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DOCUMENTING AND ASSESSING OPEN INNOVATION: CO-CREATION OF AN OPEN DATA MODEL FOR SURGICAL TRAINING

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PRAXIS REPORT

ABSTRACT

Challenge competitions have recently resurged for promoting open innovation in areas where markets fail to provide incentives, such as the Sustainable Development Goals (SDGs). Challenges call for the general public to contribute novel solutions to a well-defined problem, in exchange for prizes, credentials and the promise of further development of selected solutions. The aim of this paper is to report on the development of an open and collaborative data model to document and evaluate innovations in the context of a challenge competition, while also being compatible with the work of other open source communities to validate and improve them. By reusing open documentation standards and embedding them into a semantic collaborative platform, the model aimed to be flexible enough to respond to the evaluation needs of the project organisers and self-assessment for participants. We expect our experience provides insights on the potential of semantic, collaborative platforms and standards for increasing the impact of innovations towards the SDGs.

INTRODUCTION

Since the 2000s, organisations in the public and private sector have been increasingly experimenting with opening their innovation processes to external collaborators. Examples include firms developing kits to incentivize user-led innovation (von Hippel, 2005; Boggels et al., 2018; Redlich et al., 2019), or academic research projects seizing the power of crowds to tackle "wicked problems" (Majchrzak & Arvind, 2020). Within this context, challenge competitions or innovation prizes are initiatives that invite the general public to propose novel solutions to a well-defined problem, in exchange for credentials, monetary prizes and the promise of further development (Williams, 2012; Zelmer et al., 2017). These prizes and challenges aim to promote innovation in areas that are valuable for society, especially where market failures do not generate enough stimuli (Brunt et al., 2012).

Digital platforms have incentivised a recent upsurge of prizes in areas ranging from health (Wilson & Palriwala, 2011) to conservation ecology (Conservation X, 2022), all of which fit more broadly into the Sustainable Development Goals (OpenSeventeen, 2022), opening new opportunities for increasing the impact of innovations. For example, participants could document their innovations openly online and learn from their peers' developments, adding a layer of transparency to the challenge, and allowing solutions to be reused outside its scope. However, these opportunities remain mostly unexplored by challenge organisers who tend to reproduce the conventional model into the online territory.

Online documentation of innovations is a practice at the core of the maker, open design and open hardware movements (Bonvoisin et al., 2017), albeit a complex and time-consuming task. Researchers in these fields have examined online repositories of documentation to understand collaboration dynamics and motivations (Schroer & Hertel, 2009; Morreale et al., 2017; Bonvoisin et al., 2018) and to propose multiple frameworks to evaluate the "openness" of projects based on its project documentation (Bonvoisin & Mies, 2018; OSHWA, 2016). These metrics usually evaluate how reproducible a design is, meaning how easy it is for an independent party to recreate the designs based solely on the project documentation. These instances of evaluation are often implemented asynchronously once documentation is "complete". However, due to the multiple possible domains of application, these tools are not able to fully capture context-dependent information that is crucial for evaluating innovations.

This paper reports on the community-led design of a data model used to evaluate innovations in the context of a challenge competition. The evaluation was two-folded: participants compared their open documentation against the judgement criteria to self-assess their progress throughout the innovation process. At the same time, a judging panel used it as a completion checklist to select outstanding innovations. The design of the data model is based on a documentation standard developed by the open hardware community, and was adapted to the specific knowledge domain of the challenge through participatory workshops with domain experts. As a result, by using a Research through Design strategy (Menichinelli et al., 2021), this data model was flexible enough to respond to the documentation and evaluation needs of the project organisers and participants. Moreover, by being embedded into a wiki or collaborative platform, it allowed participants to see the evaluation criteria in action and self-assess their work throughout the challenge in an interactive way.

The paper begins by (1) introducing the Global Surgical Training Challenge as the implementation context. Next, it describes (2) the methods used to develop the platform and collect assessment data, and (3) the results of the implementation process. Section (4) discusses the evaluation processes mediated by the platform, and the use of wiki-based platforms for documenting and evaluating innovations in challenge competitions. Finally, we identify the (5) challenges and limitations of this approach, as well as future work needed.

1. THE GLOBAL SURGICAL TRAINING CHALLENGE

The Global Surgical Training Challenge (GSTC)[1] is a competition aiming to make simulation-based surgical training accessible worldwide through low-cost, open-source training modules (Appropedia, 2021). Participants around the world are invited to submit innovations that improve the remote learning of surgical skills, with a focus on Low- and Middle-Income Countries (LMIC). The initiative is organised by the Intuitive Foundation —a U.S.-based nonprofit organisation—, in collaboration with NESTA Challenges, the Royal College of Surgeons Ireland, MIT Solve, and the Appropedia Foundation.

The challenge was designed to engage a broad range of innovators, including education specialists, surgeons, midwives and nurses with experience working in resource-constrained settings; engineers and software and game developers; artists, medical illustrators, and designers. The awards are granted in phases: Discovery Awards of up to $200,000 to support prototype development, $500,000 awarded at the Finalist stage to advance model development, and $1 million to selected finalists. The Finalist Award teams have representatives from across multiple continents, but are focused on surgical training needs in LMICs, including Ethiopia, Guatemala, and Nigeria. They represent a variety of surgical specialties, including obstetrics, trauma, orthopaedics, and reconstructive surgery.

The GSTC constitutes an interesting case study of challenge competitions that strive towards the Sustainable Development Goals (SDGs). Aligned with SDG 17, building partnerships for the goals, the challenge aims to foster innovation through open collaboration and knowledge sharing between multiple stakeholders in civil society (Howaldt, 2021; Jha et al., 2016). By focusing on innovations that enable training in surgical skills, the challenge addresses two other SDGs: health and wellbeing (SDG 03) and quality education (SDG 04). Quality education, by establishing an open knowledge co-creation model that lowers access barriers for participants in LMICs. Health and wellbeing, because the ultimate goal of the challenge is to promote greater access to healthcare in under-served areas. Enabling more people to be trained in surgical skills where they are needed the most (target 3.8), but where conventional approaches to innovation can't find market incentives (Natera et al., 2019).

Similar to other innovation prizes, the GSTC opens the space to explore new solutions to a problem. However, it also aims to open the innovation processes to the general public: all submissions must make their innovations open source and reproducible for other parties after the competition. To achieve this, participants are encouraged to document their prototypes in Appropedia, an appropriate technology wiki that hosts open designs since 2005[2].

In the context of GSTC, the selection criteria for best innovations goes beyond examining the core proposals; criteria include the outlook of potential uptake, the chances of end users successfully adopting them. This poses the challenge to consider how they will not only be laid out for judges during the competition, but also communicated across different communities in new contexts, using multiple content formats, thus ensuring reproducibility and that learners will acquire and use these skills. For example, assessing how the innovation facilitates its diffusion by encouraging engagement of physicians through different means (Rogers, 1995).

For this reason, challenge organisers, mentors and members of an interdisciplinary judging panel use public documentation on Appropedia as the entry point to evaluate the novelty and fit of these innovations. The rationale behind this decision is that the same material will be used by future learners and practitioners, as they use these innovations. Participants would also be able to understand what is expected from the documentation to self-assess their progress during the life of the challenge, especially given the inability of participants to coordinate in person due to the COVID-19 pandemic.

2. METHODS

To build a platform that allows documentation and evaluation of innovations we started by defining its underlying data model (or domain ontology). In information science, ontologies are "a means to formally model the structure of a system, i.e., the relevant entities and relations that emerge from its observation, and which are useful to our purposes" (Guarino et al., 2009).

To design a domain ontology, it is therefore necessary to arrive at an agreement of what will be represented. To do this, we followed the process described by Brusa et al. (2008) based on Gruninger & Fox (1995) and Gómez-Pérez et al. (2004). This methodology consists of three main stages: the ontology specification, concretisation, and implementation. All activities took place between June and September 2020 with the intervention of the actors described in Table 1.

Table 1. List of participants (roles), stages in which they participated and denomination in the article.

Participant	Participated in stage	Denomination
Domain expert A	Specification, concretisation, implementation	Developer team
Domain expert B	Specification, concretisation, implementation	Developer team
Appropedia Foundation representative	Specification, concretisation, implementation	Developer team
Intuitive Foundation representative A	Specification, concretisation, implementation	Project owner
Intuitive Foundation representative B	Specification, concretisation, implementation	Project owner
Medical field experts (3 participants)	Specification	Consulted experts
Representatives of challenge teams (13 participants)	Specification, concretisation, implementation	Innovators

1 https://globalsurgicaltraining.challenges.org
2 https://www.appropedia.org/

All activities took place between June and September 2020 with the intervention of the following actors:

- Specification: the developer team defined the goal and scope of the ontology in collaboration with the project owners. This was done by agreeing on scenarios where the ontology will be used and establishing competency questions that the ontology must be able to respond to.
- Concretisation: the developer team used the specification outputs combined with literature review and consulted expert assessment to produce a first draft of the ontology. This included main concepts, relations between them and data constraints. After multiple iterations with the project owners, the final version was formalised in a standard graphic representation (UML).
- Implementation: the developer team produced a machine-readable version of the ontology in OWL format using the software Protégé; its internal consistency was verified using the Protégé reasoner HermiT 1.4.3 tool. The team validated the ontology with the project owners in a dedicated workshop. At this stage the team embedded the ontology into a WikiMedia instance, to turn it into an interactive, open and collaborative platform.

The data sources for designing the ontology included:

A. Workshops and informal conversations with project owners
B. Analysis of data collected by project owners
C. Literature review of open ontologies on education (Chung and Kim, 2016; Katis et al., 2018) and open hardware (Open Know-How standard , Bonvoisin & Mies, 2018)
D. Data on participants' use of the platform, collected from the MediaWiki instance

3. RESULTS

ONTOLOGY SPECIFICATION

The goal and scope of the ontology were defined based on meetings between the developer team and the challenge organisers. These meetings were guided by three questions: (a) who are the users and what are the settings for the training modules; (b) what does the project owners define as a complete documentation, (c) what information is required by the mentors and judging panel to assess the modules. These questions allowed the developer team to define the scenarios and competency questions of the ontology.

Before the first meeting, the developer team was provided with a graphic artefact that reflected the GSTC expectations and evaluation criteria (Figure 1), and a database of "lessons" that the innovators could use as inputs. As seen in Figure 1, the project owners had previously agreed on a visual representation of the model with boxes for different kinds of skills and tools, which unintentionally aided in the definition of classes and subclasses for the data model. This information was useful to understand the expectations of the project owners. This design provided by the project owners was useful to discuss what they understood

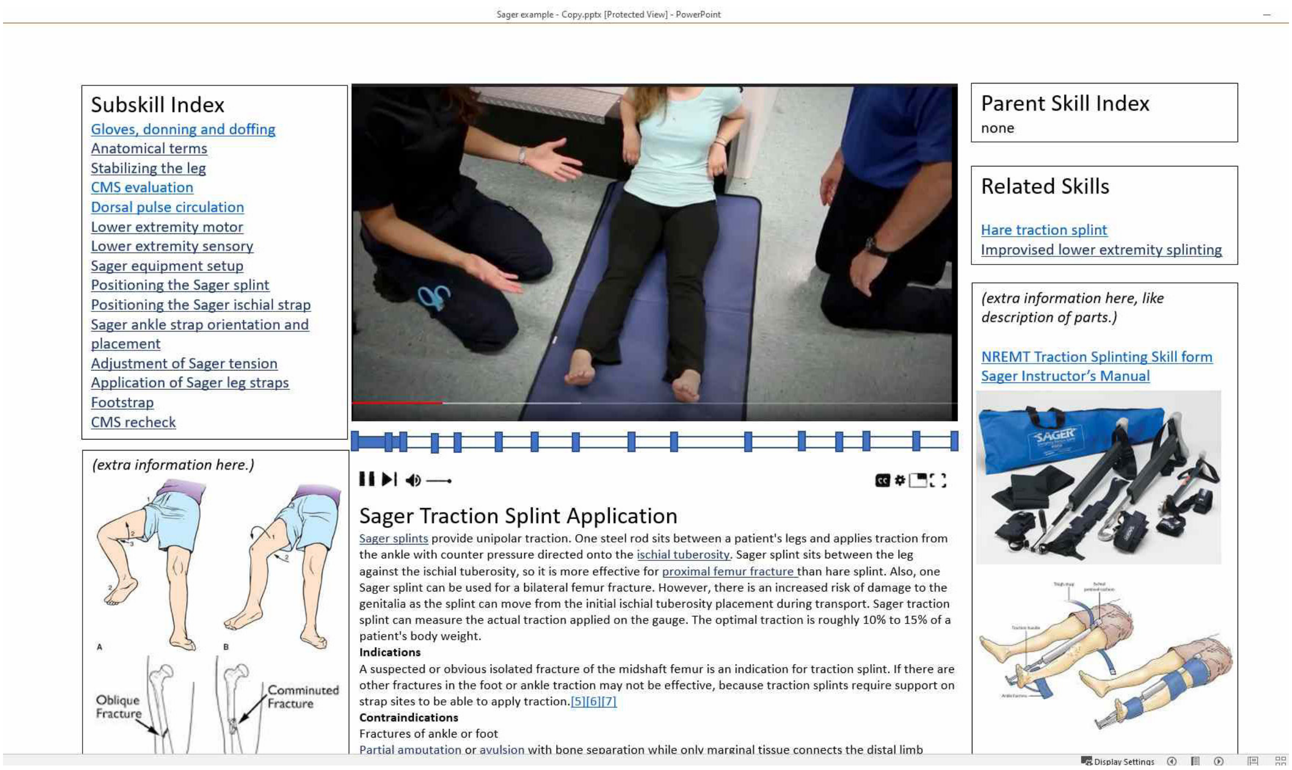

Figure 1 Graphic representation of the expectations of GSTC organisers for projects' documentation (source: Intuitive Foundation).

3 https://www.internetofproduction.org/open-know-how

as a “skill”, and making the decision of turning the skill into the main hierarchy to work with.

Once the data model was rolled out, the challenge innovators were invited to document their innovations on Appropedia using various formats that included hardware and software documentation, text materials, and self-assessment components, with a special emphasis on audio-visual materials. Project owners also conveyed the importance of hierarchic relationships between training modules, and how those sequences would determine how users navigate the platform. Based on these inputs, the developer team drafted a proposal that was iterated with the project owners and consulted experts; requirements were recorded after each workshop.

After this initial exploration, the developer team facilitated a workshop session with the project owners and consulted experts to envision the future platform from its users’ perspective. This resulted in the identification of four main motivating scenarios. Following design thinking techniques, the facilitation process led the organisers to think of the data model in relation to its users and their particular goals, actions, pains and gains. The decision to use design-thinking techniques was based on the experience of the development team and familiarity of the project owners with this approach. Figure 2 shows the instrument used to collect data, in collaboration with the session participants, who were able to modify these notes during the session. After the session, the developer team condensed the insights into a series of four motivating scenarios (Table 2, see additional materials, pp. 91) and their related competency questions (Table 3, see additional materials, pp. 92).

The goal of the data model was *“to represent the set of entities and its relations involved in the process of creating and delivering self-assessed medical training”*. The design team identified a list of use cases:

- Scenario 1: undergraduate students who are acquiring new practical skills.
- Scenario 2: professors and professionals with expertise who wish to learn new skills as part of their professional development.

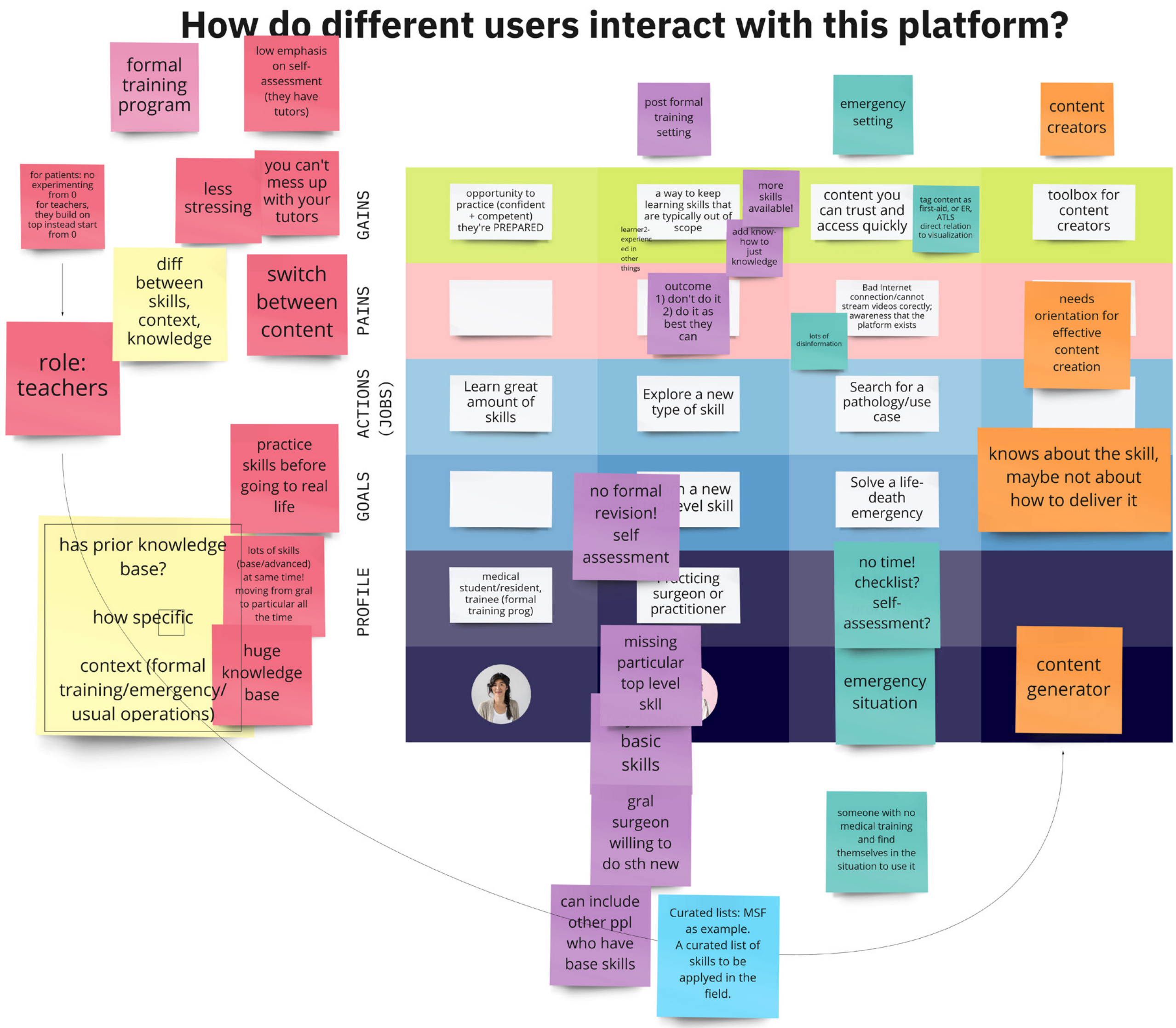

Figure 2 Notes from the session with GSTC organisers focused on envisioning users and their interaction with the platform

- Scenario 3: individuals in emergency situations
- Scenario 4: medical professionals in low-income remote areas.

As a result, the scope of the ontology was limited to scenarios 1, 2 and 4 to prioritize the most relevant use cases for the GSTC modules. Scenario 3 may be included in a future stage after running a pilot program using this version of the ontology.

ONTOLOGY CONCRETIZATION

The competency questions and scenarios were used by the developer team to understand which the most relevant concepts were to be included in the ontology, and propose an initial hierarchy of classes and subclasses. To do this, we reused open ontologies on education and open hardware, combining them with the specific medical theme of the challenge.

To model classes and subclasses we followed the priorities that emerged during the workshops: a) hierarchies within the training material (parent skill/sub skill), b) resources required for training (equipment), c) metadata for findability (body part) and module-specific information (hours, roles), d) pointers to external resources on Appropedia or external URIs to resources such as software, platforms and other assets provided as part of the modules.

After three iterations, the developer team and project owners defined a list of terms that represent the most important entities in the domain and their relations. These are shown in Figure 3, which lists the classes and subclass (<MedicalSkill>) that structure the model. As a result of the agreement, a significant component of the ontology is audio-visual material (Media class) and its annotations (MediaAnnotation).

Graphical representations were always useful to reach agreements during the design process. At this stage, the developer team produced a UML graphic representation showing the classes contained in the ontology and their relationships (Figure 4, see additional materials, pp. 92). UML or Unified Modeling Language is a standard notation consisting of an integrated set of diagrams, considered best practice in software engineering. It provides a way to visualize the design of a system, enhancing communication with users, who can visually understand the system components and their interactions at a glance. However, these representations lack interactivity. This limits the process of obtaining feedback only to synchronous instances of collaboration (e.g., workshops). For this reason, at this stage of the process the developer team decided to embed the ontology in a MediaWiki instance (Figure 5, see additional materials, pp. 93).

Class name
Course
Intervention
Material
Media
MediaAnnotation
Syllabus
Tool
Skill
↳Medical Skill

Figure 3 Classes represented in the GSTC ontology

ONTOLOGY IMPLEMENTATION

TThe ontology was formally designed and verified using the Protégé reasoner HermiT 1.4.3 tool without any detected inconsistencies.[4] To graphically verify the implementation versus the agreed UML diagram, we produced a visualisation using WebVOWL (Figure 6).[5] This diagram, representing classes (circles) and properties (rectangles), resulted in a useful and more user-friendly way to communicate the final design to the project owners.

To validate that the ontology is indeed representing the domain for which it was created, we transformed the competency questions into queries in MediaWiki. Figure 7 shows the results of the MediaWiki search engine once the competency question is translated to query language. These translations were used during a simulation workshop with the project owners and consulted experts, after loading a test dataset provided by the project owners themselves. In this session, attendees acted as future learners of each scenario and tried to achieve their goals in real time using the platform. In this way, they were able to test the functioning of the ontology by themselves and provide further feedback.

The development team gathered and systematised all the feedback from the project owners and consulted experts on each competency question. After the session, all material was reviewed and requests for changes were categorised either as "in-scope" and "future work". In-scope changes were implemented in a new iteration, while those recommendations out of scope were documented for future iterations. Future work includes two competency questions from scenario 1 (undergrad learning support), and one from scenario 4 (creation of audio-visual training material). These comprise features allowing students to provide feedback on the content of a Skill page, allowing them to use the platform to self-assess learning goals, and enabling contributors to create content that is not considered a Skill. Once the ontology was approved by the project owners, the Appropedia Foundation used it to build dedicated materials to teach how to document innovations.[6]

USE OF THE DATA MODEL FOR EVALUATION

As an outcome, innovators documented 13 innovations in the platform. Asynchronous feedback was provided during the process by using the data model to show the progress of documentation and missing elements. This included the detection of *red links*[7] or missing parameters as

4 It can be accessed in OWL format at https://github.com/cientopolis/appropedia-surgery.

5 This visualisation can be accessed at https://service.tib.eu/webvowl/#iri=https://raw.githubusercontent.com/cientopolis/appropedia-surgery/master/appropedia-skills.owl.

6 A video tutorial explaining the process can be found at https://www.appropedia.org/File:Appropedia_workshop_video.mp4.

7 A red link is a term for non-existent page links on a MediaWiki instance such as Appropedia or Wikipedia. Red links are used as content building tools by collaborative communities. https://www.mediawiki.org/wiki/Manual:Glossary#Red_link

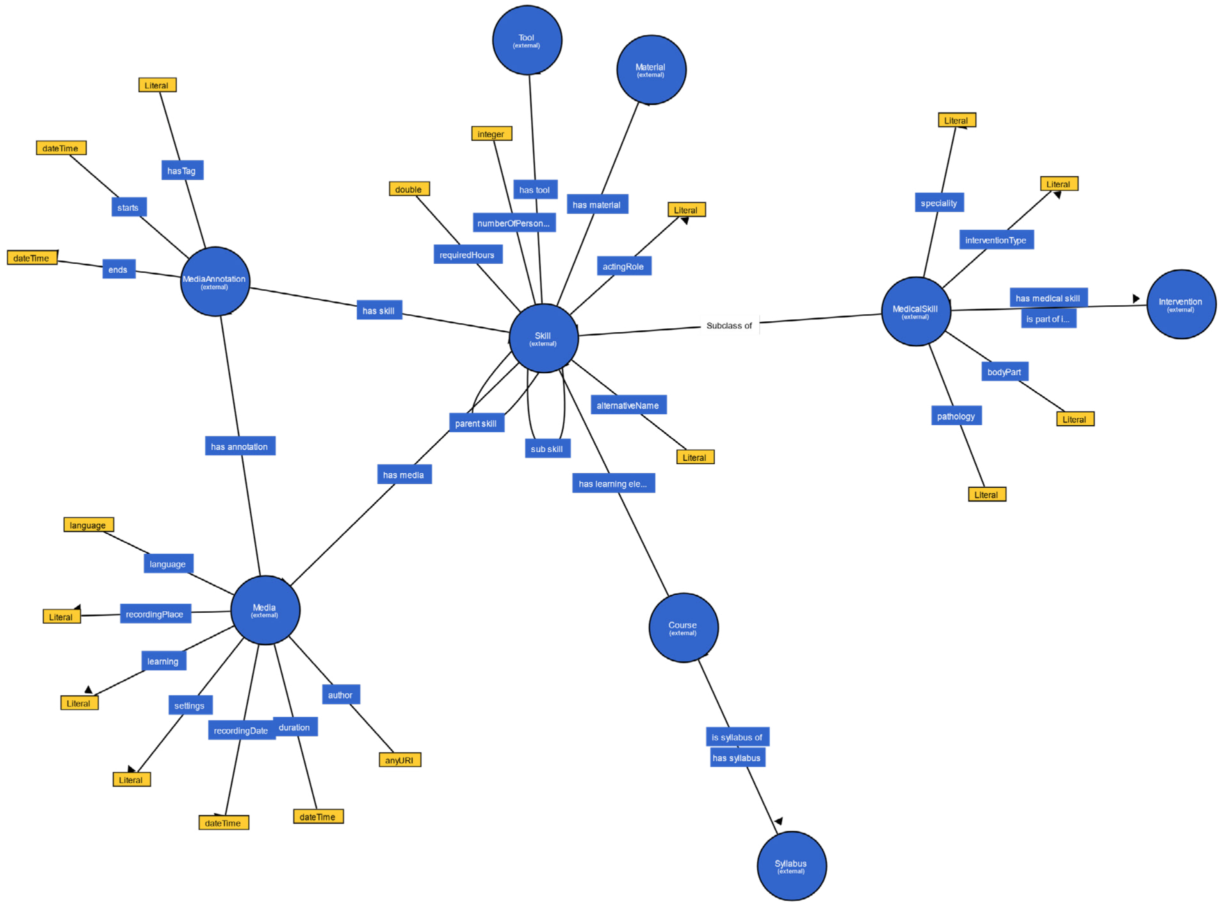

Figure 6 WebVOWL diagram representing classes and properties contained in the ontology

C. I want to access those skills that belong to a specific domain that I'm not an expert in

edit edit source

```
{{#ask:
[[Category:Medical skills]][[Pathology::Contusion]]
|format = ul
}}
```

- Alertness and Orientation Assessment (A&O)
- Hemorrhage Control
- Primary Assessment
- Sager Traction Splint Application
- Trauma Patient Assessment

Figure 7 example of competency question and its resolution, implemented in MediaWiki

indicators of incomplete information, the presence or absence of multimedia elements, and quality of text content. This information was valuable at the final stages of the challenge for the project owners, who used the public documentation in the platform as the main source of information during the judging process. The ontology allowed the judges to identify the fields that innovators planned to document but did not complete, as well as some that were left completely unused, which will be considered in future revisions of the data model. This was done through the recognition of red links, which showed which pages for each module had been planned but had not been created at the time of assessment. Innovators used elements of the model in the expected order of importance, prioritising the module structure (parent skills and sub skills) to other classes. Figure 8 (see additional materials, pp. 93) shows an example of the documentation progress for one of the most visited skills.

4. DISCUSSION

The user-centred, open, and collaborative approach that allowed the development of the platform reported different benefits to the challenge stakeholders. On the one hand, project owners increased the transparency of selection criteria and provided innovators with concrete tools to guide their documentation processes. This generated trust in the process and facilitated the judging process. Moreover, the version control feature of the platform provided access to a detailed archive of the competition and how innovators engaged in it. This is useful information for the project owners, who aim to improve future editions of the initiative based on these insights.

Project owners were able to support the innovators' journey by providing early training on how to use the platform for documentation, and closely tracking the documentation progress by using the ontology to detect any issues. This resulted in the development of new training sessions; participants also provided input on their experiences with the platform during the challenge. These were incorporated as feedback for the next version of the data model.

By reusing available open vocabularies for developing the data model, the innovations documented in the context of the GSTC are now compatible with those in the open hardware community. This increases the possibility of impact for these learning modules, as they can now be found and reused by people outside the scope of the challenge. Observing and measuring this impact is part of the work in progress with the Appropedia Foundation, in a second stage of the project. Future work on this aspect includes flagging complete GSTC projects as "pre-approved" for certification paths by using the already-existing data model, as well as developing automatic validation tools for innovators to self-assess their progress.

Innovators went through an initial steep learning curve for understanding how to document their innovations in the platform, as it was noted during screen recordings and through personal feedback gathered by the developer team. However, multiple iterations on the visual design of the platform lowered this entry barrier. Initially, project owners had concerns about innovators being "too inspired" by other teams' ideas if these were openly accessible. However, the possibility to see what fellow innovators were doing in real time resulted in participants investing more effort into enhancing their own documentation quality. Project documentation can now be used as an innovation diffusion channel by innovators to potentially attract new collaboration outside the challenge.

Platforms like MediaWiki provide interesting features for challenge competitions. Innovators were able to document their innovations in different formats: videos, images, instructions, external links, annotations. The semantic features of MediaWiki turn all these pieces of information into searchable content, regardless of the original hosting platform. As a result, documentation becomes a living instrument that can be accessed through different pathways. For the GSTC, training modules can be found by search parameters such as: tools used, body parts affected, presence of audio-visual content, location in the general curriculum, and many other fields. By using red links as a checklist, project owners were able to quickly identify incomplete sections of their training modules and respond accordingly.

Using an open data model as a tool for evaluation enables conversations among the stakeholders (project owners, innovators and even the challenge judges) that would not happen otherwise. The process of defining criteria and the tracking of how these are fulfilled are opened to discussion and examination; they can also be contested. Moreover, these become flexible to better accommodate the specific demands of the participants. Working with project owners and innovators on the ontology at the beginning of a project is a powerful exercise to capture expectations, agreements, and motivations early in the participatory process. As a result, it builds a baseline against which participants can later evaluate project performance. It is also a powerful tool for project owners, who can contrast their initial expectations with what innovators bring to the challenge, contextualising evaluation.

Using semantic tools on MediaWiki allows for these data models to evolve during the design phases of these challenges, as these data models are used by innovators, or by gathering user feedback at the end. Furthermore, version control ensures that agreements captured in different project stages can be easily accessed at any point in time; the interactive features of the wiki facilitate the design of workshops for capturing feedback. Although it was not planned for this particular iteration, changes to these models can be integrated to existing content on the platform without many of the difficulties posed by other platforms. This can help new and existing stakeholders to define and assess what should be viewed as innovative as these definitions and requirements evolve over time.

5. CONCLUSIONS AND FUTURE WORK

We have described the process of developing a user-centred, open and collaborative wiki-based ontology for documenting innovations in a challenge competition. We consider this first iteration a proof of concept that can be further adapted to other participatory projects and knowledge domains. To increase its uptake, the ontology is designed in a modular way that allows replacing or adding domain-specific knowledge in an accessible way. For example, a challenge or citizen science project on air pollution can extend the model by replacing the class <MedicalSkill> with an air pollution class and its relevant properties.

The model can be used as a tool to implement knowledge co-creation processes in citizen science projects. The wiki interactive features make it a useful platform for facilitating both in-person and remote workshops; the open and collaborative aspects of the model can increase trust and engagement of participants. In-person events such as hackathons or hardware residencies can make use of the platform to document the progress of participants towards the proposed solutions and continue work online after the event. In the case of remote sessions, the platform serves as a one-point hub for organising, running and evaluating the engagement of participants, e.g. by monitoring their work over time using the platform's version control tool. The media class of the ontology can be particularly useful for data collection activities in citizen science projects, allowing participants to share and collaboratively annotate each other's videos, sounds or images. The model provides a framework for standardising both material and non-material knowledge products in participatory research and innovation, which can be used to facilitate transfer of skills between participants. Moreover, documenting knowledge in a semantic platform increases its findability, allowing for multiple search criteria according to diverse needs.

Reusing available ontologies provides a point of connection with the communities responsible for their development, enabling interoperability and opening opportunities for future collaboration. Communities with an explicit open-source ethos can find the model useful to increase transparency and contribution upstream the innovation process. In projects where openness is not a goal, a relevant motivation for uptake is to make innovators reflect on their design assumptions and expose these to their users and contributors.

The ontology can be considered a tool for building more complex, community-based open educational resources (Downes, 2007; Tlili et al., 2020). The use of open licences and the possibility of engaging content creators in multiple settings presents advantages for fostering situated learning and innovation processes. Participants thus can use the model to self-assess their experience in challenges or other citizen science projects. In the case of GSTC, innovators were introduced to the evaluation criteria at the beginning of the competition, which outlined the expectations in terms of completeness and quality and helped them self-assess their work in an interactive manner.

Innovators with different levels of expertise were able to contribute to the documentation process according to their capabilities and interests. The ontology guided their learning process so they could incrementally enhance their documentation, while observing how others were doing it. However promising, it is necessary to consider that wiki-based learning processes may impose participation barriers for some groups (Kear et al., 2016; Biasutti, 2017). Facilitation processes led by project owners are necessary to overcome these barriers and promote the emergence of online communities of practice that increase the quality of knowledge products in citizen science projects.

Since 2020, the data model was formally used in the GSTC competition[8]. The innovators developed the learning modules and used the skills ontology as a completion guide to prepare their submission. The judging panel used it to identify the required elements and announced the four finalists of the competition. The outputs of the competition will be tested with a more thorough methodology in other countries which will reproduce the modules (physical devices, software, educational materials) using the documentation described by the ontology[9]. The model of ontology-based skill training will be used for new surgical training materials with the same partners, but also for other types of materials such as practical guides and community mapping by other institutions. The Appropedia Foundation is working on the future development of the model to include competency questions that were originally out of scope. These are focused on features for participants: improving self-assessment workflows, providing feedback between peers, creating content beyond the proposed formats. Other future work will include updating the data model to reflect better the communication needs of communities and interactive feedback tools for users.

We expect our experience provides useful insights in two ways. First, by showing the potential of semantic platforms for sustainably documenting and evaluating challenge competitions. Second, by highlighting how open documentation can increase the impact of challenges and citizen science projects (and its evaluation). We understand that connecting the valuable ongoing work of different communities is critical towards global challenges, such as the SDGs agenda. We expect our contribution is a first step towards greater collaboration and interoperability. Future research is necessary on the perceptions of users of the platform, on identifying access barriers for underrepresented groups and on criteria for adapting the model to domains outside medical training.

8 https://globalsurgicaltraining.challenges.org
9 https://www.youtube.com/watch?v=ZZFS7YaXOaA

REFERENCES

Appropedia. (2021, August 18). Global Surgical Training Challenge. Appropedia: The Sustainability Wiki. https://www.appropedia.org/Global_Surgical_Training_Challenge.

Biasutti, M. A. (2017). A comparative analysis of forums and wikis as tools for online collaborative learning. Computers & Education, 111, 158-171. doi:10.1016/j.compedu.2017.04.006Bogers, M., Chesbrough, H., & Moedas, C. (2018). Open innovation: Research, practices, and policies. California management review, 60(2), 5-16.

Bonvoisin, J., & Mies, R. (2018). Measuring Openness in Open Source Hardware with the Open-o-Meter. Procedia CIRP, 78, 388–393. https://doi.org/10.1016/j.procir.2018.08.306

Bonvoisin, J., Buchert, T., Preidel, M., & Stark, R. G. (2018). How participative is open source hardware? Insights from online repository mining. Design science, 4.

Bonvoisin, J., Mies, R., Boujut, J.-F., & Stark, R. (2017). What is the "Source" of Open Source Hardware? Journal of Open Hardware, 1(1), 5. DOI: http://doi.org/10.5334/joh.7

Bonvoisin, J., Molloy, J., Häuer, M., & Wenzel, T. (2020). Standardisation of practices in open source hardware. arXiv preprint arXiv:2004.07143.

Brunt, L., Lerner, J., & Nicholas, T. (2012). Inducement prizes and innovation. The Journal of Industrial Economics, 60(4), 657-696.

Brusa, G., Laura Caliusco, M., & Chiotti, O. (2008). Towards ontological engineering: a process for building a domain ontology from scratch in public administration. Expert Systems, 25(5), 484-503.

Challenge.gov: Toolkit - Frequently Asked Questions https://www.challenge.gov/. Accessed 21 Jan. 2022.

Chung, Hyunsook, and Jeongmin Kim. 2016. "An Ontological Approach for Semantic Modeling of Curriculum and Syllabus in Higher Education." International Journal of Information and Education Technology 6(5):365.

Downes, S. (2007). Models for sustainable open educational resources. Interdisciplinary Journal of E-Learning and Learning Objects, 3(1), 29-44.

Global Surgical Training Challenge, https://globalsurgicaltraining.challenges.org/. Accessed 21 Jan. 2022.

Gómez-Pérez, A., M. Fernández López and O. Corcho (2004) Ontological Engineering with Examples from the Areas of Knowledge Management, E-Commerce and the Semantic Web, London: Springer.

Grüninger, M. and M.S. Fox (1995) Methodology for the design and evaluation of ontologies, in IJCAI Workshop on Basic Ontological in Knowledge Sharing, D. Skuce (ed.), 6.1– 6.10.

Guarino, N., Oberle, D., & Staab, S. (2009). What is an ontology? In Handbook on ontologies (pp. 1-17). Springer, Berlin, Heidelberg.

Howaldt, J. (2019). Rethinking Innovation: Social Innovation as Important Part of a New Innovation Paradigm. Atlas of Social Innovation. 2nd Volume-A World of New Practices, 1620.

Jha, A., Kickbusch, I., Taylor, P., & Abbasi, K. (2016). Accelerating achievement of the sustainable development goals. BMJ, 352, i409. https://doi.org/10.1136/bmj.i409

Katis, Evangelos, Haridimos Kondylakis, Giannis Agathangelos, and Kostas Vassilakis. 2018. "Developing an Ontology for Curriculum and Syllabus." Pp. 55–59 in European Semantic Web Conference. Springer.

Kear, K., Jones, A., Holden, G., Curcher, M. (2016). Social technologies for online learning: Theoretical and contextual issues. Open Learning: The Journal of Open, Distance and e-Learning, 31, 42-53. doi:10.1080/02680513.2016.1140570

Majchrzak, Ann., and Arvind. Malhotra. Unleashing the Crowd: Collaborative Solutions to Wicked Business and Societal Problems. 1st Ed. 2020. ed. Cham: Springer International: Imprint: Palgrave Macmillan, 2020. Web.

Menichinelli, M., Velis, E., Rocha, A., & Schmidt, A. (2021). Collaborative ontology design for Open Hardware and Open Design. In L. Di Lucchio, L. Imbesi, A. Giambattista, & V. Malakuczi (Eds.), Design Culture(s). Cumulus Conference Proceedings Roma 2021, Volume #2 (pp. 1535–1550). Cumulus. https://cumulusroma2020.org/proceedings/.

Morreale, Fabio, Giulio Moro, Alan Chamberlain, Steve Benford, y Andrew P. McPherson. 2017. «Building a Maker Community Around an Open Hardware Platform». En Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems - CHI '17, 6948-59. Denver, Colorado, USA: ACM Press. https://doi.org/10.1145/3025453.3026056.

Natera, J. M., Tomassini, C., & Vera-Cruz, A. O. (2019). Policy analysis and knowledge application for building a healthy health innovation system in developing countries. Innovation and Development, 9(2), 159–168. https://doi.org/10.1080/2157930X.2019.1570627

Nesta Challenges. (2020). Global Surgical Training Challenge. Global Surgical Training Challenge. Retrieved September 14, 2021, from https://globalsurgicaltraining.challenges.org/.

Open Seventeen | The #Open17 Challenge. https://openseventeen.org/. Accessed 21 Jan. 2022.

Redlich, Tobias., Manuel. Moritz, and Jens P. Wulfsberg. Co-Creation: Reshaping Business and Society in the Era of Bottom-up Economics. 1st Ed. 2019. ed. Cham: Springer International: Imprint: Springer, 2019. Management for Professionals. Web.

Rogers, E. M. (1995). Lessons for Guidelines from the Diffusion of Innovations. The Joint Commission Journal on Quality Improvement, 21(7), 324–328. doi:10.1016/s1070-3241(16)30155-9

Schroer, J., & Hertel, G. (2009). Voluntary Engagement in an Open Web-Based Encyclopedia: Wikipedians and Why They Do It. Media Psychology, 12(1), 96–120. doi:10.1080/15213260802669466

Tabarrok, Alexander T., Grand Innovation Prizes to Address Pandemics: A Primer (March 19, 2020). Special Edition Policy Brief, 2020, Available at SSRN: https://ssrn.com/abstract=3571437 or http://dx.doi.org/10.2139/ssrn.3571437

Tlili, A., Huang, R., Chang, T. W., Nascimbeni, F., & Burgos, D. (2019). Open educational resources and practices in China: A systematic literature review. Sustainability, 11(18), 4867.von., Hippel, Eric (2005). Democratizing innovation. MIT Press

Williams, H. (2012). Innovation inducement prizes: Connecting research to policy. Journal of Policy Analysis and Management, 31(3), 752-776.

Zelmer, J., Ratchford, F., & Noble, J. (2017). Open Innovation Prizes and Challenges: Learnings from the ImagineNation Series. Healthcare quarterly (Toronto, Ont.), 19(4), 13-16.

"Conservation X Labs - Grand Prizes and Challenges." Conservation X Labs, https://conservationxlabs.com/grand-challenges. Accessed 21 Jan. 2022.

"Open Source Hardware Certification." OSHWA, https://certification.oshwa.org/. Accessed 21 Jan. 2022.

Wilson, P., & Palriwala, A. (2011). Prizes for global health technologies. Results for Development Institute: Washington, DC.

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ADDITIONAL MATERIALS

Table 2. Motivating scenarios identified through the co-design process, including actors involved, requirements, sequence of actions and main problems for each one. Available at https://zenodo.org/record/6607508

Scenario	Name	Description	Site	Actors	Requirements	Normal sequence	Exceptions	Main problems
1	Undergrad learning support	Tasks necessary to access online video material covering a diversity of necessary skills in medicine practice	At home, self managed practice At home, guided e-learning	Medicine students aiming to gain practice Teachers working on e-learning	Prior knowledge base (specific terminology, curriculum) Understanding of platform dynamics	1. Student logs into platform 2. Student searches available skills following different criteria a. Curriculum structure b. Pathology c. Other 3. Student selects skill of interest 4. Student watches the video 5. Student observes annotations 6. (Optional) Student edits or adds annotations 7. Student marks skill as complete 8. Teachers review progress	Students use the platform outside of a course, for example, as reinforcement to their in-person education.	Missing skill Missing video
2	Continuous learning for professionals	Access to highly specific training material for professionals in need of updating skills or gaining new ones	At work (hospital, academic institution) At field site	Physicians working in hospitals Physicians working in remote, low-resource locations Paramedics Nurses	Prior knowledge base (specific terminology, curriculum) Prior training in medicine practice Understanding of platform dynamics	1. Health professional logs into platform 2. Health professional searches for specific skill or set of skills, following criteria of: a. Specialty b. Pathology 3. Required infrastructure 4. Health professional finds and selects skill of interest 5. Health professional watches video 6. Health professional observes annotations 7. (Optional) Health professional edits or adds annotations from local practice 8. Health professional finds related skills: same specialty & similar infra 9. Health professional completes self-assessment	None detected	Missing skill Missing video
3	Emergency training for non-professionals	Access to vital training skills for addressing an emergency situation or provide preventive emergency training	Different locations (home, work, etc)	General public, non-physicians	Understanding of platform dynamics	1. Prof logs into platform 2. Prof searches for missing skills following criteria of: a. Specialty b. Pathology c. Common ER situations 3. User finds and selects skill of interest 4. User watches video 5. User observes annotations 6. (Optional) user contributes annotations based on their personal implementation a. Required infrastructure b. Context c. Missing info	None detected	Short time Poor internet connection Lack of medical vocabulary Lack of feedback Trust in content
4	Creation of audiovisual training material	A toolbox for content creators willing to upload audiovisual material to the platform	At home At university At hospital	Professors MDs Other education professionals	Understanding of platform dynamics	1. User logs into platform 2. User searches for specific skill following criteria of: a. Body part b. Common ER situations 3. User finds and selects skill of interest 4. User watches video 5. User observes annotations 6. (Afterwards) user leaves annotations on implementation, e.g. required infrastructure or context.	None detected	Lack of knowledge on successful video creation

Table 2: Motivating scenarios identified through the co-design process, including actors involved, requirements, sequence of actions and main problems for each one. Available at https://zenodo.org/record/6607508

Table 3: Competency questions for each of the four scenarios identified, available at https://zenodo.org/record/6607508

Scenario	Competency question
	Which are the skills that are part of this syllabus or unit?
	Which skills do I need to learn first before learning this one?
1	How much learning time does this skill demand?
	Which tools and materials are needed for this skill?
	Which tools and materials are needed for this course?
	How can I find skills that can be useful in a rural setting (only 1 doctor + assistant) or in a team (+2)?
2	How can I find videos in my language?
	How can I find skills for a knowledge domain that Iâ€™m not an expert in?
	What to do if someone has traumatism in this particular body part?
3	Which tools do I need to help someone who has a specific problem (e.g. deep cut)?
	What skills can be useful for one person in an emergency context?
	Which skills are missing videos?
4	Which videos are good quality and why?
	Which part of the curriculum is most demanded by students?

Figure 4: UML representation of the ontology classes and relationships between them

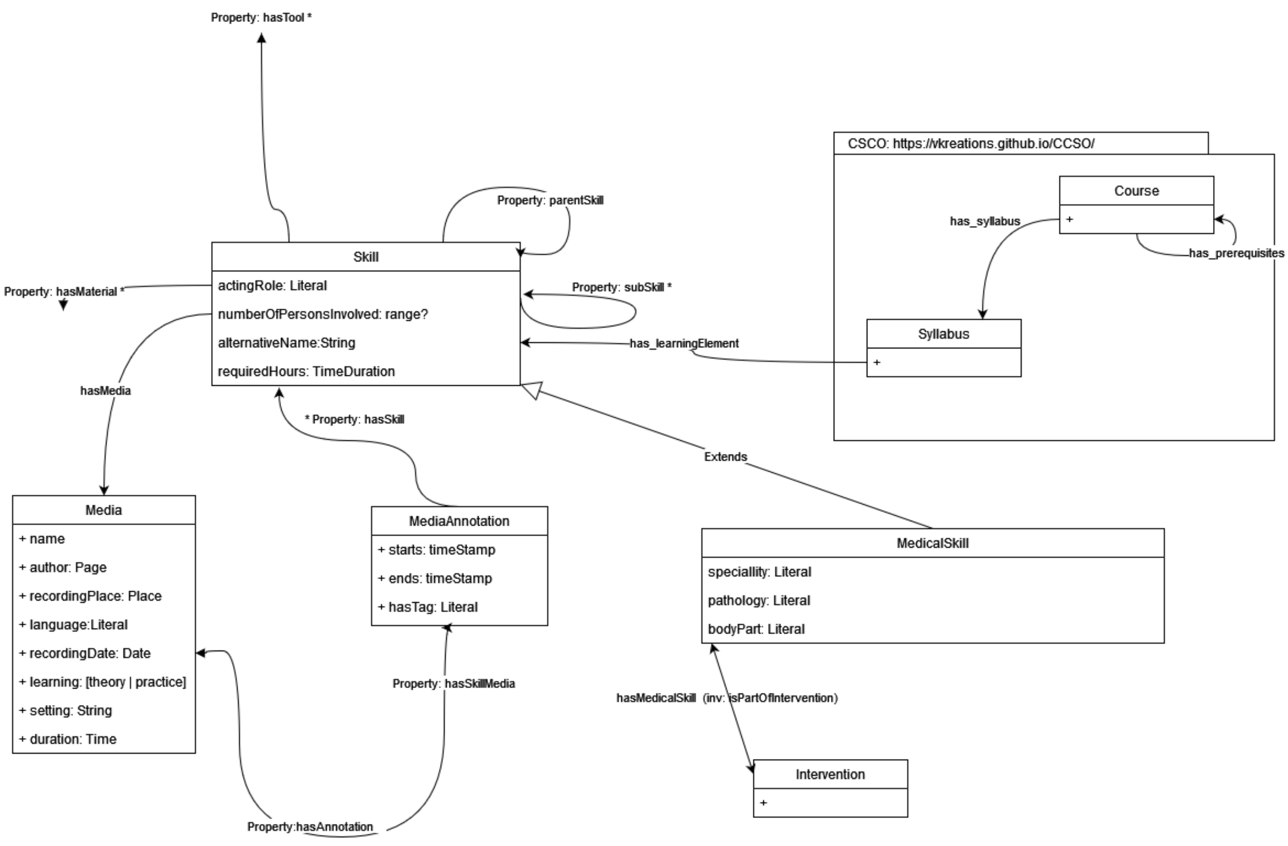

Figure 5: Visualization of the ontology embedded in the MediaWiki instance used for collaboration between the stakeholders

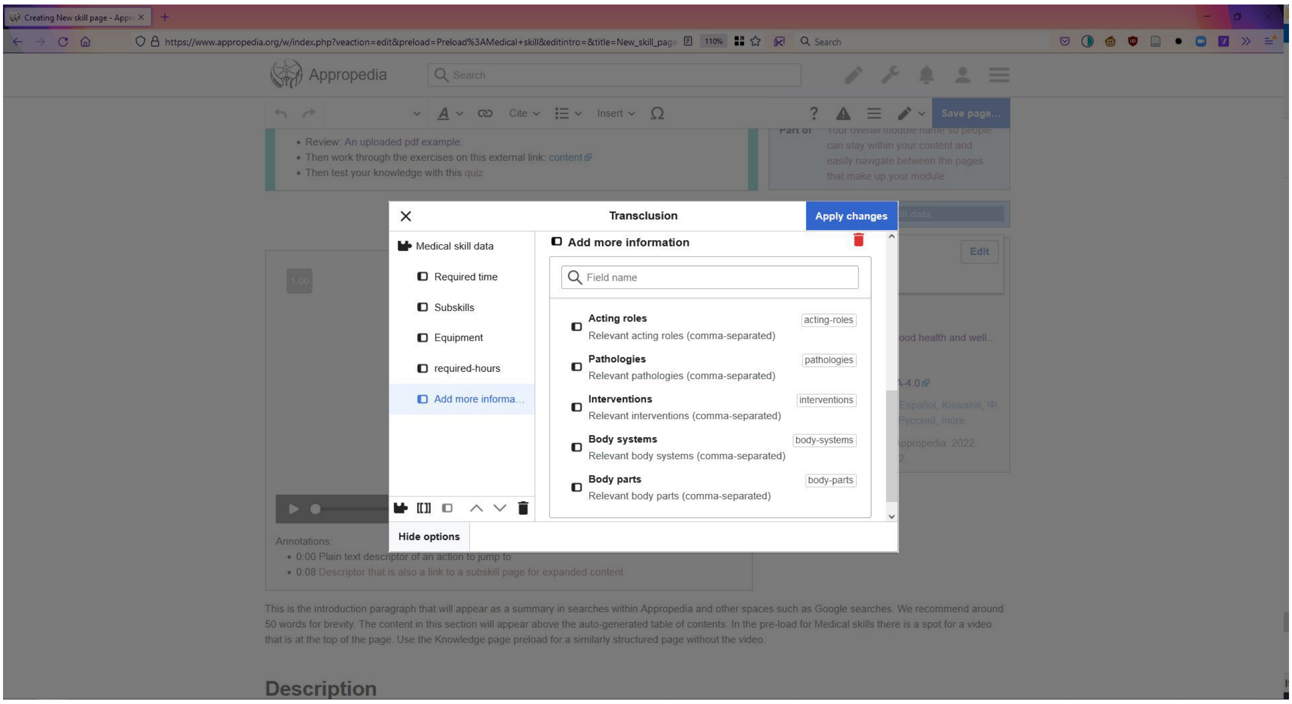

Figure 8: example of documentation progress for one of the most visited medical skills