Collaborative and Cross-Stakeholder Ontology Engineering

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Abstract

One of the major challenges in developing ontologies is to efficiently merge domain knowledge and expert knowledge to enable efficient and effective work on formal modelling of the domain in focus. This paper outlines the current state of developments in the Semantically Connected Semiconductor Supply Chains (SC3) project and its application in the BMBF-funded Cognitive Economy Intelligence Platform for Economic Ecosystem Resilience (CoyPu) project. We are using the SC3 Ontology Platform in CoyPu to promote effective information sharing among the various stakeholders in the development of the ontology. Thus, the application of SC3 Ontology Platform is used to ensure that the knowledge of non-knowledge workers (domain experts) and knowledge workers come together efficiently. This paper first introduces the CoyPu project and the current ontology development; then the SC3 Ontology Platform and its main components are presented. The paper concludes with the analysis of a first usability evaluation.

Keywords

Ontologies, Semantic Web, Sustainability, Visualization, Standardization

1. Introduction

The *Cognitive Economy Intelligence Plattform für die Resilienz wirtschaftlicher Ökosysteme* (CoyPu), is a BMBF funded project. In CoyPu, complex economic challenges in crises are analyzed, evaluated and researched for automated solution approaches. To this end, the project is working on an intelligent platform for integrating, structuring, networking, analyzing and evaluating heterogeneous data from economic value networks as well as the industry environment and social context. This intelligent web based platform will support the resilience of economic ecosystems. To achieve this goal the CoyPu project resorts and combines Semantic Web technologies with Artificial Intelligence analysis approaches. One important part of the CoyPu project therein is the COY ontology development. The COY ontology main goal is to serve as an overall project communication platform, by defining critical concepts and their interrelations. In CoyPu, we see this communication platform as a critical component for effective and efficient information exchange between the multiple actors in a supply chain.
The development of the COY ontology is a joint undertaking between domain experts and knowledge workers without expertise in economic ecosystems. One of the main challenges that

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we have faced in that work is the identification of appropriate workflows and tools to achieve a common understanding of the domain and its formal representation. Our advanced approach is based on refining two-fold mapping process where data are transformed into visual primitives. It increases flexibility in using visual primitives to merge domain and experts knowledge. It can be merged though the SC3 platform in a way that anyone can create environment that supports other team members in understanding domain. Different type of visualization helps all team members to understand their own responsibilities. In this work, we describe the use of the *Semantically Connected Semiconductor Supply Chains* (SC3) Ontology Platform in this challenge. The SC3 is a Support Action funded by the European Commission. This paper is structured as follows: First, we introduce the SC3 Ontology Platform, focusing on the visualization of ontologies for different groups of experts. We then describe a survey we created for usability analysis of the platform within CoyPu. Finally, we discuss the results of this survey.

2. The SC3 Ontology Platform

In computer science, ontologies represent a conceptual model of the world formalized as a logical theory [1]. The SC3 Ontology Platform enables collaborative ontology development under consideration of various stakeholder groups. Within this task ontology visualisation plays an important role when users need to understand the content of ontologies. To address this need within the SC3, some new approaches have been established to efficiently map between various visualisation formats. At the core of the different SC3 visualization is the so called *Resource-Relation Model* (RRM) [2, 3] (see Fig. 1). The RRM is a data model that reflects network-like structure of data expressed in Web Ontology Language (OWL) [4] with additional reorganization and classification of triples [5]. For example, Figure 7.6 published in [5] shows difference between expressing *owl:DatatypeProperty* in OWL2 and the RRM.

In general, this model is the basic data structure for various kinds of visualisation in the SC3 Ontology Platform. The RRM makes use of the fact that Semantic Web representations are described using resources, relations, annotations, axioms and type assertions. Accordingly, resources define type assertions, annotations, and axioms. Relations extend resources by providing domain and range restrictions forming the connection between resources. The RRM model reorganizes structured textual representation of Semantic Web data into representation format for further processing. This model represents network-like structures of Semantic Web data with additional grouping and classification of triples. Exactly, this is used for further information processing as preparation for various kinds of visualisation techniques; each visualisation mode is constructed from the RRM model and directly interacts with it (see Fig. 1). Any change in the RRM model impacts changes to the other views. In the rest of this paper, we introduce the visualisations in more detail.

The graph-based view of the ontology is visualized in the form of a node-dot diagram with customization options. In this graph-based visualization, the RRM is first converted into a node-link model (NLM, see Fig. 2) and this NLM is then sent to a rendering module for display in the form of a graph. The user can then choose between a UML (see Fig. 3) and a VOWL notation (see Fig. 4) at this point. The NLM consists of nodes and links. Each node has unique identifier, type and name. Links connect nodes [5]. We use two notations (UML and VOWL) to

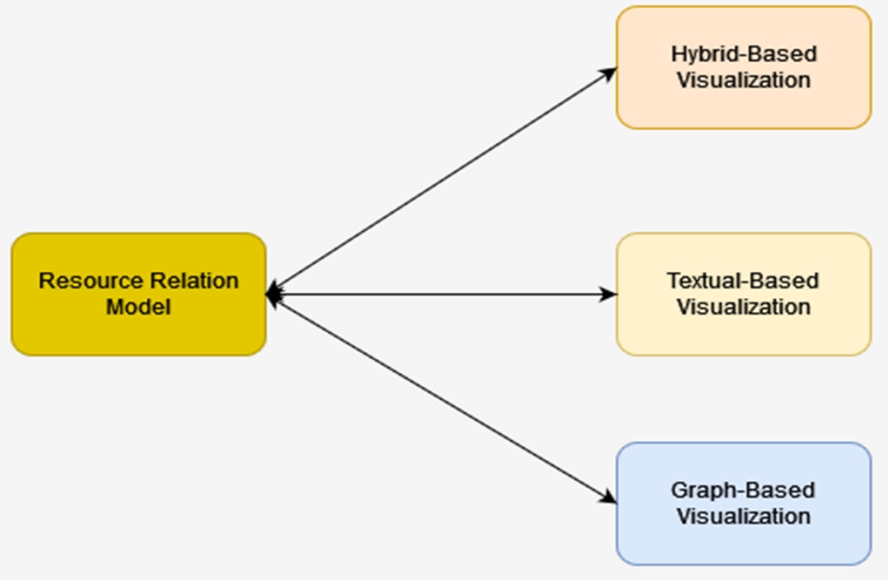

Figure 1: Resource Relation Model interaction with visual components

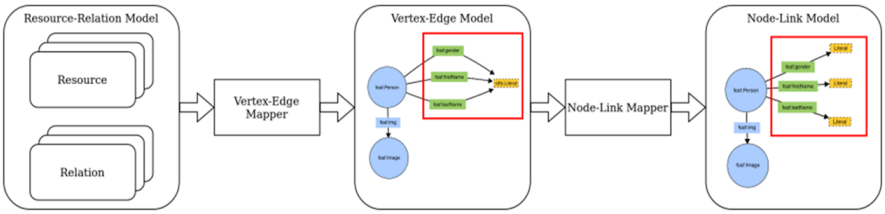

Figure 2: Two-fold mappings from Resource-Relation model to Node-Link Model (modified from [5])

visualize the NLM.

Led by disadvantages and advantages of VOWL and UML notations (see Table 2 and Table 3 in [6]) the SC3 Ontology platform supports both notations in order to benefit from them in interaction and collaboration between domain experts and knowledge engineers [6]. For example, users familiar with the UML language can read and understand easier ontology properties relations using UML notation than VOWL notation [6]. On the other hand, users who are less familiar with the UML language can read easier VOWL based visualization because they found many information in UML view redundant [6].

For the intermediate level users, ontologies in the system can be also visualized in Hybrid Mode. In this mode, information from the ontology is shown in the form of resources and relations. Each individual resource and relation is represented in the form of header, description, widget-based representation and graph-based representation. Meta information is also shown in this view (see Fig. 5). Our assumption hereby is that an intermediate user has certain knowledge about ontology construction and is interested in further detailed information as like the given axioms. Ontologies can then also be displayed in the form of a textual mode. In

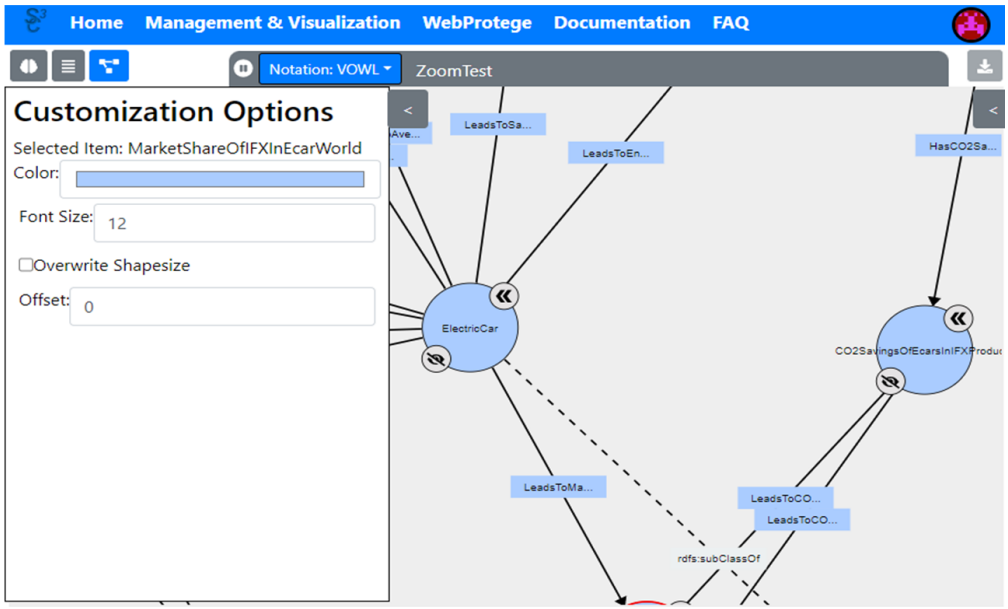

Figure 3: Graph-based Visualization in VOWL Notation

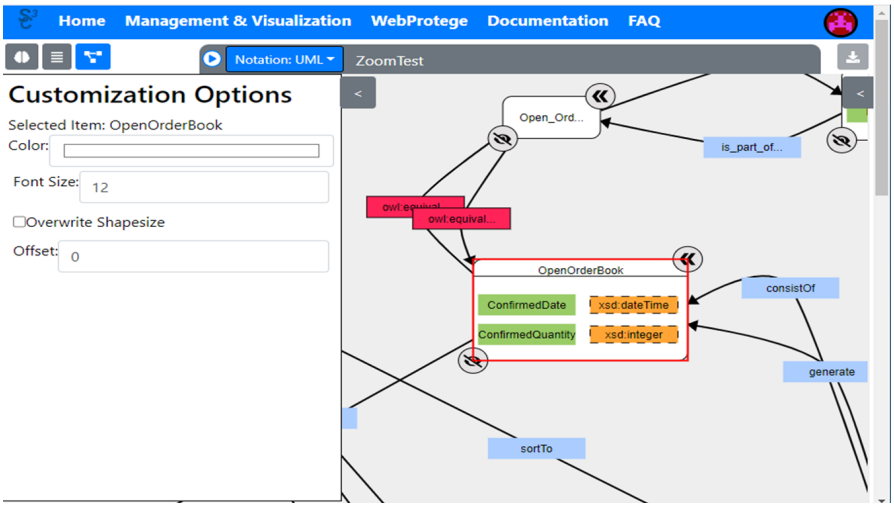

Figure 4: Graph-Based Visualization in UML Notation

this view, every detail of the ontology can be viewed in detail. We have chosen the TTL as a displaying ontology format.

A missing element of the SC3 Ontology Platform is currently the visualization of ontology rules, which should be easily understood by all users involved in the ontology development process. To extend the hybrid and graph-based visualization modes to support this feature, we plan to extend the RRM model and dual mapping mechanisms. Other features we plan to address are a comprehensive authentication and role management system. This system should allow to

create and manage own collections. In addition, the collaborative work on the creation and modification of ontologies should be implemented via a tight coupling with WebProtégé [7] and Git version control system.

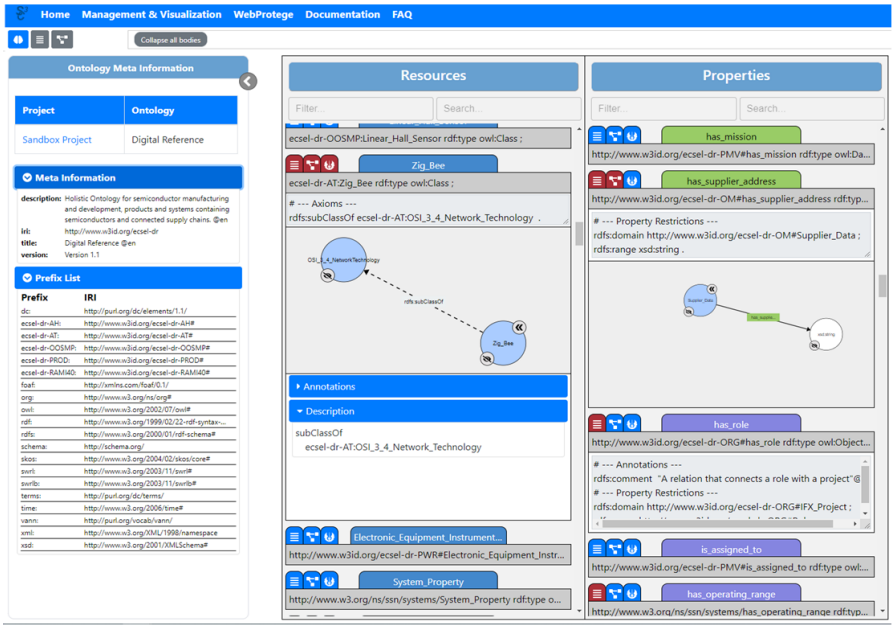

Figure 5: Hybrid Mode of Visualization

3. SC3 Ontology Platform usability evaluation in CoyPu project

To evaluate the applicability of the platform, we conduct a series of evaluations. The ongoing survey for measure usability of SC3 Ontology Platform uses the System Usability Scale (SUS, [8]). For measuring subjective mental workload assessment of the SC3 Ontology Platform, we use the NASA Task Load Index (NASA-TLX, [9]). The SUS provides a reliable questionnaire for measuring cognitive usability. Each question in the questionnaire has five response options for respondents from strongly agree to strongly disagree. The SUS can differentiate between usable and unusable systems. The NASA-TLX on the other hand is a multidimensional scale aimed to obtain the subjective mental amount of work (workload) while a participant is performing a given task. It rates performance across six dimensions in order to estimate overall workload rating. These six dimensions are mental, physical, temporal demands, as well as effort, performance, frustration [9]. In our survey, we combined the two models in the following way. We first ask users to use the platform and then respond to the questions regarding the usability of the platform and its features and then we ask users to respond to the questions regarding the mental load of the tasks. Besides these two, we ask some additional questions about the platform. From the survey, we expect to get a better understanding about the usability and applicability of the SC3 Ontology Platform. Essentially the outcome of the survey will serve as feedback for its

further refinement.
Seven researchers and software developers participated in this survey. Questions are divided into four different groups. The first group is made up of thirteen questions that are related to the user's experience with S3C Ontology Platform. Responses in this group can be scored from strongly disagree (marked as number 1) to strongly agree (marked as number 5). Table 1 shows individual scores for each question of the SUS feedback. Each participant can answer on a question using scale from 1 to 5. This table shows more precisely individual flaws or strengths with regard to the SUS. Table 2 shows the SUS raw and final scores for each participant including average for all SUS raw score and SUS final score based on results shown in Table 1. The SUS raw score is the sum of subtracting number one from each odd numbered question value and subtracting even numbered question value from five. The SUS final score for each participant is multiplication of each SUS raw score with 2.5.

Table 1
Individual scores on each question based on experience with SC3 platform

Participant	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
1	4	5	4	2	2	5	5	3	4	5	5	2	2
2	5	5	5	1	1	5	5	1	1	5	5	1	1
3	2	4	3	2	1	1	3	5	3	1	3	1	2
4	4	4	3	3	2	3	5	1	5	4	4	2	2
5	4	5	5	1	2	4	4	1	4	5	5	2	2
6	1	1	2	4	3	2	2	5	2	3	3	5	5
7	5	4	3	1	1	4	3	1	4	5	4	2	1

Table 2
System Usability Scale (SUS) raw and final scores based on individual scores

Participant	SUS raw score	SUS final score
1	27	67.5
2	28	70
3	26	65
4	31	77.5
5	31	77.5
6	21	52.5
7	27	67.5
Average:	27.29	68.21

Overall, the average of all SUS final scores is equivalent to 68.21 that is marked as C grade (65.0 – 71.0) defined in SUS proprietary scale table [10]. It means that users' experience with SC3 Ontology Platform is between OK (51.7 – 62.6) and GOOD (71.1 – 72.5) [10]. Based on the SUS proprietary scale, it is obvious from Table 1 that only three participants (second, forth, and fifth participant) have experience with using SC3 Ontology Platform which is between C+ (good) and A (excellent). We got generally positive feedback on users' experience with the current version of SC3 Ontology Platform, but still there are many spaces for improvements in

usability of the platform.
Second group of five questions is related to the general approach of the SC3 Ontology Platform. Exactly 57.1 percent of participants agreed that the Platform is a helpful tool to develop, visualise, and to modify ontology. Not all participants generally see benefits of existing the SC3 Ontology Platform over existing ontology development and visualisation tools. In addition, participants think that the SC3 Ontology Platform cannot replace existing ontology tools such as Protégé [11], but can improve visualisation services along with WebProtégé. Compared to other ontology tools, the majority of participants recognised the advantage in combining textual, graphical and widget based visualisation under the SC3 Ontology Platform rather than using only a single approach.
A set of thirty questions in the third group of the questionnaire is related to the SC3 Ontology Platform functionalities and how users are satisfied with using these functionalities. Responses in this group of questions can be scored using five grade score scale from strongly disagree to strongly agree. Table 3 shows participants' opinion about the SC3 Ontology Platform scored as agree and strongly agree. In this table the second column summarises the percentages of

Table 3
Participants' opinion about SC3 Ontology Platform functionalities

SC3 Ontology Platform functionalities / performances	Percentage of participants that agree and strongly agree
User interface is easily understandable	85.7
Hybrid mode for ontology modelling	71.5
The dropdown buttons in Hybrid mode	71.5
Easy to find the search/filter functionality valuable	85.7
Easy to interact with the graph based visualisation	71.5
The interaction with the graph is clear	71.4
Easy to navigate between different views	71.5
Performance of the platform is fast in terms of ontology editing	71.4
The role of collapsible sidebars is clear	100

agreed and strongly agreed scores about listed functionalities in the first column. In total, more than 71 percent of participants agreed or strongly agreed per a functionality. Exactly 71.4 percent of participants agreed with the statement that it is easy to understand SC3 user interface and only 14.3 of users strongly agreed with that statement. It is in total 85.7 percent of participants who find SC3 user interface easily understandable. The same result holds for finding the searching/filtering functionalities. All participants agreed that the role of collapsible sidebars is clear. Critical points in SC3 Ontology Platform functionalities, which participants observed, are interaction with graph based ontology view and how the platform is fast in terms of ontology editing, that is in total 71.4 percent of votes.

The fourth group of questions in the questionnaire is related to the amount of effort participants took to upload, visualise and modify ontology. This group has in total five questions. Table 3 shows a result of the subjective mental workload (MWL) assessment (NASA- TLX calculation) [12] based on seven responses on five questions. We did not include physical demand in the calculation. Last column in Table 4 represents individual score results across all subclasses. On

Table 4
NASA-TLX calculation

NASA-TLX subclasses	Mental	Physical	Temporal	Performance	Effort	Frustration	Individual score results
Participant No.							Raw Unweighted (Mean*)
1	40	-	80	90	30	10	50
2	20	-	10	100	10	10	30
3	30	-	50	80	80	100	68
4	50	-	50	50	50	50	50
5	20	-	80	100	30	20	50
6	20	-	50	50	50	80	50
7	60	-	60	70	40	40	54
Group score results Raw Unweighted (Mean*)	34.29	-	54.29	77.14	41.43	44.29	Overall: 50.29

the other hand last raw in Table 4 represents the group scores for every subclass separately. The overall score is given in the bottom right corner of the table. Based on the interpretation score of NASA-TLX [13], high (34.29) mental activities are required for all users to upload, modify and visualise ontology when using the SC3 Ontology Platform. The group score results show that the time pressure that participants felt during the work with the SC3 Ontology Platform is also high (54.29). The same conclusion is observed for performance subclass that is about 22 points greater than group score result for temporal subclass. All participants required a high amount of effort to achieve the requested level of performance when using the SC3 Ontology Platform. More than half participants feel high frustration when uploading, modifying and visualising ontologies in the SC3 Ontology Platform. On an individual basis, all participants, except for one, need high mental, physical, temporal activities when using the SC3 Ontology Platform. Second and fifth participants are highly satisfied with the results of their work when using the SC3 Ontology Platform. The SC3 Ontology Platform usability evaluation shows that we have to take concrete measures to improve the SC3 tool. We take in account that supervised user study could help us to collect valuable feedback for further improvement of the tool.

4. Conclusions

In this contribution, we have discussed the status of the SC3 Ontology Platform development that is based on mappings from RRM to NLM model. One contribution in this work is to offer the scientific community reach visualisation tool for developing ontologies that is built by integrating different tools, such as VOWL and WebProtégé. Such integration of different tools ensure that domain experts and knowledge engineers can work together and collaborate more efficiently. Advanced approach applied in development of the SC3 platform is a first step towards our effort to merge domain and experts knowledge when using the SC3 platform. In this publication, we have now presented the main components of the SC3 platform. This is

motivated by the work in the SC3 and CoyPu projects, where ontologies are under development between domain experts and knowledge engineers. Our concern in this paper has now been to evaluate exactly how usability of the SC3 ontology platform is actually current. To accomplish this task, we combine the System Usability Scale and the NASA Task Load Index. The results show motivating values but also gaps that need to be addressed in further development. It is obvious that more feedback about the platform still needs to be gathered. We will continue gathering feedback about the SC3 platform for the future development.

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References

[1] I. Horrocks, What are ontologies good for?, in: Evolution of semantic systems, Springer, 2013, pp. 175–188.

[2] V. Wiens, S. Lohmann, Demonstration of a customizable knowledge graph visualization framework., in: ISWC (Demos/Industry), 2020, pp. 104–109. URL: http://ceur-ws.org/Vol-2721/paper525.pdf.

[3] V. Wiens, S. Lohmann, S. Auer, Gizmo–a customizable representation model for graph-based visualizations of ontologies, in: Proceedings of the 10th International Conference on Knowledge Capture, 2019, pp. 163–170.

[4] D. L. McGuinness, F. Van Harmelen, et al., Owl web ontology language overview, W3C recommendation 10 (2004) 2004.

[5] V. Wiens, Visual exploration of semantic-web-based knowledge structures, Ph.D. thesis, Hannover: Institutionelles Repositorium der Leibniz Universität Hannover, 2022. URL: https://www.repo.uni-hannover.de/handle/123456789/12638.

[6] S. Negru, F. Haag, S. Lohmann, Towards a unified visual notation for owl ontologies: insights from a comparative user study, in: Proceedings of the 9th International Conference on Semantic Systems, 2013, pp. 73–80.

[7] T. Tudorache, J. Vendetti, N. F. Noy, Web-protege: A lightweight owl ontology editor for the web., in: OWLED, volume 432, 2008, p. 2009.

[8] J. R. Lewis, The system usability scale: past, present, and future, International Journal of Human–Computer Interaction 34 (2018) 577–590.

[9] S. G. Hart, Nasa-task load index (nasa-tlx); 20 years later, in: Proceedings of the human factors and ergonomics society annual meeting, volume 50, Sage publications Sage CA: Los Angeles, CA, 2006, pp. 904–908.

[10] Protégé, an open source ontology editor and frameworks, 2022. URL: https://about.gitlab.com/handbook/engineering/ux/performance-indicators/system-usability-scale/.

[11] System usability scale and interpreting sus scores, 2022. URL: https://protege.stanford.edu/.
[12] Nasa-tlx scoring worksheet, 2022. URL: https://testscience.org/wp-content/uploads/sites/16/formidable/15/NASA-TLX-Calculator-1.xlsx.
[13] A. D. Prabaswari, C. Basumerda, B. W. Utomo, The mental workload analysis of staff in study program of private educational organization, in: IOP Conference Series: Materials Science and Engineering, volume 528, IOP Publishing, 2019, p. 012018.