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A Community Network Ontology for Participatory Collaboration Mapping: Towards Collective Impact

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Abstract: Addressing societal wicked problems requires collaboration across many different community networks. In order for community networks to scale up their collaboration and increase their collective impact, they require a process of inter-communal sensemaking. One way to catalyze that process is by participatory collaboration mapping. In earlier work, we presented the CommunitySensor methodology for participatory mapping and sensemaking within communities. In this article, we extend this approach by introducing a community network ontology that can be used to define a customized mapping language to make sense across communities. We explore what ontologies are and how our community network ontology is developed using a participatory ontology evolution approach. We present the community network conceptual model at the heart of the ontology. We show how it classifies element and connection types derived from an analysis of 17 participatory mapping cases, and how this classification can be used in characterizing and tailoring the mapping language required by a specific community network. To illustrate the application of the community network ontology in practice, we apply it to a case of participatory collaboration mapping for global and national agricultural field building. We end the article with a discussion and conclusions.

Keywords: ontology engineering; community networks; participatory mapping; collective impact; community informatics; socio-technical design

1. Introduction

Many initiatives for impactful collaboration for the common good are centrally controlled, think UN and national government programs or classic corporate social responsibility initiatives funded by large corporations. These top-down initiatives are important, yet only effective up to a point. Combating wicked problems like climate change requires a mass mobilization for social innovation. This implies that a fundamental role is played by collaborating communities that continually make connections between seemingly disparate public initiatives [1,2].

It is not sufficient for this multitude of societal change stakeholders to work on their own. Working effectively for the common good requires achieving collective impact: the commitment of important actors from many different sectors to a common agenda for solving a specific social problem [3]. In true cross-sector collaborations, no single actor or agency monopolizes the power to set goals, shape agendas, and determine key policies and practices [4]. Keys to successful alignment of collective impact initiatives are that stakeholders should not (just) focus on their individual organizational goals, but on the joint outcomes they want to achieve. This includes drawing a picture big enough to see how and why existing initiatives can connect [5].

Aligning such a wide array of efforts toward collective impact can be supported by collective intelligence approaches for the common good (CI4CG), especially when boosted by the Internet. CI4CG approaches include—but are not limited to—online deliberation, sensemaking, argumentation and discussion-mapping, community ideation and idea management systems, collective decision making, group memory, participatory sensor networks, early warning systems, collective awareness, and crowdsourcing [6]. However, CI4CG methods and techniques by themselves are not enough. It is essential to socio-technically embed them in community networks.

Society is really a community—or rather a network—of communities [7]. Communities are groups of people sharing social ties and interactions for mutual benefit—which can be a shared purpose, interest, or need—in a common space [8–10]. Community informatics (CI) is the application of information and communications technology (ICT) to enable and empower community processes [11]. As a field of inquiry and practice, it stresses the ethics, empowerment, and legitimacy of socio-technical interventions in, for, and by communities. One angle for applying these insights is building—or more precisely, growing—individual communities, such as cultivating specific communities of practice [12], communities of interest, online communities, and so on. However, the field of community informatics also fits the collective intelligence paradigm. It goes beyond building individual communities, looking at the societal context in which multiple communities are embedded. It provides an alternative way of thinking and working that promotes effective participation from the bottom-up by local communities in regional, national and even global decision making processes [13]. The metaphor to be used here is that of "networked societies" rather than "information societies", where the network, networked relationships, and those relationships being ICT-mediated pervasively transforms all aspects of these network-based transactions and interactions [11] (pp. 15–16). This line of thinking has been solidified in the Community Informatics Declaration, which states that a just and equitable Internet provides recognition that the local is a fundamental building block of all information and communications and the "global" is a "federation of locals" [14].

Still, what does it mean to become such a federation? What does it mean to connect communities into federated networks that can achieve impact on wicked problems? Graham sees the distributed governance structures and processes of community networks as scaling fractally, society being a fractal composite of communities. Communities, in his view, are complex adaptive systems, adjusting situational individual responses to emergent experiences, such that the system stays in balance with the context that defines it. This requires a governance that occurs through self-organization rather than (top-down) control, and a relational—focusing on the network—epistemology rather than a mechanistic—top-down control—one [15]. There is some evidence that this emergent inter-communal collaboration does indeed occur. An example are forms of open-cooperativism where various communities work on their joint commons [16]. Still, this organic process is haphazard at best. Unclear is how to more systematically boost such a self-organization process of a 'federation of locals' grounded in such a 'relational epistemology' and 'scaling fractally'. How do we begin to realize these necessary but abstract goals at scale? This is where the literature gets fuzzy and few operational methods are offered.

Starting from this point of view of society consisting of federated, organically evolving communities, we need to clarify the concept of community network. Traditionally, a community network referred to the technical communications infrastructure of a community (e.g., [17]). However, from our perspective, we are more interested in the socio-technical interpretation of the term. The boundary between communities and social networks is a fuzzy one, them being part of a continuum. The network aspects refer to the relationships, personal interactions, and connections among participants, providing affordances for learning and collaboration; the community aspect refers to the development of a shared identity around a topic or set of challenges [18]. Following this interpretation, we see individual communities as being embedded in a much larger socio-technical network context of a commons of partially overlapping actors, goals, interactions, resources, tools, and so on. Vice versa, this socio-technical context is a medium, a substrate with the potential for forming new connections between multiple communities. One example is a topic of interest they may have in common, a person or an organization being a member of multiple communities, social media that act as conversational bridges between communities, a physical meeting space in which multiple communities convene, and so on. To be precise about the object of our analysis, we define a community network as a network of multiple communities, each with its individual socio-technical context, as well as the common socio-technical context in which those communities are embedded and linked.

As we saw, communities have traditionally been defined as striving towards the mutual benefit of their own members. Communities work because their members are attached to them for two reasons: identity-based attachment—they like the group as a whole—and bond-based attachment—they like individuals within the group [10]. When opening up the definition of community in terms of community networks, with their broader, overlapping contexts, what is that mutual benefit? Of course, the communities making up the network focus on their own purposes, interests, and needs first. Still, through their intersecting socio-technical contexts, those purposes, interests, and needs partially connect the communities. This means that larger, overarching, common good constructs may become focal points of interest around which inter-communal joint purposes, interests, and needs can emerge, be more explicitly defined, linked more closely, and strengthened. The question is: how? Given that communities all have their own interests, characteristics, culture, and language, how to make sense across their boundaries in order to explore and expand their common ground? How can they do so to scale up their collaboration for collective impact? Collaborative sensemaking is at the heart of the process of communities scaling up smartly. In this process, stakeholders use new understandings, processes, and tools to collaborate in complex thinking and decision-making processes [19]. To get to impact at the societal (network of communities) level, inter-communal sensemaking is of the essence, involving an ongoing, complex process of aligning resources, practices, and initiatives of multiple communities [20]. A powerful technique for making common sense is to help stakeholders map their own collaboration ecosystem: visualizing the—to themselves—network of most relevant themes and issues at play, stakeholders involved and their interrelationships, the processes in which they collaborate, the resources and tools that they use, and so on. By then jointly making sense of such visualizations through discussions in, say, brainstorming workshops or one-on-one conversations, it becomes much easier to see what are the collaborative strengths and weaknesses, opportunities, and threats. Their maps can help set the agenda for productive conversations on the community current state of affairs and directions it should grow into, as well as capture and preserve the essential outcomes of such conversations. Used in such a way, a map can act as a device for achieving common understanding and emergent coordination, while still allowing for multiple interpretations.

The participatory collaboration mapping approach presented here extends work on the CommunitySensor methodology for participatory community network mapping [20–22]. We defined this as the participatory process of capturing, visualizing, and analyzing community network relationships and interactions and applying the resulting insights for community sensemaking, building, and evaluation purposes [21]. CommunitySensor uses a cyclical approach by adopting a community network development cycle that embeds a community network sensemaking cycle. In the development cycle, community members first map relevant—to them—parts of their community networks. In the sensemaking process, relevant stakeholders subsequently reflect upon and discuss those partial maps, reaching consensus on focal issues, priorities, and next actions. This mapping and sensemaking process often needs to be reiterated several times in the sensemaking cycle. This helps weaving partial maps together, while further clarifying their meaning. The issues, priorities, and next actions that are arrived at in the sensemaking stage form inputs for their community network building interventions. In the final stage of that process, community members evaluate the results of those interventions, in turn capturing these results on the map.

In the current article, we shift our attention from the collaboration practices involved in individual communities making sense of themselves and their own socio-technical context to multiple communities making joint sense on their way to collective impact. We specifically look at how to support collaborative sensemaking within and across communities and their surrounding socio-technical networks [22]. One complicating issue when trying to make sense across multiple communities is that not only do different communities have different cultures and practices, but also different epistemologies: different languages to describe their community and the soci(et)al context it operates in, with often different meanings attached to the terminologies used. However, when communities need to work together—in order to achieve collective impact—somehow these different epistemologies need to be resolved. On the one hand, each community needs to be able to keep using its own words to describe the world according to its unique perspective, yet on the other hand, some common epistemological ground needs to be found to know how the terms and underlying concepts of the various collaborating communities might interrelate. Of course, any such potential conceptual interrelationships are hypotheses only, and need to be interpreted and agreed upon in extensive inter-communal sensemaking conversations. Still, without some minimal conceptual common ground to begin with to make sense across community boundaries, inter-communal collaboration is bound to lead to even more misunderstandings about meanings. But then, what could be such a conceptual common ground that is broad enough to stretch across community boundaries, specific enough to be useful to support collaboration towards collective impact, and customizable enough to be adapted to a community's specific terminological needs?

An ontology is an explicit specification of a conceptualization. Ontologies have many purposes, for example allowing for more systematically building knowledge bases and enabling knowledge management practices and processes [23,24]. Ontologies are inseparable from the communities in which they are being created and used [25]. Drawing from the existing theoretical work on building ontologies in information science, we propose the conceptual foundation for a relational epistemology—a tentative community network ontology—that can be used to help community networks define their own, tailored mapping languages. The contents of this ontology is grounded in a growing body of work of mapping-good practices, produced by analyzing an increasing set of real-world cases. Based on the ontology, mapping languages can be tailored to the specific mapping needs of a community network. Using a customized mapping language, the maps of their collaboration ecosystems can be made more relevant, provided the mapping and sensemaking process also fits the community network, which as we have stated above, we have paid attention to in earlier work. Making sense of more relevant maps, community networks can scale up their collaboration with more efficacy, creating stronger federations of communities working together. To clarify, our approach can also be used by individual communities to map their own collaboration ecosystem. Still, the methodology is specifically aimed at community networks of multiple communities with at least partially overlapping common ground, since in that case, conceptual confusion tends to be even larger than in communities with a more stabilized culture, language, and interactions.

Creating a community network ontology is therefore about much more than just knowledge representation. It also requires us to think about how this conceptual knowledge model affects real-world knowledge creation and application processes, in our case concerning participatory community network mapping. Its participatory nature means that we need to think hard about how to explicitly involve the community in the construction, evolution, and use of the ontology. We thus need a richer perspective than in much of the classical IS development literature. That body of knowledge often does not sufficiently take into account the human-centered aspects that predominate in community informatics, like ethics, legitimacy, empowerment, and socio-technical design. Particularly in knowledge engineering and IS design, systems specification is often driven by abstract conceptual frameworks and methodologies, not sensitive at all to the subtle knowledge constructs, modeling languages, elicitation, and validation processes that are of the essence in community networks. Ontologies are at the heart of such traditional systems designs. Exactly by focusing in this article on these ontologies, but from a community informatics perspective, we hope to shift some of the thinking of traditional knowledge engineers. Vice versa, many researchers and practitioners who are mainly interested in human-centered social constructs choose to ignore the to them often alienating world of technical systems design. This is also not the right way to go. The whole world is increasingly running on networked ICTs, big data, algorithms, and social networks like Facebook, with all of the ensuing contentious issues like loss of privacy and lack of self-determination. We can wish that technical world away, but that only increases the colonization of ordinary people's lifeworlds by those systems. The unique strength of community informatics as a field is that it aims to build bridges across the human-centered and information systems paradigms. Difficult as it is, those working from either paradigm need to find ways to make inroads into each other's domains. Community network ontologies, their creation, and use in participatory collaboration mapping are one way to bridge those two worlds and help build socio-technical systems with collective impact that are grounded in more emancipatory norms and values. This article, although only in a tentative way, hopes to make a contribution to that goal.

To show how community network ontologies driving participatory collaboration mapping can promote these goals in practice, we make the community network ontology evolution and use come to life by sharing a typical real-world example: participatory collaboration mapping for international agricultural field building, followed by the outline of a spin-off case on national agricultural field building currently underway. In the first case, we show how participatory collaboration mapping was used to establish the common ground in the interests and work of participants of a global agricultural conference. The human-centeredness of the methodology showed in how the seed map was constructed out of participants' descriptions of the context of the projects they came to represent at the conference; how during the conference the participants engaged interactively with the map through a combined process of mapping and facilitation; and how the mapping language grounded in the community network ontology was modified based on inputs from the participants as they engaged with the maps during the conference.

Out of the mapping exercises done at the conference, a spin-off case emerged: participatory mapping of stakeholder collaborations in Malawi. This country has a very complex and hierarchical agricultural governance system, resulting in a multitude of collaboration problems. A participatory collaboration mapping approach is being developed which consists of a common mapping language that is used to map the connections between local collaborations, then aggregate these maps to engage with them at the higher district and even national levels. Much attention is paid in the methodology to map ownership and community empowerment. For example, the approach allows local communities to remain in control of their own maps, while it simultaneously permits collaboration patterns to be spotted at the aggregate levels. This permits, for instance, agencies with resources to contribute to addressing relevant collaboration issues that are made visible by the maps. Both cases are an exemplary illustration of participatory collaboration mapping for collective impact, and the role that community network ontologies play in configuring the right mapping languages.

Important ontology-research questions we aim to at least partially address here include: how can we bridge the conceptual gap that often exists between networks of communities to reach beyond their individual interests and practices? How can we externalize the tacit knowledge of participants in community networks into conceptual structures that provide a means for others to interact with, react to, negotiate around, and build upon [26]? What is the essential content and structure of a community network ontology? How can we use the ontology to create inter-communal maps? How can an ontology help a network of collaborating communities to scale towards impact? What collaboration patterns grounded in the ontology can be identified to support this scaling up of the collaboration?

We introduce our community network ontology by first presenting our agricultural field building case. We then explore what are ontologies and how our community network ontology is continuously evolving. We present the community network conceptual model underlying the ontology. We show how it contains a classification of element and connection types into a set of categories, derived from an analysis of 17 mapping cases. We show how the community network ontology was developed and used in the agricultural conference case. We end the article with a discussion and conclusions.

2. Participatory Collaboration Mapping for Collective Impact: The INGENAES and SANE Agricultural Field Building Cases

One class of applications of participatory community network mapping is participatory collaboration mapping. One subset of these applications—specifically aiming to achieve collective impact across communities—concerns field building. Field building is about finding "new ways of connecting existing fields and domains to solve increasingly complex problems (https://www.rockefellerfoundation.org/blog/philanthropy-as-field-builder/). It requires the working together of many stakeholders across sectors and disciplines, with new ways of facilitating knowledge exchange, co-learning, and collaboration, while relationships and forms of collaboration continue to expand and increase in scale [27]. Field building in particular is an activity in which many different communities—communities of practice, communities of interest, online communities, communities of place, intentional communities, and so on—need to mesh, and where inter-communal sensemaking is needed. In [22], we showed how we used the CommunitySensor participatory community network mapping methodology together with the online network visualization tool Kumu to support multidisciplinary and international field building in the case of the INGENAES agricultural conference. We summarize the essence of that case in this section and extend it to show what participatory collaboration mapping looks like in practice. In Section 5, we will zoom in on the how the ontology for this community network was created and used.

We first describe the background of the case, drawing from [28]. We introduce the online Kumu network visualization tool we used in the mapping. We describe how we created a seed map of the collaboration ecosystem prior to the symposium, and used and expanded it during the conference. We evaluate the impact of the mapping process, ending with an outline of the spin-off case to map agricultural stakeholder collaborations in Malawi currently underway.

2.1. Background

Knowledge and learning exchanges as well as network building are key components of the United States Agency for International Development (USAID) funded Integrating Gender and Nutrition within Agricultural Extension Services (INGENAES) project (https://ingenaes.illinois.edu/). The project aims to stimulate the intersection between the sub-domains of gender, nutrition, and agricultural extension services so that not only are farmers maximizing their participation in the agricultural value chain, but the nutrition needs of themselves, their families and communities are also served with the additional aspect of the pivotal role of women in this field.

The January 2017, INGENAES Global Symposium and Learning Exchange in Lusaka, Zambia, aimed to use participatory collaboration mapping to catalyze this process, connecting practitioners and researchers across the sub-domains of the field, including participants designing and committing to follow-up activities back home. Participants represented many different projects and communities from around the world. The types of communities surrounding the projects they are involved in ranged from local communities, such as village-based projects in West Africa, to large international communities of practice of experts in the various domains of expertise being integrated. INGENAES itself represents a community network of such communities and other stakeholders. As a long-running program, it has been conducting many community-building activities over the years, through its programmatic activities in various countries, its smaller regional conferences and workshops, and, of course, online. The Zambia conference was to be a major community-building "heart-beat" event, along the lines of strengthening the sense of community when cultivating communities of practice [12]. Typically, such large conferences have only limited time available to do the actual match-making between participants. Many conference activities consist of speeches, lectures, and rather ad hoc group activities. It was felt that using mapping could help in (1) creating more customized conversation agendas for participants so that they knew better whom to talk to at the conference and on what topics, as well as (2) capturing key outcomes from the conference, to continue the conversation after the conference and share the findings with those who could not attend.

The mapping approach used at the conference was three-fold: (1) preparing a pre-conference online map to make sense of what the status was of the collaboration in the projects represented at the conference; (2) using group facilitation techniques to have conference participants generate new insights and make new connections—using the map as a reference and conversation agenda; and (3) visualizing some key lessons learnt and ideas for potential new actions on the map.

2.2. Mapping with the Online Kumu Network Visualization Tool

Kumu (http://kumu.io) is a web-based tool to capture, visualize, and leverage community and network relationships. Kumu maps consist of elements and connections between the elements. Elements can, for instance, be visualized by their own colors, icons and sizes, while connections can be displayed by the combination of color and width of their lines. On the map, one can define different views, in which Kumu only shows those elements and connections of interest in the way desired. Views can be constructed by selecting sub-sets of the elements and connections on the map through focus and filters. Focus allows one to zoom in on the direct context of a selection on the map. Filter is used to select which types of elements and connections should be made visible according to advanced search criteria. The resulting views get their own customized hyperlinks and can be easily shared.

2.3. Prior to the Conference: Preparing the Seed Map

Data for the pre-conference map were collected by sending out a survey to 102 conference registrants, in which participants were asked to describe a key project they represented at the conference. For each project, the respondents were asked to briefly describe their project, key expected project activities/results, key other organizations involved, country of work, estimated number of clients/beneficiaries reached, estimated number of people involved in the project, and—essential—what INGENAES themes the project contributed to. A total of 69 responses were received. In total, 54 'Projects/Initiatives' and 'Research Projects' were mapped (some of the responses described the same project and were therefore collated). A spreadsheet was created consisting of all responses, which was the basis for creating the online map using the Kumu network visualization tool. Figure 1 shows a part of the 'Themes & Projects'-view (https://kumu.io/ingenaes/2017-ingenaes-global-symposium#ingenaes/themes-projects) on the map.

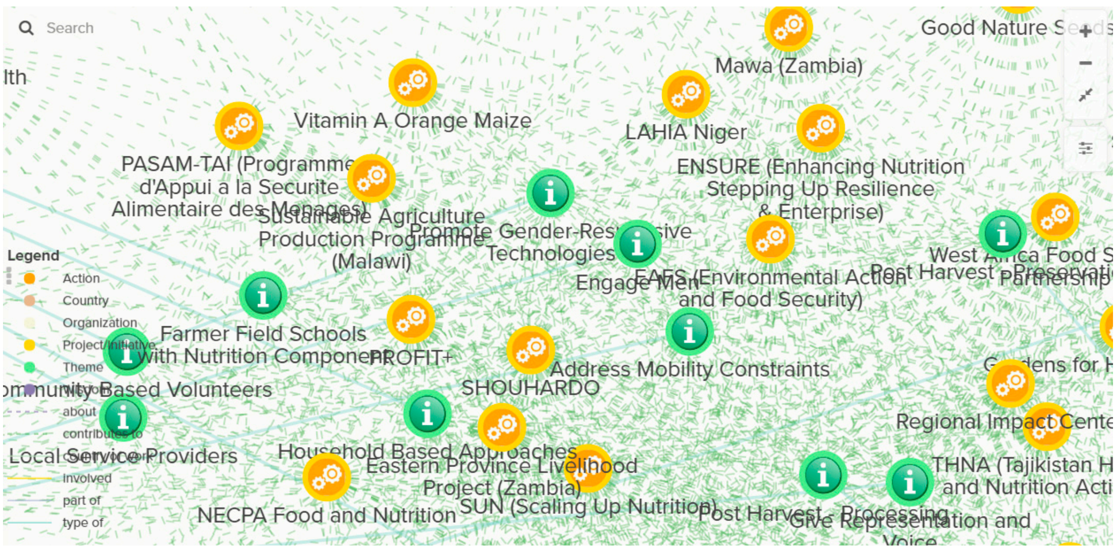


Figure 1. Part of the 'Themes & Projects' View on the map of the INGENAES Collaboration Ecosystem.

2.4. During the Conference: Expanding the Map

The mapping-related conference activities alternated between plenary sessions, in which for example the 'mapping story' was told and group work sessions in which small groups of participants explored lessons learnt so far and potential for new collaborations. A professional facilitator supported these breakout-group activities. Participants were shown how to use the map by using various forms of online documentation, plenary demonstrations, hands-on support by the facilitator during the group activities, a mapping station where participants could get assistance from the conference mapper, and sharing of links to interesting map views by the social media team on, for example, Twitter.

One way in which the map was used in small-group activities was to quickly get a sense of what INGENAES themes the projects represented by the participants in the group had in common by selecting a 'thematic view'. To illustrate, say that a breakout-group consisted of participants of the following three projects: SN4A (Sustainable Nutrition for All), Environmental Action (Benin), and Mawa (Zambia).

By selecting these three (orange) projects and then showing their direct context (the directly connected (green) themes in the overall *Themes & Projects*-view (Figure 2), the thematic common ground for these three projects can immediately be seen (see for live view https://bit.ly/2I0uSdX). The common ground for this example (indicated by the red rectangle in the figure) includes the themes 'Farmer-to-Farmer Extension', 'Utilize Gender Analysis', 'Homestead Gardens', and 'Highly Nutritious Crops'. Instead of spending precious time finding out what interests the group members have in common, such a map view of their core thematic interests helps them to immediately get to business.

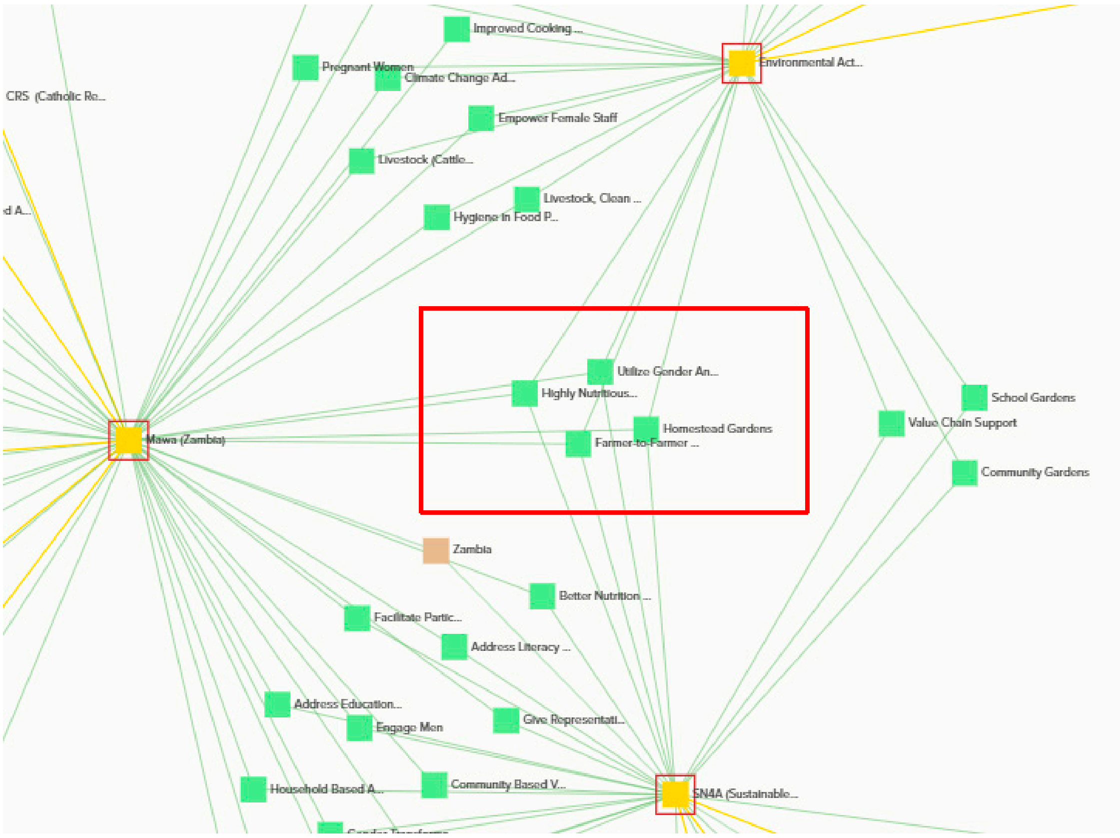
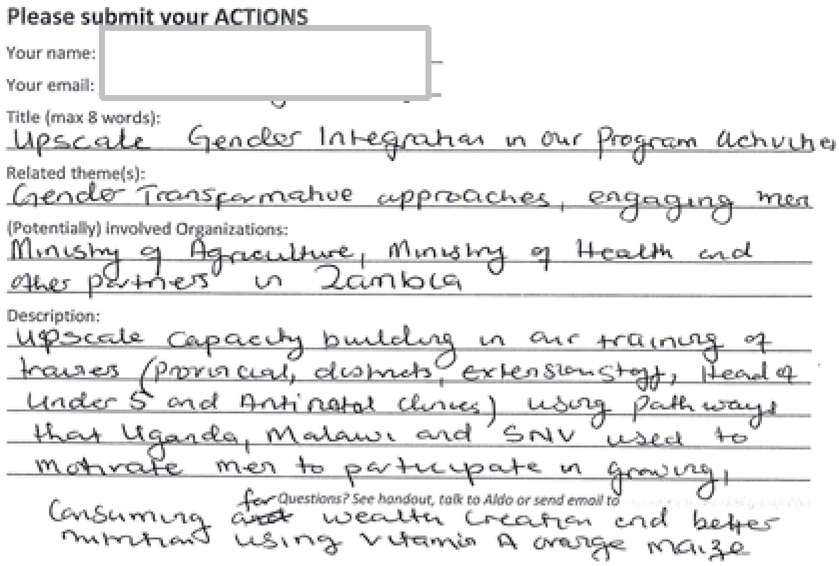


Figure 2. Thematic common ground for the SN4A, Environmental Action, and Mawa projects.

The outcomes of the sensemaking discussions in the break-out groups were first captured on forms by the participants and later added by the mapping team to the Kumu map as 'Wisdoms' (insights that participants wanted to share based on their expertise and experience) and 'Seed Actions': potential actions a selection of which could be developed further in future work (Figure 3). The submitted action descriptions were good examples of potential collective impacts as they show seeds for collaboration to be planted and nurtured after the conference.



Please submit your ACTIONS

Your name:

Your email:

Title (max 8 words):

Upscale Gender Integration in our Program activities

Related theme(s):

Gender Transformative approaches, engaging men

(Potentially) involved Organizations:

Ministry of Agriculture, Ministry of Health and other partners in Zambia

Description:

Upscale capacity building in our training of trainers (Provincial, districts, extension staff, Head of Under 5 and Anti natal clinics) using pathways that Uganda, Malawi and SNV used to motivate men to participate in growing, consuming ~~and~~ for wealth creation and better nutrition using vitamin A orange maize

Questions? See handout, talk to Aldo or send email to

Figure 3. A submitted seed action form.

As this participatory process of mapping and sensemaking continued, the map continued to grow. Whereas the seed map at the beginning of the conference contained 398 elements and 2166 connections, these numbers had grown to 524 elements and 2468 connections after the conference results had been processed.

2.5. After the Conference: Scaling Up towards Collective Impact

In [28], we presented an evaluation of the initial conference impact: "Altogether, 98 seed actions were collected during the conference, each providing the potential for growing into a field building collaboration. From a post-conference survey, filled out by 113 participants, we received promising feedback, showing real interest. 5 people indicated that the mapping approach was an action, tool, method, or approach that emerged for them and which could be integrated in their work (e.g., "I got a peek at many, but now need to go deeper. The Map and links will help"); 6 respondents reported on getting to know the mappers was their key new connection made who could help them with their work ("connection on mapping to connect volunteers in their areas"); 8 respondents mentioned the mapping was a key insight or learning, even though it was totally outside their field ("I was impressed with the mapping, and there was a lot of gender and nutrition issues")".

Taking everything into account, INGENAES program management decided to invest in further participatory collaboration mapping methodology development and application. A first seed action to be further nurtured that came out of the Lusaka conference was to use the combined CommunitySensor methodology and Kumu network visualization tool for the participatory mapping of stakeholder collaborations in Malawi. This southern African country has a very complex agricultural governance system, consisting of many intermediate hierarchical layers and organizational structures between the national and the village levels, leading to many collaboration inefficiencies. A sister project of INGENAES—both of them being implemented by the University of Illinois—is the Malawi-based SANE (Strengthening Agricultural Extension Services) project. In a joint initiative by SANE and INGENAES, a pilot was started to use participatory collaboration mapping to strengthen the District Agriculture Extension Services System (DAESS). This is Malawi's decentralised extension framework for enabling agricultural stakeholders to enhance coordination and collaboration. The aim of the mapping was to engage in a participatory process of identifying and organizing agricultural issues for collective action within and across the governance levels.

The pilot is being co-ordinated by the Malawi conference participants who had proposed this seed action. It started a few months after the INGENAES conference, and is still ongoing. Pilot activities so far have included defining a community network mapping language based on the community network ontology described in the next sections; creating a seed map using this language to capture the essence of the national Malawi agricultural collaboration and governance ecosystem; training by the author of 1 SANE project staff and 10 Malawian agricultural extension professionals in the CommunitySensor methodology and Kumu tool; two field visits applying the methodology to local agricultural communities; a stakeholder sharing session with national Malawian agricultural organizations; and SANE continuing to use and expand the mapping approach at the regional, district, and national levels.

Key to the Malawi implementation of our participatory collaboration mapping approach is that local agricultural communities are owners of their own maps. The mapping approach is being used by agricultural coordination platforms made up of diverse agricultural stakeholder (e.g., businesses, farmers, researchers, extensionists, etc.) who map initiatives within the communities where they work. As most villages do not have electrical power, posters are used to map several local initiatives at each session, thus spanning the digital divide (Figure 4). These initiatives are then presented to the overall session group by the community members. Symbolic connections between elements that the initiative maps have in common are made by connecting the posters with pieces of thread. The posters remain with the communities, since they are the owners of their own content. The trained agricultural stakeholders take pictures of the posters, then add the posters to the online Kumu maps when back at their local office. During their next visit, they bring prints of the revised online maps, which can be discussed and further annotated, The Kumu tool then allows for individual online agricultural community maps to be aggregated into new views, so that interesting connections and patterns in the combined maps at the higher (area, district, and national levels) can be discovered. An example could be a certain stakeholder role prevalent in many local agricultural communities, thus that role could bridge community initiatives across villages, regions, and districts, spawning further sensemaking activities.

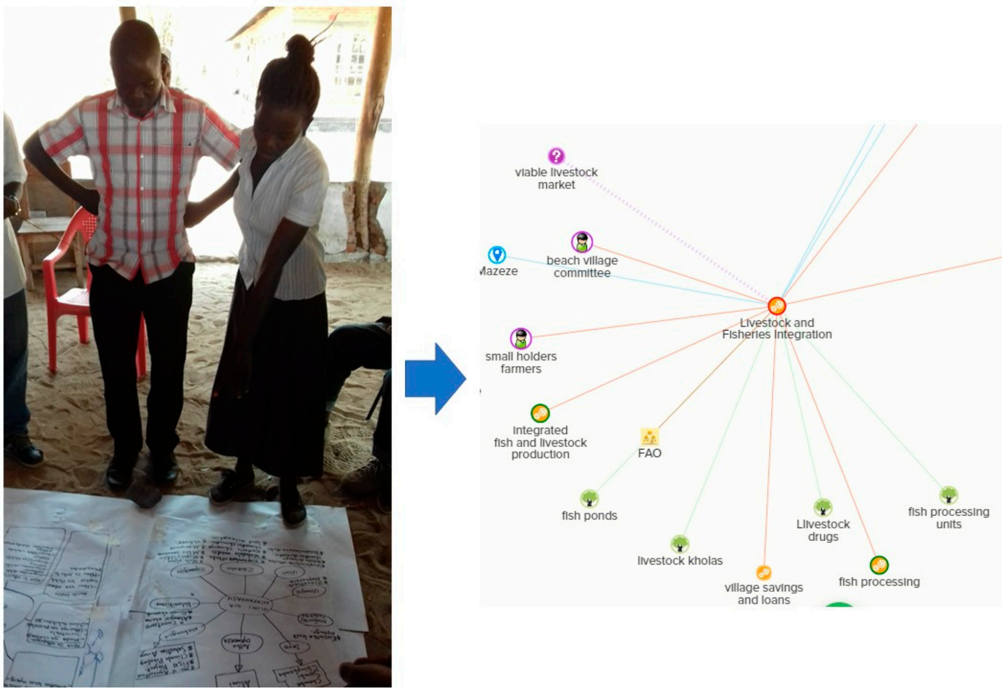


Figure 4. Participatory collaboration mapping in Malawi—spanning the digital divide.

The Malawi case is ongoing, and results are still being written up. However, we hope that—like in the INGENAES conference case—this succinct case description gives a flavor of the community network empowerment that participatory collaboration mapping can generate. To stress this point, we conclude this section with a quote from one of the ministry level representatives: "DAESS mapping provides a remarkable opportunity through which districts and DAES may easily plan and monitor the performance of the system in relation to delivery of extension services. The more people are oriented and the sooner the approach is rolled out to other districts, the more DAESS will become a force/system to reckon in the councils and at national level".

3. Towards a Community Network Ontology

The previous section demonstrated in detail how participatory collaboration mapping can contribute towards collective impact in the case of agricultural field building and development. One of the critical success factors in mapping is to use the right mapping language. Mapping is not about making abstract and comprehensive domain models by anonymous researchers in ivory towers. It is about visualizing elements, connections, and views that matter most to real world communities in practice. This means that mapping is as much about leaving things out of as putting things on the map. However, what are these things to be put on the map when the goal is to support effective collaboration in community networks? On the one hand, community networks should be able to name their own customary types of elements and connections, on the other hand, there is a growing body of knowledge about the general kinds of things that often seem to matter in typical cases of that kind. This is why we are interested in using insights and approaches from the information science branch of ontology engineering, which has been asking such questions about knowledge representation for a long time, outside of the context of communities. Insights from this field are essential for the more systematic development of both the conceptualizations (the deep layer) and the terminologies used (the surface layer) in the mapping languages, captured by the element and connection types to be mapped [22]. The alternative is the often observed trial and error of communities ad hoc trying to map their world without knowing what to map and what to leave out, getting lost in their map, and giving up.

In the remainder of this article, we aim to develop an ontology grounded in generic ontology engineering methods, but applied to the specific needs of participatory collaboration mapping. To this purpose, we reinterpret the traditional process of "ontology engineering", stating the need for a participatory ontology evolution approach. We recap our earlier work on community network patterns and show how we build on that to create our conceptual model of community networks. Although the current section may seem technical to the non-knowledge engineer, it scaffolds the community network conceptual model presented in the next section and aims to build a bridge from community informatics towards knowledge engineers in general interested in applying their skills to helping build more relevant and useful knowledge systems for collaborating communities.

3.1. Ontology Engineering Reinterpreted

Ontologies explicitly specify the essence of a domain. Ontologies are made up of concepts, relations, and their associated properties that describe the selected domain—often defined using formal specifications and constraints. Such concepts can be expressed using many different terms (which form the language used in practice). The boundaries between the (more or less informal) terminologies in use in a field and the conceptual structures contained in the ontologies explicating their meaning are often fuzzy [29]. Still, overall we can treat the ontology as the conceptual foundation of the main issues of interest of the communities of use, made relevant for their daily knowledge needs by connecting the right language terms to the related underlying concepts in the ontology.

Ontologies aim to organize canonical knowledge, often using those deeper, more stable categories for better knowledge organization and use [29]. Ontologies contain relatively generic knowledge that can be used by different kinds of applications [30]. This means that the knowledge contained in an ontology is not a goal in itself. The validation of an ontology in terms of usefulness requires embedding it in socio-technical processes and systems in the domain it is to support. Many R&D efforts have traditionally been directed at creating ontologies that support formal reasoning applications by computers, which was the traditional scope of the Semantic Web (e.g., [31]). Our ontological purpose, however, is not machine reasoning, but inter-communal sensemaking, in particular towards collaboration for collective impact.

Ontologies do not appear out of thin air. They are not static, but need to evolve as the organization expands its knowledge, and require an extensive process of formalization and structure modification [24,29]. There is a growing body of research on collaboration processes in which ontologies are being created, modified and used, resulting in a range of systematic collaborative ontology engineering methodologies. In these approaches, a community of practice in a consensus-building process agrees upon a common view on a domain of interest, and upon how their shared knowledge can be structured in terms of concepts, attributes, relationships, and constraints [32].

As we have a fundamentally different purpose in our case than in more standard collaborative ontology engineering projects—supporting informal collaborative human sensemaking instead of unambiguously and formally modeling and machine-reasoning about a domain—we will put emphasis on different aspects of ontological content, structure, process, and application. Our ontology development and use is much more practice-driven than typical Semantic Web ontology engineering efforts. Yet, at the same time, we do use a limited amount of formalization to both organize and use the ontology, for instance to define meaningful collaboration patterns. An example of such a pattern is a template used to capture the context of community initiatives, as exemplified by the simplified poster form in the Malawi agriculture communities in the previous section. Finding the right balance between what knowledge to formalize and what not, and the role of the very human community mappers in producing and interacting with this conceptual knowledge is a subtle process, some of the characteristics of which we hope to have conveyed in the previous section, and explained in more detail in our earlier work [20,22,33]. To stress this community-driven purpose, we prefer to talk about a "participatory ontology evolution" instead of "collaborative ontology engineering" approach.

3.2. The Participatory Mapping Process

The "participatory" element in the CommunitySensor community network mapping methodology is not only related to the creation and use of the content of the map. It also entails jointly with the stakeholders defining the mapping *language* to be used in their case. This language consists of the essential element and connection types, their attributes, their views, key collaboration patterns, and—given their visual nature—the layout of the map, in other words: the ontology of that community network.

To illustrate how the participatory network community mapping and ontology evolution processes intertwine within a community network, we outline the typical development trajectory of a participatory community network mapping case. In these trajectories, an expert mapping consultant (in the role of mapping architect) usually supports the project team established by the community network being mapped.

3.2.1. Defining the Mapping Scope

Using the application goals of the mapping project and the community network ontology as starting points, the project team first defines its version of the mapping language in terms of element and connection types, attributes and layouts. Furthermore, mapping processes, such as how mapping data are going to be captured, mapped, and used, as well as configurations of the mapping tools to be used are defined.

3.2.2. Creating a Seed Map

A collaboration quickscan of a relevant selection of the domain is performed by the consultant through interviews with and surveys of core community members, as well as an analysis of relevant project documents. Using the results of this quickscan, a 'seed map' is produced which can kickstart the community network sensemaking process.

3.2.3. Sensemaking Sessions

Using the seed map as a starting point, a series of sensemaking sessions with selected stakeholders are conducted. These sessions can take different formats, ranging from one-on-one interviews to large workshop and conference sessions (like in the INGENAES global conference). In the sensemaking sessions, the maps are jointly interpreted and discussed, providing common ground for thinking and action. Outputs of these sessions are issues, priorities, next actions, but also extensions and refinements of the map, leading to a mapping iteration. Refinement of the community network ontology also occurs regularly, for example by the participants requesting more specific types of elements or connections that better fit their practices.

3.2.4. Integrating Mapping Processes

Once a mapping process has been sufficiently refined and considered to be in tune with the practices of the community network, it can become part of its primary sensemaking and growth processes (including community building and evaluation). Over many iterations, it can then truly become a collective impact catalyst. Initial results at this stage are still tentative, since most cases so far have only reached Stage 3. The Malawi case is a good example of reaching Stage 4, as it is starting to be used to strengthen linkages and collaborations within and across governance levels. Here it is being piloted to support agricultural extension processes at the local, area, and district levels, with a keen interest of organizations working at the national level. When applying the developed mapping language in such a new and scaled-up context, the mapping language (and mapping processes) may require considerable adaptation.

Methodologically, our approach to participatory ontology evolution can be seen as a form of transdisciplinary research, in which research practices are issue- or problem-centered and prioritize the problem (in this case inter-communal sensemaking) instead of discipline-specific concerns, theories, or methods at the center of the research [34] (p. 9). More practically, our approach is a variation on grounded theory development. In that approach, the researcher tentatively codes observations made in a case, gradually arriving at a stable conceptualization where the observations become generalizable and modifiable to other places, times, and people [35]. In our approach, we are distilling the ontology from many different cases, not starting the coding from scratch, but continuing to build on the ontological framework developed in previous cases. We use the framework to inspire core community members in defining their own community mapping 'language codes' (i.e., element and connection types,) by helping them to select and refine element and connection types so that they best fit their case. In this way, we aim to achieve a balance between cross-case reusabilty and case-specific usefulness. The more stable the cross-case community network ontology gets over time, the easier it will become to compare maps across cases, which is essential for our overall purpose of connecting and scaling up community networks for impact.

We now recapitulate earlier work on which the CommunitySensor community network ontology is based and introduce our approach for its evolution.

3.3. Earlier Work: Communtiy Network Patterns

The genesis of the community network ontology is work we did on socio-technical collaboration patterns for communities [36], and Carroll and Rosson's conceptual model of community (in [37] (p. 15). In our ontology, we concentrate on possible element (=concept) types and connection (=relation) types between these concepts. Attributes and semantic constraints (for example, how many elements are maximally connected to one another) we leave out of our ontology description. This does not mean they do not belong in the ontology. However, collaboration patterns very quickly get very complicated, and since our main purpose is human use of the ontology, they are less relevant for inter-communal sensemaking in human conversations.

In [20], we presented our first version of the ontology as the basis of our mapping language for participatory community mapping, consisting of element types describing key entities in the community network, as well as connection types describing relations between those entities. Key element types included 'Participants' ('Persons', 'Organizations', 'Communities/Networks', 'Roles'), 'Activities', 'Results', and 'Tools' ('Physical Meetings', 'Online Tools'). As for the connection types, the focus was on the core types of community relations and interactions, which were listed in increasing degree of participant involvement: 'Informedness', 'Association', 'Participation', and 'Producing'.

In [22], we expanded this rudimentary ontology, now with more attention for the network dimension of communities. We generalized 'Activities' and 'Results' into 'Interactions' and 'Content', so that a richer variation of types of processes and their inputs/outputs could be modeled. Furthermore, we added 'Part Of'-connections to indicate structural connections between elements. This is useful, for instance, when dealing with complex organizational and interaction networks consisting of many organizational departments and work processes, key to bringing clarity in fuzzy community network cases. For example, it now becomes possible to refer to the 'Tilburg School of Humanities and Digital Sciences—Is Part Of—Tilburg University', thus referring to the more specific organizational entity when possible, and the more generic entity when needed. From the perspective of being able to work towards representing collective impact, we added a 'Goal'-element type which interactions can 'Contribute To'. This was necessary as goals are crystallization points around which new interactions—the heartbeat of communities—can start to form. The ontology was summarized in a "Core Community Interaction Pattern". Its main types were then further refined in two cases, one about a local urban farming community, the other a center of expertise consisting of a network of multiple knowledge communities. It was interesting to see how—even though the concept types on the surface seemed very different, the "deep structure" of the maps for the different cases remained more or less the same. This is important, as at that deep level one could then define more generic "meta-collaboration patterns" (e.g., "participants of community interactions in a professional context should always include some organizations"), while at the mapping surface level very different terminologies can be used to refer to those concepts, so that community members recognize them in their daily life and work.

3.4. Building the Community Network Conceptual Model

We distinguish between the cross-case CommunitySensor community network ontology and case-specific community network ontologies derived from that ontology. At the center of the CommunitySensor ontology is the community network conceptual model. To create that conceptual model, we analyzed the element and connection types used for mapping in a set of 17 cases in the period of 2014–2018. Cases ranged widely in domain, scope and scale—such as the participatory mapping of a local urban farming community, a community network of major European cities sharing lessons learnt on social innovation, and a global agricultural community network involved in field building (the INGENAES case described as an example in Section 2). Criteria for a case to be included in our ontological analysis were that it concerned a participatory community network mapping process with clear ownership and community management, with explicitly stated collaboration project and collaboration goals, a willingness to invest time and budget in the mapping process, and an active involvement of core community members in customizing the mapping language and process to their particular context. This way, we feel confident that the element and connection types arrived at were of maximum value to and to an important extent validated by the community in which they were being used.

Building on the core community interaction pattern mentioned above with the element and connection types collected from the cases, we refined and extended the element and connection categories used to organize the types used in the cases. For most categories, we have identified sub-categories (e.g., the sub-categories 'Activities', 'Services', and 'Initiatives/Projects/Programs' for the main category of 'Interactions'). Both the main categories and their sub-categories emerged organically. Our criteria for including case element or connection types as a new sub-category in the community network conceptual model were that (1) the existing set of element or connection types did not contain the type suggested by the community and (2) a more generic sub-category did not yet exist in the conceptual model. For example, in a number of cases, the type 'City' or 'Country' was used as a separate element type, each represented with its own icon on the map. However, the more generic element type 'Location' was already included in the conceptual model as a higher level sub-category, so no new sub-category was needed in that cross-case ontology. Yet, in another case, 'Capability' was proposed as a main element type, also to be included on the map with its own icon by the suggesting community network. After discussion with the community members, we agreed in consensus that none of the then existing cross-case ontology sub-categories covered this element type, hence we could include it as a new sub-category. As to the organization of the main categories: we restructured them based on logical groupings of sub-categories. For example, we renamed the 'Goals' category into 'Purposes' category, so that it could also cover 'Plans', 'Themes', and 'Topics'. Of course, (sub)categories are only tentative, and we expect them to keep evolving over time. Still, the conceptual model forming the foundation of overall our cross-case community network ontology—with its types and (sub)-categories thoroughly grounded in practice—is becoming increasingly relevant and stable.

4. The CommunitySensor Community Network Conceptual Model

The community network conceptual model defines the main architecture of the CommunitySensor community network ontology by showing how the element and connection type categories interrelate and what sub-categories each category consists of (Figure 5).

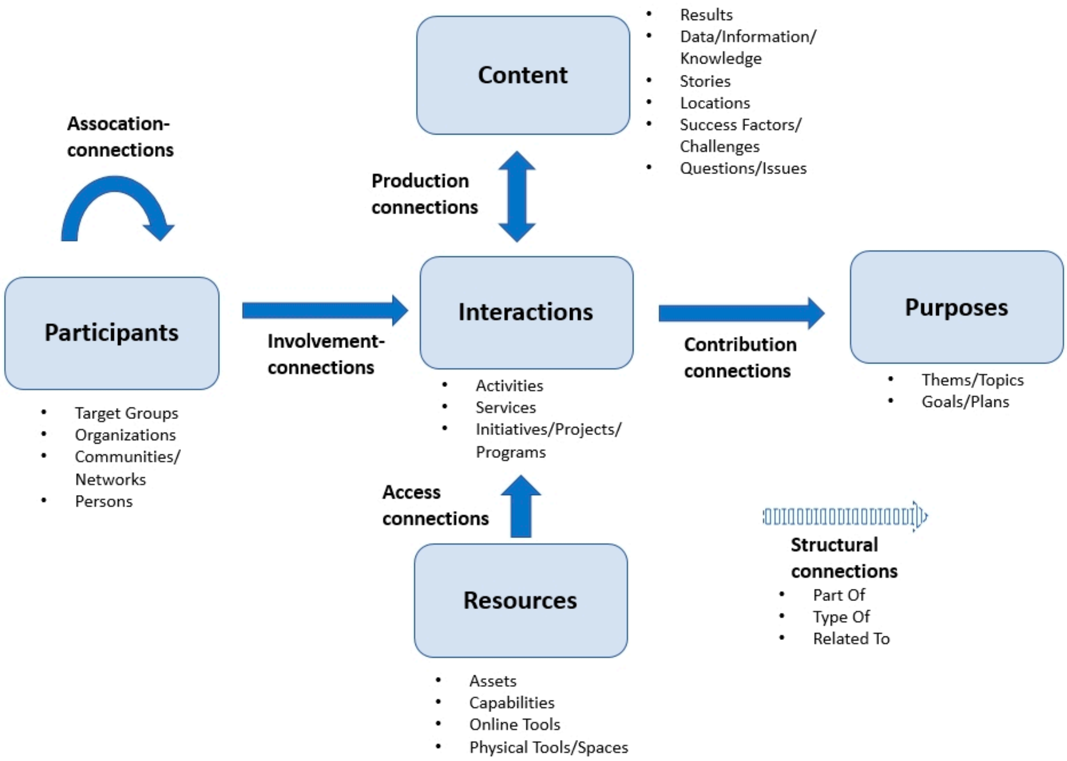


Figure 5. The community network conceptual model.

In this section, we introduce the main categories and sub-categories organizing the element and connection types making up our conceptual model. Note that in the following, we will refer to element and connection types just by their label for brevity's sake. So, when talking about 'Participants' we in fact mean "participant element types" as our model is to classify the types, not the actual instances of that type being put on community network maps. Likewise, 'Involvement Connections' stands for "involvement-connection types".

4.1. Element Type-Categories

We currently distinguish five categories of community network-element types: 'Participants' indicate who is involved in the interactions; 'Interactions' capture the operational processes of the community network; 'Resources' designate necessary conditions to make those interactions work; 'Content' describes physical or digital inputs into and outputs from the interaction; and 'Purposes' define what the interactions are about.

4.1.1. Participants

These are the actors in the community network (potentially) involved in emerging collaborations. We distinguish between four often occurring sub-categories of participants:

Target Groups

These element types are particularly important, as they indicate the roles that organizations, communities/networks and persons play in the collaboration. A wide variety of target groups has been observed in our cases, reflecting the specific interests and needs of the various community networks.

Examples: citizens, education, youth, small and medium enterprises

Organizations

Organizations are important kinds of participants, since they often have the mandate, resources, and capabilities to create actions at scale.

Examples: WorldFish, Malawi Ministry of Agriculture

Communities/Networks

Communities and networks are often less structured types of participants than organizations. Still, they can play very important roles as informal bridges between different domains and sectors and as catalysts for collective impact.

Examples: The Tilburg Urban Farming Community

Persons

Occasionally, a community network requests to map individual persons. In general, it is not advisable to map individuals, as such maps are hard to maintain and motivational complications can emerge when community members do not see themselves represented accurately.

4.1.2. Interactions

Interactions are the essence of communities. They are where social capital is being built, outputs are being created, and outcomes and impact are being generated. Interactions take many shapes and forms. They range from one-on-one conversations between community members to large projects, which in fact are containers for a multitude of interactions between participants. Especially in inter-communal sensemaking, project-element types are often used as placeholders for a whole community of interest or practice, as observed from the outside by other communities. Classifications of interactions in the literature are widely divergent. The below classification has worked in our cases so far, but will likely evolve significantly, as there are many different ways to ontologically represent such dynamic and fuzzy process concepts.

Activities

Often ongoing and informally structured interactions that a group of participants is involved in.

Examples: brainstorming, lunch meeting

Services

Ongoing productive interactions performed by an—often organizational—participant to satisfy some well-defined need

Examples: book lending

Initiatives/Projects/Programs

Projects and programs are well-defined interactions, with specific goals, scopes, and resources, and of larger scale and longer duration than activities. Especially in a community network context, we found there is also the need for the type of informal 'Initiatives', which may still be rather nascent and undefined, such as many of the Malawi agricultural initiatives. They are an important sub-category of interactions to be mapped, however, as they are often essential catalysts of other community network interactions.

Examples: Kamanzi River Bank Protection Initiative, Neighbourly Houses Project; Integrating Gender, Nutrition and Agricultural Extension Program

4.1.3. Resources

Interactions need many resources to lead to productive collaboration. Assets and capabilities help to do the work professionally, online tools and physical tools/spaces are where the interactions take place.

Assets

Assets are often tangible resources needed to produce results.

Examples: river banks, time, people, seed stock

Capabilities

Capabilities are participants' competencies and skills needed to make interactions work.

Examples: interoperability, community engagement

Online Tools

Since online tools are such an important part of the community network ecosystem, they require their own sub-category. Note that often, communities are equated with the digital platforms they use, for example "we created a community on Facebook". This is a misnomer: communities may use such platforms, but are entities in their own right, which often use a multitude of tools, both online and face-to-face.

Examples: The Urban Farmers App

Physical (Interaction) Tools/Spaces

Interactions are not just mediated by online tools. Physical (interaction) tools, such as meetings and workshops, are essential in building trust and shared sense of purpose and direction. However, they are often neglected when representing collaboration ecosystems. Furthermore, we found that spaces are more than just geographical locations. They are at the intersection of locations, organizations, and bundles of services. Since they are so crucial as hubs for community catalyzation and meetings, they require their own representation.

Examples: workshops, GNRation Creative Hub

4.1.4. Content

Communities use and produce a wide range of content. Content is to be considered in a very broad sense. It is not just digital content, but includes anything—tangible or intangible—being used (in the sense of being processed) in or produced by the interactions. When mapping, it is important to capture content at the right level of detail. The goal is not to develop a comprehensive data or information architecture. Maps are not complete nor completely accurate representations of the world. Only what is of the essence for community members to drive their sensemaking and power their interactions should be captured. Less is often more, especially in the case of content where there is the natural tendency to try and map too much.

Results

Any kind of outputs that the interaction aims to produce.

Examples: opportunities map, Research Report 2015

Data/Information/Knowledge

Any kind of—often digital—entity describing the state-of-affairs of the community network

Examples: data sources, information, documents

Stories

Stories are a very important separate sub-category of content in community networks, as they make participants understand complex phenomena related to the interactions, motivate them to engage, and give them practical ideas about how to do so.

Examples: "The personal story of John in starting this social innovation."

Locations

Places where interactions take place.

Examples: Barcelona, Malawi.

Success Factors/Challenges

These turn the spotlight on what makes interactions work, on the one hand, or, hampers them on the other hand. They are essential for communities making better sense of themselves.

Examples: "Close match between the real world and the models (success factor)", "High pressure learning (challenge)"

Questions/Issues

Questions or issues about specific (combinations of) elements or connections of the map.

Examples: "Who is going to provide this data?"

4.1.5. Purposes

A sense of purpose is what helps catalyze interactions, within but especially across community networks. Representing purpose in a variety of ways helps in making sense of what collective impacts could be reached and how community networks can contribute towards that joint sense of purpose. This is in line with systems practice, which defines purpose in terms of longer term and more abstract aspirational states—"guiding stars"—and shorter term, more concrete desired outcomes—"near stars" (https://docs.kumu.io/content/Workbook-012617.pdf). We have come across two main sub-categories of purpose elements: 'Themes' and 'Topics' (guiding stars) and 'Goals' and 'Plans' (near stars).

Themes/Topics

Especially in an inter-communal setting, it is important to represent the broader impacts that go beyond the operational goals and outcomes of the individual community network. Examples are more general topics and themes that many community networks are working on, each doing so with their own focus, capacities, and resources. Themes and topics can be anything potentially connecting joint work across communities, such as the countries communities are based in, but can also reflect larger, (societal) themes such as the EU URBACT Urban Topics that represent long-term and widely scoped ambitions in terms of European cities involved in social innovation (http://urbact.eu). Perhaps the best known and most ambitious such a thematic classification are the *UN Sustainable Development Goals* (*SDGs*) (https://sustainabledevelopment.un.org/). Even though the SDGs are labeled "goals", they in fact serve as distant "guiding stars" that can help orient and connect ways of working of stakeholders across the globe in the long run. Such comprehensive constructs play the crucial role of conceptual boundary objects, helping to communicate and coordinate the perspectives of multiple constituencies, where each constituency has only partial knowledge and control over the interpretation of the object [26]. These more abstract themes are often neglected in intra-communal sensemaking, as within a community there may appear to be a common understanding among members of the larger context in which the community operates, without that actually being the case. As the community is often so set in its ways, and thinking from one dominant perspective, such differences of interpretation of the outer context of the community may not come to light. Explicating these external themes and making explicit sense of the role they play in guiding the collaboration is of the essence, however, when working towards collective impact with large community networks consisting of many communities with very different backgrounds, cultures, and goals.

Examples: low carbon, better nutrition for all, treating women as equals

Goals/Plans

These are the near stars for the community networks, with achievable outputs and outcomes, often SMART. Since goals and plans are very common and well-understood concepts in collaboration, we do not discuss them further here.

Examples: the regional strategic agenda, Gdansk Integrated Action Plan

The purpose of Table 1 is to act as a meta-sensemaking device to support the configuration of the mapping language for specific cases. It shows all element types that were actually used in the mapping languages of each of the selected 17 cases and the (sub)-categories that emerged out of this ongoing analysis. Note that we did not include domain-specific thematic taxonomies in the analysis, such as the taxonomy of INGENAES themes or the URBACT Urban Topics, as these are generally not re-usable across cases. All types have been classified by their element type categories. Main categories are listed in bold, sub-categories in italics. The types have been ordered by the number of occurrence in the various cases. Note that this does not indicate how many instances of each of these element types occurred in the maps produced using the mapping language containing these types. For example, no specific organization names were included, just in how many cases the type (e.g., 'Organization') was included in the mapping languages of all the cases combined. Although these numbers do not have statistical significance, they give somewhat of an indication of the reusability of each of the types across communities.

Table 1. Community network ontology element-type classification

ELEMENT TYPE (SUB)-CATEGORIES	CASE ELEMENT TYPES
Participants	
Target groups	Stakeholder/Target Group (8); Role
Organizations	Organization (16); School Organization (2); School Training Program [as organization]; (2); Competence Area [as organization]; Extension Structure; External School; Organization Type; Operating Unit; Partner Organization; Research Group; Science Hub
Communities/networks	Community/Network (11); Community of Practice (2); Collaborative; Local Group
Persons	Person (2)
Interactions	
Activities	Activity (7); Core Activity (2); School Education Activity (2); Action; Agricultural Activity; Extension Method; Sharing; Workflow
Services	Library Service; Service
Initiative/Projects/programs	Project (3); Program (2); External Program; External Project; Initiative/Project/Program; Intervention; Project/Activity; Project/Initiative; Research Program; Research Project; Work Package; Work Package Activity
Resources	
Assets	Resource (4); Library Tool
Capabilities	Capability
Online Tools	Online Tool (2); Tool
Physical Tools/Spaces	Space; Physical Meeting (2); External Meeting; Internal Meeting
Content	
Results	Result (7); Result/Outcome (2); Work Package Deliverable; Work Package Output; Product
Data/Information/Knowledge	Knowledge (2); Contra; Contract; Data Source; Explanation; Idea; Label; Methodology;Pro; Research [as content]; Wisdom
Stories	Story (3); Case (2); Network-Case
Locations	Location (5); Country (3); City (2)
Success Factors/Challenges	Success Factor (7); Challenge (7)
Questions/Issues	Question (2); Question/Issue (2)
Purposes	
Themes/Topics	Theme (9); Societal Theme; Domain (2); Library Function
Goals/Plans	Goal/Objective (5); Plan

4.2. Commuity Network Ontology Connection Type Categories

The connection types denote the kinds of links between element types permitted in mapping the community network. We distinguish six main categories of community network connection types. 'Association' connection types capture relationships between participants, 'Involvement' types how participants are involved in the interactions, 'Access' connection types indicate what resources are needed to make the interactions work, 'Production' connection types what content is used and produced in the interactions, 'Contribution' connection types to what purpose, and 'Structural' connection types show the inner structure of the elements. As there is such a rich diversity in connection types, we have not further sub-classified them yet (although we do indicate what element types they can connect). Only for the 'Structural' connection types did we define some sub-categories, as they are so common in standard ontology engineering practice. Not sub-classifying the connection types is also in line with our regularly made participatory mapping practice observation that participants tend to focus on the elements to express their domain knowledge, while having less attention for the naming and content of the connections.

4.2.1. 'Association' Connections

'Association' connections represent how participants of the community are related to one another. These connections help to define the relationship network embedding the interaction network.

Examples: member of, collaborator of, stakeholder of, has beneficiary

4.2.2. 'Involvement' Connections

'Involvement' connections depict the essence of collaboration in community networks, defining which participants are involved in what interactions. This is where the communication and collaboration work gets done.

Examples: being informed about, involved in, responsible partner

4.2.3. 'Access' Connections

'Access' connections represent the resources that enable interactions to take place, including the assets, capabilities, and tools. Note that particularly the 'Uses' connection type is an interesting example of evolving meaning, as so far the same label has been used for using e.g., 'Tools' in 'Access' connections, but also for using 'Content' in 'Production' connections. To be more precise, and to allow for more refined views, it may in many cases be useful to use more explicit 'Uses Tool' and 'Uses Content' connections. What is the "best" way to represent these connections is still an open question.

Examples: has capability, has resource, uses tool, enables

4.2.4. 'Production' Connections

These connections contextualize the interactions in terms of the physical and online content used and produced.

Examples: uses content, produces, has result

4.2.5. 'Contribution' Connections

These types of connections all have to do with what contributions the interactions make to the purposes of the community network.

Examples: has goal, outcome, has impact, contributes to, is about

4.2.6. Structural Connections

Structural connections have to do with representing the inner complexity of elements in the ontology. Participatory mapping is not about trying to model the whole world. Often, it is necessary to make part of this complexity visible, however, only to the degree relevant to the participants. Three important sub-categories of structural connections are:

Part Of

This connection type is used extensively, for example to map the structure of organizations (e.g., specific departments of large bureaucratic organizations participants are working with) or decomposing work processes (e.g., specific workflows of certain key business processes involving many stakeholders).

Examples: part of

Type Of

'Type Of' connections are key types of relations in more formal knowledge engineering ontologies, as they are often used to create classifications like taxonomies. However, in live mapping sessions, 'Type Of' connections are rarely used, as participants are more interested in capturing their actual world using the types available. Still, as a conceptual aid, 'Type Of' relations can be useful to create extra meaning by classifying element or connection types prior to or after sensemaking sessions.

Examples: type of

Related To

This is a catch all-kind of connection, often used in sensemaking when participants want to indicate there is some kind of connection, but it is not clear yet exactly of what kind.

Examples: related to

Like the previous table, Table 2 is to act as a meta-sensemaking device to support the configuration of the mapping language in specific community network cases. It shows all connection types that were actually used in the mapping languages of each of the selected 17 cases. The types have been classified by their connection type categories. Main categories are listed in bold. As we currently only have one connection type for each of the 'Structural' connection sub-categories ('Part Of', 'Type Of', 'Related To'), we have all placed them on the same line.

Table 2. Community network ontology connection-type classification.

CONNECTION TYPE CATEGORIES	CASE CONNECTION TYPES
Association-connections	Member Of (5); Owner Of (2); Beneficiary Of; Has Client; Involved Partner; Research Partner Of; Stakeholder Of
Involvement-connections	Involved In (15); Organizes (6); Informedness (2); Sponsor Of (2); Responsible Partner;
Access-connections	Supports (3); Used In (2); Enables; Has Capability; Has Resource; Uses
Production-connections	Strengthens (6); Weakens (6); Has Result (4); Produces (4); Located In (3); Story About (2); Used In (2); Case About; Dialogue; Followed By; Generates; Gives; Has Capability; Has Contract; Country of Origin; Country of Work; Data Source About; Involved Organization; Question/Issue About; Uses; Working On
Contribution-connections	Contributes To (7); About (5); Aimed At; Has Domain; Has Impact; Has Theme
Structural-connections	Part Of (16); Related To (3); Type Of

5. Applying the Community Network Ontology: The INGENAES Conference Case

An ontology is not a goal in itself. It only becomes useful when it is applied in practice. In Section 2, we showed how participatory collaboration mapping can be used to work towards collective impact by giving examples of how we are applying it in global and local agricultural field building. In [22], we extensively described the participatory mapping process used in the INGENAES conference case: how we prepared the seed map; integrated the mapping process with the conference facilitation process as well as the symposium content and process strategy; used the map during the conference, harvested the wisdoms and actions, and evaluated the approach by the conference participants. We also briefly introduced the conceptual model underlying the map.

We now zoom in on the conceptual model used to design the INGENAES map from the ontological perspective developed in the current article. We describe how the ontology informed the INGENAES global conference case, in particular by providing relevant element and connection types, how these were used in the map, how the types can be used to characterize the resulting map, and to design collective impact views for intercommunal sensemaking purposes. Similar stories could be told for the SANE-INGENAES Malawi case, or the other 15 cases that were used in grounding the ontology so far.

5.1. The INGENAES Community Network Ontology

Prior to starting the map, a community network ontology was defined for the INGENAES community network by the program manager supported by the mapping consultant. Inputs for the ontology were the CommunitySensor community network conceptual model and an analysis by the program manager of key concepts in use when collaborating across projects at the INGENAES network level. In [22], we described the INGENAES community network conceptual model at the heart of the community network ontology as a list of constraints by defining which element types could be attached to which connection types (e.g., a 'Project' Contributes To a 'Theme', a 'Project' has as its Country of Work a 'Country', a 'Wisdom' is About a 'Theme'). In Figure 6, we integrate these statements into a visual conceptual model, making it easier to see the possible relations between the element types.

Figure 6. INGENAES community network conceptual model.

In the emerging INGENAES field of research and practice, an important distinction is made between 'Projects/Initiatives' and 'Research Projects'. The first element type concerns agricultural implementation projects, which have immediate impact on the people they are meant to support. The impact of research projects, on the other hand, is more diffuse, as they often have no direct implementation in the field. This example demonstrates how important of a consideration (collective) impact is for the participants involved in inter-communal sensemaking and how such considerations even filter through to the type definition level.

One way in which conference participants were prompted to help think about the evolution of their community network ontology was by having a "mapping wall" in the conference room, with the themes distributed across it (Figure 7). One of the exercises was for participants to contribute post-its about ideas they picked up individually in the conference sessions or the conversations they were having among themselves. The program manager then positioned these post-its below the most appropriate theme from the ontology. Participants could stop by the wall and discuss with the program manager about the thematic positioning of their idea. If an idea did not fit any one of the existing themes, new themes could be added to the wall. The mapping consultant then added these themes to the map, so that they could immediately be used to index the wisdoms and seed actions proposed during the conference (Figure 8). In all, 26 new 'Themes' were added to the ontology, based on these suggestions. This process, in which the INGENAES community network members themselves actively contributed to the extension of their own mapping language is a very good example of the "participatory ontology evolution approach" discussed earlier.

Figure 7. Thematic "mapping wall".

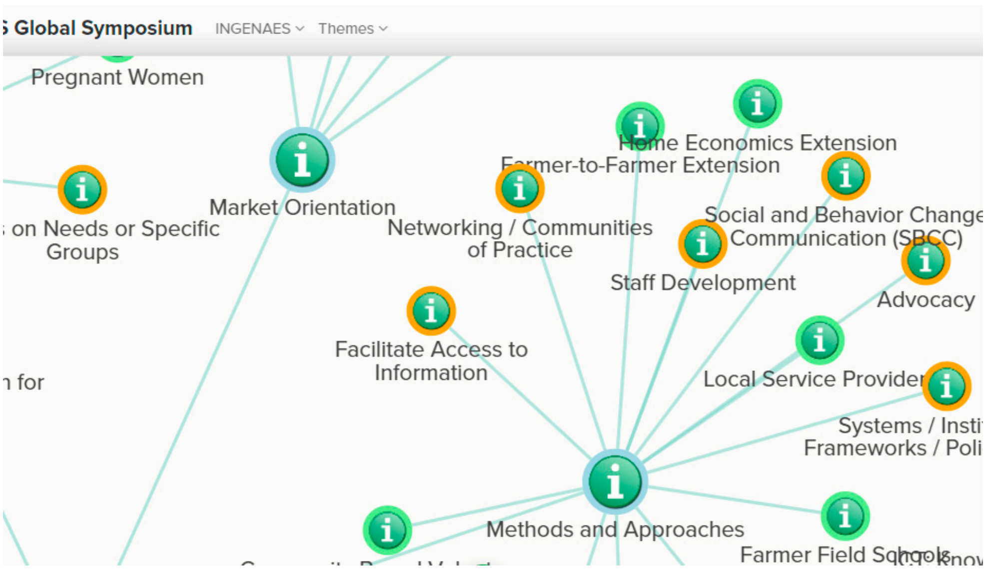


Figure 8. New themes (in orange) of the INGENAES community network ontology.

In Table 3, we have classified the INGENAES element and connection types according to the community network ontology categories (showing only the sub-categories of the CommunitySensor ontology used in the INGENAES case). The classification summarizes the nature and key characteristics of the INGENAES case ontology. At a glance, we can see that the thrust of the ontology is to help model the purposes of the large-scale (particularly project) interactions at the country level, with organizations as the main participants. This means the ontology is particularly useful for inter-communal sensemaking at the macro (i.e., global field level). Should another community network want to configure an ontology for its own sensemaking purposes, then this ontology would be a good source of inspiration for similar international field-building community networks, but possibly less so if it were a local, closely-knit community network working much more on strengthening its micro-operational community building interactions, such as organizing events and meet-ups.

Table 3. INGENAES element and connection types.

ELEMENT TYPE CATEGORIES	INGENAES ELEMENT TYPES
Participants	
Organizations	Organization, Organization Type
Interactions	
Activities	Action
Initiative/Projects/programs	Action; Project/Initiative; Research Project
Resources	N/A
Content	
Data/Information/Knowledge	Wisdom
Location	Country
Purposes	
Themes/Topics	Theme
CONNECTION TYPE CATEGORIES	**INGENAES CONNECTION TYPES**
Association-connections	N/A
Involvement-connections	Involved In
Access-connections	N/A
Production-connections	Country of Origin; Country of Work
Contribution-connections	About; Contributes To
Structural-connections	
Part Of	Part Of
Type Of	Type Of

When looking at the element and connection types in more detail, some further interesting observations can be made. For example, 'Resources' used and 'Association'/'Access'-connections among participants are not modeled in the INGENAES case. This is in line with the global, thematically-oriented WHY/WHAT focus of the ontology. When going into socio-technical design mode on HOW to get the community network interactions going, such 'Resources' and 'Association'/'Access' connection categories would be needed, though. This is indeed the case in the Malawi community network ontology (not included in this article), which needs to serve the mapping needs of local agricultural communities, 'Resources' being a very important consideration at the village level. Another observation is that two types of 'Contribution' connections ('About' and 'Contributes To') are used. In the INGENAES conceptual model of Figure 6, we can see that the 'About' connection type was used for indicating the purpose of 'Wisdoms' and 'Actions', whereas the 'Contributes To' connection type designated the purpose of projects. This use of synonyms often happens in real-world ontology use. Such synonyms may seem redundant, but their existence can often be explained from the particular perspective of the culture and language used by the community. Another observation points in the opposite direction, that of homonyms. The 'Action' element type in this case refers to two sub-categories of elements in our model: in the INGENAES community network it can refer both to the ongoing, informal 'Activities' and more formal, project-oriented 'Initiatives'/'Projects'/'Programs'. Our classification framework helps us to spot such semantic issues. It thus helps the community to get into meta-sensemaking mode by providing discussion points about what the mapping language constructs mean and whether they need to be changed.

5.2. Using the INGENAES Community Network Ontology: Creating the Collaboration Ecosystem Map

As we saw, a key application of any community network ontology is to design the conceptual structure of the mapping language being used in the participatory collaboration mapping process of a specific community network. At the end of the conference, after also having added all collected wisdoms and seed actions, the map consisted of 524 elements and 2468 connections. Whereas Table 3 outlined the INGENAES element and connection types comprising the mapping language, Table 4 summarizes the actual element and connection instances that were mapped using those types. It shows the names of the element and connection types included in the map, their sub-categories, number of instances of that type on the map, and some telling examples. This table helps to get a sense of the application of the case-specific INGENAES community network ontology characterized in the previous table.

Again, some immediate observations can be made. For example, the number of 'Contribution' connections stands out: 1919 of the 2468 connections are either 'About' or 'Contributes To' connections, with 1860 of those being 'Contributes To' connections. As that connection type indicates the purpose of INGENAES projects, we can say that the map summary is an indicator of the (potential) collective impact of the community network: the 'Projects'/'Initiatives' mapped to these 'Themes' provide an "action potential" as it were to operationalize these themes in the real world. We also see that relatively few 'Interactions' (only 155) were mapped. This strengthens the interpretation of the map being mainly purpose-oriented (the WHY/WHAT), rather than how these projects are actually being conducted (the HOW). In the follow-up participatory collaboration mapping project we are involved in—mapping the linkages and collaborations in Malawi's agricultural governance system—the focus has indeed shifted to that more detailed HOW-level, including mapping many of the resources used and associations between participants involved in initiatives, projects, and programs at the village level, which then are used as inputs for discussion by the higher governance levels in which especially the larger projects and programs are being facilitated and coordinated.

Table 4. INGENAES collaboration ecosystem map summary.

ELEMENT TYPE (SUB)-CATEGORIES	INGENAES ELEMENT TYPES	# In-Stances	Examples
Participants		**214**	
Organizations	Organization	206	CARE Bangladesh; Environment Ministry Senegal
	Organization Type	8	Donors, NGOs, Private-for-Profit Organizations
Interactions		**155**	
Activities	Action	(../100)	Disseminate food choice motives findings to extension agents and stakeholders
Initiative/Projects/programs	Action	(../100)	National Dialogue on Extension Services in Zambia
	Project/Initiative	53	Home Garden Project Phase IV
	Research Project	2	Nutrition Knowledge of Agricultural Extension Agents

Table 4. *Cont.*

ELEMENT TYPE (SUB)-CATEGORIES	INGENAES ELEMENT TYPES	# In-Stances	Examples
Content		**58**	
Data/Information/Knowledge	Wisdom	19	Chronic Malnutrition Mural / Height for Age Mural
Location	Country	39	Cambodia; Ethiopia; Guatemala; Peru
Purposes		**97**	
Themes/Topics	Theme	97	Empower Female Staff; Children Under 2; Hygiene and Safe Water
CONNECTION TYPE CATEGORIES	**INGENAES CONNECTION TYPES**		
Involvement-connections		**222**	
	Involved In	222	Njala University–Involved In-SAP (Scaling Up Aquaculture Production)
Production-connections		**98**	
	Country of Work	98	SANE (Strengthening Agriculture and Nutrition Extension)–Country of Work—Malawi
Contribution-connections		**1919**	
	About	59	Next steps for women farmers!-About-Give Representation and Voice
	Contributes To	1860	EAFS (Environmental Action and Food Security)-Contributes To-Better Nutrition for All
Structural-connections		**229**	
Part Of	Part Of	19	USAID West Africa-Part Of-USAID
Type Of	Type Of	210	Safe Agricultural Labor Practices-Type Of-Supporting Production

5.3. Collective Impact Network Analysis

Besides using the community network ontology to seed the mapping language that drives the participatory mapping process, and characterize the maps produced, it can also be used to help define the views on those maps. A multitude of views can be defined. Research on how to use them for inter-communal sensemaking towards collective impact is still in its infancy. Still, to explore the possibilities, we present a detailed example of what—analogously to social network analysis [38]—we call 'collective impact network analysis'.

The full 'bird's eye' view on the collaboration ecosystem can be seen on the live public map: https://kumu.io/ingenaes/2017-ingenaes-global-symposium. As the map consists of so many elements and connections, this full ecosystem view is necessarily very complex. Still, at a glance, we can already see an important determinant of the collective impact of the emerging INGENAES field: its 'thematic common ground' (Figure 9). The Kumu mapping algorithm centers the elements that have the most connections. In this case, the green squares in the center are the themes that are most connected to the other elements of the maps (be they projects, actions, wisdoms, or other elements).

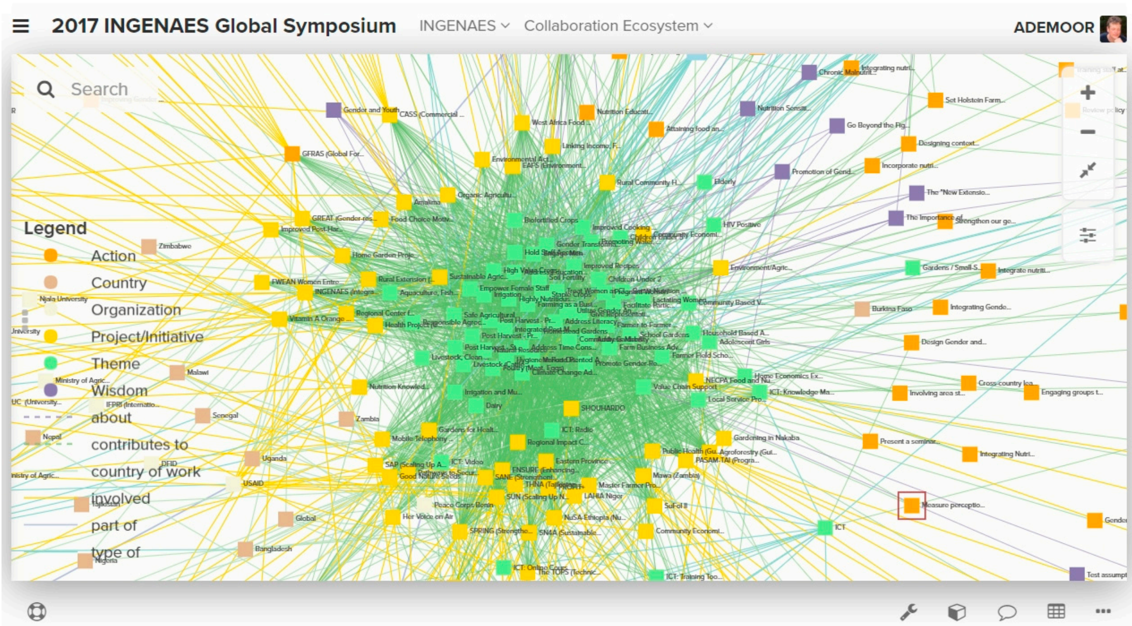


Figure 9. INGENAES thematic common ground.

One way to use this map, is to select some of the themes in that center and then see what other elements, for example projects, are connected to them, being an indication of how close they are to contributing to the core of the field. That, of course, is still only a very informal measure of collective impact.

Another feature of Kumu, its built-in social network analysis (SNA) metrics, can be of use to get a more systematic grip on the collective impact potential of the community network (https://docs.kumu.io/guides/sna-network-mapping.html). Three key SNA metrics built-in to Kumu are 'Degree' (the number of connections an element has), 'Closeness Centrality' (the distance each element is from all other elements), and 'Betweenness Centrality' (how many times an element lies on the shortest path between two other elements). 'Degree' often identifies local connectors and hubs (but not necessarily connected to the wider network); 'Closeness Centrality' the elements most connected to the network as a whole; and 'Betweenness Centrality' the key bridges in the network (but also possibly the bottlenecks).

Normally, in SNA, these metrics are used to analyze how connected social actors are, hence its name. However, in our case, we aim to use it in particular to analyze the connectedness of purposes, in particular the sub-category of 'Themes', as a proxy for how central they are in the network and thus impactful they may be. Let us zoom in on 'Closeness Centrality', assuming that the elements best connected to the network as a whole (to the 'Themes', 'Projects', 'Organizations', etc.) are a rough measure of making a significant contribution to the collective impact. Figure 10 shows the 10 highest ranked elements on the map according to this closeness-criterion:

Show top 10 elements by closeness

Rank	Label	Value
#1	Better Nutrition for All	0.486
#2	Facilitate Participation	0.482
#3	Give Representation and Voice	0.460
#4	Farmer-to-Farmer Extension	0.459
#5	Highly Nutritious Crops	0.457
#6	Utilize Gender Analysis	0.455
#7	Value Chain Support	0.452
#8	Engage Men	0.446
#9	Farming as a Business	0.446
#10	SPRING (Strengthening Partnerships, Results, and Innovations in Nutrition Globally)	0.445

Figure 10. Impactful INGENAES elements ('Closeness Degree').

We see that 9 of 10 elements are 'Themes', which makes sense, since there are so many 'Contributes To' connections on the map and there are likely some themes that constitute a central core of common interests among the conference participants. #10—SPRING—is a 'Project/Initiative', however, a project network active in many countries. Using the map, we can now zoom in on that particular project and examine its direct thematic context, for example (Figure 11, see https://kumu.io/ingenaes/2017-ingenaes-global-symposium#ingenaes/spring-strengthening-partnerships-results-and-innovations-in-nutrition-globally?focus=1 for a live view). If such an 'Project/Initiative'–'Contributes To'–'Theme' view is indeed deemed useful in examining collective impact, it can be added to the community network ontology, as a relevant collaboration pattern for that purpose.

Of course, many refinements in measures, data sets used, and interpretations of the results are needed, which are an important objective of our future research. Also, besides social network analysis, other forms of network analysis—like value network analysis [39]—could be included to come up with other potentially interesting views. Note that these measures should never be taken at face value. There are many reasons the mapping data might not represent the reality in the field. For example, some of our survey submitters might have over-represented their project in terms of themes they contribute to (there was no limit on the amount of themes they could choose in the INGENAES conference survey used to put the projects on the map), connections might mean different things to different mappers and interpreters, or simply the community might have very different things in mind about what else determines collective impact. Still, the alternative is to have no overview at all. Often, participants of huge community networks—especially emerging ones like INGENAES—have no idea who is working on what and why. The participatory collaboration mapping process—imperfect as it is—at least helps to break the paralysis and produces a highly relevant discussion agenda from which to start collective sensemaking towards collective impact. Feeding the sensemaking process with as content that is as relevant as possible is what the community network maps are for.

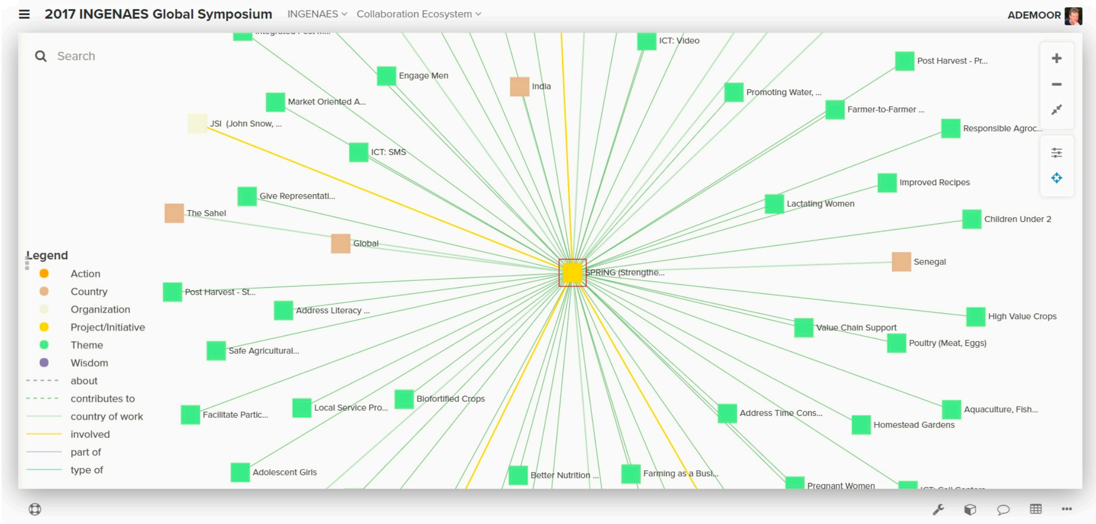


Figure 11. SPRING—a highly connected community network participant.

6. Discussion

In a globalizing world, many communities—ranging from local place-based communities to global communities of practice—are increasingly in flux and need to collaborate with one another. It is important to realize that such communities are embedded in a much larger socio-technical context, including a networked commons of overlapping stakeholder relations, goals, interactions, resources, tools, and so on. For society to address its wicked problems by building the necessary collaborative capacity towards collective impact, a much better understanding of such community networks and their socio-technical context in common(s) is of the essence. In this article, we have therefore not concentrated on what binds particular communities internally, but rather tried to shed light on their ill-understood outer context, and in particular the (potential) overlaps with other communities. In other words, our interest was in representing and understanding this networked community commons, how communities can make sense of it across their boundaries, and use these insights to increase their inter-communal collaboration.

Engaging in a participatory process of mapping the overlap between their collaboration ecosystems can help communities better understand one another and build productive bridges across their boundaries, without each community in the network losing its identity. In this article, we introduced the community network ontology that is at the heart of the CommunitySensor methodology for participatory community network mapping, described how it was distilled out of large number of participatory mapping cases, and illustrated how it is being used in practice.

The foundation of our cross-case CommunitySensor community network ontology is a community network conceptual model, consisting of element and connection types classified in categories and sub-categories. Main categories of element types are 'Participants', 'Interactions', 'Resources', 'Content', and 'Purposes'; connection types include 'Association', 'Involvement', 'Access', 'Production', 'Contribution', and 'Structural connections'. The most important application of the ontology is in the design of mapping languages tailored to the specific collaborative interests of particular community networks, but grounded in a growing general body of cross-case mapping insights. The ontology provides the conceptual structures for efficiently creating meaningful maps that matter to the community network. To do so, a community network first examines the cross-case CommunitySensor community network ontology, in order to create its own, customized mapping language. It does so by selecting relevant element and connection types, by refining and extending these types where needed, and by defining views on the map relevant to that particular community network case. Views are essentially selections of the elements and connections of a map, potentially each with a different layout.

They can be used, for instance, to create highly focused and relevant discussion agendas for meetings and conferences.

Our ontology has a different purpose than 'classical' ontologies aimed at supporting formal knowledge representation and reasoning purposes, such as prevalent in the Semantic Web. Ours is to support human collective mapping and sensemaking purposes, with the aim to increase the collective impact of the community networks in which these people engage. To explain what this means in practice, we described one particular application of the ontology—participatory collaboration mapping for field building—and presented—in considerable detail—a case of mapping a global conference of the international and interdisciplinary INGENAES agricultural community network. We showed how we used the CommunitySensor community network conceptual model to design the tailored ontology for the INGENAES community network. The INGENAES ontology in turn was used as the language to map the collaboration ecosystem of that community network. Using this language, a map of the INGENAES collaboration ecosystem was created, with extensive input from conference participants. Those participants not only provided the data for the map and made sense of it in many different hands-on ways, but even helped refine the mapping language itself. The map shows how existing projects, organizations, wisdoms, and proposed seed actions contribute to a comprehensive network of themes representing the purpose of this emerging international and interdisciplinary field. The dense web of connections between the various elements of the map can be seen as a proxy for the collective impact jointly being realized. Of course, the maps and their views are not the territory: they are only very partial and partially accurate interpretations of that very complex real world-collaboration ecosystem. Still, being able to at least outline the contours of the common collaboration ground was considered very useful by the conference participants.

A field is not a single community with a shared identity and common set of practices, but rather a more loosely-knit network of stakeholders intersecting around various themes, projects, organizations, etc. In field building, relationships and forms of collaboration continue to expand and increase in scale [27]. As such, field building is an interesting testing ground for developing participatory community network mapping approaches with the aim to grow new collaborations between communities towards collective impact. Such community networks are different from the ones usually described in the literature, which often focus on well demarcated communities of practice or place with a clear identity, history, and boundaries. We would argue that the more diffuse and composite community networks (in the sense of [18]) that mesh in the case of emerging fields, like in the INGENAES case, need even more adequate sensemaking support to build a common identity, working culture, and set of practices. Sensemaking is the interplay of action and interpretation, where meanings materialize that inform and constrain both identity and action, and where types and categories being socially defined have considerable plasticity [40]. The INGENAES case, combining a "dance of participatory mapping and facilitation" [28], has shown both the need and a fruitful approach for making that complex and engaged kind of sensemaking towards collective impact happen. A related case further showing promising signs in that direction is the SANE-INGENAES follow-up project currently underway in Malawi, where agricultural coordination platforms actively engage in mapping their own local community agricultural initiatives, and where (aggregates of) these maps are starting to be used to make sense at the local, area, district, and national levels. In future work, we aim to expand this rudimentary conceptualization of collective impact by using insights from collective impact research and practice, social and value network analysis theory; and the large body of social innovation and community informatics work on monitoring and evaluation (e.g., [1,3,5,37–39]).

Using the element and connection types of our community network ontology cannot only be used to define a mapping language and relevant views on the map, but also to construct collaboration patterns used for eliciting relevant knowledge. Collaboration patterns are meaningful conceptual networks of elements and connections capturing good collaborative practices [36]. Different communities and domains require different such patterns and practical sensemaking approaches in which these patterns are filled out and applied (like using the mapping wall in the INGENAES conference case to evolve the meanings of themes, as well as the posters used to fill out the initiative templates by the Malawi agricultural stakeholders). These patterns thus need to capture the often subtle interplay between the mapping tools and artefacts and the social mapping and sensemaking processes in which they are being created and used. Often, collaboration patterns for effective use entail a combination of the high-tech and low-tech, online and physical, synchronous and asynchronous. The online Kumu map embedded in the use of a mapping story, facilitated group processes, and the mapping wall in the INGENAES conference case, as well as the mapping and sensemaking process to use posters to capture agricultural initiatives during field visits in the Malawi case are good examples of such complex socio-technical patterns. Further inspirations for designing such hybrid collaboration patterns can be found in, for instance, the "community orientations" that summarize good practices in the socio-technical design of effectively using online tools to support community interactions like meetings, access to expertise, and community cultivation [41]. Along similar lines, in [42] we shared how we distilled best practice lessons out of a series of social innovation cases to form a library of re-usable collaboration patterns. A similar approach could be used in developing collaboration pattern knowledge bases for community networks.

Shifting towards a more explicit ontology engineering point of view, ontologies can range from a simple hierarchy of concepts with subsumption relations (i.e., a taxonomy) to complex networks of relationships, concepts, and constraints [24]. Our ontology so far is a rather basic one from the point of view of structural complexity. It only contains element and connection type (sub-)categories and simple constraints that define which element types can be attached to what connection types. In future work, we also aim to include attribute values on element and connection types and visualization constraints. For example, a mandatory—or at least recommended—attribute of an 'Organization' element type could be a 'Contact' attribute, so that there is always somebody on the map who can speak on behalf of that organization. An example of a visualization constraint could be that the width of a connection between an 'Interaction' and a 'Participant' involved in that interaction indicates the strength of the connection. How to measure that strength depends on the mores of the particular community network being developed, but we also want to learn more about that from the rapidly growing data visualization literature, e.g. [43].

Formalizations can facilitate the creation of more congruent understandings among participants in interorganizational relationships. Besides being a means to achieve coordination, control, and legitimacy, the right kind of formalizations are especially useful when there are large inter-partner differences and high degrees of ambiguity and uncertainty [44]. However, what is this right level of formalization in a community network? Our participatory ontology evolution approach is very much in line with the recent trend in decentralized ontology engineering methodologies emphasizing less formal, more lightweight ontologies [32]. The degree of formality of ontologies ranges from informal folksonomies to the very formal controlled vocabularies in use in the Semantic Web [25], Folksonomies are collaborative categorizations using keywords freely chosen by users. Even though these keywords are sometimes completely informal—think of tag clouds—they are still ontologies, be it lightweight, dynamic, and limited in sharing scope [25]. The CommunitySensor community network ontology can be positioned somewhere in the middle of this spectrum: community network representatives are totally free to come up with their own terms for element and connection types in their own ontologies. However, these terms are organized in a deep structure with community-specific element and connection types being classified by higher-order element and connection type (sub)categories described in the CommunitySensor community network conceptual model. The CommunitySensor community network ontology contains conceptual mapping lessons learnt in many different cases about which element and connection types work in practice. Such a grounded approach to defining a community network mapping language is essential when creating meaningful conceptual bridges across the mapping languages of potentially very different community networks. Although our ontology is only tentative, both in terms of the element and connection types and their classification into (sub-)categories, we believe that it has already shown its usefulness as a basic conceptual framework on which to build inter-communal collaborative ontology engineering approaches.

Note that we do not propose to create one semantically tightly integrated network of community ontologies, which is often the goal of traditional inter-organizational ontology engineering [45,46]. Yet, when making sense across community networks, we do need some form of common language. This language is to act as an inter-lingua to define some basic conceptual common ground, and to align potential collaboration opportunities when engaged in collective sensemaking of that common ground, as we have shown to work in our cases. However, we do not need formal, fully-specified definitions of the meaning of the elements and connections in the ontology. Instead of being unambiguous formal meaning specifications, our ontological elements and connections generally act as boundary objects. Such boundary objects play a brokering role involving translation, coordination, and alignment among the perspectives of different communities coming together in a kind of meta-community [26], which is the case in our fractalized community networks. One way to identify such boundary objects is by reflecting on what (sub)-categories the element and connection types of the mapping languages of different community networks have in common (even though the names of the types used may be very different). Such common meanings make it possible to link different community network maps by identifying conceptually similar elements and connections, think of stakeholders or activities in common. These meaningful linking pins across maps can serve as concrete starting points for (facilitated) discussion when different community networks meet for the first time, for example in a joint exploratory workshop. Starting right away from meaningful links between their own maps—well-understood by the communities that created them but often not by the other communities that try to read them—may significantly accelerate the potential for achieving collective impact [22].

Collective impact processes may benefit from dedicated “backbone organizations”, whose mission it is to catalyze collective impact networks by facilitating organizations aligning numerous initiatives addressing wicked problems [5]. However, we would argue that such centralized approaches are not enough to scale up towards collective impact. The fundamental problem in social innovation—addressing wicked social problems with a multitude of stakeholders who cannot solve these problems on their own—is not in the early stages of prompts, proposals, and pilots, but in the later stages of sustaining, scaling, and systemic change [47]. Besides backbone organizations, we propose we also need “backbone processes”, designed out of participatory collaboration mapping and other collective intelligence approaches. Such mapping-based backbone processes may also help to increase stakeholder engagement competence, as this has been shown to benefit from the invention of new forms of stakeholder engagement that makes communication possible that may be otherwise difficult, impossible, or unimagined [48].

We want to mention one example in particular of a profound, yet ambitious potential backbone process for increasing collective impact. Etzioni astutely observed that all communities have a serious defect: they exclude. To prevent communities from over-excluding, they should be able to maintain some limitations on membership, yet at the same time greatly restrict the criteria that communities may use to enforce such exclusivity. He therefore proposed the idea of “megalogues”: society-wide dialogues that link many community dialogues into one, often nation-wide conversation [7]. Although this sounds lofty, it is also not practical, nor does unconstrained society-wide conversation necessarily led to inter-communal sensemaking. On the contrary, unfettered social media use often leads to more misinformation, polarization and division, as many individual users lack the civic online reasoning competencies to distinguish reliable from misleading information [49]. Still, there have recently been many developments on the front of crowd-scale online deliberation support technologies, including time-centric, topic-centric, question-centric, debate-centric, and argument centric deliberation technologies [50]. It would not be enough to just deploy these technologies and hope for the best, though. If the deliberation support provided by such technologies could be combined with participatory collaboration mapping support grounded in meaningful community network ontologies, more scalable approaches to designing focused and productive debates on selected topics with relevant participants might emerge. Participatory collaboration mapping approaches do more than just finding common ground: they help in driving for accountability and transparency, towards fair, unbiased representation of the community [51]. The collaboration patterns of community network ontologies could represent the balanced socio-technical mix of relationships, interactions, and purposes for seeding the media configurations and conversation processes leading towards more common ground and collective impact. Such scaled-up communication and collaboration processes would also require meta-design principles to collaboratively construct the required design rationale, media and environments [23]. Combining deliberation support technologies with participatory collaboration mapping and meta-design principles could create socio-technical "safe (or at least: safer) spaces" in a way that promotes more productive interactions between members of many different community networks than currently the case.

There is a growing body of related community informatics work that can be connected to further develop our approach. A powerful example of ICT-mediated visual approaches to community empowerment at the local level is how favela residents used cameras to bear witness of what is happening and what is needed in the slums of Brazil [52]. Besides visually mapping a community's lifeworld at the grassroots level, however, we also need to be able to scale up towards collective impact. Community informatics can also help developing such an inter-communal network perspective, as it views ICT not only as the carrier and facilitator of the connections within a community, but also between communities [11] (pp. 16–17). For example, Van Biljon and Marais [51] outline a community network ontology and participatory mapping process for research collaboration mapping and sensemaking across organizations and research communities in the domain of development informatics. Finally, participatory collaboration mapping and sensemaking are meaningless if not suffused with community norms, values, goals, and ethics, and analyzed from an emancipatory critical-interpretive point of view: the essence of the budding field of community informatics [14,53–55]. Although this article paid a lot of attention to the more technical aspects of community network ontologies, we are very much inspired by these fundamental community empowerment principles driving our field of research and practice. We have and will continue to be guided by them in the further development of the CommunitySensor methodology.

7. Conclusions

The world is in dire need of wicked problem-solving capacity. The ecological, economic, social, and political crises keep multiplying. Organizations and communities can no longer address these issues in a top down way on their own. However, even individual community network initiatives are not enough. For truly collective impact, collective intelligence by community networks of stakeholders acting in concert is needed. Those initiatives themselves need to align and be interwoven, so that in a fractalized way, collective impact can be scaled from the bottom-up to societal transformation. For this smart scaling, ongoing inter-communal participatory mapping and sensemaking is needed, in which community network initiatives find common ground, without losing their own identity and foregoing their own interests and needs.

In earlier work, we introduced the CommunitySensor methodology for participatory community network mapping. It supports the mapping and sensemaking processes both within and across communities, in order to strengthen their network development. The main contribution of the current article is our community network ontology—with the CommunitySensor community network conceptual model at its core. The ontology is not the result of a theoretical exercise conducted in a lab, but hard-won practical knowledge that we have distilled over time out of 17 funded cases, with real interests and resources at stake. We showed how the community network ontology scaffolds the CommunitySensor participatory mapping methodology by using it to effectively and efficiently configure and customize the language of the element and connection types, map views, and collaboration patterns most relevant to the specific community network being mapped. We illustrated this potential by sharing how the community network conceptual model was used to configure the design of the map ontology at the heart of participatory collaboration mapping efforts to promote learning and collaboration for field building in a global agricultural community network. If widely adopted, such an ontological approach could significantly increase the efficacy of inter-communal sensemaking processes for collective impact.

The work we presented is far from finished. Many criticisms can be leveled against the current implementation. As a community informatics field of researchers and practitioners, we still have disagreements about the fundamental nature of community networks, and how the community and network dimensions should be defined and interrelate. The community network ontology introduced is only tentative in its classification, contents, and application. The participatory collaboration mapping methodology is very much under construction and its co-dependence with the ontology is still under investigation. We are a long way from such methodologies being able to support collective impact at the full society-transforming scale. Still, the use case examples we presented here (and many more we have left out) show that there are both a need for and promising practical ways to make an ontology-driven participatory collaboration mapping way of thinking and working work.

Although the world is facing many societal challenges, there is an enormous reservoir of good will and capacity to effect change for the common good. However, awareness of stakeholders needs, intentions, and potential collaborations is scattered. We believe that growing community network mapping and sensemaking capacity is of the essence to increase the collective intelligence needed to overcome this fragmentation of collaboration. CommunitySensor is one initiative to increase that capacity. Development of the participatory collaboration mapping methodology and supporting community network ontology are far from finished. However, we hope that sharing our intermediate results will inspire others in developing related work. The road we have to travel is still long, but we have taken more than a few steps already.

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