other hand, preprint versioning reflects the self-correcting nature of research and demonstrates the evolution of a piece of research. Hiding early versions projects a ‘version of record’ mentality onto preprints, whereas no version has such a definitive status. Instead, preprints are a record of versions, and the complexity that exists should be reflected and modelled by the metadata.

What makes a version?

Versions include the following:

- Minor update: typographical and other superficial edits but no difference in academic content.
- Scholarly significant update: the conclusions, data, or methods are updated in a way that will change interpretation of the preprint.
- Duplication: exactly the same preprint posted on a different platform and with a different DOI.
- Mirrored content: the same preprint posted on a different platform using the same DOI.
- Translation: the same content translated into a different language.
- Journal article version: this is represented differently in Crossref metadata, using the ‘isPreprintOf’ relationship rather than ‘isVersionOf’ and we won’t consider it further in this section.
- Postprint: a peer-reviewed version of a published journal article.

The first two here are perhaps what initially comes to mind when thinking about preprint versioning, but the difference between them is subjective and either the authors or the platform provider need to make a judgement. It is not clear where this responsibility should lie and to

what extent preprint servers should be responsible for checking and reporting the contents of an update. Crossref's guidance is that a new DOI should be assigned to a work when its citation changes. That could include addition of new content (scholarly significant update) or an editorial decision to include it as part of a journal (which would fall under duplication in the list above).

Many preprint platforms (although not all) have policies that don't allow for a preprint to be posted to more than one platform. However, authors may want to justify posting on different platforms, such as to reach different audiences or to make a revised version available in a different location. This could become a more common occurrence as journals increasingly give the option for submitted manuscripts to be displayed as preprints. Authors may submit a revised version of a previous preprint which the publisher makes available during peer review. It would be advisable for publishers to routinely ask for previous versions of submitted works to be disclosed by authors.

Guidance on what to cite in the case of preprints also varies. For example, some journals recommend or require that a journal article version of a preprint is cited in all cases instead of the preprint. Alternatively, the text cited may have been removed or altered between versions, so it is more accurate to cite a specific preprint version. Concerns are frequently raised that citations across multiple versions will be split and are not routinely summed by providers of citation counts. Links established between metadata records should make collating citations straightforward and it may be done in the future.

Versioning within platforms

In the most naive and simple setup, the date that a preprint is posted could be used to determine the order of versions. This was considered inadequate by the AG and there was unanimous agreement that a field to identify version number should be part of the Crossref preprint schema, as well as an optional text field with notes describing the differences between versions.

To date there have been three main approaches to versioning preprints.

One DOI for all preprint versions

One approach is where a new version receives the same DOI as its predecessor. Examples include bioRxiv.

This has the advantage that it is less critical whether an updated version makes a unique scholarly contribution: the same process can be used for minor typographic changes and significant rewrites. It also means that citations are collated without needing to sum across different versions. It mirrors the approach for journals where an article might be updated with a published correction but the original paper keeps the same DOI.

For metadata there are some downsides. Currently there is no way to tell which version number the latest version has or whether a change to metadata included a new version — addition of a version number field to the metadata would solve this problem. When a version is updated, the

bibliographic metadata is overwritten and the title, authors list, and abstract may change. Previous values for these fields are no longer visible in the metadata, and there is no simple way to know whether they have changed. Version notes would need to be additive when a version changes and include changes made for previous versions.

One DOI per preprint version

An alternative approach is for a Crossref member to assign a DOI to every version that they (or the authors) consider to make a distinct contribution. Examples include ChemRxiv and Research Square. This is analogous to software versioning, where each new release receives a version number. The main advantage here is the direct citation of individual versions. Metadata for each version has its own record, so nothing is removed when a version is changed. Some see this as a disadvantage, in that erroneous data is still available, while others would see this as an advantage because it retains a permanent record for each work. This approach requires relationships between each version and citations are recorded separately for each version. Currently a number of platforms that collect citations do not sum citations across different versions, and a concern with this model is that authors may not receive sufficient recognition because citations are spread across multiple works.

Parent and child DOIs

An approach to versioning that isn't used by any Crossref members, but is used by Zenodo who register DOIs with DataCite, is to have a single 'parent' DOI for a preprint and further DOIs for each version. The parent DOI resolves to the latest version. In the discussions there wasn't great enthusiasm for this approach and it wasn't clear what problem it aims to solve.

A related approach is to assign a work a 'citable' DOI that is recommended for use in citation. This approach separates the use case of unique identification and citation splitting. However, the majority of the group thought that this changes the notion of a DOI, that it would cause confusion, and that the cited version would not be used consistently in practice.

Versioning across platforms

An area that has previously received little attention is versioning between different platforms, as the same work might be posted on more than one preprint server. There is not currently the same stigma attached to posting preprints in multiple places as there is in publishing peer-reviewed work in multiple journals, which is considered a serious ethical breach. Policies vary between preprint servers as to whether they will permit previously posted work to be submitted. When a preprint does appear on two different platforms it is usually not clear whether they are the same version or whose responsibility it should be to establish similarity. Authors can be asked to report whether they have posted previous versions, but platforms will likely want to verify these claims. On the other hand, platforms don't typically have the resources or expertise to discover versions on other platforms and determine whether they are significantly different.

If a preprint is found during submission to be identical to another that was previously posted, it could be reposted using the previously registered DOI. A new DOI could be created since any citations would be different, although this is not recommended practice and the authors should be made aware of the confusion that stems from two identical works with different DOIs.

The implication for metadata is that there should be a mechanism to connect versions that exist on different platforms. Indeed, such a relationship can already be established, but it is not clear who should take responsibility to look for them. There could be a role for Crossref to play in looking for preprints that have been posted multiple times by different members, creating a relationship between them, and informing the parties involved.

It is worth noting that the current guidance from Crossref for author-accepted manuscripts of journal articles is that a separate DOI should not be registered. This is because the content is likely to be very similar to the final version and hosted on the same platform without significant changes to the interpretation of the work. This is an area in flux with few established norms and we invite the broader community to discuss further.

Translations are a special case, and there is much support for publication of translated content, which has clear benefits for increasing its reach. Three-letter codes to identify the languages in which a preprint is available would be helpful. Translated versions can be assigned their own DOI and related to any previous versions. There is a risk that citations are split across different versions, and it is not clear whether or how to recommend which version to cite. There was general agreement that the benefits of preprints being available in multiple languages warrants exploration of creative solutions to associated challenges.

Relationships

Versioning of preprints has already been discussed above; however, it is only one kind of relationship that preprints can have with other objects. The Crossref schema for relationships is well established and applies equally to preprints and other types. There are several considerations specific to preprints and these were surfaced in the discussions by the AG.

Relationships can apply both to other research objects, and to people and organisations. One of the most important types of relationship for preprints is peer review because it expresses something about the status of the preprint and is increasingly in the public domain, this will be discussed further below. Many different types of relationships exist, including versioning; links to journal articles and citations; and links to discussions such as those in blog posts, on forums, in news articles, or on social media. Like peer review status, these can be used to add context around a preprint.

The proliferation of identifiers for various types of research outputs in multiple versions can be seen to drive complexity and create confusion, as discussed above with regards to the visibility of earlier versions. One view is that, whether we like it or not, assignment of identifiers is seen as a sign of validation and thus should be done selectively. The other view sees the assignment of identifiers to all outputs as a way to promote transparency and keep an accurate and

comprehensive scholarly record. Crossref prefers that known relationships are included in metadata and downstream services and processes can decide what is relevant to their use case.

A consideration specific to preprints concerns the correctness of reported relationships. Checks made before posting a preprint typically don't include validating relationships reported by authors. For example, is supplementary data really a dataset, are author ORCIDs or institutions correct, is an earlier version available? This makes some members hesitant to deposit metadata that they cannot be certain is correct, as discussed above in the section on preprint metadata characteristics.

The issue of trusting metadata also comes into assertions made by third parties. For example, a number of efforts have been made outside of Crossref to match preprints to journal articles and in the future Crossref might work with some of those organisations to enhance relationship metadata. This would be a valuable addition, but should checks of this metadata be made before making it public, and should Crossref only work with organisations that meet certain criteria of trustworthiness and can demonstrate transparency in their processes? Again, this is an open question but one that is likely to become relevant in the coming years.

The top request by members who deposit preprints, including unanimously in the AG, is that notifications of matches between preprints and articles should be delivered in a machine-readable format. Currently, when a match is found, Crossref sends an email notifying the member who deposited the preprint. These are hard to parse and many members do not take action on them, which leads to a loss of valuable relationship metadata. First, Crossref should build an API integration to deliver these messages. However, the group also discussed the option that these relationships are added directly to metadata records and can be removed by the member if necessary. There was broad agreement with this approach, with the main concern that the matching process should be conservative so as to avoid false positives where possible.

Discussions covered relationships with a number of specific external organisations. There was enthusiasm for using identifiers such as ROR IDs for institutions and ORCID iDs for authors, with the same policies available for preprints as for other work types. The group also encouraged Crossref to consult DataCite on their relationship ontology. DataCite has a broader range of relationships than Crossref because of the more complex ways in which data can be related, and there could be useful relationship types that would be relevant to preprints.

There are outputs relevant to preprints that do not currently have DOIs or a similar identifier assigned. For example, there are several platforms that offer the option to review a preprint, with the review being neither on a publisher platform nor the preprint platform. A metadata relationship is the natural way to make the review visible and link it to the corresponding preprint. This could be done via Crossref Event Data, which collects mentions of research on platforms such as Wikipedia, news websites, and Twitter. This has not yet been explored but is a possibility that would add value to preprint metadata.

While there are some improvements that can be made to the way in which relationship metadata is captured, the mechanisms are mostly well established and the main challenge is around uptake. It is clear that there is more work to do with the community to ensure that more relationships are captured within metadata.

Conclusion

In 2016, Crossref launched a new section of its schema for 'posted content', intended to cover research works falling outside the existing types of journal articles, books, conference papers, and so on. The aim was to better accommodate the metadata needs for preprints, working papers, theses, reports, and related formats, which are not typically peer-reviewed. In 2021, Crossref formed an Advisory Group (AG) representing a diversity of preprint practices to assess the existing Crossref schema and discuss how the metadata could be improved to better support discovery and linking. Rather than reaching consensus or establishing standards, the purpose of the AG was to document the diversity of practice within the community. After considering various ideas, the group decided to focus on four topics:

1. Withdrawal/removal of preprints.
2. Preprints as an article type rather than subtype of posted content.
3. Version number.
4. Relationships to/from preprints.

The recommendations that resulted from the group's deliberations were published in (Crossref Preprint Advisory Group, 2022). Given that the document provided a synopsis of discussion, this document aims to relay the detailed discussions that illustrate the variations among different preprint servers and topics that are not yet settled within the community as well as areas where there is consensus.

The preprint community remains diverse and, with new publishing workflows emerging, it may remain in flux for some time. On the one hand, there are innovations related to author-led preprinting of individual sections of an article, along with software and data; while on the other hand, publishers are increasingly integrating preprints into their editorial workflows. Various publishers that make use of community-based preprint review are being established and continue to develop rapidly, and that may change how preprints are perceived and how research outputs are evaluated. In short, the lines are blurring between early-stage research outputs and peer-reviewed literature. Metadata plays an important role in communicating the status of research output and it looks like there will be plenty to discuss around preprints for some time to come.

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