IGSN - building and expanding a community-driven PID system

Pablo de Castro, Ulrich Herb, Laura Rothfritz, Joachim Schöpfel

Knowledge Exchange

Case study

IGSN - building and expanding a community-driven PID system

February 2023

This case study is part of a series that has been produced within the study on “Risks and Trust in pursuit of a well-functioning PID infrastructure for research” commissioned by the Knowledge Exchange in July 2021. The main outcome of this study is a report examining the current PID landscape with an emphasis on its risks and trust-related issues.

This complementary series of case studies aims to provide a deeper insight into specific areas of activity, workflows and stakeholders within this wider PID landscape.

DFG CSC Jisc cnrs SURF DeiC

Title: IGSN - building and expanding a community-driven PID system

Authored by: Pablo de Castro, Ulrich Herb, Laura Rothfritz and Joachim Schöpfel (scidecode science consulting).

Email: **office@knowledge-exchange.info**

DOI: **10.5281/zenodo.7330498**

Contents

1. Rationale

The International Generic Sample Number (IGSN) was initially a persistent identifier for physical objects (samples).

It is used by a range of organizations as for instance System for Earth Sample Registration (SESAR), Geoscience Australia, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australian Research Data Commons (ARDC), University of Bremen's MARUM, German Research Center for Geosciences (GFZ), Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER) and the Korea Institute of Geoscience & Mineral Resources (KIGAM). Even though it was developed to assign PIDs only to physical samples from the Geosciences, it can be used today to assign PIDs to any physical object or collection of objects. Due to its technical and organisational openness to other use cases, IGSN became an interesting service for other communities - which is also reflected by the IGSN implementation organisation's (IGSN e.V.)[1] decision to change the initial name of the identifier from International Geo Sample Number to International Generic Sample Number and rename the organisation accordingly. In late 2021 the IGSN e.V. and DataCite agreed that DataCite will operate the IGSN ID registration services and supporting technology. On the 21st of September 2022, DataCite announced that the registration of IGSNs was now technically possible.[2]

IGSN is considered a valuable case study first because its IDs point to physical objects instead of intellectual property or outcomes (as DOIs mostly do) or their creators. Besides, the service itself and its organisational framework were developed bottom-up in a sheer community-based effort. This effort succeeded in a way that makes it worthwhile to investigate the preconditions of this success in terms of organisational/technical growth (and how this is managed and scaled). From the beginning, the service sought technical-organisational similarity to a best practice - a strategy that made it easy to drop its own handle systems in favour of a partnership with an established PID provider as DataCite.

Given that this also means that IGSN identifiers would become DataCite DOIs, and any DataCite member will be able to register identifiers for samples as IGSNs through DataCite, the IGSN Case Study may also help to illustrate how the PID system itself evolves by bringing up new PIDs through community services – especially where the initial needs are regarded as too marginal to be satisfied by established service providers not serving a community. IGSN made systematic use of brand effects (or produced them through cooperation), and made systematic use of funding to safeguard its growth and clearly identified the need for professionalisation. It also benefited from experience (organisational and technical) gained by one of the main actors in the implementation and operation of the service, which had a far-reaching impact on the chosen technology and organisational form.

1. https://www.igsn.org/
2. https://blog.datacite.org/start-registering-igsn-ids-with-datacite-now/

2 Building a community-driven PID

2.1 Community-demand as a driver

The need to build a dedicated PID for samples or physical objects arose from the lack of one that could be used across organisations: *"Organisations such as museums, geological surveys, and networked research programmes like the International Ocean Discovery Program (IODP) have systems in place for the unique identification of their samples. These systems, however, are limited to the scope of the organisation, they do not extend beyond institutional boundaries."*
(Klump et al. 2021)

At the time there was a need for PIDs for physical samples articulated, there was no organization insight to operate such a service: *"The concept of IGSN was developed by Kerstin Lehnert at the Lamont-Doherty Earth Observatory in 2004 in a precursor project as the System for Earth Sample Registration (SESAR) (Lehnert et al, 2004). At this time DataCite had not yet been founded and the few first DOIs for datasets were registered through the German National Library of Science and Technology (TIB) (Brase, 2004). TIB saw the need for a persistent identifier system for samples but considered this use case to be out of scope of their DOI operations."*
(Interview with Jens Klump).

Also a membership in "the International DOI Foundation (IDF) to be able to mint DOI independently of TIB was ruled out due to the high fees for IDF membership." (Klump et al. 2021). Consequently, it was decided to run the IGSN on a *"generic implementation of the Handle.net System, which went into operation in 2008."*
(Interview with Jens Klump).

2.2 Incorporated expertise and best practices as facilitators

A central player in IGSN development (both technically and organizationally) was and is Jens Klump, with whom the consultants conducted an interview. IGSN benefited from his experience in the implementation of DOIs in Germany by TIB Hannover which addressed disciplinary demands that were not met by existing services: *"I got to know Kerstin Lehnert at Lamont-Doherty Earth Observatory, and learned about her idea of developing an identifier for geological samples. To me, it was an obvious thing to use persistent identifiers like DOI to identify geological samples, not something homegrown. (...) So we approached TIB Hannover to ask them whether we could use DOI for rocks and Irina Sens said she loves the concept, but it was out of scope of TIB's mandate. So I put down 50 US dollars to buy a Handle namespace. 'Okay, then we do our own thing.'. We just cloned the STD DOI as it was called at the time. And since parts of the infrastructure were built by my team anyway, so that was easy."*
(Interview with Jens Klump)

After these first steps, IGSN focused on its organizational growth and further development, again following a best practice familiar to Jens Klump: *"And then DataCite started to emerge and was incorporated in 2009 and then we could see this concept of IGSN growing. And we saw that it wouldn't really flourish if we kept it as an NSF project, as a just purely US based project. So I suggested that we first think about what it should look like and look at the example of DOI and DataCite, and maybe also copy the organizational model. So we did that too, we copied the statutes and founded an 'Eingetragener Verein' (e.V.), went to the German consulate in San Francisco to get it registered, because that American Geophysical Union meeting in San Francisco was the only place where we could get all the founding members into one room. And that's how that started."*
(Interview with Jens Klump).

Unlike DataCite, however, IGSN focused on community advocacy rather than national infrastructure institutions during this phase of differentiation. Nevertheless IGSN again followed the example of DataCite and incorporated the governance and operation of the central IGSN services into the International Geo Sample Number Implementation Organization (IGSN e.V.).

Since IGSN obviously met a pressing need in the community and no significant alternatives existed, IGSN prevailed as the standard identifier for samples: *"Over the past years, IGSN has grown dramatically from a niche solution for petrology to becoming a global identification system for samples with nearly 10 million registered objects. The uptake of IGSN by national geological survey organisations and major collections, as well as the integration of IGSN into the scientific record through links into the scientific literature, make IGSN a strong candidate solution for a globally unique identifier for physical samples"*
(Interview with Jens Klump).

Obviously, other PIDs for physical objects have been discussed, e.g., the Life Science Identifier LSID, however, these are not gaining acceptance to the extent that the IGSN has: *"At the same time, community-specific sample identifier systems have been introduced, most actively pursued in life sciences and geosciences. For example, the bioinformatics and biodiversity communities created an identifier system (Life Sciences Identifier, LSID) to identify samples and biological taxa. Due to various socio-technical reasons, LSID was not adopted, and the community pragmatically decided to discontinue LSID"*.
(Interview with Jens Klump, see also Klump & Huber 2017).

LSID was based on an urn:nbn namespace without being registered with the Internet Assigned Numbers Authority (IANA), why these IDs are not strictly URNs or URIs. However, the implementation and uptake of LSID suffered from controversy whether the LSID URN approach or an HTTP URIs approach should be followed. Nevertheless, services likeZoobank are still assigning LSIDs to records.[3]

2.3 Managing growth

In turn, the success of IGSN was so challenging that an organizational and technical realignment was advisable. *"[T]he governance and the technical solutions are both in transition at the moment, because one of the things that we did realize was that we were struggling to keep everything going. And I asked for what I at the time called professionalization of the organization, to not run it on a volunteer basis with contributions from the members, but to run it with somebody in charge whose career it is to keep it going. The same path that DataCite had gone. But not necessarily copying that. So we applied to the Sloan Foundation for project funding. (...) And we realized in this project that we needed to change our business model, we needed to find a partner (...)... where we could partner in sharing some fundamental aspects of running the organization. And it then turned out, (...) that DataCite actually was very interested to partner with IGSN. So in May last year, we started negotiating the terms and in late September, we signed a memorandum of agreement between the two organizations to partner on running the technical infrastructure of IGSN. So IGSN, now segwaying into the technical side, is transitioning from being a Handle on its own into DOIs issued through DataCite."*
(Interview with Jens Klump).

In late 2021 the IGSN e.V. and DataCite agreed that DataCite will operate the IGSN ID registration services and supporting technology. This also means that IGSN identifiers will become DataCite DOIs, and any DataCite member will be able to register identifiers for samples as IGSNs through DataCite. (Klump, 2021).[4]

2.4 Adaptable responses to community needs

As mentioned at the beginning of section 2.1, identification systems for physical objects existed, but they did not work across organizations and thus did not ensure, for example, the disambiguation of an object: *"Addressing these types of ambiguities was a primary motivation for the development of a globally unique identifier, then called the International Geo Sample Number"* (Interview with Jens Klump), so there was a strong community need for a PID meeting their demands.

Another requirement addressed by IGSN is the need to identify not only specific samples, but also physical collections: *"IGSN is now both a governance and technical system for assigning and preserving globally unique persistent identifiers to physical samples and aggregates of samples."*
(Interview with Jens Klump).

Another disciplinary characteristic is the fact that IGSN IDs are assigned not only to objects or collections of objects, but to objects/entities that were necessary for generating the samples: *"IGSN can be used to identify related entities that are closely linked to physical samples. Examples are boreholes, mines, outcrops, or*

3. See for instance https://zoobank.org/References/33521a45-4306-4a49-89fc-ac47a015551d
4. As mentioned, on the 21st of September 2022, DataCite announced that the registration of IGSNs was now technically possible.

other sites. They all have in common that they are not samples themselves, but (...) sampling features."
(Interview with Jens Klump).

2.5 Success factors

Meeting specific needs and knowing these needs of the community
Furthermore, the IGSN ID enables the management of different metadata schemas, which allows sub-disciplinary applications and increased the adoption of IGSN:

"Separating the registration metadata of the identifier from the description of the object gives the IGSN system the flexibility to accommodate a greater variety of applications, which may require different metadata profiles to describe their samples, e.g. for different disciplines or use cases."
(Interview with Jens Klump).

"Allowing such application-specific metadata profiles gives IGSN agents greater flexibility to describe samples for different applications, e.g. allowing harvesting of certain sample types with their domain-specific description metadata required for domain-specific catalogues and applications [see Devaraju et al, 2017]."
(Interview with Jens Klump)

The intensive participation of the communities in the development of these schemes is likely to have had a positive influence on their applicability and adaptation:

"The IGSN Description Metadata schema[5] is developed by the IGSN members with inputs from a community of practice in the earth and environmental sciences. It is used to catalogue a minimum set of descriptive properties of samples and sample collections, such as sample type, material type, contributor, and sampling activity, to aggregate catalogues of samples across IGSN agents into overarching portals. This schema was deliberately kept general to allow the compilation of a global catalogue of, e.g., geological and biological samples and sample collections."
(Interview with Jens Klump)

This flexibility also enabled the transformation/growth of IGSN from a PID for petrology to a PID for physical objects and collections per se: *"We had to find some meaning to it, but in the communication, it will just be IGSN. But the question then is what does this mean for the community? It's a very geo and environmental community at the moment, we have some observers from archaeology and material science, but the concept that we develop for broadening the application of IGSN identifiers is by developing this concept of a 'community of communities'. So the kind of disciplinary communities operate by themselves, because they know what they need."*
(Interview with Jens Klump).

This conceptual openness makes ISGN an attractive partner for PID implementations also from other disciplines and contexts: *"We were approached by DiSSCo[6], the Consortium for national history collections in Europe, whether we could provide identifiers for them, and they expected three billion objects. And DataCite had already said,'No, too big.' And I thought, well, then this is not going to happen tomorrow, this is going to take 10 years, in 10 years time we can do that. So I said yes, of course. But we will have to think of a way how to do this."*
(Interview with Jens Klump).[7]

5. http://schema.igsn.org/description/ and http://igsn.github.io/metadata, see also the crosswalk from IGSN to DataCite metadata, https://support.datacite.org/docs/igsn-id-metadata-recommendations
6. https://www.dissco.eu/
7. DiSSCo, the Distributed System of Scientific Collections (DiSSCo) is a research infrastructure planned in Europe to commence implementation in 2024. In order to start out as a FAIRified system, different handle-based PIDs were evaluated by the project to determine their approach to persistent identification. IGSN was one of them, but DiSSCo, after careful evaluation decided to implement a "DOI-driven approach", because of the "substantial achievements, operational experience and reputation of DOI/ IDF to date". (Hardisty et al., 2021)

Flexible use cases and social, technical-conceptual openness

IGSN is governed by an international body, the IGSN Implementation Organization (IGSN e.V., http://www.igsn.org) (Klump, 2021). In 2021, IGSN and DataCite signed a Memorandum of Agreement and entered into a partnership. This means that existing IGSN ID handles will now be registered IGSN ID DOIs and the handles aliased to the DOIs to ensure that these continue to resolve. DataCite will provide the technical infrastructure and all DataCite members will be able to assign IGSN IDs as well.

The metadata scheme for IGSNs will not be changed, however, because persistent identification of geological samples has very different requirements than the publication oriented DataCite scheme can offer. IGSN's approach of assigning metadata based on decisions by communities of practice[8] while requirements for a basic set of descriptive metadata has been agreed upon[9] is somehow unique. This allows IGSN to be very flexible and attractive for different communities and use cases. For example domain specific community portals, such as the System for Earth Science Sample Registration (SESAR)[10] function as a hub to make samples searchable and accessible.

Community-engagement

It would certainly not be wrong to also mention the trust in the competence of responsible people within the community, who have proven to have the technical-organizational knowledge (in this case from the DOI application in Germany) to develop a PID application for the community.

Community engagement is vital for PID systems that specifically cater to the needs of a research discipline or community, because features of the service are developed with much closer regards to the community-centric use cases than generic PID systems (see above). The establishment of a IGSN Community manager new role at DataCite emphasises this critical factor.

Merging with established PID providers

Since a central actor, Jens Klump, was familiar with the DOI implementations by TIB Hannover, the design of IGSN was strongly oriented to the developments at TIB and subsequently DataCite from the beginning: Starting with the cloning of the implementation of DOIs in Germany by TIB Hannover (mentioned in the interview), up to the organizational form as a registered association (Eingetragener Verein, e.V.). The alignment with DataCite was a crucial element in the development of IGSN from the very start: *"This includes the choice of Handle as the underlying persistent identifier protocol, which was chosen in 2008 to keep IGSN as much as possible interoperable with DataCite."*
(Interview with Jens Klump)

As this approach was not only based on familiarity with TIB/DataCite, but also on the consideration of alternatives, not only did familiarity work as a trust factor, but also the evaluation of DataCite as a best practice - especially its capability to build or integrate communities.

8. https://igsn.github.io/communities/
9. https://igsn.github.io/metadata/
10. https://www.geosamples.org/

"The reason why we decided to partner with DataCite was because of the now mature model of the experience of bringing new members on board. And today, they are eager to broaden their services to other applications. And that they started out with something that was very bibliographical. So the original metadata starting from STD DOI were based on ISO 690[11] bibliographic metadata, that was the kernel and describes the intended purpose because it all had to flow into the TIB catalogue, because there were no portals at the time, portal was a novel thing. And then things changed over those years. But it's still that DataCite is a very bibliographic heavy system, but now other applications want to use persistent identifiers, like ROR and instruments, and others are now approaching DataCite. And DataCite is open to that. But with IGSN, they also saw an opportunity to bring a quite mature community on board, with a different use case, where the system already has 10 million identifiers registered, that's not much smaller than DataCite."
(Interview with Jens Klump)

This trust in DataCite's ability to manage communities was underpinned by DataCite's provision of resources, which of course further strengthened the trust:

"Because what I actually didn't expect from DataCite was the commitment to this partnership. So DataCite did go for funding to do this, but they're committing two persons to implement IGSN. So they just hired a community manager. And they are in the process of hiring a technical support role to help IGSN members on the technical level to make the transition. But the samples Community Manager is somebody who will work both with the existing IGSN membership who are all DataCite members, and with DataCite members who might be interested in registering PID for physical samples to get them on board with this process. (...) For this person, it will be much easier to use the existing DataCite network to approach potential new users for this aspect, for something that they already know. (...) They are already using DataCite DOI. They're just not maybe using the resource type physical object. I actually would say, IGSN is in a quite privileged position at the moment of having this fantastic support from DataCite, that they commit two people to working with this community. And through the partnership agreement there's a partnership steering group that links between the two organizations".
(Interview with Jens Klump).

11. ISO. (2010). Guidelines for bibliographic references and citations to information resources (ISO 690:2010) (Standard No. ISO 690:2010). Geneva, Switzerland: International Organization for Standardization (ISO).

3. Issues around risks and trust regarding the emergence of new PIDs

3.1 Sustainability

In the Interview, the IGSN representative strongly emphasized the role of sustainable business models, just as he and Robert Huber did in their publication from 2017: *"It might be a bitter pill to swallow for some members in the research data community wary of all things commercial, but business models are essential aspects of PID systems – sustainable PID systems do not come for free."*
(Klump & Huber 2017)

3.2 Community requirements

This sustainability is complemented as a trust marker by the community's perception that the PID is valuable for it, that it is functional and serves their requirements: *"I think the key factors here are that there's a sustainable business model. Because at the end, you have to have people that run it. It's a socio-technical system, where the easier part is running the technology, the more difficult part is the social part, to have the trust of the community that this is actually something that is worthwhile, that it works, it serves their needs."*
(Interview with Jens Klump).

3.3 Brand effects

Besides, the IGSN representative highlights the trust signal that a well-known brand gives and that IGSN wants to benefit from by partnering with DataCite: *"And so putting side by side IGSN and DOI, DataCite DOI and URN is an interesting comparison, because even though IGSN ran since 2008, without downtime, it's still seen as immature[12], by some. So you do find this in studies and in the literature that it's seen as an emerging identifier. And that's not true for the technical side, because it's actually quite advanced. But on the community trust side, it is an emerging system. So that's quite interesting to see that aspect. DOI has a fantastic brand value, it had it right from the start, this is why STD DOI chose DOI and not something else."*
(Interview with Jens Klump).

This point can also be witnessed in DiSSCo's decision process. Following Park et al. (2001) they noted that: *"Consistent, high-quality and excellent delivery of PID services built behind a branding that creates instant recognition for PIDs of the chosen scheme as the unambiguous pointers to specific accurate and authentic digital data about a specimen, including an unbreakable link to the corresponding physical specimen acts to confer authority. Trustworthiness should follow. Information quality is the strongest factor to influence organizational benefits through perceived usefulness and user satisfaction."* They concluded that *"operating under another Handle-system prefix than those used by IDF and ePIC is the substantially weakest option because of the difficulties associated with introducing an identifier that is not perceived to be a DOI."*
(Hardisty et al., 2021)

In its early days, before it partnered with DataCite, IGSN itself sought to establish trustworthiness through cooperation with a reputable institution: *"We try to mirror that in IGSN, where, even though it started out with working with individual researchers, very early on we said we must work with the National Geological Surveys. Because they are trustworthy, and they have large collections. Working with individual researchers*

12. See Kotarski et al. (2020)

will be piecemeal, it will be very hard. But if we get those large organizations on board, we can demonstrate trust, and we can grow very fast."
(Interview with Jens Klump).

Even DataCite benefits to a certain extent from the brand value of another institution, the TIB Hannover, which operates the DataCites office: *"Well, I think what you said earlier about the organization having a good backing, then it has its own sustainability and resilience. I think TIB offered a very fortunate combination in that they were well established, but also forward looking. And that DOI wasn't the only opportunity where I could see them realizing the potential of a new development, seizing it. So with TIB, it's a very good combination. But to have a solid foundation, I think, was really important. And in the early days getting from DFG funded project to being a line item in the TIB budget was a really important thing."*
(Interview with Jens Klump)

3.4 Technical reliability and up-to-dateness

As another trust component, the expert makes the technical reliability and up-to-dateness, which spoke in the evaluation phase against URN and for Handle: *"And when we evaluated and implemented URN, we ran into an interesting problem there because here we had to deal with a kind of immature technology. There were parts in place and others were promised, but they never materialized. (...) And in the URN example, this was an interesting learning experience in service quality. So the service was very reliable, because it was run by the National Library. But it was so cumbersome. But we're talking about 2004 here, so Web Services is something new. When Michael Diepenbroek and I asked TIB to provide us with a web service endpoint, at the next meeting, we were presented with a web form and we just looked at him quizzically: 'What?' There was a bit of a cultural divide there. And the National Library worked in the same way that for us to register URNs for datasets, they wanted us to send Excel spreadsheets by email, and then they would return the identifiers to us with the checksum appended. No, that's not how it works. We have more than a million identifiers already! This is not that we're pushing 40 books per day across the counter".*
(Interview with Jens Klump)

The remark that national libraries, while having the trust advantage of having existed for centuries, are technically somewhat less agile, may lead to the idea of an ideal picture of a PID provider which combines both characteristics, a long-standing existence and a willingness to innovate technically, with solid funding on top (which perhaps was manifested to some extent in the TIB Hannover and DataCite): *"So you can see these separate lines where, technically it's not that difficult, but you need to have a strong organizational base that can run this for decades. There has to be money coming in. And you have to find a way that it does serve the community, solves the problems and is seen as trustworthy."*
(Interview with Jens Klump)

3.5 Indicators of trust

Jens Klump also introduced an indicator that can provide information on the extent to which the community (or at least organizations as representatives of the community) trusts a service, its willingness to commit to and invest in the service[13]:

"So one important measure for me whether they trust in the system is whether they invest in it. Whether they put resources to it. This is in particular, with government agencies, when they make a commitment. Once they make this a line item, they stick with it. But to get to that point is hard. So they have to be convinced it's worthwhile going through all this. So that's from an infrastructure perspective."
(Interview with Jens Klump)

Away from organizations, with individuals as representatives of a community, indicators of trust are more difficult to identify, most likely as demand for the service:

13. Perhaps the caveat might be: provided the community has funds and can invest sovereignly to support the service.

"And the user perspective, it's much more difficult to pinpoint whether the community has trust in the system or not. It's because the uptake is difficult to measure. (...) So when we then see people asking for the service to be provided, then … this is also an indication of trust. With other homegrown identifier systems, we wouldn't see the community advocating anywhere that this should be used and see the uptake on the provider side is also not that frequent."
(Interview with Jens Klump)

3.6 Issues of risks

So far, no elements of risks have been identified in this case study, even though the signs of the partnership with DataCite are very positive (outreach, possible adaptations by other communities, investment in the form of human resources), possible resulting risks (overburdening of the provider DataCite or loss of IGSN's agility through cooperation with DataCite) can only be identified over time.

4. Authorship

This case study has mainly been written by Ulrich Herb (Saarland University, ORCID https://orcid.org/0000-0002-3500-3119) within a team of consultants including Pablo de Castro (University of Strathclyde and euroCRIS, ORCID https://orcid.org/0000-0001-6300-1033), Laura Rothfritz (Humboldt University Berlin, ORCID https://orcid.org/0000-0001-7525-0635) and Joachim Schöpfel (University of Lille and euroCRIS, ORCID https://orcid.org/0000-0002-4000-807X) under the umbrella of scidecode science consulting (ROR https://ror.org/02c0bjd31). The work has been overseen by the Knowledge Exchange Task & Finish Group whose composition is listed at https://www.knowledge-exchange.info/event/pids-risk-and-trust.

5. Literature

Brase, J (2004). Using Digital Library Techniques – Registration of Scientific Primary Data. In R. Heery & L. Lyon (Hrsg.), Research and Advanced Technology for Digital Libraries (vol. 3232, p. 488–494). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-30230-8_44

Devaraju, A, Klump, J, Tey, V, Cox, SJD and Fraser, R. 2017. Towards a web-enabled geo-sample web: An open source registration and management system for connecting geo-samples to the web. In: *Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings*. Presented at the FOSS4G 2017. Boston, MA: OSGEO. p. Article 16. DOI: https://doi.org/10.7275/R5P26W9H

Hardisty AR, Addink W, Glöckler F, Güntsch A, Islam S, Weiland C (2021) A choice of persistent identifier schemes for the Distributed System of Scientific Collections (DiSSCo).
Research Ideas and Outcomes 7: e67379. https://doi.org/10.3897/rio.7.e67379

Klump, J et al, (2021). Towards Globally Unique Identification of Physical Samples: Governance and Technical Implementation of the IGSN Global Sample Number. *Data Science Journal,* 20(1), p.33. DOI: http://doi.org/10.5334/dsj-2021-033

Klump, J., & Huber, R. (2017). 20 Years of Persistent Identifiers – Which Systems are Here to Stay? Data Science Journal, 16, 09. https://doi.org/10.5334/dsj-2017-009

Kotarski, R., Kirby, J., Madden, F., Mitchell, L., Padfield, J., Page, R., et al. (2020). PIDs as IRO Infrastructure - Early Findings. London, UK: British Library. https://doi.org/10.23636/1214

Lehnert, KA, Goldstein, SL, Lenhardt, C, & Vinayagamoorthy, S (2004). SESAR: Addressing the need for unique sample identification in the Solid Earth Sciences. AGU Fall Meeting Abstracts, 2004, SF32A-06. https://ui.adsabs.harvard.edu/abs/2004AGUFMSF32A..06L/abstract

Park, S., Zo, H., Ciganek, A. P., & Lim, G. G. (2011). Examining success factors in the adoption of digital object identifier systems. Electronic Commerce Research and Applications, 10(6), 626–636. http://doi.org/10.1016/j.elerap.2011.05.004

Knowledge Exchange
C/O Jisc
4 Portwall Lane,
Bristol, BS1 6NB
United Kingdom

T +44 203 697 5804
E office@knowledge-exchange.info