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COMPUTABLE KNOWLEDGE PUBLICATIONS

Learning Health Systems

Evidence Hub: A place to exchange medical knowledge and form communities

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Abstract

Introduction: Medical knowledge is complex and constantly evolving, making it challenging to disseminate and retrieve effectively. To address these challenges, researchers are exploring the use of formal knowledge representations that can be easily interpreted by computers.

Methods: Evidence Hub is a new, free, online platform that hosts computable clinical knowledge in the form of "Knowledge Objects". These objects represent various types of computer-interpretable knowledge. The platform includes features that encourage advancing medical knowledge, such as public discussion threads for civil discourse about each Knowledge Object, thus building communities of interest that can form and reach consensus on the correctness, applicability, and proper use of the object. Knowledge Objects are maintained by volunteers and published on Evidence Hub under GPL 2.0. Peer review and quality assurance are provided by volunteers.

Results: Users can explore Evidence Hub and participate in discussions using a web browser. An application programming interface allows applications to register themselves as handlers of specific object types and provide editing and execution capabilities for particular object types.

Conclusions: By providing a platform for computable clinical knowledge and fostering discussion and collaboration, Evidence Hub improves the dissemination and use of medical knowledge.

KEYWORDS
clinical knowledge, computable knowledge representation, Evidence Hub, knowledge objects, medical knowledge dissemination

1 | INTRODUCTION

Medical knowledge is a crucial aspect of healthcare that involves comprehending human physiology, disease processes, and treatment methods, all of which are essential for healthcare professionals.[1] However, sharing this synthesized understanding is challenging due to various factors that include jurisdictional barriers, lack of standardization, and the vast amount of available information and data (Box 1).[2] Conventional methods of knowledge sharing, such as medical journals and conferences, are fragmented and difficult to access, which limits healthcare professionals' ability to collaborate, gain access to, and contribute to the latest evidence.[3] As a result, there is a pressing need for a more effective solution that facilitates the sharing of medical knowledge and promotes collaboration.

BOX 1 Glossary of terms used in this article

Data: Raw and unprocessed facts, observations, or measurements that are typically stored and represented in a structured or unstructured format. Data are often restricted to jurisdictional borders, meaning they are specific to a particular region or organization.

Information: The result of processing and analyzing data to derive meaning or insights. Information encompasses any meaningful interpretation, inference, or conclusion that can be obtained from the data. Unlike data, information is not bound by jurisdictional borders and can be shared and accessed across different contexts or locations.

Knowledge: Synthesized and organized understanding of information that is relevant and applicable to a particular domain or subject. It represents a model or framework that integrates various pieces of information, enabling individuals to comprehend and interpret a specific topic. Knowledge goes beyond individual data points and encompasses broader insights and principles.

Evidence: Knowledge or information that is based on verifiable and reliable data. It represents supporting facts, observations, or research findings that contribute to the validity or credibility of a claim, hypothesis, or theory. Evidence is explicitly linked to the data on which it is founded, establishing a transparent and traceable connection between the information and its source.

The field of medical knowledge faces challenges in the dissemination of this knowledge, including poor scientific quality, irreproducibility, and poor documentation.[4]

Formal description of medical knowledge is a growing area of research set to alleviate many of the problems mentioned above.[5] Formal knowledge representations (ie, Knowledge Objects) are 'computable', meaning they are directly and unambiguously interpretable by computers, as well as made FAIR (findable, accessible, interoperable, reusable), at scale. The success of computable knowledge in achieving widespread dissemination depends on the knowledge retrieval infrastructure.

A Knowledge Object is a reusable, human-readable, and importantly, a computable representation of medical knowledge. A Knowledge Object can take various forms, such as text, images, or numerical data. It can be representational, used to convey a concept, or computable, processed by a computer. The concept of a Knowledge Object is a flexible and adaptable approach to managing and working with information. Examples of Knowledge Objects are:

- An analytic workflow, which is a series of steps or processes used to analyze data or information to derive insights or make decisions related to patient care or research.
- An ingress workflow, which is a process for importing medical data into a database. It typically involves several steps, including data extraction, transformation, and loading.
- A value set, which is a defined list of coded terms or concepts used to represent a particular clinical concept.
- An outcome measure, which is a tool or method used to assess the effects of a healthcare intervention or treatment on a patient's health status or quality of life.
- A cohort definition, which is a set of criteria used to identify a group of patients who share common characteristics or experiences.
- A risk score definition, which is a tool or method used to estimate an individual's risk of developing a particular health outcome or disease based on specific risk factors.
- Observational Medical Outcomes Partnership (OMOP) extensions, which are additional components that can be added to the OMOP common data model.

It is important to note that medical knowledge is not solely derived from scientific research and empirical evidence; it can also be synthesized from empirical information and insights from various sources.

Medical knowledge not only relies on current research and evidence but also involves the development of analytical workflows, decision criteria for decision support systems, outcome measures, and phenotypes to facilitate evidence-based decision-making.[6] These tools help healthcare professionals make informed decisions about patient care by providing a systematic and structured approach to clinical decision-making. Additionally, it is possible for new types of medical knowledge to be invented and created as advances in technology and research continue to push the boundaries of medical practice.

We present a novel, user-friendly, and free online computable knowledge dissemination platform called Evidence Hub. Evidence Hub leverages computable clinical knowledge presented as "Knowledge Objects," whose representation is loosely based on Knowledge Grid.[6] Like Knowledge Grid objects, Evidence Hub Knowledge Objects are represented using JSON and include high-level sections payload, primary identifier, resource metadata fact sheet, and service specifications. In addition, Knowledge Objects on Evidence Hub have a section called metadata that stores the object's version, owner, and contributions. Another notable difference is that Evidence Hub uses Collision Resistant IDs instead of ARK identifiers. Collision Resistant IDs reduce the computational resources required for ID generation and minimize the likelihood of conflicts between different objects within Evidence Hub.

2 | EVIDENCE HUB

Evidence Hub is a platform that fosters civil discourse through moderated public discussions on various Knowledge Objects. These discussions aim to facilitate consensus among communities of interest regarding the accuracy, applicability, and proper usage of each object.

The initial creator of a Knowledge Object is assigned the "owner" status for this object, but ownership can be transferred to another user later. Knowledge Objects published on Evidence Hub are freely

available under the General Public License version 2 (GPL 2.0[7];). This means that anyone can access, copy, and even distribute modified versions of objects, as long as these copies are also protected by GPL 2.0 and that modifications are posted on Evidence Hub.

Participation in discussions about knowledge objects is open to anyone, but the owner of the object can moderate the discussion. To reduce the burden on owners, Evidence Hub staff eliminate spam and other obvious distractions.

The primary purpose of discussions on Evidence Hub is to reach consensus in areas where it has not yet been established. Participation in the discussion constitutes a kind of peer review and can, therefore, play a vital role in the process of evaluating and improving Knowledge Objects on the platform.

Users can explore Evidence Hub, participate and contribute to discussions using a web browser. An application programming interface (API) allows applications to contribute and retrieve Knowledge Objects and register themselves as "handlers" of particular object types. Users of Evidence Hub can choose to automatically transfer objects to an appropriate handler of their choice, where objects can be examined and used.

The format used by the platform for storing and exchanging medical knowledge arranged as "objects," which includes a computable representation of the knowledge, a readable description of the knowledge, and prerequisites for using the knowledge. This format is inspired by the Knowledge Grid format.

The proposed format and the contents of the knowledge are curated through a review workflow to ensure their quality. These objects can be discussed and debated through a moderated discussion page, helping community members to reach a consensus, improving the quality of medical knowledge, and ultimately leading to better patient outcomes.

In the rest of this article, we describe the high-level architecture and the features of Evidence Hub. We show how the platform can be used to improve the sharing of medical knowledge and enhance collaboration among healthcare professionals.

3 | ARCHITECTURE AND FEATURES

In this section, we present the main architecture and features of Evidence Hub:

- Viewing and Managing Knowledge Objects
- Social features for communities of practice
- Reviewing and Managing Quality
- Application Programming Interface (API)

3.1 | Viewing and managing knowledge objects

When searching for and displaying Knowledge Objects on Evidence Hub, each Knowledge Object typically appears as a clearly defined item with a distinct title and summary. The title provides a brief but descriptive name for the Knowledge Object, while the summary gives an overview of its content and key findings, as shown in Figure 1.

Once a user selects a Knowledge Object to view, they can find a more detailed description of the Knowledge Object's contents, which may include elements such as graphs, tables, or other visual aids. Most objects also include additional metadata or other contextual information about the Knowledge Object, such as the author or publication date, as shown in Figure 2. The search function of Evidence Hub ranks objects so that versions and branches with little or no activity remain available while avoiding clutter in the search results.

The object database is the core of Evidence Hub and is responsible for storing and managing the Knowledge Objects. It supports version control and branching, allowing users to track changes and collaborate on the development of Knowledge Objects.

3.2 | Versioning and branching

Versioning and branching medical knowledge allow community members to track changes, collaborate without interfering with each other's work, ensure quality, customize for specific use cases, and create large, complex knowledge systems that are easily managed over time.

Evidence Hub automatically creates a new version of the Knowledge Object by comparing changes to the incoming content of the Knowledge Object update, giving users a seamless experience.

Versioning and branching are also supported by an integration with Evidence Hub via the API that is presented in a later section of this paper.

4 | SOCIAL FEATURES AND COMMUNITIES OF PRACTICE

The UI provides an intuitive and user-friendly interface for users to explore, interact with, and moderate the Knowledge Objects. The social features, such as discussions and commenting, facilitate the formation of communities around shared knowledge and encourage civil discourse.

The page of each Knowledge Object on Evidence encourages focused collaboration via the following features:

- Multi-threaded discussions allow users to publicly contribute insights and perspectives, provide feedback on the object and its proper use, and request changes. The maintainer of the object moderates the discussions.
- Users can subscribe to "watch" objects. Watchers of an object are notified by email of new versions and new discussion threads.
- Object pages can be shared via their web address or by various social media buttons. Sharing and watching objects help raise awareness, invite participation from collaborators and potential collaborators, and form communities of interest in the knowledge captured in the object.

The collaborative nature of Evidence Hub's platform makes it easier for users to work together to analyze and interpret data, derive

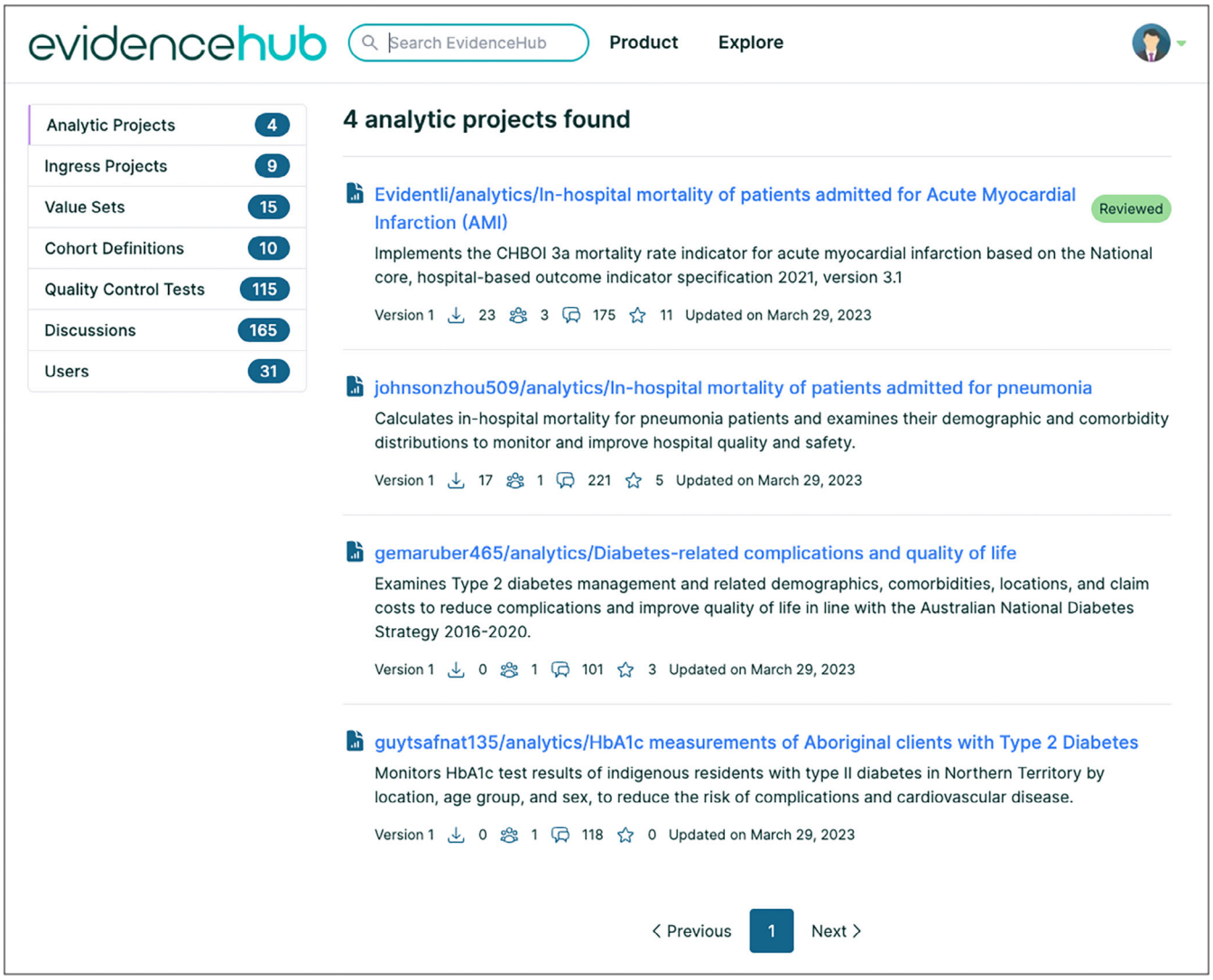

FIGURE 1 Search results showing published and reviewed Knowledge Objects.

meaningful information, synthesize knowledge, advance the understanding in their respective fields, identify gaps in knowledge that require attention, and foster new collaborations. Transparency is achieved through the open nature of discussions, and safety is maintained through moderated discussions.

Some important public discourse is very important to the advancement of medical knowledge and may not be associated with a computable object. Knowledge Objects created on Evidence Hub can have an empty "computable" section and still have the benefit of collaboration that other Knowledge Objects benefit from.

5 | REVIEWING AND MANAGING QUALITY

5.1 | Review workflow

Users on Evidence Hub can publish their Knowledge Objects by themselves and have them reviewed. This publication workflow typically involves the owner taking on the responsibility of self-publishing their work. This means that the owner creates the Knowledge Object themselves and then makes it available for review and distribution through Evidence Hub.

Evidence Hub's editorial team monitors contributions for spam and obvious irrelevant comments to uphold a high standard of quality on Evidence Hub and to reduce the review burden on owners. Object owners moderate comments' content and have the final say on approving or rejecting them. The review workflow feature is a part of Evidence Hub's platform that allows reviewers to provide feedback to the owner. Having a Knowledge Object reviewed promotes credibility, and this is notable in the search results where review badges associated with a Knowledge Object are visible, as shown in Figure 1.

After the review process, the Knowledge Object can be found by searches on Evidence Hub. This means that other users can search for the Knowledge Object using relevant keywords or other criteria and view its contents if it is relevant to their needs. This helps ensure that

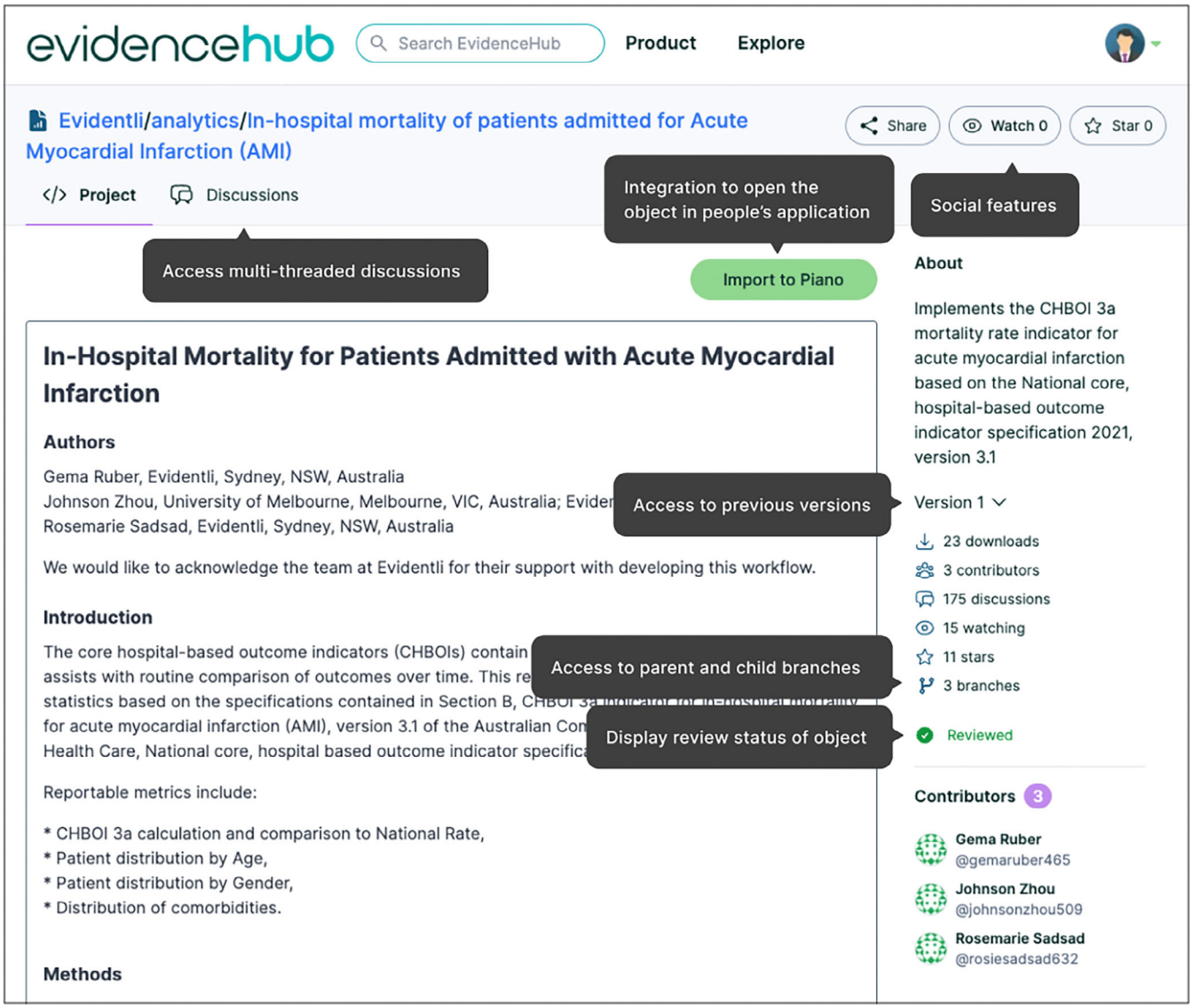

FIGURE 2 Example Knowledge Object page.

the Knowledge Object is discoverable and accessible to a wider audience, potentially leading to increased impact and visibility for the author's work.

During the review process, editors examine the contents of the Knowledge Object against a number of criteria, including:

a. Does the object contain personally identifiable information (PII) (eg, patient name) apart from the authors' names and contact? PII is not permitted on the platform.
b. Does the object contain undocumented code? The human-readable form of the object needs to correspond, as closely as possible, to the computable version.
c. Does the object include content that should not be published, such as trade secrets and copyrighted material? Such content is not permitted on the platform.
d. Does the object contain logical errors or have other technical issues as identified by the reviewer?

A flowchart describing the publication workflow is presented in Figure 3.

If and when the owner makes the amendments, the new version of the Knowledge Object and the changes are also reviewed. Knowledge Objects that pass peer review receive a "Reviewed" badge, which is displayed next to the Knowledge Object in the search results, as shown in Figure 1, and a 'Reviewed' status in the Knowledge Object page, as shown in Figure 2.

Contributions from the community can be submitted through the discussion threads, which are moderated by the owner of the object.

6 | APPLICATION PROGRAMMING INTERFACE (API)

The API allows third-party applications, such as Knowledge Object editing tools, to interact with Evidence Hub.

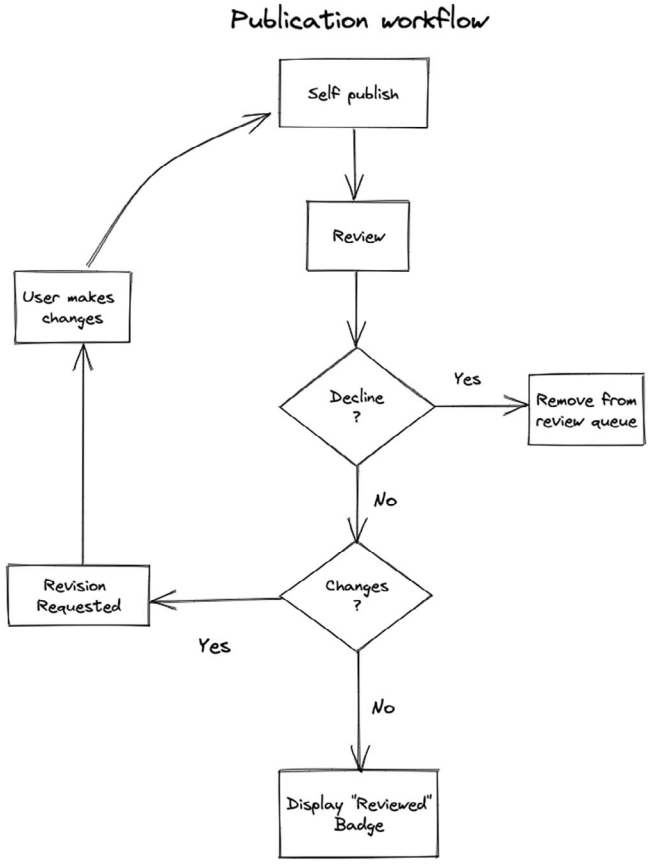

FIGURE 3 Flowchart of the publication workflow.

The API enables developers to integrate Evidence Hub with other systems and applications, allowing for the seamless exchange of Knowledge Objects. Finally, the review workflow allows users to identify high-quality Knowledge Objects and ensures that they meet the accepted standards of the healthcare community. Overall, Evidence Hub provides a robust and comprehensive platform for the dissemination, sharing, and collaboration of medical knowledge.

6.1 | Structure of a Knowledge Object

Evidence Hub uses a lightweight data-interchange format for storing Knowledge Object data that is easy for humans to read and write, and easy for machines to parse and generate. The format contains the following data:

Name	Description	Mandatory
Owner	The primary author's name and email are used for receiving feedback from reviewers and users on Evidence Hub. For existing users, the user's unique identifier may be used instead.	Yes
Name	A short name to identify the Knowledge Object. This name is unique within the author's collection.	Yes
Description	A short summary about the Knowledge Object.	No
Type	A short label for grouping similar Knowledge Objects.	Yes
Computable Information	Has all the information necessary for sharing the Knowledge Object across compatible systems which can ingest that content.	Yes
Human-readable Information	Detailed and insightful information presented to the users for discussion.	Yes
Contributors	The contributor's name and email. For existing users, the user's unique identifier may be used instead.	No
Dependencies	References other Knowledge Objects that are required for the payload to be fully usable. This property is used to specify resources that are required by a Knowledge Object to run, such as datasets, libraries, or other Knowledge Objects. These resources can be from multiple sources. By specifying these resources as dependencies, you can create modular, reusable parts of a Knowledge Object that can evolve independently from one another. For example, a Knowledge Object that represents an experiment coded in the Python programming language, and that requires a dataset stored outside of Evidence Hub, can specify how to retrieve temporary credentials and how to access that dataset in the "dependencies" property.	No
Parent	References an existing Knowledge Object on which this originates.	No
Keywords	A list of keywords used to improve search results	No

7 | PRIVATE EVIDENCE HUB INSTANCES

Organizations and teams can use Evidence Hub to collaborate without risking intellectual property (IP) leaking, by using a private instance of Evidence Hub. Private Evidence Hub instances are a paid service and can be created on premises or in a private cloud environment, within the organization's complete control. Knowledge Objects created on private Evidence Hub instances are not available on the internet;

moderation, editorial review, and social features can be disabled or assigned to individuals within the organization, and free use can be restricted to organizationally authenticated users.

8 | CONCLUSION

Evidence Hub is a modern, user-friendly online platform that aims to improve the exchange of medical knowledge and facilitate the formation of communities. Its key contributions include a new streamlined format for storing and exchanging Knowledge Objects, peer-review workflows, moderation, watching, sharing, and multi-threaded discussions. These features work together to promote knowledge dissemination, form communities, and reach consensus through discussion. The proposed format for exchanging knowledge helps ensure that information is accurate and reliable, while the review workflow helps maintain quality control by allowing reviewers to evaluate and validate the information. Moreover, the moderation, watching, and sharing features of Evidence Hub make it easier for users to engage in productive discussions and collaborations, which can help foster the growth of communities by encouraging users to contribute to discussions and share knowledge. With future use and gained experience, Evidence Hub will be adjusted to better serve the user community.

CONFLICT OF INTEREST STATEMENT

All authors of this paper are employees of Evidentli Pty Ltd. As such, all authors hold securities tied to the success of the company. This potential source of conflict of interest is directly relevant to the work described in this manuscript. We declare that we have no other potential conflicts of interest to disclose.

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